Sedimentology, provenance, and tectonic implications of the Cretaceous Newark Canyon Formation, east-central Nevada
by Dirk Sheridan Vandervoort

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Earth Sciences
Montana State University

Abstract:
Cretaceous strata in the hinterland of the Sevier thrust belt are sparse. Strata of the early Cretaceous Newark Canyon Formation in east-central Nevada provide a link between poorly documented hinterland tectonism and concomitant sedimentation. Facies analyses of these strata in the Diamond Mountains and the Fish Creek Range indicate the presence of spatially unrelated depositional systems. At Overland Pass in the central Diamond Mountains, the Newark Canyon Formation is characterized by deposits of east to southeast flowing, gravel- and sand-bed braided fluvial systems. The age of this sequence is in question due to lack of fossil data. In the Eureka District in the southern Diamond Mountains and at Cockalorum Wash in the southern Fish Creek Range, the Newark Canyon Formation is characterized by deposits of muddy floodplains, freshwater lakes, and east to southeast flowing, high-energy gravel-and sand-bed braided and meandering fluvial systems. Fossil data indicate the age of these strata to be Barremian to middle Albian. Similarities in facies assemblages in the Eureka District and at Cockalorum Wash suggest that these strata are lithostratigraphic equivalents.

Presence of two distinct petrofacies is indicated by sandstone framework modes. The Quartzo-lithic Petrofacies consists exclusively of Overland Pass sandstone. The Chertarenite Petrofacies consists of both Eureka District and Cockalorum Wash sandstone. Conglomerate clast compositions indicate that highland source terrains consisted of Mississippian Antler foreland basin sediments and middle to late Paleozoic miogeoclinal strata. Presence of Eureka Quartzite cobbles indicates that stratigraphic levels as old as Ordovician were exposed to erosion during Newark Canyon Formation deposition.

Development of Newark Canyon Formation basins was in response to sediment dispersal and basin subsidence from the poorly documented late Mesozoic Eureka thrust belt. Deposition of these strata pre-dates Sevier foreland basin subsidence and sedimentation. Presence of high-energy, east flowing, fluvial systems and pre-Basin and Range proximity of these strata to the site of the Sevier foreland basin indicates that they represent a fortuitously preserved, proximal paleodrainage system which was denuding the hinterland uplands and transporting sediment to the nascent foreland basin.

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APPROVAL

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Dirk Sheridan Vandervoort

This thesis has been read by each member of the thesis committee and has been found to be satisfactory regarding content, English usage, format, citations, bibliographic style, and consistency, and is ready for submission to the College of Graduate Studies.

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ABSTRACT

Cretaceous strata in the hinterland of the Sevier thrust belt are sparse. Strata of the early Cretaceous Newark Canyon Formation in east-central Nevada provide a link between poorly documented hinterland tectonism and concomitant sedimentation. Facies analyses of these strata in the Diamond Mountains and the Fish Creek Range indicate the presence of spatially unrelated depositional systems. At Overland Pass in the central Diamond Mountains, the Newark Canyon Formation is characterized by deposits of east to southeast flowing, gravel- and sand-bed braided fluvial systems. The age of this sequence is in question due to lack of fossil data. In the Eureka District in the southern Diamond Mountains and at Cockalorum Wash in the southern Fish Creek Range, the Newark Canyon Formation is characterized by deposits of muddy floodplains, freshwater lakes, and east to southeast flowing, high-energy gravel- and sand-bed braided and meandering fluvial systems. Fossil data indicate the age of these strata to be Barremian to middle Albian. Similarities in facies assemblages in the Eureka District and at Cockalorum Wash suggest that these strata are lithostratigraphic equivalents.

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Development of Newark Canyon Formation basins was in response to sediment dispersal and basin subsidence from the poorly documented late Mesozoic Eureka thrust belt. Deposition of these strata pre-dates Sevier foreland basin subsidence and sedimentation. Presence of high-energy, east flowing, fluvial systems and pre-Basin and Range proximity of these strata to the site of the Sevier foreland basin indicates that they represent a fortuitously preserved, proximal paleodrainage system which was denuding the hinterland uplands and transporting sediment to the nascent foreland basin.

INTRODUCTION

Cretaceous sedimentary rocks in east-central Nevada are sparse (Stewart, 1980). Lower Cretaceous strata of the Newark Canyon Formation occupy scattered outcrops in east-central Nevada in a tectonic enclave between the Luning-Fencemaker thrust system to the west (Oldow, 1983) and Sevier thrust system to the east (Armstrong, 1968) (Figure 1). Exposures of these strata occupy an approximately north-south trending belt parallel to the trend of the poorly documented late Mesozoic Eureka thrust belt (Speed, 1983; Heck and others, 1986). This region has been referred to as the hinterland of the Sevier orogenic belt by Armstrong (1968; 1972), which he defined as the area between the laterally continuous, thin-skinned Sevier thrust belt to the east and a broad region several hundred kilometers to the west composed of plutons and diverse allochthonous terranes. Armstrong's concept of the hinterland as a broad, gently folded region cut by sparse low-angle faults and plutons has changed little since his studies (Allmendinger and others, 1984).

In contrast to the relative sparcity of Cretaceous strata in east-central Nevada, a thick clastic wedge of Cretaceous strata is present to the east of the Sevier thrust belt, where thrust loading and sedimentation led to development of the assymetrical Sevier foreland basin (Jordan, 1981). Sedimentologic, stratigraphic, and provenance studies of Upper Jurassic through Eocene coarse clastic units preserved in the foreland basin provide a substantial knowledge of the sequence of tectonic development within the Sevier thrust belt (Wiltschko and Dorr, 1983).

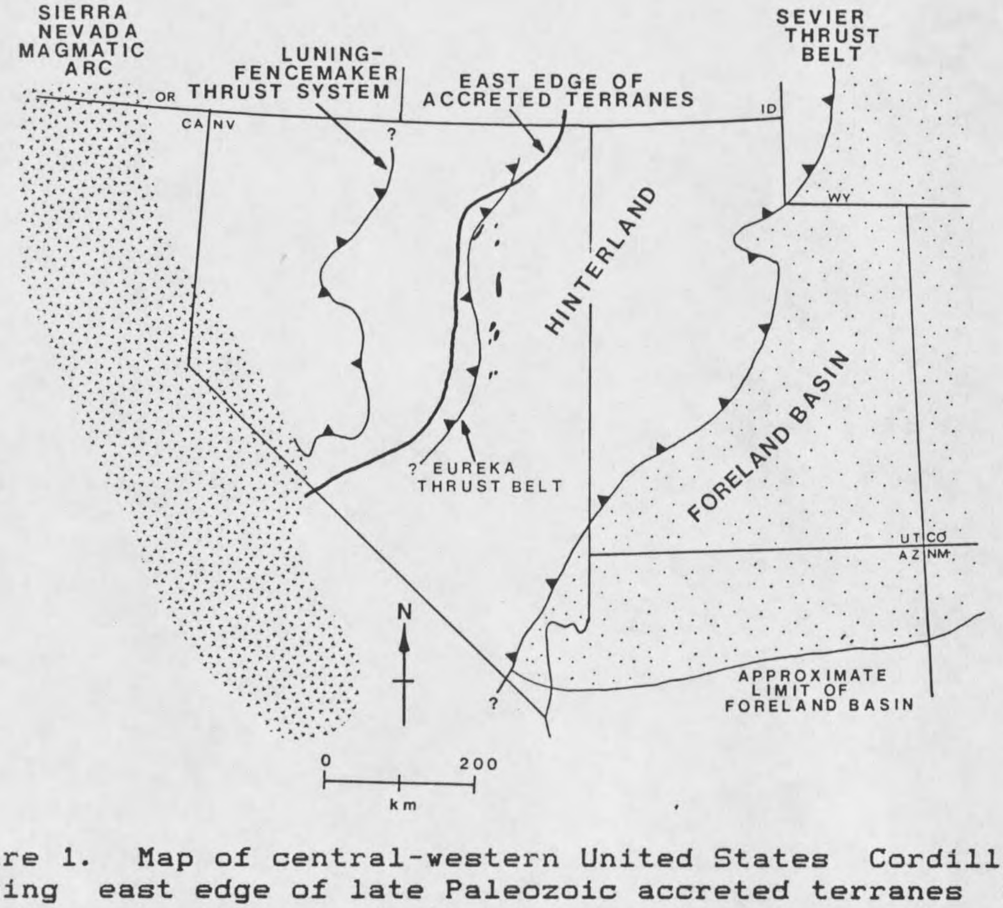

Figure 1. Map of central-western United States Cordillera showing east edge of late Paleozoic accreted terranes and late Mesozoic tectonic features in relation to exposures of Cretaceous Newark Canyon Formation (black). From Stewart (1980) and Allmendinger and others (1987).

However, very little is known of the late Mesozoic sedimentary/tectonic history of the hinterland of the Sevier orogenic belt. Coney and Harms (1984) suggest that scarcity of Cretaceous strata in this region indicates that it was a vast altiplano-like plateau during this time until its collapse due to mid- to late-Tertiary metamorphism and extension, which obscured pre-existing structures (Armstrong, 1972; Compton and others, 1977; Allmendinger and Jordan, 1983). Gans and others (1987) suggest that low conodont alteration indicies of uppermost Paleozoic units in the eastern Great Basin indicate that this area was never buried beneath a significant Mesozoic sedimentary cover. Jordan and Alonso (1987) suggest that analogues for these strata are the late Tertiary to Recent synorogenic deposits of basins developed in the interior of the Andes Mountains.

This investigation examines selected exposures of strata mapped as Cretaceous Newark Canyon Formation in the Diamond Mountains and Fish Creek Range in east-central Nevada (Figure 2). This study, in addition to continuing investigations of Cretaceous-early Tertiary sedimentary strata in east-central Nevada, contributes toward a better understanding of the late Mesozoic-early Tertiary sedimentary/tectonic history of east-central Nevada.

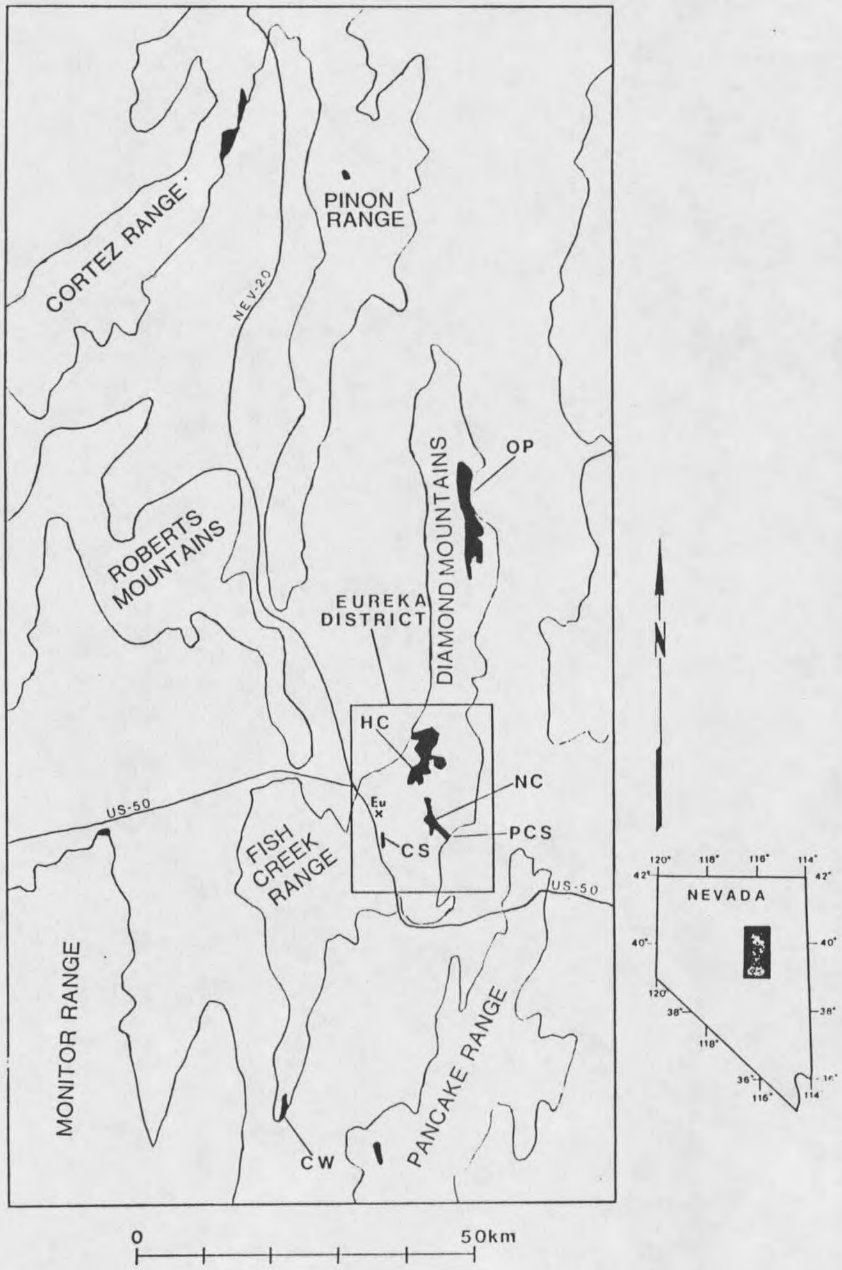

Figure 2. Index map of east-central Nevada showing the distribution of strata mapped as Newark Canyon Formation (black) in relation to major ranges. Strata examined in this study includes: Overland Pass (OP) in the central Diamond Mountains; Hildebrand Canyon (HC), Newark Canyon (NC), Cherry Spring (CS), and Pinto Creek Spring (PCS) in the Eureka District of the southern Diamond Mountains; and Cockalorum Wash (CW) in the southern Fish Creek Range. From Stewart and Carlson (1978). Eu is the town of Eureka.

Purpose of Investigation

The purpose of this investigation is to evaluate the sedimentology, provenance, and tectonic significance of selected exposures of Lower Cretaceous strata assigned to the Newark Canyon Formation. More specifically, questions addressed are: 1) What depositional environments characterize the Newark Canyon Formation? 2) What are the sediment dispersal patterns? 3) What is the provenance of terrigenous clastic units? 4) What is the early Cretaceous paleogeography of east-central Nevada? and 5) What does the Newark Canyon Formation reveal about the tectonic setting of its basin(s) of deposition?

Previous Studies

Strata of the Newark Canyon Formation were named and defined by Nolan and others (1956) based on scattered exposures in the Eureka Mining District in the southern Diamond Mountains (Figure 2) (Nolan, 1962). Smith and Ketner (1976) identified Lower and Upper Cretaceous strata they assign to the Newark Canyon Formation in the Cortez and Pinon Ranges near Carlin, Nevada. Stewart (1980) noted that strata located along the crest of the central Diamond Mountains, originally assigned to the Permian system by Larsen and Riva (1963), have been subsequently reassigned to the Newark Canyon Formation (Larsen, pers. comm., in

Stewart, 1980). Lower Cretaceous strata exposed at Cockalorum Wash in the southern Fish Creek Range have also been assigned to the Newark Canyon Formation (Hose, 1983). Fouch and others (1979) noted that the Newark Canyon Formation near Eureka, Nevada, is the temporal equivalent of parts of Lower Cretaceous strata in the Rocky Mountains and Alberta, and that exposures in the Pinon Range are the temporal equivalent of the lower part of the Late Cretaceous (Maastrichtian) to Eocene Sheep Pass Formation in the Egan Range, Nevada. Despite these correlations, all investigations of these strata have been of a reconnaissance nature and detailed knowledge of depositional systems, sediment provenance, and sedimentary tectonics have been poorly understood.

Methodology

Field Methods

To assemble the data used in making the following interpretations, more than 3 km of stratigraphic section were measured by Jacob's staff. Sections were selected on the premise that each chosen locality should contribute to an understanding of vertical and lateral facies relationships. Additionally, the quality of exposures often dictated the location of section measurement. Lithofacies present were classified using the terminology of Miall (1977, 1978, 1985). Where terminology did not exist, lithofacies nomenclature was erected to describe observed lithofacies. During section measurement, paleocurrent measurements were made on imbricated cobbles and crossbedding at representative intervals to evaluate paleocurrent trends. The size of the largest 5 to 20 gravel-sized clasts was measured at representative intervals in each section to evaluate grain size trends. More than 200 lithologic samples were collected for petrographic analysis. Samples were chosen on the basis of being most representative of distinctive lithofacies and locations in the Newark Canyon Formation sections. Clast composition counts of more than 14,000 clasts were conducted on conglomerate units at representative locations for provenance evaluation. Cobbles were counted by drawing random grids on conglomerate exposures containing clasts larger than gravel-sized. Mudstone intraclasts were excluded from clast counts. Orientation of more than 500 clasts and cross beds were measured on a region-wide basis to determine overall paleoflow trends. Covered sections were selectively trenched for lithologic identification. Fossils were collected where present to add biostratigraphic information and to reinforce facies interpretations.

Laboratory Methods

Cobble imbrication and crossbed orientation data were rotated about structural strike on an equal-area net to determine paleocurrent trends. Vector orientation and magnitude were calculated using the methods of Carver (1977) and Curray (1956).

A total of 100 thin sections were prepared from representative lithologic samples for study with the petrographic microscope. Thirty-eight thin sections were determined to be suitable for modal analysis. The composition of each grain was determined for each point on a fixed-grid spacing that exceeded the mean grain size of the sample until at least 400 grains were identified. In all cases, data were tabulated exclusive of carbonate framework grains. Carbonate grains were excluded because resedimented carbonates could not be systematically differentiated from intraclasts (Mack, 1984). Modal grain size was visually estimated for most samples in thin section. Sandstone framework modal data were treated using standard statistical techniques (Dickinson and Suczek, 1979).

Study Area and Stratigraphic Nomenclature

Rocks mapped as Newark Canyon Formation occupy scattered outcrops in four different mountain ranges in east-central Nevada (Figure 2). Effort was concentrated at

Overland Pass in the central Diamond Mountains, in the Eureka District in the southern Diamond Mountains, and at Cockalorum Wash in the southern Fish Creek Range. The restriction of geographic extent of the study area was based on: 1) relative proximity of these Newark Canyon Formation exposures to each other, 2) reasonable accessibility of diagnostic sections, and 3) emphasis on detailed facies analysis. Exposures of Newark Canyon Formation strata at locations not covered by this investigation are the subject of ongoing investigations conducted on late Mesozoic-early Tertiary strata in east-central Nevada and will not be covered here.

The Newark Canyon Formation in the central Diamond Mountains (Figure 2) (Larsen and Riva, 1963) is variable in thickness and consists of a lower conglomerate that attains a maximum thickness of 450 m and an upper sequence of sandstone with conglomerate interbeds which attains a maximum thickness of 750 m (Figure 3). These members are refered to as the Lower Conglomerate and Upper Sandstone, respectively. One 105 m thick section of the Lower Conglomerate and one 60 m thick section of the Upper Sandstone were measured near Overland Pass. At this locality, the Newark Canyon Formation rests with angular unconformity on a thick sequence of Permian strata and is exposed at the top of the section.

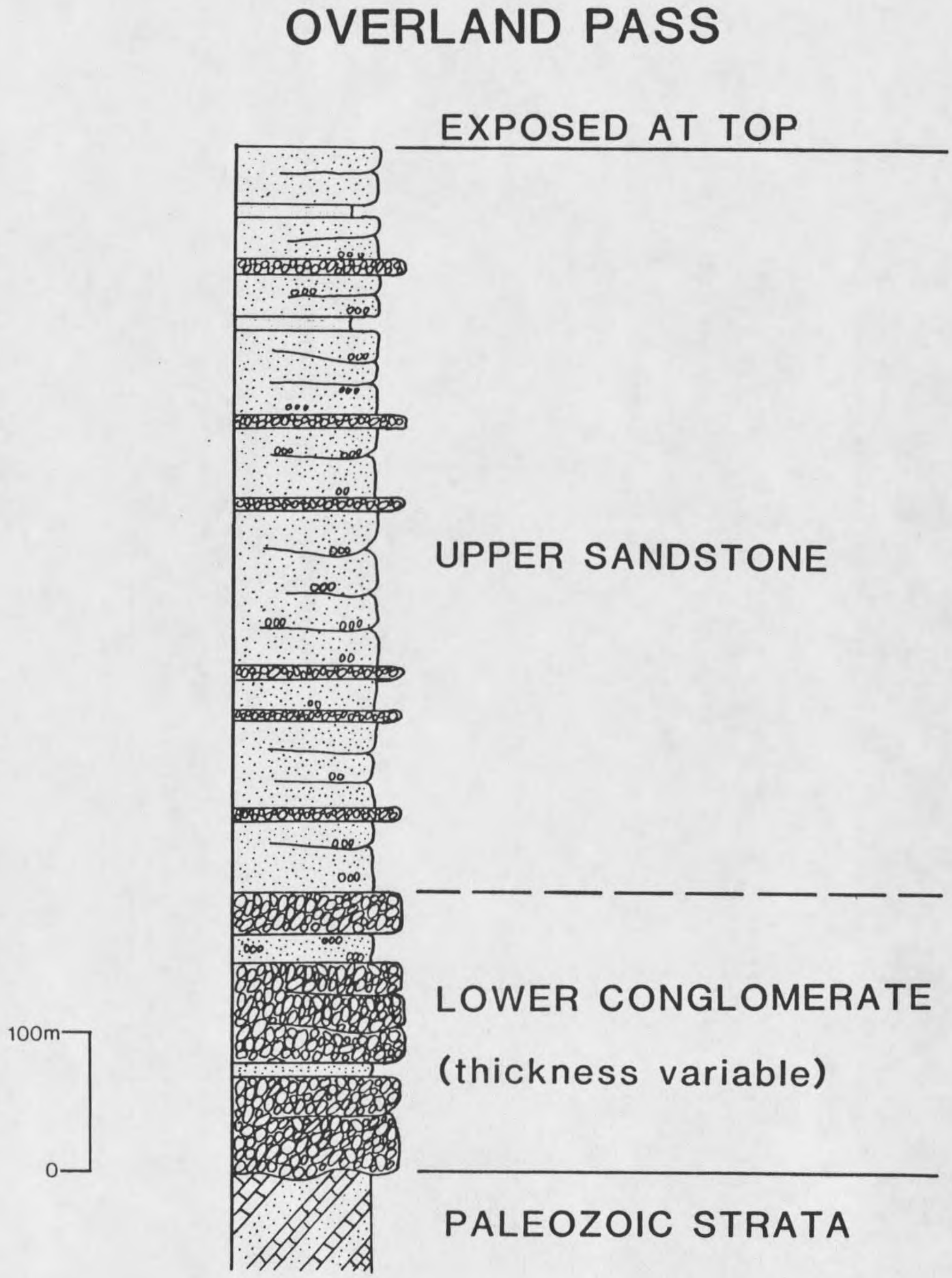

Figure 3. Generalized, schematic stratigraphic column of the Newark Canyon Formation at Overland Pass in the central Diamond Mountains showing stratigraphic nomenclature used in this report. Thicknesses are approximate.

In the Eureka District (Figure 2) (Nolan and others, 1956; 1971; 1974), the Newark Canyon Formation is lithologically heterogeneous and attains a maximum thickness of 520 m. Due to the poorly exposed nature of outcrops, several sections were measured and a representative stratigraphic section was determined based on localized correlations between adjacent sections (Figure 4). In this region, the Newark Canyon Formation overlies Ordovician through Permian strata above an unconformity that is, in most places, angular. Members in the Newark Canyon Formation in the Eureka District are, from the base up, the Basal Conglomerate/Mudstone, Lower Fine-Grained Assemblage, Middle Sandstone, Upper Conglomerate, and Upper Carbonaceous Assemblage.

Four separate areas in the Eureka District contain diagnostic sections of Newark Canyon Formation strata (Figure 2) and will be referred to throughout this report. The westernmost area is located 3 km southeast of the town of Eureka near Cherry Spring and is referred to as the Cherry Spring section. Here the Newark Canyon Formation rests with angular unconformity upon Mississippian Diamond Peak Formation and attains a maximum thickness of 260 m. Ten km east of Eureka is the type area of the Newark Canyon Formation where these strata attain a maximum thickness of 520 m. This area contains the most complete section of

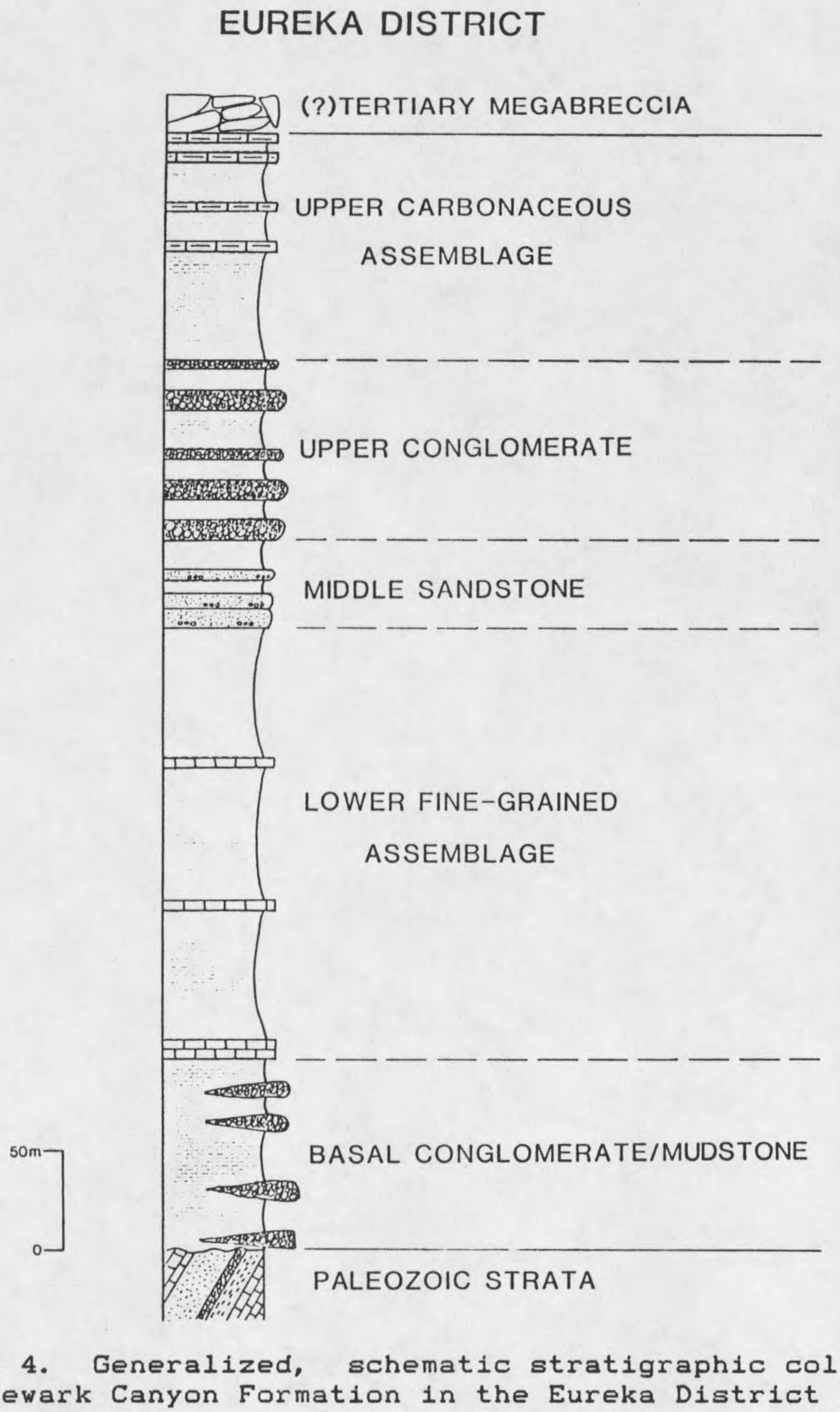

Figure 4. Generalized, schematic stratigraphic column of the Newark Canyon Formation in the Eureka District in the southern Diamond Mountains showing stratigraphic nomenclature used in this report. Note the difference in vertical scale used in the Overland Pass stratigraphic column. Thicknesses are approximate.

Newark Canyon Formation strata in the Eureka District. Here the Newark Canyon Formation rests with angular unconformity on Pennsylvanian Ely Limestone and Permian Carbon Ridge Formation and is overlain by (?)Tertiary monolithologic megabreccia, and Oligocene and Miocene volcanic rocks. Twelve kilometers east-southeast of the town of Eureka, the Newark Canyon Formation rests with angular unconformity on Mississippian Diamond Peak Formation, attains a maximum thickness of 390 m, and is overlain by Miocene volcanic rocks. This area is referred to as the Pinto Creek Spring section. Fifteen kilometers north of the town of Eureka is the largest exposure of the Newark Canyon Formation; however, this region, referred to as the Hildebrand Canyon area, is also the most poorly exposed and structurally most complex of the areas studied. Here, an accurate determination of actual thicknesses of the section could not be ascertained. However, distinctive facies were identified and evaluated where exposures permitted. In this region, the Newark Canyon Formation overlies Mississipian Chainman Shale and Diamond Peak Formation along a low angle fault, and is overlain by (?)Tertiary monolithologic megabreccia.

Exposures of Newark Canyon Formation at Cockalorum Wash in the southern Fish Creek Range (Figure 2) (Hose, 1983) are characterized by a 200 m thick sequence of, from the base up, Basal Conglomerate, Lower Sandstone, Upper

Sandstone, and Upper Carbonate Assemblage (Figure 5). The base of the exposed formation is in fault contact with underlying Devonian through Pennsylvanian strata (Hose, 1983). In this region, the Newark Canyon Formation is overlain in angular unconformity by Late Cretaceous (Maastrichtian) to Eocene Sheep Pass Formation.

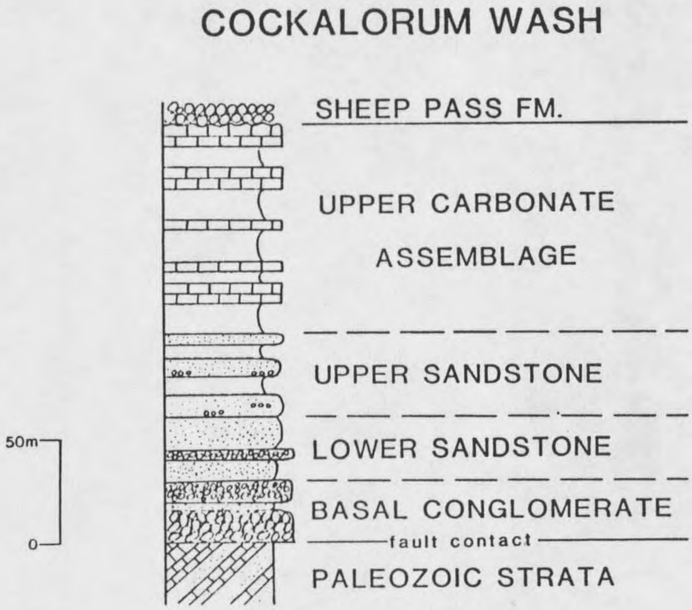

Figure 5. Generalized, schematic stratigraphic column of the Newark Canyon Formation at Cockalorum Wash in the Southern Fish Creek Range showing stratigraphic nomenclature used in this report. Vertical scale is the same as that used in the Eureka District stratigraphic column (Figure 4). Thicknesses are approximate.

Structural Complications

At all localities examined, the Newark Canyon Formation is characterized by structurally complex outcrops. In most instances, tectonic disruption could be accounted for in making facies evaluations. However, at some locations, structural disruptions were so great as to hinder facies interpretations. The following discussion is a brief account of the structures present at each of the locations studied.

Overland Pass

At Overland Pass (Figure 2), the entire Newark Canyon Formation along with underlying strata have been folded into an east-verging open syncline. Locally, mesoscopic tear faults and associated displacement transfer structures are present. Additionally, the Newark Canyon Formation has been locally offset by high angle normal faults. Some parts of the Newark Canyon Formation have been pervaded with solution fractures, although in most cases this did not hinder lithofacies evaluation.

Eureka District

This region (Figure 2) is characterized by the most complex structures observed in the three areas studied. At most localities (Cherry Spring, Newark Canyon, and Pinto Creek Spring), the Newark Canyon section has been folded into east-verging open folds. However, in the Hildebrand Canyon area, the Newark Canyon Formation has been highly deformed and is allochthonous (Nolan and others, 1973). The contact between Newark Canyon Formation and underlying Mississippian strata is poorly exposed and both units are highly sheared. The very poorly exposed nature and complex structure of the Newark Canyon Formation in the Hildebrand Canyon area preclude as thorough an evaluation of these strata as would be desired.

Cockalorum Wash

The majority of the Newark Canyon Formation section at Cockalorum Wash (Figure 2) is tilted into an east-dipping monocline, although it has been locally folded. In some places the Newark Canyon Formation has been offset by high angle normal faults. Additionally extremely poorly exposed Paleozoic carbonate and quartzite have been found to overlie the Newark Canyon Formation. It cannot be determined with certainty whether these Paleozoic rocks are the result of thrust emplacement or large-scale landslide blocks. Their origin remains enigmatic.

Biostratigraphy

With exception of the section at Overland Pass, the age of the Newark Canyon Formation is reasonably well constrained by fossil data. Figure 6 is a correlation chart showing ages of the Newark Canyon Formation at the three areas examined (Fouch and others, 1979). Below are descriptions of fossils collected during this and previous investigations.

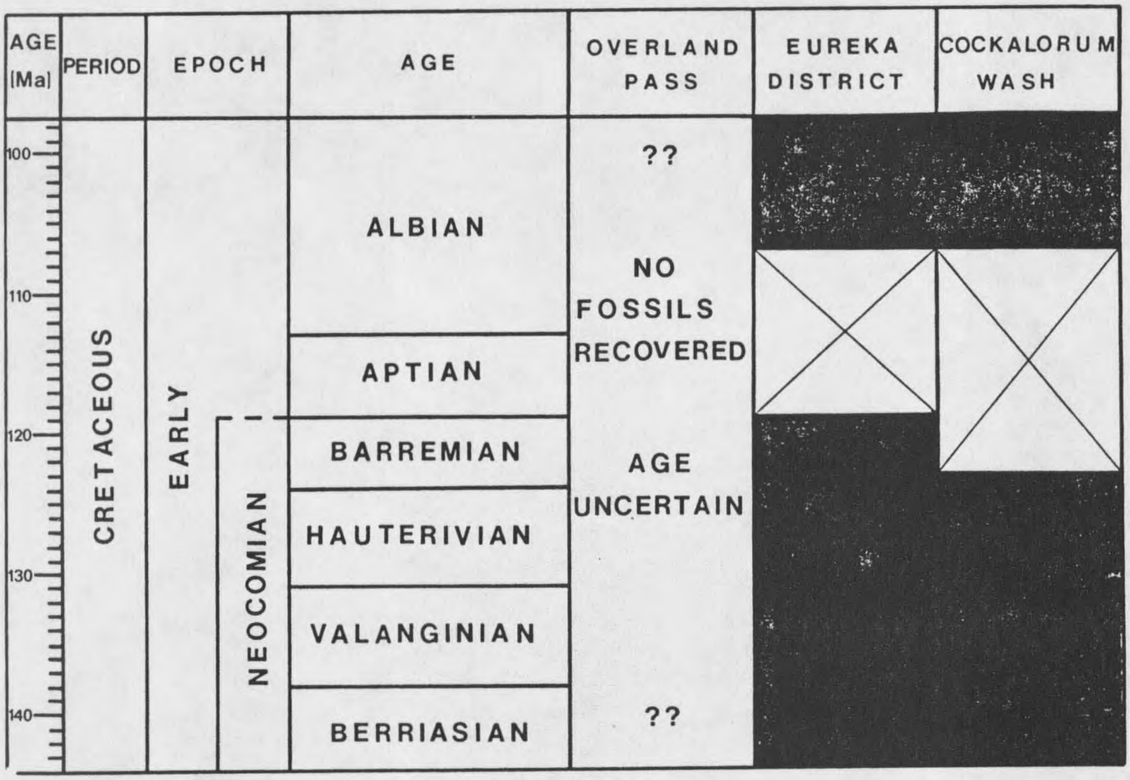

Figure 6. Chart showing ages of the Newark Canyon Formation examined in this investigation. Data from Fouch and others (1979).

Overland Pass

No vertebrate or invertebrate fossils have been found in the Newark Canyon Formation at Overland Pass. Therefore, the specific age of the Newark Canyon Formation here remains in question. These strata are assigned to the Newark Canyon Formation based on vague lithologic similarities with known Cretaceous Newark Canyon Formation exposures at other locations (Dott, 1955) and by the presence of sponge spicules within chert clasts (Keith Ketner, pers. comm., 1986). Based on this, the age of the Newark Canyon Formation at Overland Pass can be, at best, constrained to be post-Paleozoic.

Eureka District

The Newark Canyon Formation in the Eureka District contains the most abundant flora and fauna of the three areas studied. Fossils present include gastropods, pelecypods, ostracodes, fish, charophytes, angiosperms, and palynomorphs (MacNeil, 1939; David, 1941; Nolan and others, 1956; Fouch and others, 1979). Parts of the Newark Canyon Formation in the Eureka District contain abundant petrified wood; some logs approach 75 cm in diameter. Additionally, cursory prospecting has recovered an unidentifiable dinosaur bone fragment from Newark Canyon Formation talus. On the basis of nonmarine mollusk biostratigraphy, MacNeil (1939) interpreted the Newark Canyon Formation in the Eureka District to be temporally equivalent to the lower part of the Blairmore Group in Alberta, Canada, which is upper Barremian to early Albian.

Cockalorum Wash

Fossils present in the Newark Canyon Formation at Cockalorum Wash include ostracodes, charophytes, and palynomorphs (Fouch and others, 1979). R.H. Tschudy (writ. comm., 1979, in Fouch and others, 1979) indicated that the palynomorph assemblage recovered from Cockalorum Wash is Barremian to early Albian and is temporally equivalent to the Burro Canyon, Cedar Mountain, and Latoka Formations of the Rocky Mountains. Additionally, data in Fouch and others (1979) indicate temporal equivalence for Cockalorum Wash and Eureka District strata.

LITHOFACIES

Lithofacies are identified by simple one- to three-letter codes (Miall, 1977, 1978). Where lithofacies elements are not previously defined, new coding schemes are erected. Lithofacies in the Newark Canyon Formation include conglomerate (G), sandstone (S), fine-grained (F), and carbonate lithofacies. Figure 7 shows lithofacies symbols and patterns used in measured stratigraphic sections presented herein.

Conglomerate Lithofacies(G)

Massive or crudely stratified conglomerate (Gm)

Massive or crudely stratified conglomerate (Gm) occurs as both organized and disorganized clast-supported conglomerate beds. Organized conglomerates generally have a bimodal grain-size distribution, with pebble to boulder-sized framework clasts and a medium-grained sand to granular matrix (Miall, 1977). Crude horizontal stratification may or may not be apparent. Organized, clast-supported, massive conglomerate may have an erosive base as well as an upwards-fining clast size trend. Normal grading commonly occurs in the matrix. Sorting ranges from poor to moderate, and rounding ranges from angular to

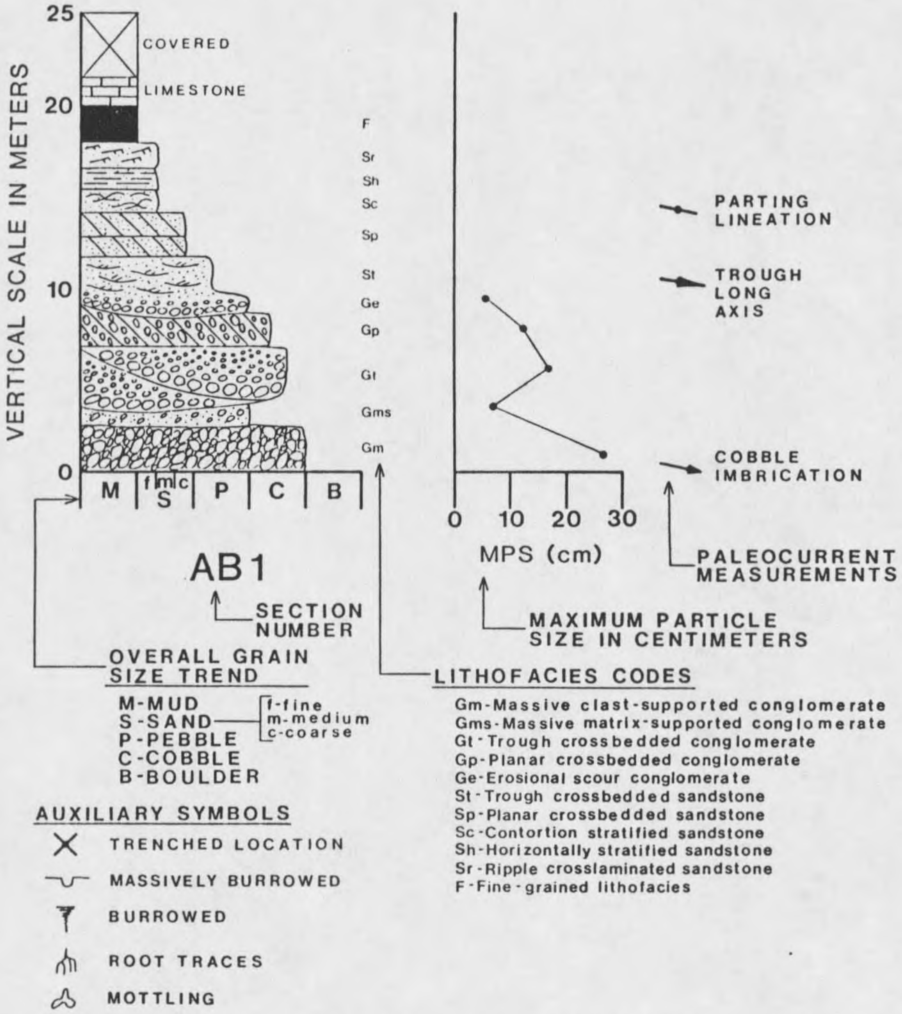

Figure 7. Key to lithofacies and symbols used in measured stratigraphic sections presented in this report. Refer to text for descriptions of individual lithofacies.

rounded. Organized Gm beds generally exhibit closed-framework packing, but units with open-framework packing are also present. Contact clast imbrication (long (a) axis transverse to flow, intermediate (b) axis imbricate, coded a(t)b(i)) is common (Harms and others, 1982). Some units display channel-shaped geometry, whereas others are tabular.

Disorganized, massive, clast-supported conglomerate (Gm) beds are characterized by a lack of sedimentary structures and organized fabric. They are more poorly sorted than organized massive conglomerates and the matrix consists of poorly sorted sand and pebbles. Both inverse and normal grading are present and conglomerates tend to occur in lenticular units. Contact clast (a(t)b(i)) and long-axis clast imbrication (a(p)a(i)) are present (Harms and others, 1982).

Massive matrix-supported conglomerate (Gms)

Gms lithofacies is characterized by polymodal gravel set in a matrix of poorly sorted sand and mud. In addition to matrix support, Gms lithofacies are characterized by an unordered fabric with no clast imbrication, grading, or apparent internal partings (Rust, 1978; Miall, 1978). The lower portions of some Gms units may be clast supported, with clasts aligned parallel to the basal contact. Basal contacts are typically non-erosive.

Trough crossbedded conglomerate (Gt)

These framework-supported conglomerates are characterized by distinct erosional, concave-up, scoop-shaped bases with coarse channel lags and upwards-fining tangential foresets separated by internal partings. Scour bases grade upward into smaller scale, finer grained crossbedded trough fill (Miall, 1977). Foresets generally occur at low angles, commonly less than 15 degrees. The long axes of elliptical scours are parallel to local flow directions, and elongate troughs are filled with scoop-shaped beds that plunge in a downcurrent direction (DeCelles and others, 1983). Trough cross-stratified conglomerates occur as broadly lenticular (on the scale of several tens of meters) or apparently tabular cosets.

Planar crossbedded conglomerate (Gp)

The Gp lithofacies is characterized by individual sets or cosets of tabular crossbedded conglomerate that rest upon essentially planar bases (Miall, 1977). Gravel foresets are commonly defined by sandy interbeds and/or alignment of flat pebbles or cobbles along dipping foreset surfaces. Erosional surfaces cross-cut foresets in the same sense, but at a lower angle of dip than the foresets (Collinson, 1970).

Erosional scour conglomerate (Ge)

The erosional scour conglomerate lithofacies (Ge - erected here) consists of planar to low angle concave-up symmetric or somewhat assymmetic erosional surfaces overlain by thin (commonly less than 50 cm) layers of massive pebble conglomerate. Ge lithofacies are commonly rich in mudclasts. This lithofacies is considered analogous to lithofacies Se as defined by Rust (1978) for erosional-based sandstone rich in intraclasts. Ge lithofacies tend to grade upwards into trough crossbedded sandstone.

Sandstone Lithofacies (S)

Trough crossbedded sandstone (St)

Trough crossbedded sandstone (St) consists of solitary concave-up scoops with an erosional relationship to underlying units, or cosets of mutually cross-cutting trough cross-strata (Miall, 1977). Each trough-shaped set consists of an elongate erosional scour filled with curved strata tangential to the underlying erosion surface. Long axes of the elliptical scours are parallel to local flow directions (Harms and others, 1975). Elongate troughs are filled with scoop-shaped laminae that plunge in a down-current direction. Fill of the troughs can be symmetric or somewhat asymmetric (Harms and others, 1975). Grain size ranges from medium to very coarse sand; pebbles may also be present. Cosets commonly display general upwards-fining trends with coarse sand and occasionally pebbly foresets resticted to lower sets and medium to fine-grained sand to higher sets.

Planar crossbedded sandstone (Sp)

Planar crossbedded sandstone (Sp) is characterized by grain size and sorting characteristics similar to those of lithofacies St. However, planar-tabular crossbed sets are distinguished from trough sets by: 1) straight or subsinuous laminae, as opposed to arcuate laminae (Harms and others ,1975), and 2) presence of flat, or slightly scoured planar bases and tops (Miall, 1977). Individual sets rest on essentially planar bases and possess tabular morphologies. Reactivation surfaces within grouped sets which truncate underlying foresets are common (Harms and others, 1975). Individual sets can persist laterally for several tens of meters.

Contortion stratified sandstone (Sc)

Contortion stratified sandstone lithofacies (Sc - erected here) are characterized by chaotic folds of graded beds and associated stratal disruptions (Coleman, 1969). Folded laminae consist of gentle to overturned isoclinal small-scale folds. Sandstone beds with highly contorted bedding are found associated with other crossbedded and stratified sandstone lithofacies.

Horizontally stratified sandstone (Sh)

Horizontal stratification is defined as tabular sets of horizontal to sub-horizontal layers of silt and sand (Miall, 1977). Parting lineation may be well developed and very small scale ripple marks may be present (Harms and others, 1982).

Ripple crosslaminated sandstone (Sr)

A variety of assymetric ripple types characterize Sr lithofacies. Ripple amplitude is less than 5 cm and grain size ranges from coarse to very fine sand; however, medium sand is most common (Miall, 1977). Internal stratification is defined by small scale trough sets with trough axes aligned parallel to local flow directions (Harms and others, 1975).

Fine-Grained Lithofacies (F)

This lithofacies is characterized by laminated fine-grained sediment, the grain size of which rarely exceeds that of fine sand. Interbedding of fine-grained sand, silt, and mud on a small scale is common. Very small-scale ripple marks, undulatory bedding, bioturbation, freshwater molluscs, and rootlet traces may be present (Miall, 1977).

Carbonate Lithofacies

A variety of carbonate lithofacies are present in the Newark Canyon Formation. Carbonate lithofacies, as defined by Miall (1977, 1978), are most commonly interpreted in terms of backswamp pond and pedogenic environments associated with fluvial systems. However, in the Newark Canyon Formation, carbonate lithofacies are interpreted in terms of lacustrine as well as pond and pedogenic environments. Therefore, for carbonates in the Newark Canyon Formation, the lithofacies nomenclature of Miall (1977, 1978) is abandoned and carbonates are described in terms of texture and primary structure. Additionally, since a high degree of textural variation is present within individual carbonate lithofacies, and carbonates in the Newark Canyon Formation are generally poorly exposed, a lithofacies coding scheme is not used.

Nodular micrite occurs as individual and amalgamated irregular masses encased within massive and laminated mudstone and siltstone (F). Beds of amalgamated micrite nodules are found only in the Eureka District. Sandy micrite also occurs interbedded with finely laminated silt- and mudstone (F) and nodular micrite in the Eureka District. Marlstone beds are characterized by massive calcareous claystone that forms irregular interbeds with massive micrite at Cockalorum Wash. Massive micrite is found in the Eureka District and at Cockalorum Wash.

Carbonaceous biomicrite beds occur in the Eureka District where they are interbedded with massive micrite and graded micrite. Laterally extensive, organic-rich, laminated calcareous mudstone contains calcified ostracodes, gastropods, pelecypods, and fish remains. Graded silty micrite beds consist of calcareous, upwards-fining beds on a millimeter to centimeter scale and are restricted to the Eureka District.

DEPOSITIONAL SYSTEMS

The nature of depositional facies in the Newark Canyon Formation at the three locations examined are suggestive of a variety of fluvial, fluvio-lacustrine, and lacustrine depositional environments. At each of the three locations examined, the stratigraphic sections are different with respect to thicknesses and lithofacies associations. Thus, they are treated separately in this section. Relationships between Newark Canyon strata at the different locations examined are discussed in later sections.

Overland Pass

Lower Conglomerate

Facies Assemblage. The Lower Conglomerate at Overland Pass is characterized by a dominance of clast-supported massive and horizontally stratified conglomerate (Gm), with subordinate trough crossbedded conglomerate (Gt) and planar crossbedded conglomerate (Gp), and trough crossbedded pebbly sandstone (St). One section was measured near Overland Pass where the Lower Conglomerate is relatively thin (105 m) (Figure 8); in exposures to the north and south the Lower Conglomerate is considerably thicker (greater than 450 m).

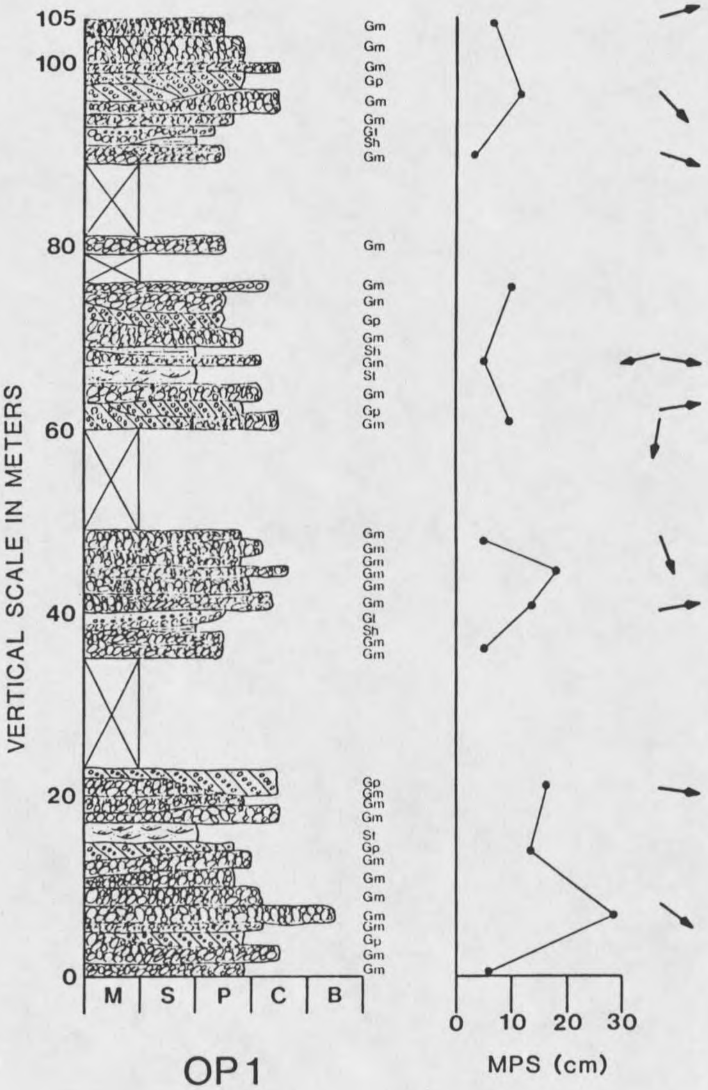

Figure 8. Measured stratigraphic section of the Overland Pass Lower Conglomerate. Refer to Figure 7 for key to lithofacies symbols and to Appendix A for section location.

Massive and horizontally stratified conglomerate (Gm) occurs as stacked and offset, superimposed, organized pebble to cobble conglomerate bodies up to 4 m thick. Closed-framework packing is most common, but units with open framework are also present.

Planar crossbedded conglomerate (Gp) occurs locally as tabular bodies adjacent to massive framework conglomerate (Gm) beds. Planar crossbedded conglomerate (Gp) beds average about 1 m thick and foresets average 30 cm thick. As many as 3 stacked sets are found although tabular sets are most commonly solitary. Clast sizes are pebble to small cobble. Trough crossbedded conglomerate (Gt) beds locally overlie massive and horizontally stratified conglomerate (Gm) (Figure 9) and are characterized by solitary, and rarely, amalgamated troughs averaging 1 m thick.

Trough crossbedded sandstone (St) interbeds occur as capping zones for planar or trough crossbedded conglomerate (Gp or Gt). Individual St beds up to 50 cm thick or amalgamated coset beds up to 3 m thick are present. Erosive bases of large scale solitary troughs are commonly rich in gravel lag.

Lithofacies are stacked and offset to form composite sheets that average about 15 m thick. Composite sheets have lateral dimensions on the scale of hundreds of meters. In turn, these composite sheets are also stacked and offset to form a broad multistory amalgam of lithofacies assemblage sheets.

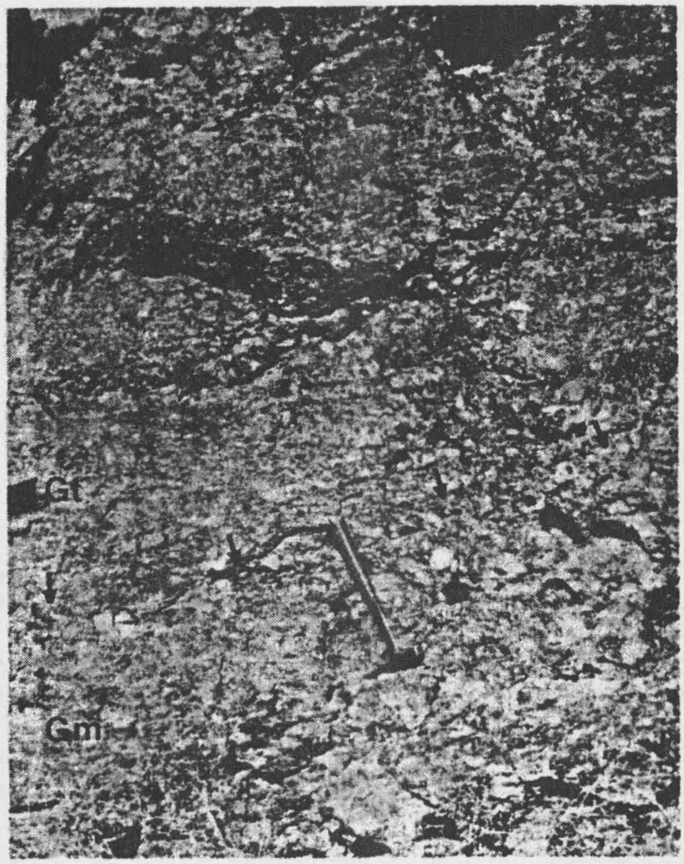

Figure 9. Large-scale trough crossbedded conglomerate (Gt) overlying massive, framework-supported cobble conglomerate (Gm) in Overland Pass Lower Conglomerate. Arrows point to Gt scour surface.

Considerable thickness variation occurs in the Lower Conglomerate. The Lower Conglomerate dominates the lower part of the Newark Canyon Formation section along the crest of the Diamond Mountains, but thins drastically eastward from a maximum of 450 m to less than 10 m along the eastern flank of the range. Thickness variations also occur in the Lower Conglomerate along strike of the Diamond Mountains, where the basal beds thicken and thin from a minimum of 60 m at Overland Pass to a maximum of 450 m in exposures 5 km to the south. Clast imbrication and crossbed data suggest a south-southeastward paleoflow direction; this indicates that thickness variations occur both approximately parallel and perpendicular to paleoflow direction.

Interpretation. The Lower Conglomerate is interpreted as the deposits of a proximal, gravel-bed, braided fluvial system. This conglomerate closely resembles the idealized Scott Type facies model of Miall (1978) and the Facies Assemblage GII of the Donjek River of Rust (1978).

The Lower Conglomerate is marked by a paucity of crossbedded conglomerate (lithofacies Gp and Gt), indicating that slip facies developed only occasionally. Hein and Walker (1977) suggest that slip faces develop when both sediment load and fluid discharge decrease after a flood event. With waning flow, bars aggrade faster vertically than laterally. The imbricated massive or horizontally stratified gravel (lithofacies Gm) was deposited as diffuse sheets (Hein and Walker, 1977) which aggraded vertically into longitudinal bars (Rust, 1972). Tabular bodies of planar crossbedded conglomerate (Gp) adjacent to massive and crudely horizontally stratified conglomerate (Gm) are interpreted as deltaic growths from modified dissected bar remnants formed during falling stage flow (Hein and Walker, 1977).

Trough crossbedded conglomerate (Gt) beds formed by in-filling of channel scours which developed during flood stage, during subsequent migration of three-dimensional large gravel ripples (Enyon and Walker, 1974; Bluck, 1974). Rust (1972) suggests that sandstone lithofacies (S) associated with trough crossbedded conglomerate (Gt) are deposited during falling stages where the water is not flowing rapidly enough to transport gravel, but is still capable of traction transport of coarse sand. Such conditions are common on the tops of bars as well as in channels (Bluck, 1979). Trough crossbedded sandstone (St), interbedded with crossbedded conglomerate, is interpreted as the deposits of migrating subaqueous dunes in open channel reaches where stream competence was lowered during low-stage flow.

Upper Sandstone

Facies Assemblage. Beds in the Upper Sandstone are dominated by trough crossbedded sandstone (St) with subordinate planar crossbedded sandstone (Sp), horizontally bedded sandstone (Sh), massive or horizontally bedded conglomerate (Gm), and minor laminated siltstone (F). A measured section of the Upper Sandstone is shown in Figure 10. This partial section is considered to be representative of the Upper Sandstone, although it is considerably thicker in exposures to the north and south of the location of the measured section.

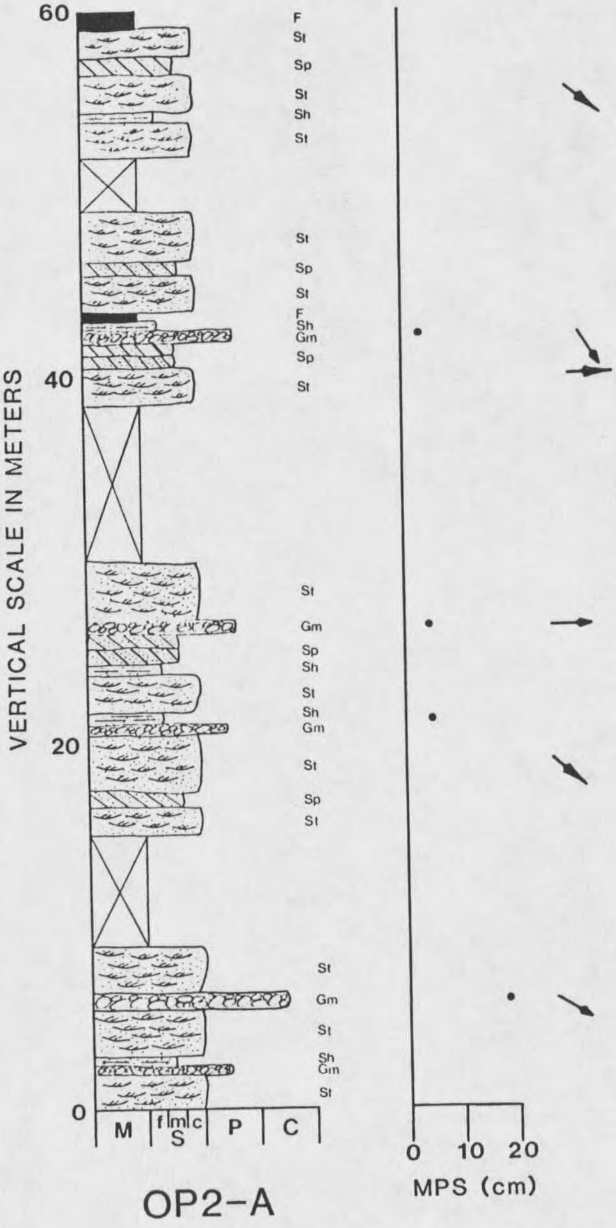

Figure 10. Measured stratigraphic section of the Overland Pass Upper Sandstone. Refer to Figure 7 for key to lithofacies symbols and to Appendix A for section location.

Lithofacies sequences in the Upper Sandstone consist of pebble to cobble massive conglomerate (Gm) interbedded with a sequence of crossbedded and stratified sandstone. Massive conglomerate bodies are laterally discontinuous and average about 0.75 m thick. Fine-grained, horizontally bedded sandstone (Sh) capping zones up to 40 cm thick, occasionally overlies Gm lithofacies. Medium grained trough crossbedded sandstone (St) cosets commonly overly conglomerates (Figure 11) and are broad, lenticular sheets that attain a maximum thickness of about 5 m. Trough crossbedded coset sheets commonly contain intraclasts. Planar crossbedded sandstone (Sp) beds are interbedded with trough crossbedded sandstone beds. Sp beds are medium grained, solitary set sheets averaging 40 cm thick, and locally grouped set sheets averaging about 2 m thick. Sp beds tend to grade upward into ripple crosslaminated sandstone (Sr). Laminated siltstone (F) beds form broad, thin sheets (commonly less than 50 cm thick) that are restricted to upper portions of the Upper Sandstone.

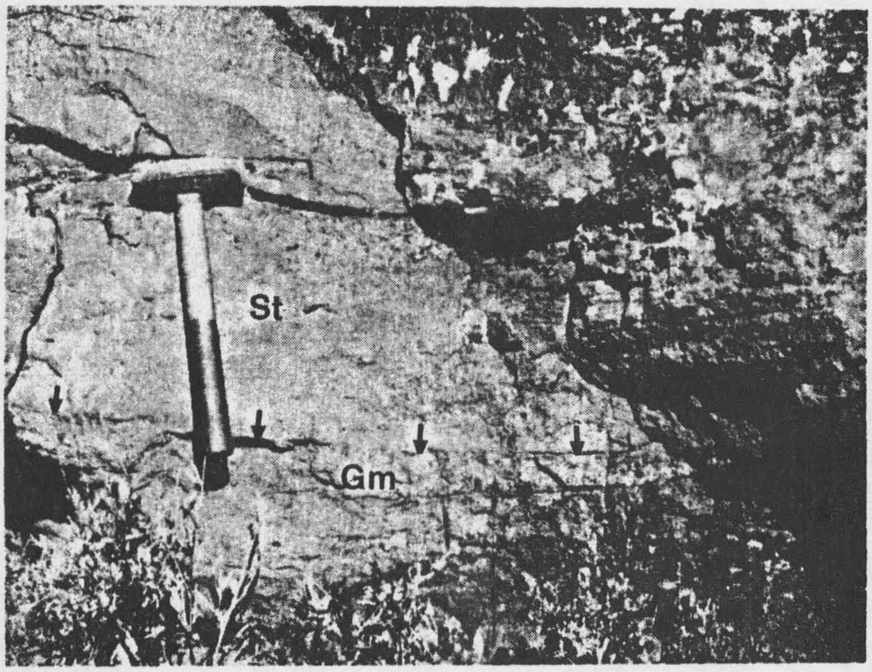

Figure 11. Trough crossbedded sandstone (St) overlying thin, massive, pebble conglomerate (Gm) in the Overland Pass Upper Sandstone. Arrows point to St scour surface.

Interpretation. The Upper Sandstone is interpreted as deposits of a distal, sand-dominant, braided fluvial system. Miall's (1978) South Saskatchewan Type model and Rust's (1978) Facies Assemblage S II serve as useful generalizations for comparison.

Cant (1978) shows that deposits of the braided South Saskatchewan River are dominated by an abundance of trough crossbedded sandstone (St) with subordinate massive conglomerate (Gm), planar crossbedded sandstone (Sp), horizontally bedded sandstone (Sh), rippled sandstone (Sr), and mudstone (F). Cant and Walker (1976) draw similarities between the South Saskatchewan River and the Devonian Battery Point Formation in Quebec, Canada, in which they identify repetitive upwards-finning sequences. Gm lithofacies beds are interpreted as the deposits of diffuse gravel sheets and low amplitude longitudinal bars (Smith, 1970). Horizontally stratified fine-grained sandstone (Sh), which overlies massive conglomerate (Gm), is interpreted as the deposit of transitional upper to lower flow regime conditions as waning high magnitude flow covered diffuse gravel sheets (Gm). Trough crossbedded sandstone (St) is interpreted to represent lower flow regime solitary or coalesced subaqueous migrating dunes (Smith, 1970). Solitary and grouped sets of planar crossbedded sandstone (Sp) are interpreted as deposits of sandy foreset accretion surfaces along the down stream margins of transverse bars, or sinuous crested transverse bars (liguoid bars) (Harms and Fahnestock, 1965). Under unidirectional flow, transverse sandwaves indicate lower flow strength conditions than are required for subaqueous dune migration (Harms and others, 1975). Ripple crosslaminated sandstone (Sr) indicates deposition by lower flow regime migrating ripples during waning flow and in shallow channels (Harms and Fahnestock, 1965; Smith, 1970). Laminated siltstone (F) deposition occurred by vertical accretion in overbank areas during waning flow conditions (Miall, 1977).

Predominance of trough cross-stratification and relative paucity of planar cross-stratification in the Upper Sandstone suggests that minimal volumes of transverse-bar and sand-flat deposits were preserved and that most preserved lithofacies were deposited in-channel. The rarity of vertical accretion deposits probably resulted from the erosive capacity of numerous concurrently active, shifting channels.

Eureka District

Basal Conglomerate/Mudstone

Facies Assemblage. Basal beds of the Newark Canyon Formation in the Eureka District consist of solitary and locally multistoried conglomerate lenses encased within massive and laminated, red and grey, siltstone and mudstone. Thickness of the Basal Conglomerate/Mudstone varies from 55 m at Cherry Spring to 70 m at Newark Canyon. Underlying Paleozoic formations display well developed weathering profiles up to 1.5 m. thick characterized by fracturing, brecciation, and leached and precipitated iron oxides. A measured section of the Basal Conglomerate/ Mudstone from the Newark Canyon area is shown in Figure 12.

Conglomerate lenses are highly variable in thickness and lateral dimension. Thicknesses range from 40 cm to 2.5 m and minimum lateral dimensions range from 5 to 15 m.

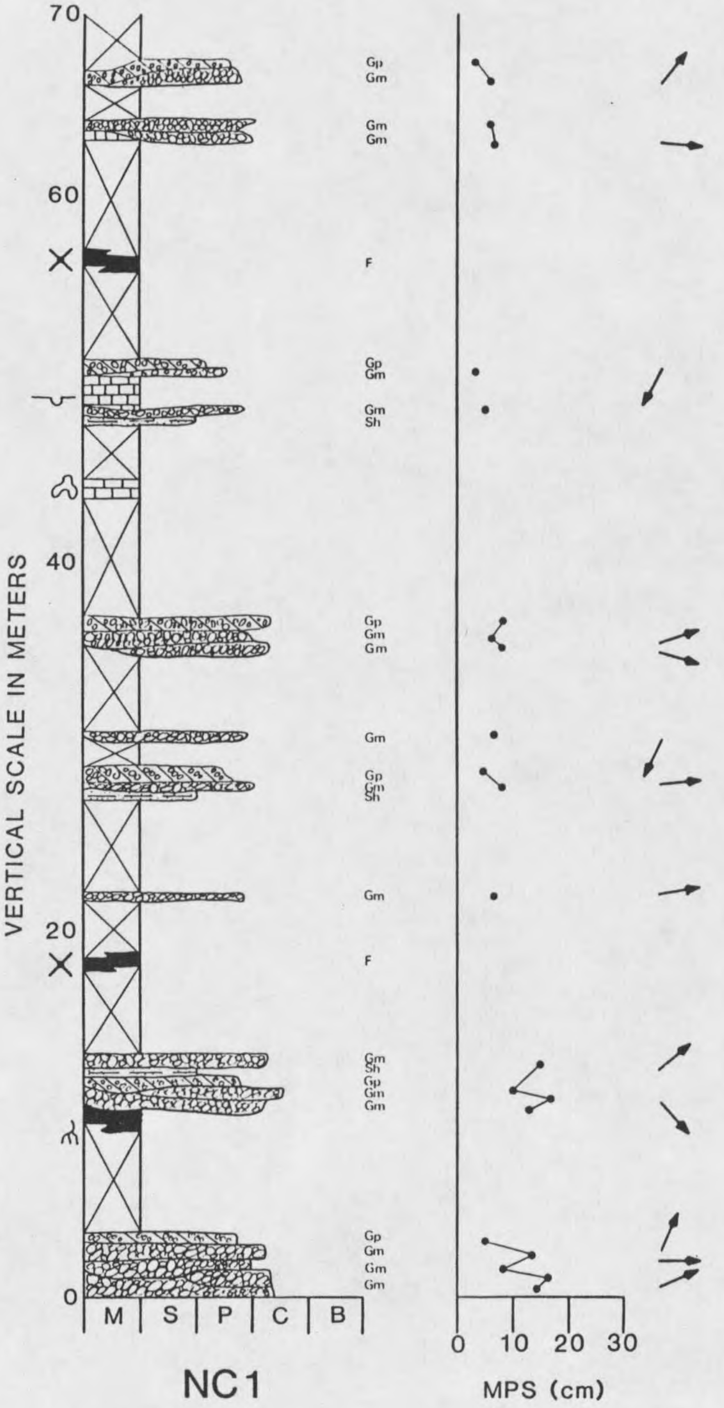

Figure 12. Stratigraphic section of the Eureka District Basal Conglomerate/Mudstone measured at Newark Canyon. Refer to Figure 7 for key to lithofacies symbols and to Appendix A for section location.

Bases of conglomerate lenses are shallow and concave-up, with locally abundant scour furrows into underlying fine-grained beds. Conglomerate bed margins tend to be steep-sided and rich in siliceous and calcareous mudclasts.

Conglomerate lenses consist of subequal amounts of disorganized massive pebble to cobble conglomerate (Gm) (Figure 13) and low-angle planar crossbedded pebble conglomerate (Gp). Clast imbrication in Gm beds is characterized by a(p)a(i) imbrication. Individual massive conglomerate beds are usually solitary, although locally up to 3 stacked beds are present. Planar crossbedded conglomerate (Gp) beds are characterized by very shallow dipping foresets (commonly less than 10 degrees), and are found overlying massive conglomerate beds, and occur down paleoflow from cobble to boulder massive conglomerate (Gm).

Unordered, matrix-supported, very poorly sorted conglomerate (Gms) forms lobate accumulations restricted to outer margins of conglomerate lenses. They appear to be entirely encased within massive, fine-grained rocks (F). Gms beds rarely exceed 1 m thick and lateral dimensions rarely exceed 7 m. Clasts are angular to rounded and clast sizes are pebble to cobble. Matrix consists of poorly sorted siliciclastic sand and silt and calcareous silt and mud. Clast imbrication is absent.

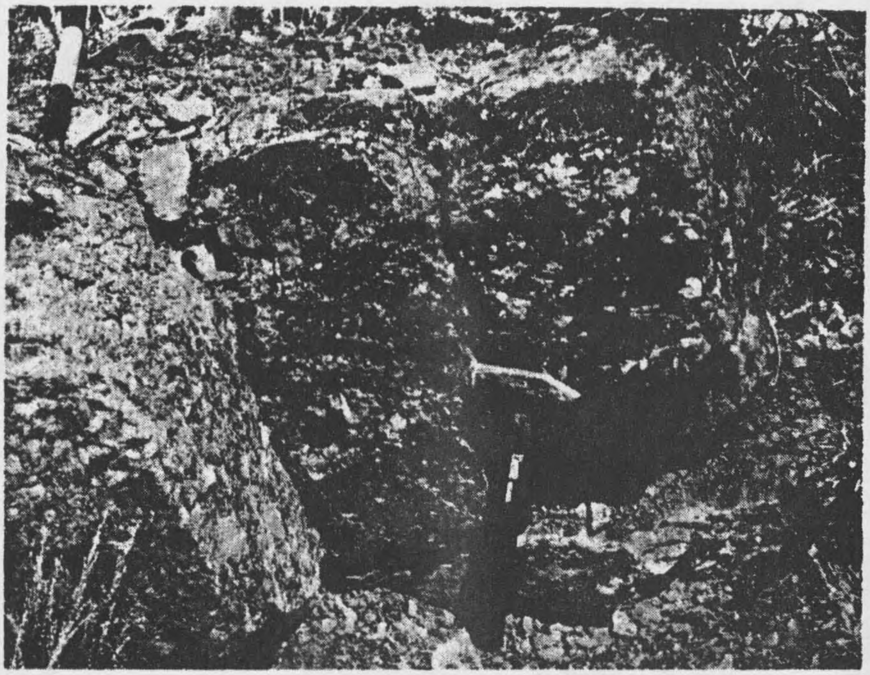

Figure 13. Disorganized, open-framework, massive, pebble-cobble conglomerate (Gm) lenticular bed in the Eureka District Basal Conglomerate/Mudstone at Newark Canyon. Note crude inverse grading.

Conglomerate lenses are typically entirely encased within fine-grained rocks (F). Unfortunately, interpretation of fine-grained rocks is hindered by poor exposure. At a few localities, trenches were dug allowing some general conclusions to be drawn. The fine-grained beds consist of red and grey, massive and laminated siltstone and mudstone (F). Zones of bioturbation, rootlet traces, and pedogenic microfabrics are common.

Interpretation. Crude clast imbrication, low-angle planar cross-stratification, and channel geometry suggests that conglomerate channelform bodies were deposited in alluvial channels which occupied a mud-dominant alluvial surface. The well preserved channel geometry, lack of lateral scour or accretion surfaces, and coarse-grained nature of channel-fill sediment in a mud-dominant system suggest that channel sediments aggraded vertically at a relatively high rate. Had the rate of aggradation been low, individual channels would have had time to scour into adjacent and underlying channel deposits. Additionally, a lower rate of aggradation would also have promoted the establishment of point bars, scroll bars, and meander loops, evidence for which is lacking. Scarcity of lateral-accretion surfaces (epsilon cross-stratification), and decrease in magnitude of sedimentary structures and grain-size in conglomerate beds serve to distinguish these beds from the deposits of meandering rivers (Jackson, 1978). Dominance of this sequence by fine-grained sediments with subordinate conglomerate, and channelforms which are steep-sided with little evidence of lateral scouring of adjacent channelfills serve to distinguish these beds from deposits of a braided fluvial system (Miall, 1977).

Within channelforms, occurrence of disorganized massive conglomerate (Gm) and low-angle planar foresets (Gp) indicates that down-current accretion surfaces were developed (Hein and Walker, 1977). Gm lithofacies are interpreted as vertically aggraded channel lags which formed the bed surface. Bed surface topography was created by accumulation of coarse sediment where stream competence was diminished to the point of being unable to transport the largest clasts; low-angle accretion surfaces were developed as fine-grained gravel was transported over and deposited on the lee-side of these coarse-grained accumulations (Enyon and Walker, 1974). Localized accumulation of coarse gravels within channelforms is suggestive of highly variable fluid-flow conditions. Presence of both inverse and normal grading, in addition to substantial amounts of a(p)a(i) clast imbrication, are further suggestive of variable flow competence and sediment load character (Harms and others, 1982). That a(p)a(i) clast imbrication is present suggests that elongate clasts did not roll on the bed surface (Harms and others, 1982); rather, they were transported in a dense dispersion above the bed until a sufficient decrease in flow strength occurred. According to Rees (1968), a(p)a(i) clast imbrication is a result of tilting of the principle clast axes during collision of the clasts. This type of fabric suggests that dispersive pressure, produced by clast collisions, was probably the most important supporting mechanism during transport. Maintenence of such a coarse-grained dispersion must have required considerable flow velocity and sediment load as might be attained in a flash flood (e.g. McKee and others, 1967).

Lobate accumulations of massive, unordered, matrix-supported conglomerate (Gms) adjacent to channelforms suggets that deposition of these beds occurred rapidly by sediment concentrated aqueous flow which breached fluvial channel banks resulting in the deposition of gravel intermixed with poorly-sorted matrix material. Although Gms lithofacies beds are most commonly interpreted in terms of a debris flow origin (e.g. Shultz, 1984), these beds lack characteristics commonly associated with deposits of debris flow origin such as well-developed inverse grading, channel-fill forms, and imbrication of elongate clasts (Smith, 1986).

The disconnected nature of floodplain channels and the mudstone asssociation indicates that sediment aggraded rapidly in an area of elevated base level (Allen, 1978). Smith and Smith (1980) note that vertically aggrading, disconnected (anastamosing) fluvial systems form in areas where relatively large amounts of sediment availability and low gradients result in rapid aggradation of floodplain alluvium. In many modern anastamosed systems, bank stability is maintained by abundant vegetation and organic material which form a significant proportion of the overall facies assemblage (Smith, 1976, 1983; Smith and Smith, 1980). However, unequivocal evidence for abundant plant colonization in the basal beds in the Eureka District is lacking. Conversely, Rust (1981) has indicated that anastamosed systems can develop in areas with arid climates and sparse vegetation. Bank stability is maintained by the natural cohesiveness of fine-grained overbank material and duricrust formation. Mudstone intraclasts are present in conglomerate channelforms suggesting early cementation and minimal transport of these clasts (Smith, 1972). Channel-bank stability in the Eureka District basal beds is interpreted to have been maintained by the natural cohesiveness of overbank fine sediment.

Lower Fine-Grained Assemblage

Facies Assemblage. Interbedded massive and laminated mudstone (F), sandy micritic carbonate, and nodular micritic carbonate characterize the middle portion of the Newark Canyon Formation in the Eureka District. This facies is thickest at Newark Canyon (220 m). Very poor exposure prevents as thorough evaluation of these strata as would be desired. However, scattered exposures and local trenching of unexposed sections allow some conclusions to be drawn.

Massive and laminated mudstone (F) is the dominant lithology in the Lower Fine-Grained Assemblage. Pink sandy micrite interbeds up to 0.5 m thick are localized towards the base of this sequence and exhibit close association with conglomerate channelforms of the underlying Basal Conglomerate/Mudstone. Grey nodular and amalgamated nodular micrite beds up to 1 m thick are interbedded throughout this facies.

Interpretation. The Lower Fine-Grained Assemblage is interpreted as the deposits of a siliciclastic and calcareous floodplain influenced by pedogenic processes. The assemblage of sandy micrite, nodular and amalgamated nodular micrite, and massive siliceous mudstone (F) is suggestive of paleosols and shallow lakes and ponds developed on a floodplain (Freytet, 1973). Nodular micrite resembles nodules which occur in some modern soils near the water table (Brewer, 1964). Carbonate mud, in the presence of an oscillating water, table was remobilized and concentrated with repeated wetting and drying (Brewer, 1964). Petrographically, sandy micrites show no textural trends. Micritic carbonate, silt- to fine sand-sized grains, and rare floating siderite rhombs are the sole constituents. Because of their small size, lateral impersistance, and close association with overbank mudstones and paleosols, sandy micrites are interpreted as small lake and pond deposits. Presence of siderite suggests locally reducing conditions on a poorly drained flood plain (Blatt and others, 1980, p.602). Petrographic analysis of indurated siliceous mudstone from this assemblage indicates the presence of altered glass shards (Figure 14). However, due to the extremely poor nature of outcrops, the distribution of volcanic ash vertically or laterally is unknown. Additionally, it is uncertain whether this ash is primary air-fall ash or has been reworked by fluvial processes.

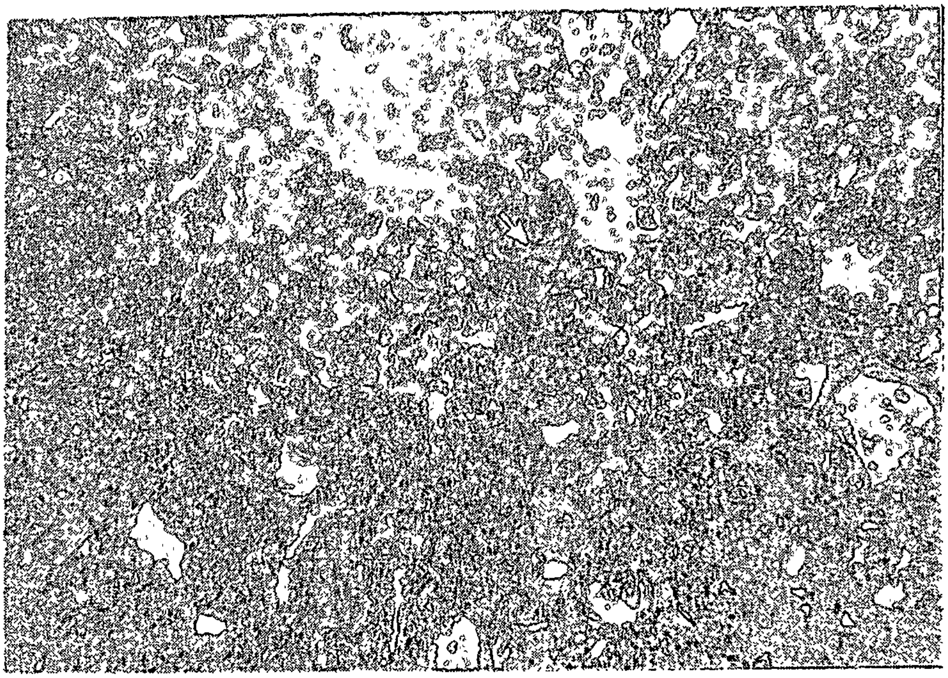

Figure 14. Photomicrograph of indurated mudstone containing altered volcanic ash in the Lower Fine-Grained Assemblage in the Eureka District. Arrow points to relict glass shards.

Middle Sandstone

Facies Assemblage. This assemblage consists of upward-fining lenticular sandstone bodies encased in fine-grained sediments (F). Measured sections of the Middle Sandstone are shown in Figures 15 and 16. Within sandstone bodies, both grain size and magnitude of sedimentary stuctures decreases upwards. Upward-fining sandstone bodies average 2.5 m thick. Sandstone bodies overlie scoured bases consisting of concave-up scoops of crudely stratified, erosional-based conglomerate (Ge). Basal conglomerates tend to be rich in mudstone intraclasts and grade upward into trough crossbedded pebbly sandstone (St), contortion stratified sandstone (Sc), horizontally stratified sandstone (Sh), and ripple crosslaminated sandstone (Sr). St lithofacies beds are coset amalgams which average 1.5 m thick with individual trough sets averaging about 30 cm thick. Contortion stratified sandstone (Sc) occurs as isolated lenticles near tops of trough crossbedded sandstone (St) beds. They attain a maximum thickness of 50 cm and are laterally discontinuous. Trough crossbedded sandstone (St) and contortion stratified sandstone (Sc) lenticles are overlain along planar bases by fine-grained horizontally stratified sandstone (Sh). Sh beds seldom exceed 20 cm thick. Overlying ripple crosslaminated sandstone (Sr) beds seldom exceed 40 cm thick, and consist of well sorted, fine-grained sand.

Upward-fining channelforms are best developed at Cherry Spring (Figure 15), where up to seven separate stacked and offset sandstone bodies are identified (Figure 17). At the other localities in the Eureka District, lenticular sandstone beds are not well developed and the Middle Sandstone is dominated by horizonatly stratified sandstone (Sh), and ripple crosslaminated sandstone (Sr) with subordinate, poorly-developed crossbedded sandstone (Figure 16).

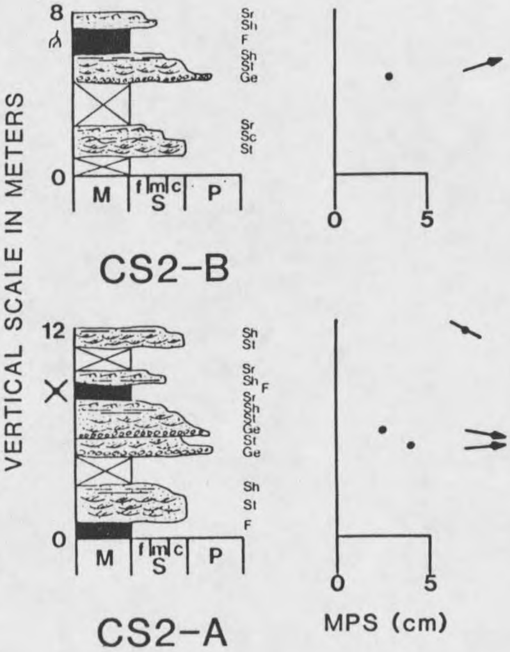

Figure 15. Measured stratigraphic sections of the Middle Sandstone at Cherry Spring in the Eureka District. Note well developed upward-fining sequences. Refer to Figure 7 for key to lithofacies symbols and to Appendix A for section locations.

<u>Interpretation.</u> Upward-fining beds in the Middle Sandstone are interpreted as deposits of a graveliferous sand-bed meandering fluvial system (Jackson, 1978). Erosional-based conglomerate (Ge) is interpreted as diffuse gravel lag deposited in channel scours (Bluck, 1971). Mudclasts originated from bank erosion and destruction of mud layers deposited during low-stage flow (Williams, 1966). Flume experiments by Smith (1972) indicate that mudstone intraclasts withstand little transport and must originate locally. Crossbedded sandstone overlying basal conglomerate lags are interpreted as lower point bar

deposits (Levey, 1978). The trough-shaped sets were formed by migrating dunes similar to those found on recent point bar lower surfaces (Harms and others, 1963; Levey, 1978). Contortion stratified sandstone (Sc) represents syndepositional deformation of liquified sediments. Similar structures are common in recent fluvial sediments where they may form in response to rapid fluctuations in river stage (Coleman, 1969). Horizontally bedded sandstone (Sh) and ripple crosslaminated sandstone (Sr) are interpreted as deposits of upper point bar surfaces (Bluck, 1971). Horizontally laminated sandstone is produced in shallow water on tops of bars where increasing flow velocities result from large volumes of water being forced into a confined space (Harms and Fahnestock, 1965; Smith, 1971). Erosion at the base of horizontally laminated sandstones occurred during flood stage, followed by deposition of upper flow regime beds at falling stage (Allen, 1974). The upward transition from flat bedding to ripple crosslamination has been recorded from flood deposits (McKee and others, 1967) and was produced by migrating ripple trains formed at lower flow regimes (Harms and Fahnstock, 1965). Fine-grained sediments interbedded with conglomerate-sandstone channelforms represent levee deposits which accumulated adjacent to fluvial channels (Stewart, 1982). The complex intertonguing of conglomerate-sandstone and siltstone lithologies is caused by repeated erosion and deposition during the flood cycle (Jackson, 1978).

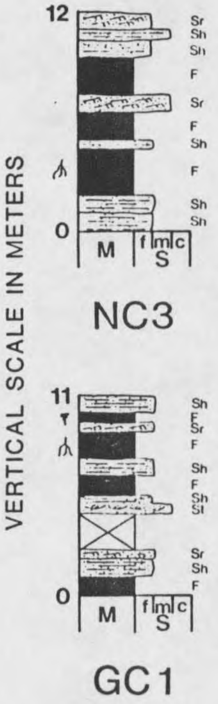

Figure 16. Measured stratigraphic sections of the Middle Sandstone at Newark Canyon in the Eureka District. Note the predominance of fine-grained lithofacies (F), and interbedded horizontally stratified and ripple crosslaminated sandstone (Sh and Sr). Refer to Figure 7 for key to lithofacies symbols and to Appendix A for section location.

Channel lag and point bar sequences dominate sandstone beds in the Middle Sandstone at Cherry Spring (Figure 15). At other locations (Newark Canyon, and Pinto Creek Spring), this assemblage is dominated by laminated sandstone and siltstone (Figure 16). Meanderbelt channel development was restricted to the southern extent of the outcrop area (at Cherry Spring); at other locations, deposition was by channel levee, crevass splay, and floodplain mud deposition with subordinate channel development. In the Newark Canyon area, this facies is dominated by sediments interpreted as floodplain crevass splay and vertical aggradation deposits (Figure 16).

Figure 17. Stacked, superimposed, upward-fining sandstone beds in the Middle Sandstone at Cherry Spring in the Eureka District. Arrows point to base of erosion-based conglomerate (Ge), scoured into underlying sandstone bed. Note upward decrease in grain size and magnitude of sedimentary structures in each sandstone bed. Figure for scale.

Upper Conglomerate

Facies Assemblage. Conglomerate beds interbedded with massive and laminated fine sandstone and siltstone (F) form the Upper Conglomerate. The most complete preserved and exposed sequence of this assemblage is found at Newark Canyon, where these strata attain a maximum thickness of 70 m. At Newark Canyon, up to six distinct lenticular conglomerate beds are identified (Figure 18). At other locations (Cherry Spring, Hildebrand Canyon, and Pinto Creek Spring), the upper portions of this facies and the overlying Upper Carbonaceous assemblage have been removed by erosion or are tectonically obscured. A measured section of the Upper Conglomerate at Newark Canyon is shown in Figure 19.

Conglomerate beds are 2 to 8 m thick and range from about 50 to 250 m in minimum horizontal extent. Most conglomerates are encased in fine-grained strata (F), although a few are amalgamated and offset. Conglomerate beds are characterized by large-scale trough crossbedded pebble to cobble conglomerate (Gt), with subordinate massive and crudely stratified pebble to cobble conglomerate (Gm), trough crossbedded pebbly sandstone (St) and horizontally bedded sandstone (Sh). Organized, massive conglomerate (Gm) wedges commonly form the basal beds in conglomerate sheets. Gm beds occur as scour-based beds that are 0.75 to 2.5 m thick. Massive framework conglomerate

(Gm) beds are either overlain gradationally by horizontally bedded pebbly sandstone (Sh), or are overlain along scour bases by trough crossbedded conglomerate (Gt). Trough crossbedded conglomerate beds are well sorted, with well developed channel scour and fill. Individual scoop-shaped trough sets range from 1 to 2.5 m thick by 6 to 10 m wide. Maximum clast sizes locally approach cobble, although trough sets are usually comprised of well-sorted pebble conglomerate with minimal coarser or finer material. Trough crossbedded conglomerates are occasionally rich in muddy or silty intraclasts. As many as three stacked and laterally offset trough sets may be found, although sets are most commonly solitary and tend to grade upwards into trough crossbedded pebbly sandstone (St). St beds occur as isolated scoop-shaped troughs up to 1 m thick, or as coset amalgams up to 2 m thick. Isolated sandstone troughs are usually rich in lag gravel. Coset amalgams are broad, shallow, concave-up based sheets that grade upwards into horizontally stratified sandstone (Sh). Sh beds near the top of conglomerate beds are thin (usually less than 30 cm) sheets of pebbly, coarse-grained sandstone with parting lineation. Although poorly exposed, scattered exposures and local trenching indicate that fine-grained beds which encase conglomerate sheets appear to be dominated by massive and faintly laminated fine-grained sandstone and siltstone (F).

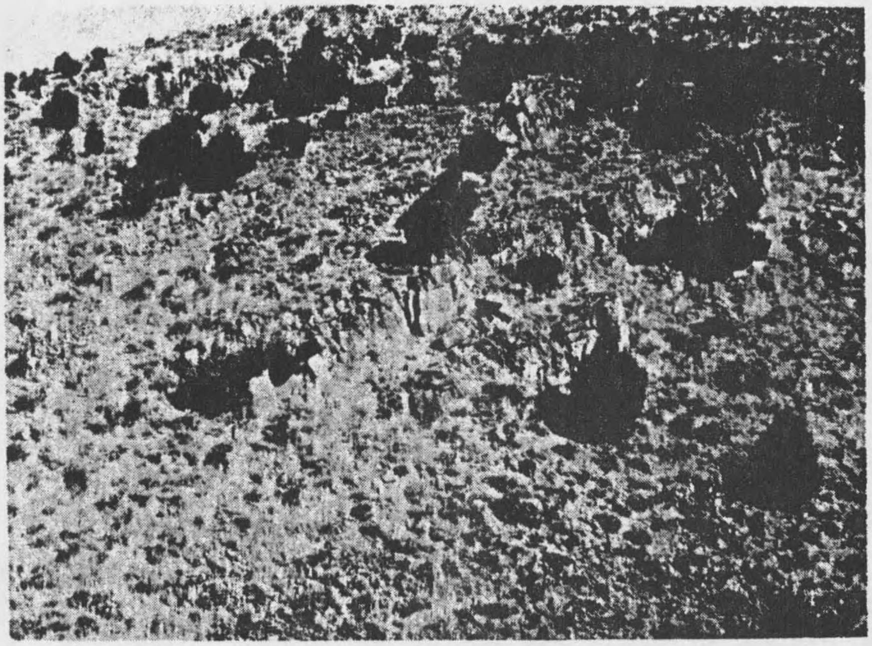

Figure 18. Sequence of six conglomerate beds in the Upper Conglomerate at Newark Canyon in the Eureka District. Arrow points to person for scale.

Interpretation. Conglomerate beds in the Upper Conglomerate are interpreted as deposits of high magnitude flow, gravel-bed, braided fluvial systems. Conglomerate sheets resemble the idealized Donjek type facies model of Miall (1978), representative of gravel-bed, braided fluvial environments intermediate between proximal and distal for alluvial systems. Deposits of modern gravel-bed, braided systems are commonly sheet-like and display a high degree of lateral variability and discontinuity, resulting from the relative ease with which braided channels shift back and forth across the alluvial surface (Rust, 1972; Smith, 1974).

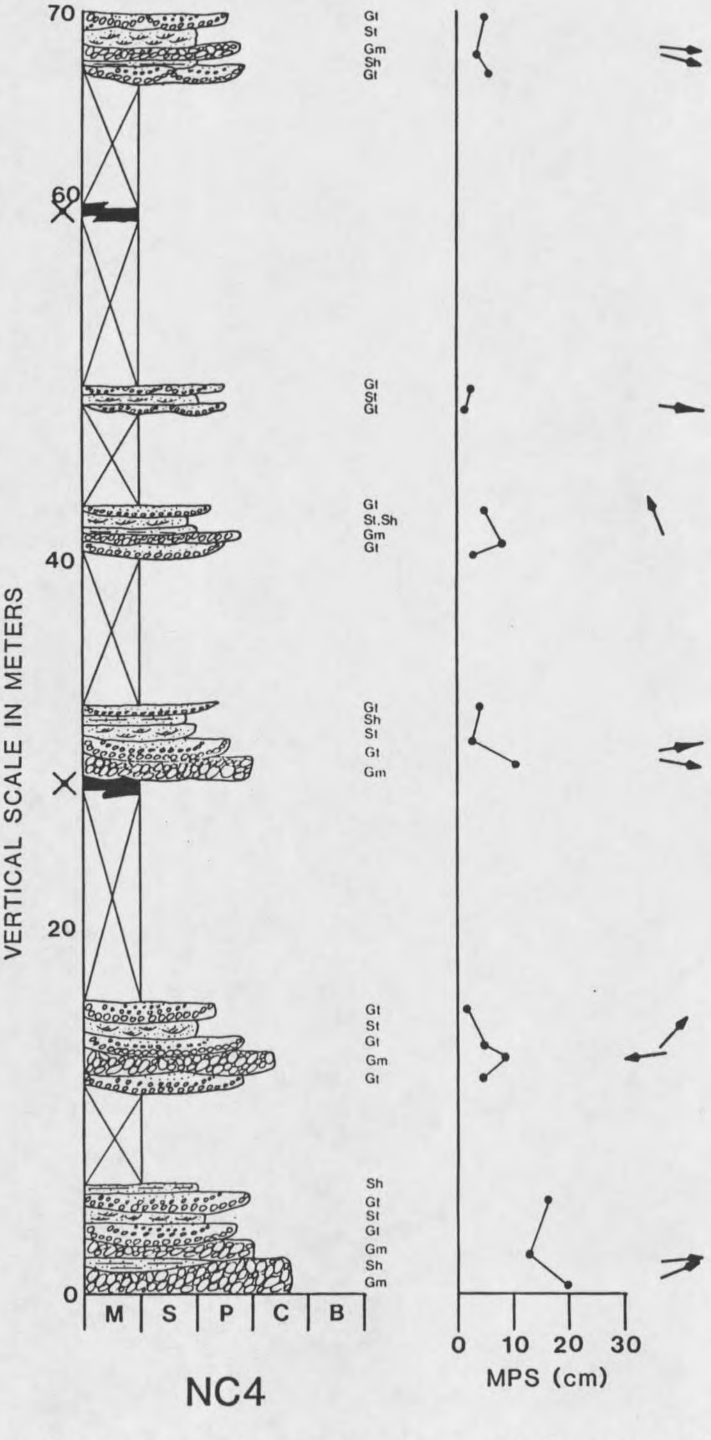

Figure 19. Stratigraphic section of the Eureka District Upper Conglomerate measured at Newark Canyon. Refer to Figure 7 for key to lithofacies symbols and to Appendix A for section location.

Conglomerate beds are marked by an abundance of trough crossbedded conglomerate (Gt), which usually truncates adjacent massive conglomerate (Gm), suggesting that fluid flow modifications of massive gravels occurred (Hein and Walker, 1977). Diffuse gravel sheets aggraded vertically into longitudinal bars; as the bars grew in height, gravel rolled across the top and avalanched down the sides and end of the bars. With persistant discharge and sufficient flow depth, longitudinal bar dissection occurred as vertically aggrading gravel sheets had time to equilibrate with fluid discharge (Rust, 1978). Trough crossbedded conglomerates in Upper Conglomerate represent channel cut and fills, formed during dissection of the bar top and/or front, and subsequently filled in by large-scale gravel ripples during rising stage (Enyon and Walker, 1974). Upward gradation from trough crossbedded conglomerate (Gt) to trough crossbedded sandstone (St) and horizontally laminated (Sh) sandstone indicates that as channel depths decreased, flow competence was decreased. At this point, water was not flowing rapidly enough to transport a gravel load, but was still capable of traction transport of coarse sand and granules (Smith, 1970).

Presence of large-scale conglomerate sheet channelforms in an overall fine-grained sequence suggests deposition on an inland interdistributary alluvial plain similar to that of the Kosi River in India (Gole and

Chitale, 1966). Where the Kosi River enters the Gangetic Plain, it creates an alluvial plain by dividing into several fluvial channels spread over a width of up to 20 km. The large catchment basin above the Gangetic plain provides enormous amounts of water and transported sediment that, upon entering the Gangetic plain, the Kosi River is unable to transport and unload in the main channel. The result is that, in the process of building its alluvial plain, channel development is characterized by numerous channel avulsions (Wells and Dorr, 1987). Overbank flood events result in deposition of copious amounts of overbank fine-grained sediment adjacent to braided fluvial channels. The consequence is that thick overbank deposits are preserved because channels occupy a small portion of the alluvial surface. Large portions of the floodplain are frequently inundated during the flood events. These conditions allow for accumulation of significant amounts of overbank material between times when braided fluvial channels shift across any particular region.

Upper Carbonaceous Assemblage

Facies Assemblage. The Upper Carbonaceous Assemblage consists of four distinctive lithofacies: 1) grey siliciclastic mudstone (F), 2) massive micritic carbonate, 3) biomicritic carbonate, and 4) graded micritic carbonate. This assemblage is best exposed at Newark Canyon; at Cherry Spring and Pinto Creek Spring, this part of the section has been removed by erosion. At Hildebrand Canyon, this facies was recognized, but structural complications and poor exposure prevent thorough evaluation. The Upper Carbonaceous Assemblage is potentially thicker at Hildebrand Canyon than at Newark Canyon, but this remains uncertain. At Newark Canyon the Upper Carbonaceous Assemblage attains a thickness of 120 m.

Grey massive siliciclastic mudstone (F) similar to mudstones in underlying facies dominates the lower portion of and is interbedded throughout this assemblage. Towards the top of this assemblage, biomicrite, graded micrite, and massive micrite interbeds are found. Micrite beds weather to a tan color, but fresh surfaces tend to be dark black and are rich in organic material. Biomicrite beds contain flora and fauna that characterize the Newark Canyon Formation (MacNiel, 1939; David, 1943; Bradley, 1963; Fouch and others, 1979). Fossils present include gastropods, pelecypods, ostracodes, charophytes, and palynomorphs. Micrite beds contain individual graded laminations that range in thickness from less than 1 mm to greater than 1 cm and are composed of silt to mud-sized detrital quartz and feldspar-rich micrite that grade upward into more pure carbonate mudstone (Figure 20). All contacts between individual laminae are sharp and erosional. Many are wavey, and display convolute bedding, microflame structures, and micro-loadcasts.

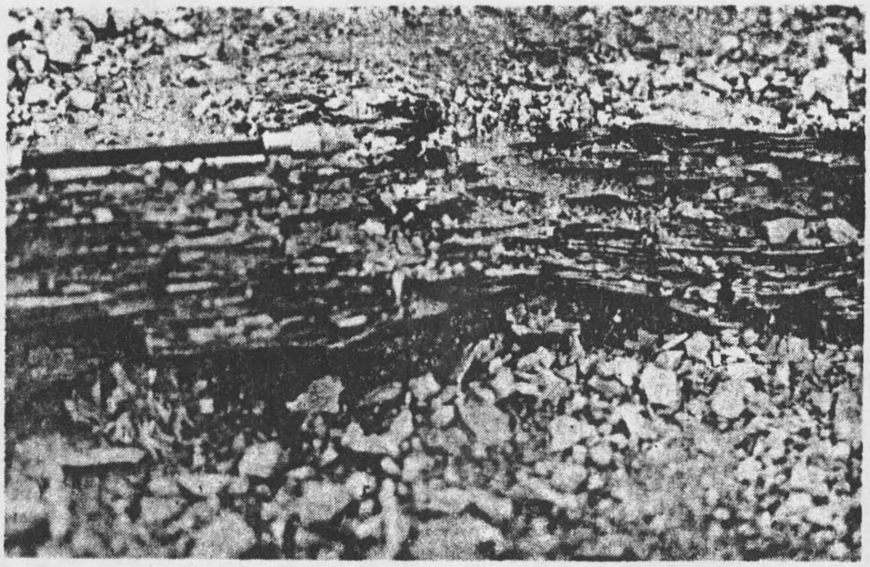

Figure 20. Micrite laminations in the Upper Carbonaceous Assemblage at Newark Canyon in the Eureka District. Note slightly undulatory nature of bedding and truncation of preceeding layers by successive beds.

<u>Interpretation.</u> The Upper Carbonaceous Assemblage is interpreted as the deposits of a progressively deepening, temperate, freshwater, lake. Glass and Wilkinson (1980) describe early Cretaceous lacustrine carbonate sediments in the Peterson Limestone in western Wyoming and southeastern Idaho that bear many similarities with carbonaceous mudstones in the Eureka District. Glass and Wilkinson (1980) interpret graded micrite beds as the deposits of turbid waters carrying terrigeneous silt and carbonate mud from shallow lake margin areas towards deeper parts of the lake basin. Abrupt lateral terminations of rhythemic sequences and folded laminations were caused by soft-sediment gravity slumping during deposition of successive units.

Biomicrite beds are interbedded with graded micrite beds. Glass and Wilkinson (1980) note this relationship in the Peterson Limestone and suggest that biomicrite beds were deposited in shallower water than were graded micrite beds. Massive micrite beds are interbedded with biomicrite beds suggesting that massive micrite beds were extensively bioturbated, thus obscuring primary sedimentary textures.

Carbonaceous mudstone at the top of the Newark Canyon Formation in the Eureka District contains several meters of "oil shale" (T.B. Nolan, pers. comm., 1986) that has a pyrolitic oil yield of greater than 10 gallons per ton (40 liters per tonne) (Fouch and others, 1979). Bradley (1963) indicates that the source of lipids here is locally abundant carbonaceous bacteria, and suggets that these beds were deposited in an organic-rich, closed basin lacustrine environment similar in nature to the Green River Formation (Desborough, 1978).

Cockalorum Wash

Basal Conglomerate

Facies Assemblage. The lower 30 m of the Newark Canyon Formation at Cockalorum Wash is characterized by massive and crossbedded conglomerate with lesser amounts of crossbedded and stratified sandstone. A measured section of the Basal Conglomerate is shown in Figure 21. At the base of the Basal Conglomerate, organized, massive and crudely stratified cobble to boulder conglomerate (Gm) beds predominate (Figure 22). As much as 10 m of amalgamated scour-based framework conglomerate (Gm) beds averaging 2 to 3 m thick are present. Mudstone intraclasts locally make up to 5% of the clast populations. Locally, where these lithofacies have not been scoured, Gm beds grade upward into horizontally bedded pebbly sandstone (Sh). Sh beds tend to be wedge-shaped and average 50 cm thick.

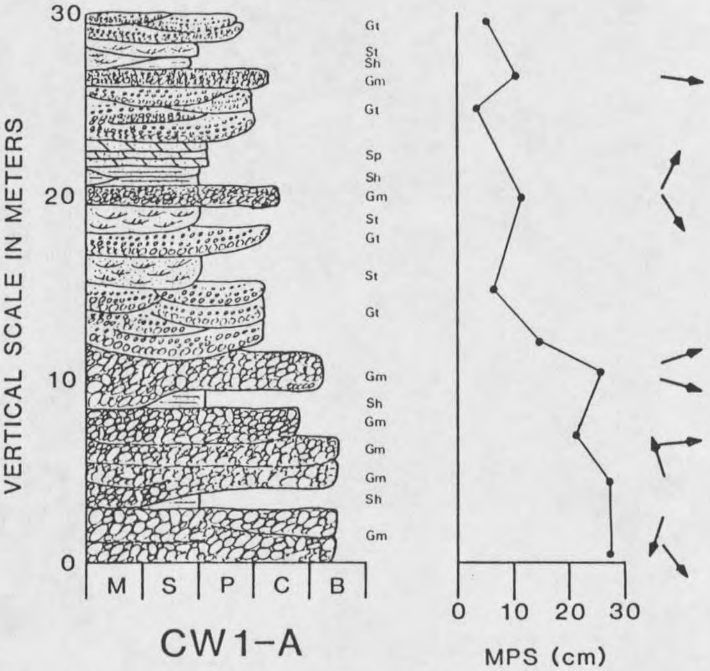

Figure 21. Measured stratigraphic section of the Cockalorum Wash Basal Conglomerate. Refer to Figure 7 for key to lithofacies symbols and to Appendix A for section location.

Above the Gm dominated sequence, the Basal Conglomerate grades upward into a trough crossbedded conglomerate (Gt) dominated sequence (Figure 21). Massive framework conglomerate (Gm), trough crossbedded sandstone

(St), planar crossbedded sandstone (Sp), and horizontally stratified sandstone are subordinate lithofacies in the upper portion of the Basal Conglomerate. Gt lithofacies beds are moderately-sorted pebble to cobble conglomerate of solitary, and locally grouped, scoop-shaped troughs. Massive and horizontally statified pebble to cobble conglomerate (Gm) beds in the upper Basal Conglomerate occur as wedge-shaped bodies which average about 0.75 m thick. Trough crossbedded pebbly sandstone (St) occurs as broad, shallow, amalgamated cosets which attain a maximum thickness of 2 m. Coarse-grained, planar crossbedded sandstone (Sp) occurs in planar based solitary sets interbedded with trough crossbedded sandstone (St) and massive conglomerate (Gm) (Figure 23). Horizontally stratified sandstone (Sh) occurs as thin (usually less than 20 cm thick) impersistant beds interbedded with other sandstone lithofacies.

Interpretation. The Basal Conglomerate is interpreted as the deposits of a transitional proximal to distal gravel-bed, braided fluvial system. The idealized Scott Type and Donjek Type facies models of Miall (1978) and the Facies Assemblage GII and GIII of the Donjek River of Rust (1978) serve as useful analogues for comparison.

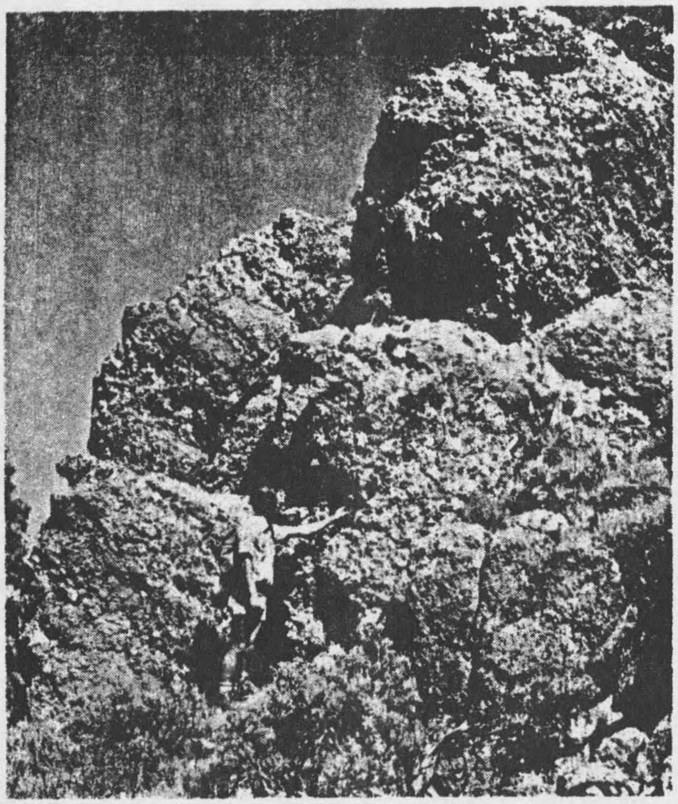

Figure 22. Stacked and offset massive cobble to boulder framework conglomerate (Gm) beds at the base of the Cockalorum Wash Basal Conglomerate. Note wedge-shaped bodies of horizontally stratified sandstone (Sh) interbedded with massive conglomerate. Figure for scale.

Presence of large amounts of mudstone intraclasts in the basal beds suggests that deposition was on unconsolidated fine-grained sediments and that mudclasts were transported minimal distances (Smith, 1972). Absence of mudstone in the Basal Conglomerate, in contrast with a preponderance of mudclasts, is problematic; underlying fine-grained strata are not exposed and may have been tectonically removed, since the Basal Conglomerate is in fault contact with underlying Paleozoic formations (Hose, 1983).

Figure 23. Massive pebble to cobble conglomerate (Gm) overlain along a planar base by planar crossbedded sandstone (Sp) and scoured into by large-scale trough crossbedded conglomerate (Gt). From the upper part of the Cockalorum Wash Basal Conglomerate.

The massive and horizontally stratified conglomerate (Gm) dominated base is characterized by a marked lack of cross-stratification, indicating that slip faces were not developed. Deposition is interpreted to have occurred as numerous superimposed longitudinal bars accumulated during falling flow stage as vertically aggraded coarse-grained bedload (Rust, 1972; Smith, 1974). Subsequent bar growth took place by addition of finer sediment on top of and downstream from the bar nucleus during high-magnitude flow events (Hein and Walker, 1977). Cross-stratification is not developed because longitudinal bars were primary bedforms that had equilibrated with flow conditions (Rust, 1978).

A stream-flow dominated system is indicated by the presence of an upward gradation from massive, framework conglomerate (Gm) to horizontally laminated pebbly sandstone (Sh), indicating that bar top planar bedflow occurred (Bluck, 1979).

The upper 20 m of the Basal Conglomerate is interpreted as the deposit of a distal, gravel-bed braided fluvial system. Rust (1978) notes that the Facies Assemblage GIII (Donjek Type facies model of Miall (1978)) is characterized by a cyclic nature of lithofacies. Cyclicity in the upper Basal Conglomerate consists of a basal massive conglomerate (Gm) overlain successively by trough crossbedded conglomerate (Gt), trough crossbedded sandstone (St), planar crossbedded sandstone (Sp), and horizontally bedded sandstone (Sh). These lithofacies sequences are repeated at least three times and as many as five times in the Basal Conglomerate (Figure 21). Massive conglomerate (Gm) is interpreted as the result of deposition of in-channel diffuse gravel sheets and vertically aggraded low amplitude longitudinal bars (Hein and Walker, 1977). Trough crossbedded conglomerate (Gt) is interpreted as in-channel deposition of migrating gravel foresets with crescentic slip faces (Rust, 1978). Overlying crossbedded and laminated sandstone is interpreted as deposition of foreset macroforms in broad, shallow channels (Harms and others, 1975). Individual cycles record development of major gravelly channel or channel systems, followed by deposition of foreset macroforms in open channel reaches, and finally planar bedflow during waning flow conditions (Bluck, 1979).

Lower Sandstone

Facies Assemblage. Thirty meters of poorly exposed sandstone with subordinate framework conglomerate interbeds lies above the Basal Conglomerate . Scattered outcrops suggest that this assemblage consists of, in order of abundance, trough crossbedded sandstone (St), massive pebble conglomerate (Gm), planar crossbedded sandstone (Sp), horizontally bedded sandstone (Sh), and ripple crosslaminated sandstone (Sr). Measured partial sections of the Lower Sandstone are shown in Figure 24. Medium-grained, trough crossbedded sandstone (St) beds consist of large scale amalgamated trough cosets which approach 3 m thick. Laterally discontinuous Gm beds approach 1 m thick and rest on concave-up bases. Fine-grained, planar crossbedded sandstone (Sp) commonly overlies massive pebble conglomerate (Gm) along planar bases. Planar crossbedded sandstone (Sp) beds are characterized by as many as four grouped sets which attain a maximum thickness of 1.5 m. Sp beds, in turn, grade upward into fine-grained, horizontally bedded sandstone (Sh), and fine-grained ripple crosslaminated sandstone (Sr).

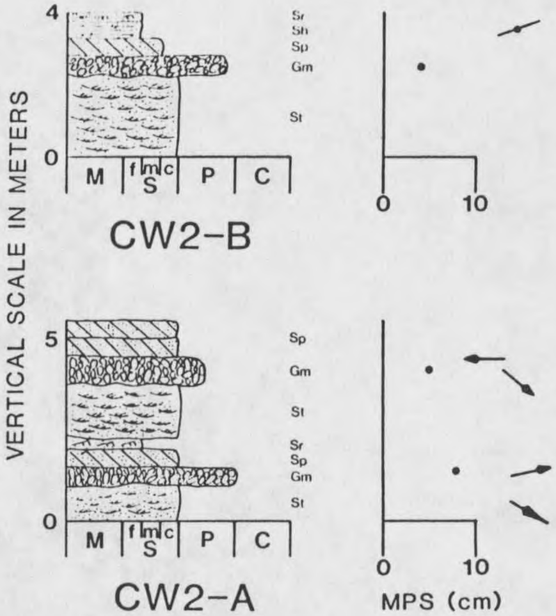

Figure 24. Measured stratigraphic sections of the Cockalorum Wash Lower Sandstone. Refer to Figure 7 for key to lithofacies symbols and to Appendix A for section locations.

<u>Interpretation.</u> The Lower Sandstone is interpreted as the deposit of a distal, sand-dominant braided fluvial system. Miall's (1978) South Saskatchewan Type model serves as a useful example for comparison with the Cockalorum Wash Lower Sandstone.

Cant (1978) showed that deposits of the South Saskatchewan River are dominated by trough crossbedded sand (St), with subordinate planar crossbedded sand (Sp), massive gravel (Gm), horizontally stratified sand (Sh), and ripple crosslaminated sand (Sr), and minor amounts of overbank fine-grained material (F). Compound bars, representing transverse bar and sand-flat deposition, are characterized by a basal conglomerate channel lag (Gm), with overlying planar crossbedded sand (Sp) successively overlain by horizontally laminated and ripple crosslaminated sand (Sh and Sr), and fine material (F) (Rust, 1978). Channel systems are characterized by basal channel lags (Gm) with overlying large-scale trough crossbed sets.

The Lower Sandstone is characterized by alternating major channels and compound bars as defined by Cant (1978). Compound bars are represented by Gm-Sp-Sh-Sr intervals and channel systems are represented by Gm-St intervals. Channel systems and compound bars are stacked and laterally offset with respect to each other. Predominance of trough crossbedded sandstone (St) indicates that the braided fluvial system was dominated by numerous shifting channels which inhibited preservation of transverse bar and sand-flat deposits.

Upper Sandstone

Facies Assemblage. The Upper Sandstone consists of upward-fining beds which average 1.5 m thick. Sandstone beds are encased within laminated siltstone (F). This assemblage attains a maximum thickness of 40 m. Measured sections of the Upper Sandstone are shown in Figure 25.

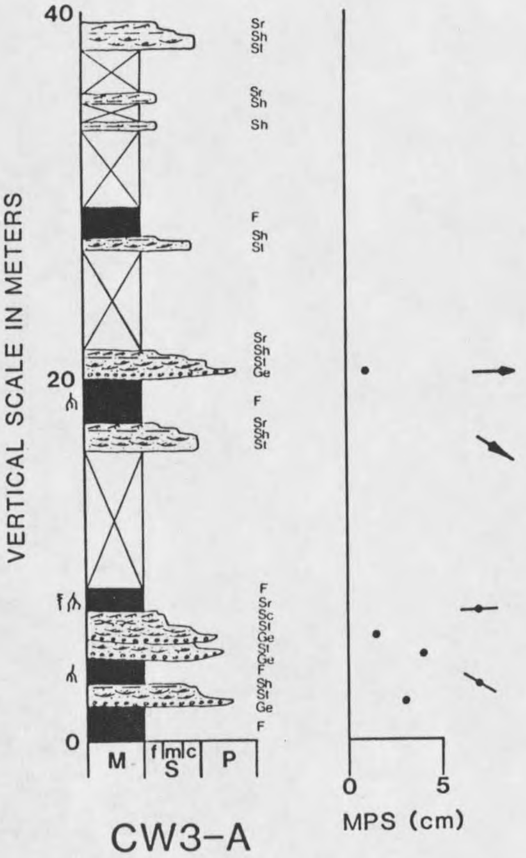

Figure 25. Measured stratigraphic section of the Cockalorum Wash Upper Sandstone. Refer to Figure 7 for key to lithofacies symbols and to Appendix A for section location.

Upward-fining cycles are comprised of broadly lenticular beds, averaging 30 m wide, which tend to pinch out laterally into laminated siltstone (F). Conglomerate-sandstone cycles are characterized by a basal channel lag consisting of concave-up crescent-shaped, massive, erosion-based framework-supported conglomerate (Ge). Ge beds grade upward into trough crossbedded sandstone (St) which, in turn, grades upward into contortion stratified (Sc), horizontally stratified (Sh), and ripple crosslaminated sandstone (Sr) (Figure 26). Both grain size and magnitude of sedimentary structures decrease upward. Trough crossbedded sandstone (St) coset amalgams attain a maximum thickness of about 1 m. Contortion stratified sandstone occurs as isolated lenticles, averaging 30 cm thick, toward the top of St beds. Horizontally bedded sandstone (Sh) rests upon trough crossbedded sandstone (St) and contortion stratified sandstone (Sc) along planar bases. Overlying ripple crosslaminated sandstone (Sr) beds are well-sorted, fine-grained beds which average 30 cm thick. Most channelform beds are solitary and entirely suported by laminated siltstone (F), although up to three upwards-fining beds are stacked and offset. Laminated siltstone (F) is locally rich in rootlet traces and plant fragments. Horizontally stratified sandstone (Sh) and ripple crosslaminated sandstone (Sr) interbeds locally exceed the lateral dimensions of channelform bodies and are interbedded with laminated siltstone (F) adjacent to channelform beds.

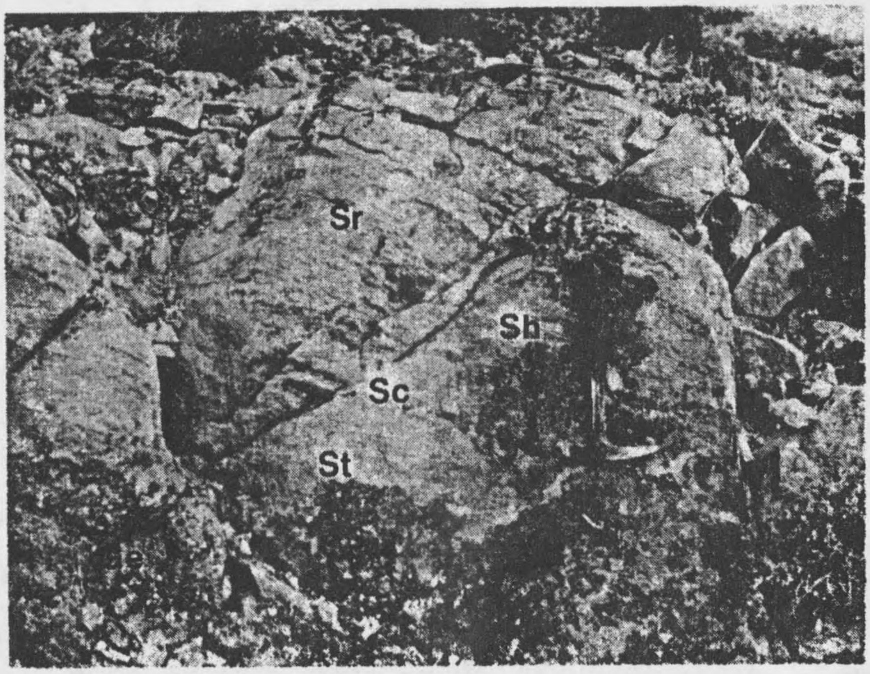

Figure 26. Upward-fining sandstone bed in Cockalorum Wash Upper Sandstone. From the base up: erosion scour conglomerate (Ge), trough crossbedded sandstone (St), contortion stratified sandstone (Sc), horizontally stratified sandstone (Sh), and ripple crosslaminated sandstone (Sr).

<u>Interpretation.</u> Upward-fining conglomerate-sandstone intervals represent deposits of a graveliferous, sand-bed, meandering fluvial environment (Jackson, 1978). Basal concave-up erosion-based massive conglomerate (Ge) is interpreted as lag gravel of the channel complex (Bluck, 1971). Overlying trough crossbedded sandstone (St) and contortion stratified sandstone (Sc) represent lower point-bar sequences. Horizontally stratified sandstone (Sh) and ripple crosslaminated sandstone (Sr) are interpreted as

upper point bar sequences (Levey, 1978). Overlying and adjacent laminated siltstone and silty mudstone (F) are overbank vertical accretion deposits (Stewart, 1982). Local interbeds of horizontally stratified sandstone (Sh) and ripple crosslaminated sandstone (Sr) within laminated siltstone (F) formed as crevass splay deposits (Allen, 1974).

Upper Carbonate Assemblage

Facies Assemblage. Poorly exposed, massive micritic carbonate with marlstone interbeds characterize this assemblage. It attains a maximum thicness of 100 m. Massive micrite appears to dominate this assemblage; marlstone forms interbeds up to 3 m thick. Poor exposures and locally intense Tertiary supergene mineralization obscure primary sedimentary features.

Interpretation. The Cockalorum Wash Upper Carbonate Assemblage was deposited in a hardwater lacustrine environment. Massive micrite was deposited in deeper parts of the lake, whereas marlstone interbeds accumulated nearer to shore (Picard and High, 1981). The interbedded nature of massive micrite and marlstone is suggestive of a fluctuating lake shoreline.

PALEOCURRENTS

Paleocurrent analysis of pebble imbrication and crossbedding was undertaken to help delineate sediment dispersal patterns and highland source locations. A total of 522 measurements were made. Preference was given to trough long axes and planar cross strata, although poor exposures and structural complications generally prevented as thorough an evaluation of cross strata as would be desired. Cobble imbrication data were taken at as many locations as possible. The following discussion concerns sediment dipersal patterns and paleoflow directions at the three areas examined in this investigation.

Overland Pass

At Overland Pass, the overall paleoflow configuration is dominantly southeast (Figure 27), with a vector mean of 100.0 degrees and vector magnitude of 59.2. Since only part of the entire Overland Pass section was examined and considerable thickness variations exist within these strata, it is possible that these data are not indicative of the overall sediment dispersal patterns. These data are therefore considered to be representative of the Overland Pass section only in the immediate vicinity of Overland Pass.

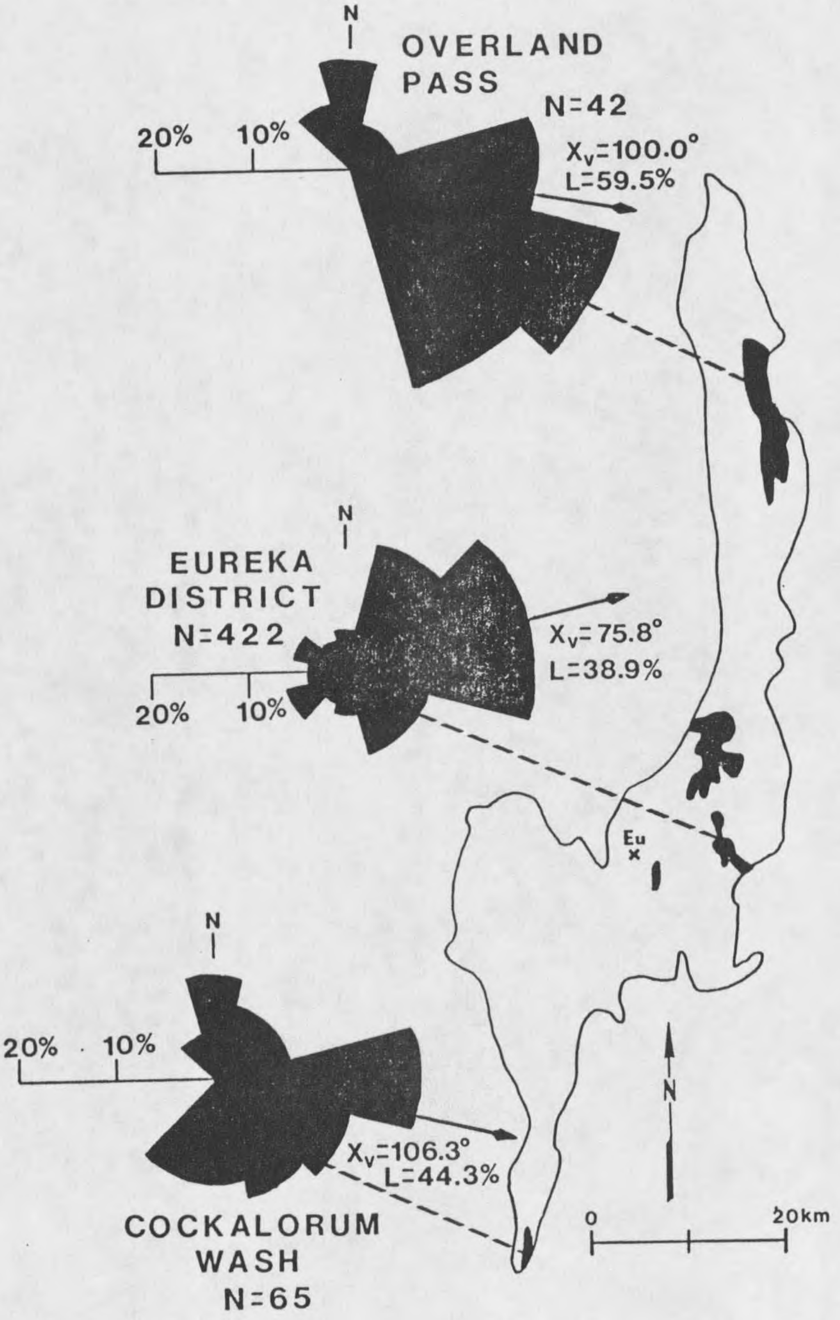

Figure 27. Summary rose diagrams for paleocurrent measurements at Overland Pass, the Eureka District, and Cockalorum Wash. X sub v is the vector mean expressed in degrees and L is the length of the resultant vector expressed as a percentage of readings. Eu is the town of Eureka.

Eureka District

The overall configuration of sediment transport direction in the Eureka District is an east-northeast paleoflow (Figure 27). The vector mean is 75.8 degrees and vector magnitude is 38.9. Paleocurrent measurements were made at Cherry Spring, Newark Canyon, and Pinto Creek Spring. A statistically insignificant number of paleocurrent measurements were made in the Hildebrand Canyon area; these are presented in measured sections discussed in the previous section. Paleocurrent measurements in the Hildebrand Canyon area were hindered by structural complications and extremely poor outcrops. Conglomerate beds in the Basal Conglomerate/Mudstone are extremely disconnected and strike in highly variable directions. Since these beds are apparently deformed into plunging folds and orientation of the axes of these folds is indeterminable, correction for tectonic tilt is impossible (Ragan, 1973). Beds in the Upper Conglomerate in the Hildebrand Canyon area are vertically dipping and marker beds above and below these conglomerates are not exposed. Additionally, poor outcrops of these beds prevent the use of sedimentologic evidence to determine the tops of beds. Furthermore, clasts in these beds are dominated by subequant carbonate cobbles giving rise to poorly-developed cobble imbrication. Therefore, paleocurrent data from the

Hildebrand Canyon area is excluded from this report. The following discussion concerns the sediment dispersal patterns in the Basal Conglomerate/Mudstone and Upper Conglomerate.

Basal Conglomerate/Mudstone

Cobble imbrication in the Basal Conglomerate/Mudstone is poorly developed; where it is developed it is dominated by a(p)a(i) imbrication. This is probably due to grain to grain interactions which occurred during sediment transport, preventing clasts from vibrating in place or rolling on the bed to assume the a(t)b(i) orientation more typical of fluvial sediments (Harms and others, 1982). Cross strata were found to be unsuitable for paleocurrent analysis due to the very low angle of dip of foresets. Although there is much scatter in the rose diagrams, the overall general trend in the Basal Conglomerate/Mudstone is an east to northeast sediment transport direction (Figure 28). At Cherry Spring and Pinto Creek Spring, the vector means are 100.0 and 88.0 degrees, respectively, and the vector magnitudes are 11.4 and 22.6, respectively. The Cherry Spring rose diagram (Figure 28) shows a weakly bimodal pattern which results in a vector mean that is about 90 degrees askew from the 15 to 45 degree group which contains the largest number of readings. At Newark Canyon, a more strongly unimodal paleocurrent pattern is apparent from the rose diagram, suggesting a northeast sediment

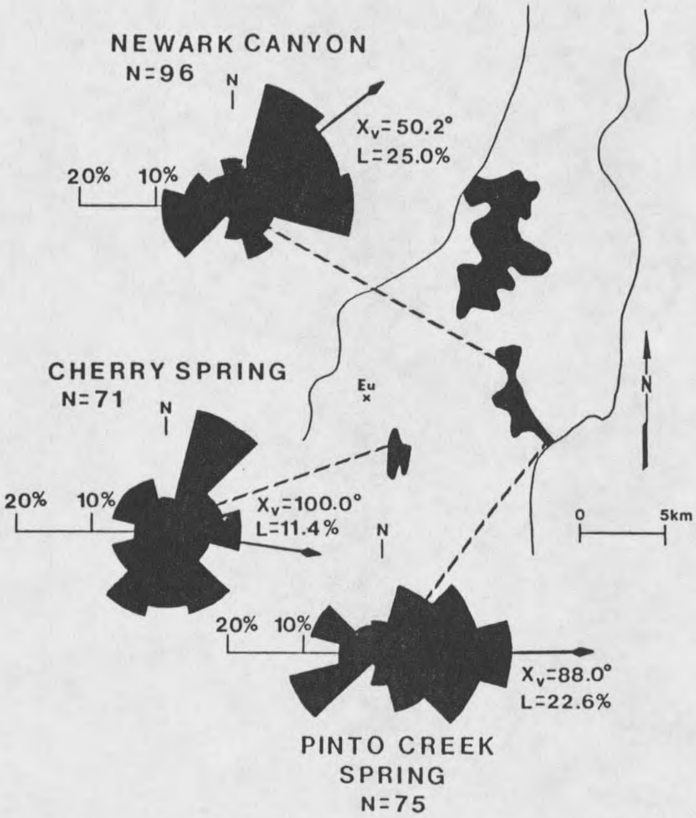

Figure 28. Summary rose diagrams for paleocurrent measurements in the Eureka District Basal Conglomerate/ Mudstone. X sub v is the vector mean expressed in degrees and L is the length of the resultant vector expressed as a percentage of readings. Eu is the town of Eureka.

transport direction (Figure 28). At Newark Canyon the vector mean is 50.2 degrees and vector magniture 25.0. Therefore, the sediment transport direction in the Basal Conglomerate/Mudstone is east-northeast.

Upper Conglomerate

The overall configuration for the Upper Conglomerate is an eastward sediment transport direction (Figure 29). Cobbles from massive conglomerates have a more uniform clast orientation because the nature of depositional systems dictated that elongate clasts were allowed to assume an a(t)b(i) orientation under the influence of fluid flow (Harms and others, 1982). Additionally, trough long axes further substantiate the eastward sediment transport directions (see measured sections in the previous section for trough long axis orientations). Overall, the vector mean of the Upper Conglomerate is 76.9 and the vector magnitude 66.3, revealing an east-northeast sediment transport direction.

Cockalorum Wash

Although there is a certain amount of scatter in the rose diagram, pebble imbrication and cross strata orientations indicate an east-southeast sediment transport direction (Figure 27). The vector mean is 106.3 degrees and vector magnitude 44.3.

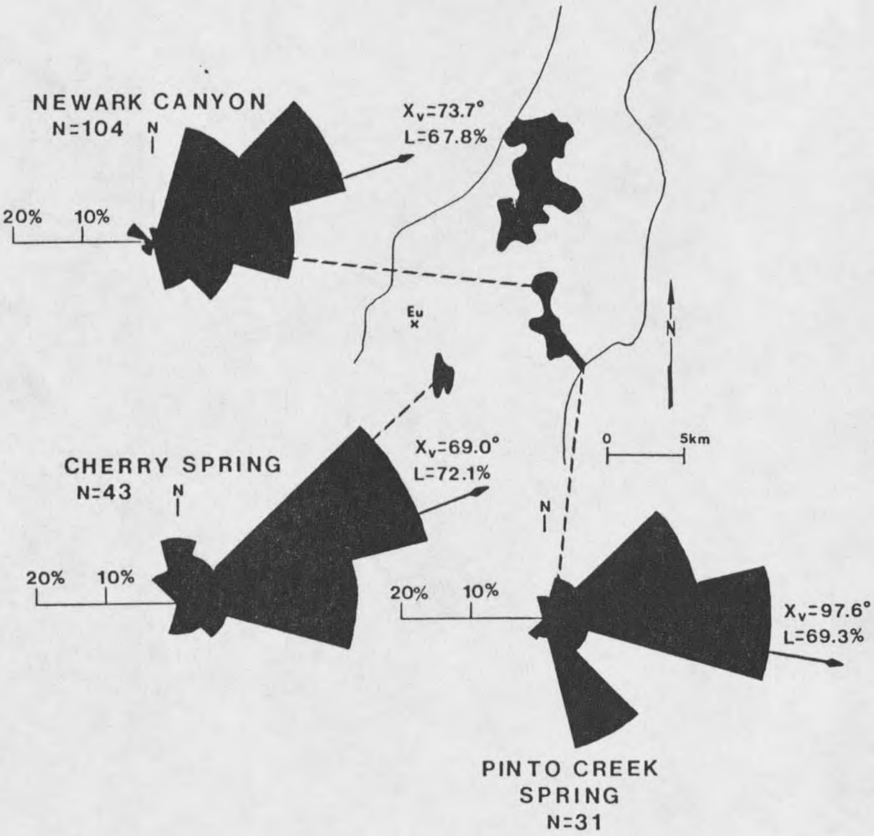

Figure 29. Summary rose diagrams for paleocurrent measurements from the Eureka District Upper Conglomerate. X sub v is the vector mean expressed in degrees and L is the length of the resultant vector expressed as percentage of readings. Eu is the town of Eureka.

CORRELATIONS

A major stratigraphic problem in east-central Nevada concerns the origin and distribution of sedimentary strata mapped as Newark Canyon Formation. The Overland Pass section was originally correlated with the Newark Canyon Formation in the Eureka District by Dott (1955) on the basis of the presence of coarse siliciclatic sediments. This correlation was continued by E.R. Larsen after Larsen and Riva (1963) mapped these strata as Permian and later assigned age of these strata to Cretaceous (Larsen, pers. comm., in Stewart, 1980). However, Larsen did not state a reason for this correlation and biostratigraphic data are apparently still lacking (J. Stewart, writ. comm., 1987). Facies analysis in this investigation indicates that the Newark Canyon Formation at Overland Pass and in the Eureka District each represent separate and distinct depositional systems. Despite the lack of biostratigraphic data from Overland Pass, it is probable that the depositional systems represented at Overland Pass were not active at the same time that those in the Eureka District were active. If, however, these strata do represent different parts of the same depositional system, the discordance between depositional styles requires more geographic seperation than is present between the two outcrop areas (Figure 2).

This would require post-Newark Canyon Formation structural dislocation to bring these distinct stratigraphic packages into the relative proximity represented by the present outcrop distribution. Evidence for this structural dislocation is absent (Stewert and Carlson, 1978; Stewert, 1980).

The Newark Canyon Formation at Cockalorum Wash has been determined to be the temporal equivalent of the Newark Canyon Formation in the Eureka District based on biostratigaphic evidence of Fouch and others (1979). However, evidence for lithostratigraphic correlation has been lacking. Although the Newark Canyon Formation at Cockalorum Wash is much thinner than in the Eureka District, previously discussed evidence indicates that the lower portions of the Cockalorum Wash section have been tectonically obscured. Potentially, the Cockalorum Wash section is the lithostratigraphic equivalent of the upper parts of the Eureka District section. The Cockalorum Wash Basal Conglomerate may represent the same influx of coarse siliciclastic sediment that is represented by the Upper Conglomerate in the Eureka District. Additionally, the lacustrine deposits of the Upper Carbonate Assemblage at Cockalorum Wash may have accumulated in the same lacustrine system represented by the Upper Carbonaceous Assemblage in the Eureka District. Minor differences exist in depositional styles at each of these areas in that sandy braided and meandering fluvial systems were developed following the influx of coarse sediment at Cockalorum Wash, where, these depositional systems are apparently absent in the Eureka District. Enough geographic separation exists between these two areas that minor differences in depositional styles could have existed at each of these areas while they were both part of the same depositional basin.

PETROLOGY

Conglomerate

Composition

Newark Canyon Formation conglomerates are mostly clast-supported, chert pebble to cobble conglomerate, although limestone cobble conglomerate is found in the Eureka District. Clast types present at all locations studied include, in order of decreasing abundance, grey chert, black chert, white quartzite, limestone, red chert, brown chert, sandstone, and green chert. Most grey and black chert clasts are dense and massive; some appear to be laminated. Observation in thin section indicates the presence of sponge spicules and fusulinids. Red chert clasts are massive in hand specimen. Thin section observation indicates that some of these grains have been stained red by a thin film of hematite that penetrates only the outer 1/8 of the grain. Other red chert grains, however, are entirely pervaded with hematite. Adjacent chert clasts have not been stained by hematite, indicating that staining of these grains occurred prior to Newark Canyon Formation deposition. Additionally, presence of only a thin hematite rind suggests that this stain is not primary to the grain. Green and brown chert grains are massive in hand sample; observation in thin section indicates no textural trends. White quartzite clasts are characteristically gleaming-white, fine- to medium-grained, well-sorted, quartz cemented, quartzarenites (terminology of Folk, 1980). Sandstone clasts, exclusive of white quartzite, vary in composition from litharenite to subarkose and are buff to dark grey in color. Sandstone clasts vary from fine- to coarse-grained and sorting is very poor- to well-sorted. Limestone clasts are massive grey sparry limestone or dolomite; some are fossiliferous and contain fusilinids, crinoids, and brachiopods. Additionally, some limestone clasts have been silicified. It is uncertain whether the silicification is pre-Newark Canyon deposition or an effect of post-depositional diagenesis.

Clast Compsition Modes

Clast percentages are plotted on histograms and are correlated with the corresponding Newark Canyon Formation exposures. Figure 30 shows the distribution of clast lithologies for the three major areas covered in this investigation, and Figures 31 and 32 show the distribution of clast lithologies in outcrops studied in the Eureka District for the Basal Conglomerate/Mudstone and Upper Conglomerate, respectively. Original clast count data are presented in Appendix B.

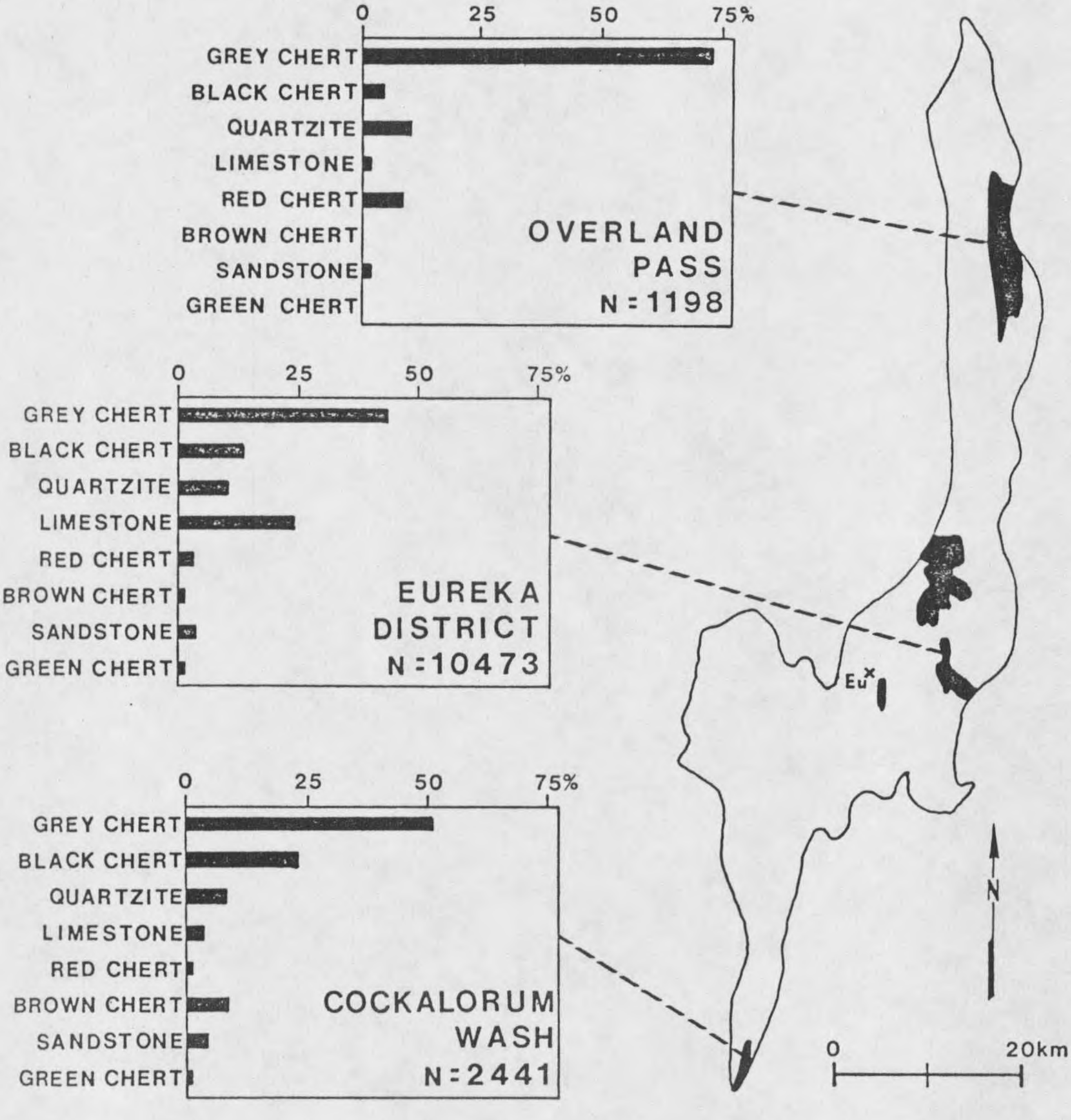

Figure 30. Histograms of clast lithology percentages for Overland Pass, the Eureka District, and Cockalorum Wash. Eu is the town of Eureka.

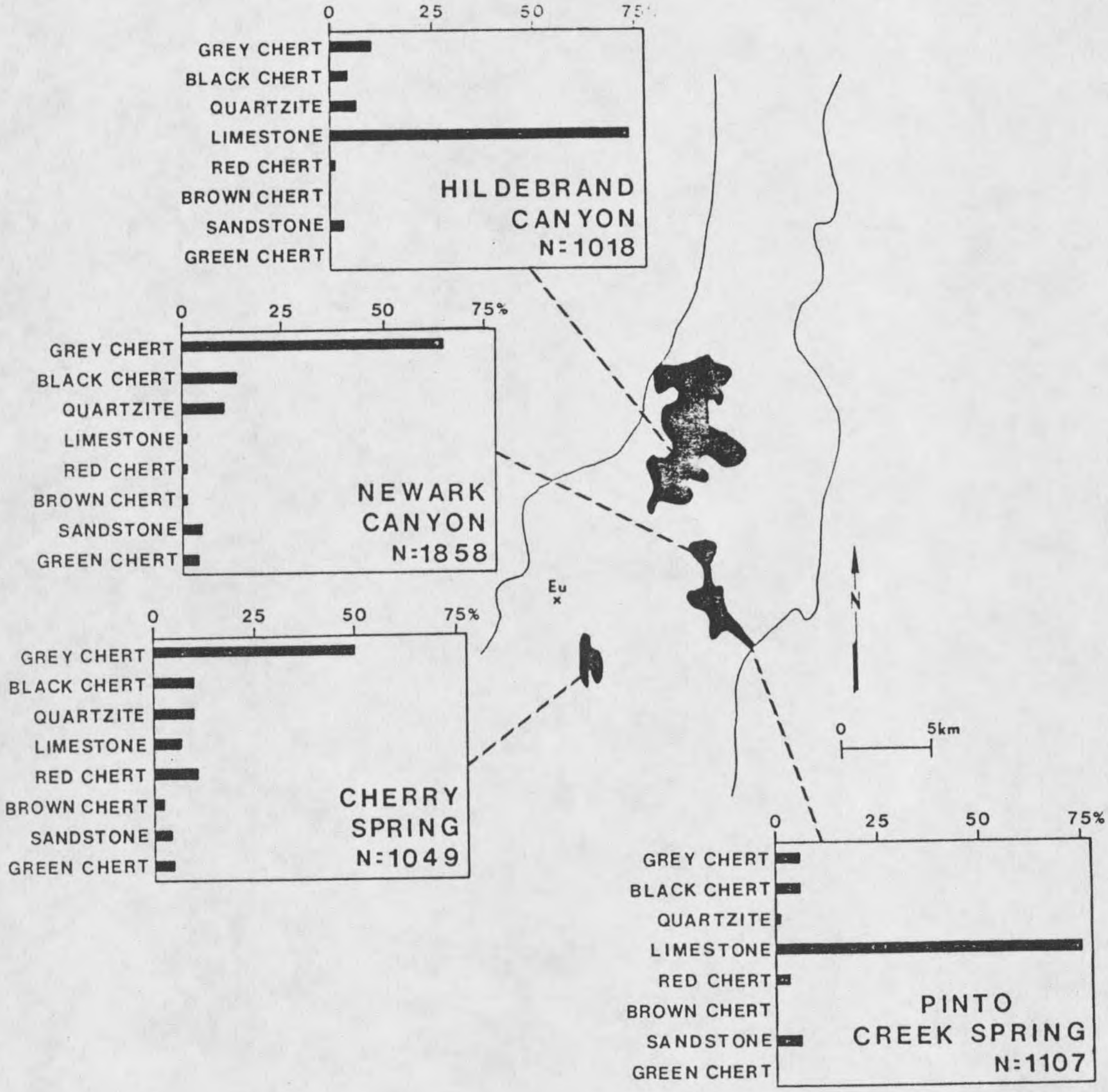

Figure 31. Histograms of clast lithology percentages for the Eureka District Basal Conglomerate/Mudstone. Eu is the town of Eureka.

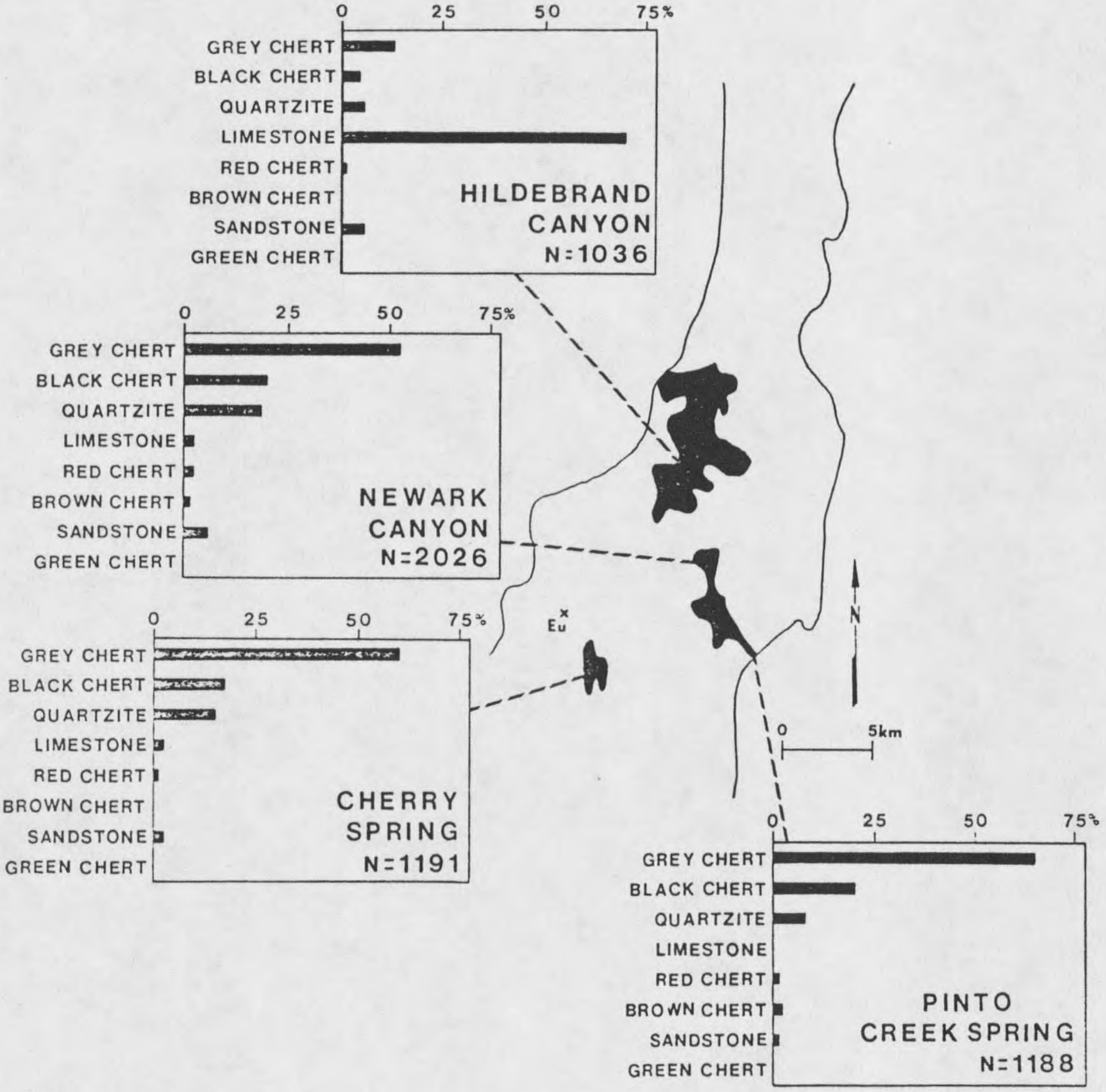

Figure 32. Histograms of clast lithology percentages for the Eureka District Upper Conglomerate. Eu is the town of Eureka.

Spongue spicule-bearing grey chert dominates clast populations at all areas (Figure 30). At Overland Pass, clasts are mostly grey chert, with subordinate red chert, and white quartzite; other clast lithologies are volumetricallly insignificant. Clast suites in the Eureka District are highly variable (Figures 31 and 32). Clast suites in the Basal Conglomerate/Mudstone (Figure 31) are either dominated by spicule-bearing grey chert (Newark Canyon and Cherry Spring), or by limestone (Hildebrand Canyon and Pinto Creek Spring) (Figure 31); other clast lithologies are present in variable amounts. In the Upper Conglomerate, grey chert clasts dominate at all locations except Hildebrand Canyon, where limestone is the dominant clast type (Figure 32). Structural complications and poor exposures in the Hildebrand Canyon area prevent confirmation of the conglomerates exposed in this area to be from the Upper Conglomerate. With the exception of exposures in Hildebrand Canyon, black chert, quartzite, and sandstone are all present in subequal amounts in the Upper Conglomerate; other clast types are volumetrically insignificant. At Cockalorum Wash, conglomerates are characterized by blended clast lithologies with only red and green chert being volumetrically insignificant (Figure 30). Grey chert predominates; black chert, quartzite, brown chert and sandstone are present in subequal amounts.

Sandstone

Texture

Newark Canyon Formation sandstones are texturally highly variable. Grain size varies from very fine to very coarse sand. Sandstones are most commonly poorly- to moderately-sorted. Sand grains are predominantly subangular to subrounded. Quartzose and feldspar grains are subequant and sedimentary lithic fragments are elongate to subequant. Grain contacts are primarily tangential to long. Textural maturity varies from immature to submature.

The diagenetic history of Newark Canyon Formation sandstones is complex and variable as indicated by different cement types and numerous textural features. No trends in the diagenesis of Newark Canyon Formation sandstones were observed. Diagenetic features include, not necessarily in order of development: 1) quartz overgrowths, 2) thick clay rinds that also fill pores, 3) formation of poikilotopic sparite as a pore filler, 4) replacement of detrital grains by calcite, 5) silicification of carbonate grains into chalcedony or chert, 6) dissolution of detrital grains and matrix to create secondary porosity, and 7) (?) hematite/clay that stains detrital grains and cement and also coats and partially fills secondary pores.

Composition

Recognition and classification of grain types follows the criteria of Dickinson (1970). Framework grains present include monocrystalline quartz (Qm), polycrystalline quartz (Qp), feldspar (F), and sedimentary lithic fragments (Ls). Appendix C contains a summary of framework grain abundances obtained from point coints.

Since thin sections were neither stained nor etched, differentiation of quartz and potassium feldspar was subject to consequential error. Few of the potassium feldspar grains were twinned. Differentiation of monocrystalline quartz and monocrystalline potassium felspar was based on the following: 1) cleavage in feldspar versus fracture in quartz, 2) sericitization in feldspar, 3) incipient potassium feldspar framework grain dissolution, 4) potassium feldspar grains clouded with alteration products arranged in vague grids or lines subparallel to crystallographic directions, and 5) optic signs of quartz (uniaxial negative) versus potassium feldspar (biaxial negative). Additionally, thin section chips were stained for potassium feldspar; analysis of these chips indicated that minimal amounts of potassium feldspar are present.

Framework Grain Types

Monocrystalline Quartz (Qm). Monocrystalline quartz consists of single grains with straight to slightly undulose extinction as defined by Folk (1980). These can contain trains of vacuoles; microlites are rare to absent. Monocrystalline quartz grains commonly have abraded quartz overgrowths.

Polycrystalline Quartz (Qp). Polycrystalline quartz types include chert, chalcedonic chert and composite quartz grains. Chert grains commonly contain relict sponge spicules. Composite quartz grains consist of polygonized quartz with straight contacts, elongate, slightly sutured grains, and coarse, interlocking mosaics of crystals (Pettijohn and others, 1972). Composite quartz grains are relatively rare in Newark Canyon Formation sandstones and usually constitute less than 1% of framework grains.

Feldspar (F). Feldspar types are almost exclusively monocrystalline orthoclase feldspar with trace amounts of microcline found in Overland Pass and Cockalorum Wash sandstones and plagioclase in Overland Pass sandstones. Orthoclase usually shows cleavage and is commonly clouded with alteration products. Occasionally, orthoclase grains have abraded orthoclase overgrowths.

Sedimentary Lithic Fragments (Ls). Sedimentary rock fragments in Newark Canyon Formation sandstones consist of siliceous shale, calcareous shale, siltstone, and calcareous siltstone. Shaley rock fragments commonly have been deformed or show compaction indentations from adjacent grains.

Sandstone Petrofacies

Sandstones from strata mapped as Newark Canyon Formation examined in this investigation can be divided into two petrofacies based on separate and distinct fields on sandstone-composition ternary diagrams (Figure 32). Table 1 shows the mean detrital grain percentages for sandstones from the areas studied. The Quartzo-lithic Petrofacies consists of sublitharentites with subordinate high-quartzose litharentites of sandstones from Overland Pass. Sandstones of the Chertarenite Petrofacies are exclusively chertarenites and are represented by sandstones from the Eureka District and from Cockalorum Wash.

Quartzo-lithic Petrofacies

These sandstones are characterized by abundant monocrystalline quartz (Qm=67), lesser total lithic fragments (Lt=27), and subordinate feldspar (F=6) (Figure 34). Sedimentary lithic fragments (Ls=6) consist of indurated argillaceous rock fragments and polycrystalline quartz (Qp=23) characterized by spicule-bearing chert.

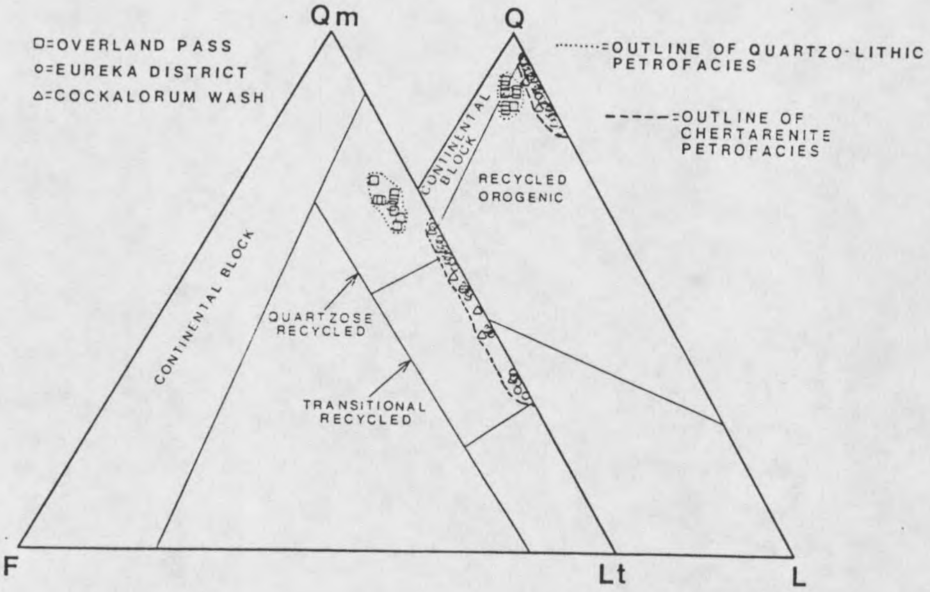

Figure 33. QFL and QmFLt diagrams for sandstones of the Newark Canyon Formation in the areas examined. Note the separation of the Quartzo-lithic Petrofacies and the Chertarenite Petrofacies and that the Quartzo-lithic Petrofacies consists exclusively of Overland Pass sandstones and the Chertarenite Petrofacies consists of sandstones from the Eureka District and Cockalorum Wash. Provenance fields after Dickinson and others (1983a).

Table 1. Mean framework grain percentages for Newark Canyon Formation sandstones.

LOCATION	N	STAT	Q	Qm	Qp	F	L	Lt
Overland Pass	9	Mean	88.2	66.6	21.6	6.1	5.4	27.0
		Std dev	1.6	2.5	3.3	0.8	1.3	2.8
Eureka District	20	Mean	88.0	45.0	43.1	0.7	11.4	54.2
		Std dev	4.5	12.4	10.8	0.5	4.4	12.7
Cockalorum Wash	8	Mean	91.5	52.2	39.1	2.3	7.1	46.6
		Std dev	2.9	7.3	6.9	2.5	2.4	7.5

	QFL	QmFLt
Overland Pass	88, 6, 6	67, 6, 27
Eureka District	88, 1, 11	45, 1, 54
Cockalorum Wash	91, 2, 7	51, 2, 47

Monocrystalline quartz is characterized by common abraded quartz overgrowths. Feldspar types include monocrystalline orthoclase, plagioclase, and microcline. Orthoclase and plagioclase are most common and microcline is present in trace amounts.

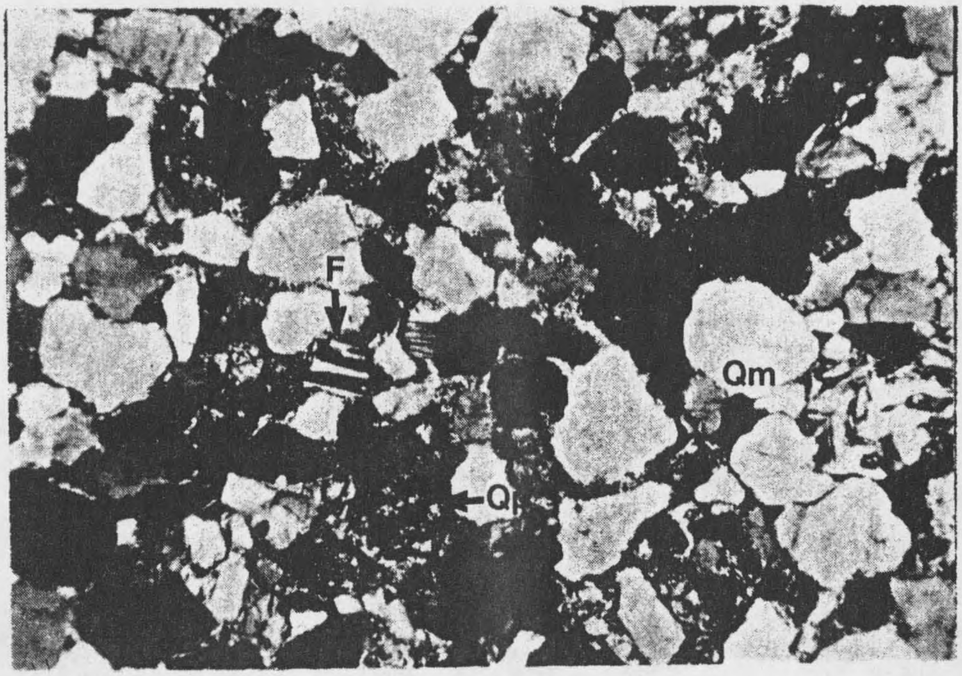

Figure 34. Photomicrograph of Overland Pass sandstone. Note predominant monocrystalline quartz (Qm) and subordinate chert (Qp) and plagioclase feldspar (F).

Chertarenite Petrofacies

These rocks are characterized by abundant quartzose grains (Eureka District Q=88; Cockalorum Wash Q=91), of which monocrystalline quartz and polycrystalline quartz (spicule-bearing chert) are present in subequal amounts (Eureka District: Qm=45, Qp=43; Cockaloum Wash Qm=53, Qp =40) (Figures 34 and 35). Feldspar is present in minor quantities (Eureka District: F=1; Cockalorum Wash: F=2); in the Eureka District, feldspar is exclusively monocrystalline orthoclase, whereas at Cockalorum Wash, feldspar is mostly orthoclase with trace amounts of microcline. Sedimentary lithic fragments are present in minor amounts and comprise up to 11 percent of framework grains present (Eureka District: Ls=11; Cockalorum Wash: Ls=7). Total lithic fragments constitute about 50% of the total framework grains present (Eureka District: Lt=54; Cockalorum Wash: Lt=47).

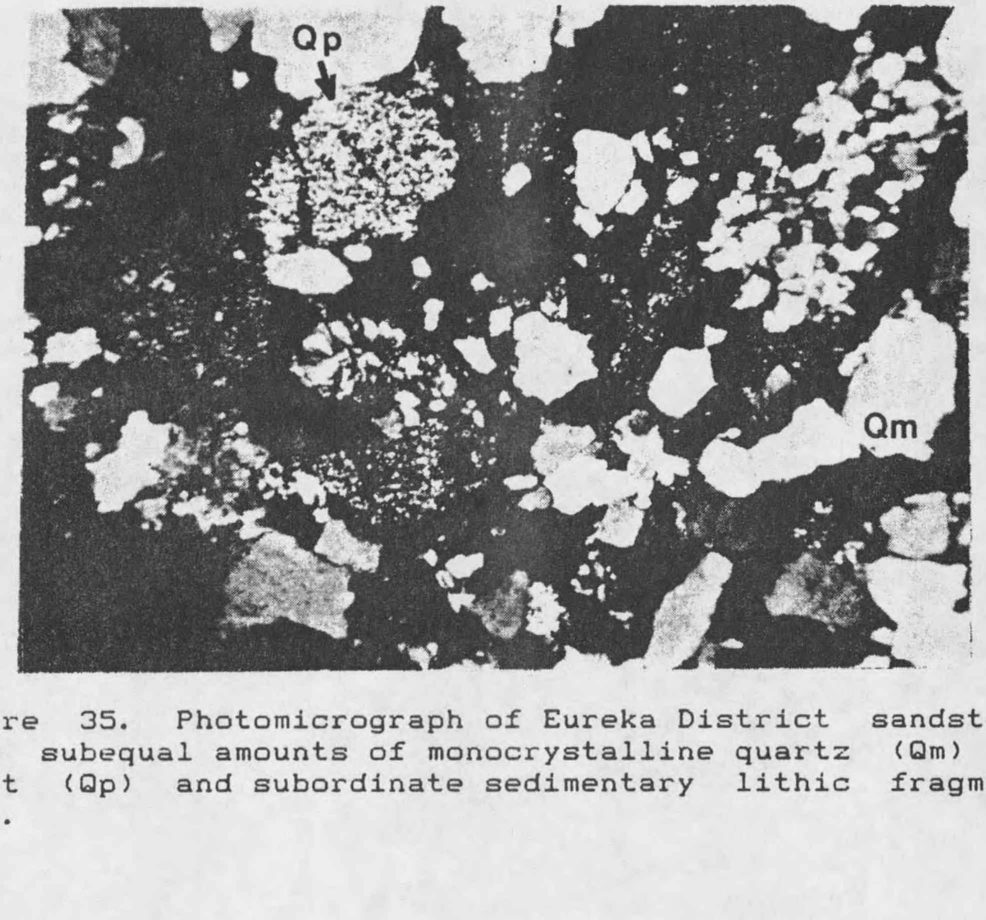

Figure 35. Photomicrograph of Eureka District sandstone. Note subequal amounts of monocrystalline quartz (Qm) and chert (Qp) and subordinate sedimentary lithic fragments (Ls).

Abundance of sedimentary lithic fragments, relative paucity of feldspar grains, and subequal amounts of monocrystalline and polycrystalline quartz in Eureka District and Cockalorum Wash sandstones serve to distinguish them from sandstones of Overland Pass.

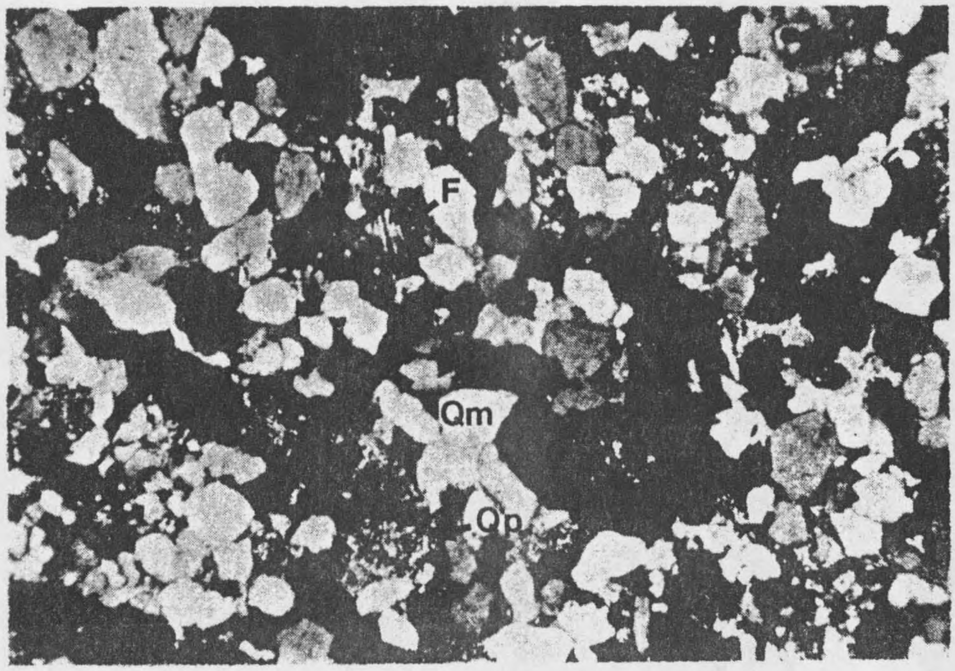

Figure 36. Photomicrograph of Cockalorum Wash sandstone. Note similarity in composition to Eureka District sandstone (Figure 35). Note also the presence of microcline (F).

PROVENANCE

Conglomerate clast and sandstone framework composition data suggest that highland source terrains providing sand and gravel to the Newark Canyon Formation consisted almost exclusively of pre-Mesozoic sedimentary rocks. Paleozoic rocks which were potential contributors of sediment to the Newark Canyon Formation can be divided into five main sequences (Stewart, 1980). The miogeocline, a westward-thickening prism of upper Precambrian and Paleozoic shelf-facies clastic and carbonate rocks, is the easternmost of these sequences. Structurally above the miogeocline is the Roberts Mountains allochthon, which consists of deformed lower Paleozoic deep-water rocks thrust eastward over coeval shallow-water rocks in the Late Devonian-Early Mississippian (Roberts and others, 1958). A Mississippian-Pennsylvanian clastic wedge, derived from erosion of the Roberts Mountains allochthon and deposited in the Antler foreland basin, constitutes the third of these sequences (Brew and Gordon, 1971; Poole, 1974). Late Paleozoic fluvial and shallow-marine deposits of the Antler "overlap sequence" (Roberts and others, 1958), deposited unconformably on the Roberts Mountain allochthon represent the fourth major sequence. The westernmost sequence consists of deformed upper Paleozoic basinal rocks of the

Golconda allochthon that rest in thrust contact above coeval rocks of the Antler overlap sequence. Eastward thrust emplacement of the Roberts Mountain allochthon and the Golconda allochthon during the Antler and Sonoma orogenies, respectively, represents brief episodes of compressional tectonics in the otherwise "passive" continental-margin history of Paleozoic western North America (Speed, 1983). The following discussion will focus of the provenance of conglomerates and sandstones in the Newark Canyon Formation, and the role that the aforementioned sequences played in supplying sediment to the Newark Canyon Formation.

Newark Canyon Formation Conglomerate

Analysis of potential source lithologies indicate that late Paleozoic miogeoclinal shelf sediments were the predominant source for clasts in Newark Canyon Formation conglomerates. Specifically, grey, black, and brown spicule-bearing chert, and fusilinid- and brachiopod-bearing limestone are indicative of source rocks being of the post-Antler orogeny carbonate miogeoclinal province (Stewart, 1980). However, the presence of red and green chert clasts in Newark Canyon Formation conglomerates is significant. Presence of hematite stain in red chert clasts, where this stain is neither primary to the chert nor a result of Newark Canyon Formation diagenesis, suggests that red chert clasts have been recycled from previous conglomerates and have been influenced by an earlier episode of diagenesis. Mississippian Diamond Peak Formation conglomerates in the vicinity of Newark Canyon Formation exposures contain red chert (Brew and Gordon, 1971). Additionally, green chert clasts are locally abundant in Diamond Peak Formation conglomerates. Diamond Peak Formation chert clasts are interpreted to have been derived from bedded cherts of the Roberts Mountain allochthon and constitute part of the Antler foreland basin deposits (Brew and Gordon, 1971; Poole, 1974). Therefore, red and green chert clasts in Newark Canyon Formation conglomerates are interpreted to have their source either in Mississippian clastic deposits of the Antler foreland basin or in bedded cherts of the Roberts Mountain allochthon (Roberts and others, 1958). Assuming that these clasts have been recycled from the Antler clastics, this places a minimum age of source rocks at Mississippian (Late Mermacian-Chesterian) (Brew and Gordon, 1971). If these clasts have a primary source in Western Assemblage bedded cherts, this places a pre-Mississippian age for strata exposed in highland source terrains during Newark Canyon Formation deposition (Stewart, 1980).

Perhaps more significant is the presence of white quartzite clasts in Newark Canyon Formation conglomerates. Clasts of this type closely resemble the Ordovician Eureka

Quartzite from the miogeoclinal sequence, which is widely distributed throughout eastern Nevada (Ketner, 1968). The Eureka Quartzite is considered to be the ultimate source for these clasts, although it is possible that these clasts have been through previous cycles of erosion, transport, and deposition. However, other conglomerates in east-central Nevada have not been shown to contain Eureka Quartzite clasts (Stewart, 1980). The Mississippian Diamond Peak Formation contains quartzite clasts, but these are generally buff to dark grey in color (Brew and Gordon, 1971). Assuming that white quartzite clasts are derived directly from the Eureka Quartzite, this places a maximum age of Ordovician for sedimentary source terrains that were contributing coarse detritus to Newark Canyon Formation sediments.

Sandstone clasts in Newark Canyon Formation conglomerates can have any number of sources. Potential sources include: 1) first cycle sandstones from Mississippian Diamond Peak Formation (Brew and Gordon, 1971), 2) sandstone clasts recycled from Diamond Peak Formation conglomerate (Brew and Gordon, 1971), 3) sandstones from Western Assemblage "quartzites" of the Ordovician Valmy Formation of the Roberts Mountain allochthon (Gilluly and Gates, 1965; Roberts, 1964, Ketner, 1966), and 4) sandstones in lower to upper Paleozoic miogeoclinal strata (Stewart, 1980), and 5) "quartzites" as old as latest Precambrian to Cambrian (e.g. the Prospect Mountain Quartzite and equivalents) (Stewart, 1970). Thus, source terrains for coarse clastic sediment in the Newark Canyon Formation can be concluded to range in age from late Paleozoic to possibly as old as latest Precambrian. However, Mississippian through Permian strata are considered to have contributed the bulk of coarse clastic sediment to Newark Canyon Formation conglomerates.

At Overland Pass (Figure 30), although the age of these strata is uncertain, the presence of red chert is suggestive of recycled detrital chert. White quartzite clasts suggest a component of Ordovician Eureka Quartzite in source terrains, although these too may have been recycled.

Clast suites in the Eureka District (Figure 31 and 32) are highly variable, due, in part, to the nature of the depositional systems, and perhaps due, in part, to a supply of blended clast lithologies from compositionally variable source terrains. In the Basal Conglomerate/Mudstone (Figure 31), the dominance of limestone at some localities is perhaps due to the flashy nature of the fluvial systems which supplied coarse, proximally derived, detritus to the Eureka District depositional system. In the Upper Conglomerate (Figure 32), with the exception of the Hildebrand Canyon area, mechanically more stable chert and quartzite clasts dominate the clast suites. This is perhaps due to the competent nature of fluvial systems present during deposition of the Upper Conglomerate. This dictated that mechanically less stable grains such as limestone were disintigrated during sediment transport. Dominance of limestone in the Hildebrand Canyon area is problematic; as stated previously, it remains uncertain whether these beds are from the Upper Conglomerate. Additionally, the paleogeographic position of these beds relative to the rest of the Eureka District strata is uncertain.

Clast suites at Cockalorum Wash show no anomalous trends with respect to those of other locations (Figure 30). Red and green chert clasts are volumetrically insignificant, probably because the Mississippian Diamond Peak Formation may not have been providing a significant component of detritus to the Cockalorum Wash conglomerate. Presence of white quartzite suggests that Ordovician Eureka Quartzite clasts, either primary or recycled, were supplied to Cockalorum Wash conglomerate.

Newark Canyon Formation Sandstone

Although the Overland Pass sandstones and the Eureka District/Cockalorum Wash sandstones comprise different petrofacies, all Newark Canyon Formation sandstones fall within the quartzose and transitional recycled orogen provenance fields of Dickinson and others (1983a) (Figure 33). Thus, the sublitharenites and litharenites of the

Newark Canyon Formation require a compositionally mature to submature sedimentary provenance. Paleocurrent data indicate that highland source terrains lay to the west of the present outcrop area. The following discussion concerns the composition and provenance of rocks which may have contributed sand to Newark Canyon Formation sandstones.

During late Precambrian to mid-Devonian time, sandstone suites in the Cordilleran region are of cratonic and transitional origin and occur not only within the miogeoclinal belt, but were evidently also transported off the edge of the continent to be deposited as turbidites within the eugeoclinal belt (Dickinson and others, 1983a). Sandstones derived from the Antler highlands are uniformly of the chert-rich, subquartzose lithic type characteristic of derivation from a recycled orogenic provenance (Dickinson and others, 1983b). Sandstones within the Antler overlap sequence are similar to those in the Antler foreland basin succession (Dickinson and others, 1983b). Sandstones of the Sonoma highland terrain include calclithites as well as both quartzose and lithic sandstones (Dickinson and others, 1983a). During mid-Triassic to Late Jurassic time, an arc-trench system developed along the Cordilleran margin of the continent; sandstone suites of this age are dominated by volcaniclastic frameworks. Associated suites consist of framework grains derived from dissected transitional arc terranes, from uplifted subduction complexes, and from other recycled orogenic provenances (Dickinson and others, 1983a).

Framework modes of mid-Devonian through mid-Triassic sandstones west of the present-day Newark Canyon Formation exposures fall predominantly within the recycled orogenic provenance of Dickinson and others (1983a), and are similar in composition to Newark Canyon Formation sandstones. Since volcanic lithic fragments are absent in Newark Canyon Formation sandstones, rocks of mid-Triassic through late-Jurassic age derived from magmatic arc systems along the Cordilleran margin were probably insignificant in providing detritus to Newark Canyon Formation depositional systems. Additionally, absence of volcanic lithic fragments in Newark Canyon Formation sandstones indicates that volcanic rocks were not significant sources of coarse sediment to Newark Canyon Formation depositional systems. However, the presence of altered volcanic ash in the Lower Fine-Grained Assemblage in the Eureka District suggests syn-depositional volcanism. Speed and Kistler (1980) note that siliceous volcanic rocks in the Excelsior and Pilot Mountains in western Nevada yield Rb-Sr isochrons which indicate ages, repectively, of 103 Ma and 142 Ma. Additionally, the Cretaceous Baseline Sandstone in southern Nevada has volcanic ash in it that has a K/Ar age determination of 98 Ma (Fleck, 1970). Kauffman (1977) notes an abundance of volcanic ash in early Cretaceous foreland basin deposits and suggests that the source for this ash may be the Cordilleran magmatic arc. These ages are roughly contemporaneous with a late Barremian to early Albian age for Newark Canyon Formation in the Eureka District (Fouch and others, 1979). Ash eruptions associated with these or other unrecognized silicic eruptions were probably reponsible for providing this sediment to the Eureka District depositional system.

Framework modes of Newark Canyon Formation sandstones at Overland Pass and Cockalorum Wash both contain plagioclase and microcline. Microcline is present in Cockalorum Wash sandstones in trace amounts, but is more abundant in Overland Pass sandstones. Since microcline typically indicates a plutonic source rock (Folk, 1980), this presents a problem as to the source of these grains. This can be reconciled by either of two possibilities. One is that plutonic rocks of pre-Newark Canyon age were exposed to erosion during Newark Canyon Formation deposition. The only plutonic rocks of pre-Newark Canyon Formation age west of the present outcrop area are Jurassic and early Cretaceous plutons asssociated with the Cordilleran magmatic arc system (Stewart, 1980). Since volcanism coeval with intrusion of these plutons was active partly contemporaneously with Newark Canyon Formation deposition (Speed and Kistler, 1980), it is unlikely that plutonic rocks of this age were exposed to erosion during Newark Canyon Formation deposition. A more reasonable source of microcline in Cockalorum Wash and Overland Pass sandstones is from sandstones of late Precambrian through mid-Devonian age. Miogeoclinal and eugeoclinal sandstones of this age fall into the transitional continental provenance field of Dickinson and others (1983a). Latest Precambrian miogeoclinal sandstones along the Cordilleran margin are subarkosic and contain microcline (Lobo and Osborne, 1976). Miogeoclinal sandstones of Middle and Late Cambrian age have slightly feldspathic frameworks of which microcline can be an important constituent (Lobo and Osborne, 1976; Suczeck, 1977; Stewart and Suczeck, 1977; Rowell and others, 1979). Silurian sandstones (e.g. Elder Sandstone) in western Nevada also contain relatively abundant microcline (Gilluly and Gates, 1965). Therefore, rocks of latest Precambrian through mid-Devonian age were probably the source for microcline in sandstones at Overland Pass and Cockalorum Wash.

Overland Pass sandstones contain the only plagioclase feldspar grains noted in the Newark Canyon Formation sandstones examined. Plagioclase occurs exclusively in Overland Pass sandstone and is one of the criteria used for compositionally separating the Overland Pass from Eureka District/Cockalorum Wash sandstones. The source of plagioclase framework grains in Overland Pass sandstones was probably the volcanic provinces of late Paleozoic age in central and western Nevada (Stewart, 1980) or Jurassic volcanic rocks found in east-central Nevada (Smith and Ketner, 1976).

PALEOGEOGRAPHY

Sedimentologic and petrographic data from the Newark Canyon Formation allow refined interpretations of the Early Cretaceous paleogeography of east-central Nevada. The dissimiarity of lithofacies assemblages at Overland Pass, in the Eureka District, and at Cockalorum Wash suggest the presence of separate and isolated alluvial basins. Lack of lacustrine deposits at Overland Pass, and differences in fluvial architecture of Overland Pass and in Eureka District/Cockalorum Wash strata preclude any spatial connection between these areas. Additionally, distinct petrofacies for Overland Pass and Eureka District/Cockalorum Wash sandstones indicate different sediment provenance. Since the age of deposition of the Overland Pass Newark Canyon Formation is still in question, the temporal relationship between these strata and the Newark Canyon Formation to the south remains in question.

Since the temporal equivalence of the Newark Canyon Formation in the Eureka District and at Cockalorum Wash has been established (Fouch and others, 1979), two alternatives exists with respect to stratigraphic relationships between these two locations. These are: 1) the upper portion of the Eureka District section is the lithostratigraphic equivalent of the exposed portion of the Cockalorum Wash section, and these two sequences represent different parts of the same depositional basin, or 2) these two sequences represent depositionally and/or structurally isolated basins that were contemporaneous. Evidence for lithostratigraphic equivalence is that: 1) the upper portions of the Eureka District and Cockalorum Wash sections represent an influx of coarse, westerly-derived siliciclastic sediment followed by development of a restricted basin lacustrine depositional setting, and 2) these sandstones and conglomerates have the same composition and likely, provenance. Conversely, the similarities in depositional systems could be a response to extrabasinal controls, the effect of which was the influx of coarse, westerly-derived siliciclastic sediment into isolated topographic lows, each representing separate depositional basins. In addition, the compositional similarity could be a manifestation of these same extrabasinal controls, resulting in influx of compositionally similar sediment from the same or similar provenances into separate depositional basins. Furthermore, differences in the nature of lacustrine sediments at these two areas may indicate development of discrete basins. The Eureka District Upper Carbonaceous Assemblage is characterized by graded, carbonaceous micritic strata, which are locally very fossiliferous, whereas the Cockalorum Wash Upper Carbonate is characterized by interbedded marly claystone and massive micrite and is relatively sparse in fossils.

TECTONIC IMPLICATIONS

The late Mesozoic tectonic history of east-central Nevada is poorly understood. In contrast to the Sevier thrust belt to the east, the style and timing of late Mesozoic tectonics in the hinterland are poorly known (Allmendinger and others, 1984). A principle problem with the dating of tectonic events in the hinterland is the sparcity of sedimentary rocks deposited coeval with deformation. If the Newark Canyon Formation represents alluvial sedimentation in response to surface expressions of hinterland tectonism, these strata provide a critical link between poorly documented deformation and concomitant alluvial sedimentation.

Nolan and others (1974) suggested that thrust faulting in the Eureka District and contemporaneous structural block formation resulted in the localized deposition of Newark Canyon Formation sediments in isolated structural depressions. This study has, however, documented large-scale fluvial systems in the Newark Canyon Formation (particularly the Middle Sandstone and the Upper Conglomerate in the Eureka District and lower parts of the Cockalorum Wash section) which appear to represent through-flowing drainage systems. Additionally, if the upper portions of the Eureka District section and exposed

Cockalorum Wash section are lithostratigraphic equivalents, this would preclude Nolan's interpretation of the Newark Canyon Formation as being restricted to structurally partitioned alluvial basins.

Speed (1983) suggested the presence of a major north-south trending belt of deformation which passes through central Nevada roughly parallel to and partly overlapping the trend of Lower Cretaceous strata in east-central Nevada (Figure 1). According to him, deformation occurred at least partly in the Lower Cretaceous, and probably before and after that time. This belt includes contractional structures mapped in the Eureka District by Nolan and others (1971; 1974) and in north-central Nevada by Smith and Ketner (1977). Displacements include east verging older-over-younger transport and throws of greater of than several kilometers. Heck and others (1986) referred to this belt of deformation as the Eureka thrust belt, and state that the enclave between the Sevier thrust belt to the east and Eureka thrust belt to the west is a zone of little Mesozoic deformation that is probably a meganappe (see also Speed, 1983 and Oldow, 1984). This meganappe could have shared the same decollement as the Luning-Fencemaker thrust system to the west and Sevier thrust system to the east (Figure 1) (Oldow, 1984). If the Newark Canyon Formation represents syntectonic sedimentation in response to Eureka thrust belt deformation, then clast composition data indicate that stratigraphic levels at least as old as Ordovician were exposed to erosion as a result of tectonically uplifted highlands. Additionally, the presence of blended clast lithologies in Newark Canyon Formation conglomerates suggests that highland source terrains consisted of compositionally diverse sedimentary strata which may have been a manifestation of structurally complex highland source terrains.

Another consequence of the east vergent Eureka thrust belt is the temporal significance of the Overland Pass Newark Canyon Formation. The Overland Pass section is involved in eastward vergent folding which may be a part of the Eureka thrust belt. Small scale structures in the Overland Pass section, such as solution cleavage and brittle fractures, suggest lithification prior to deformation. If the Overland Pass Newark Canyon Formation is involved in Eureka thrust belt deformation, then these strata would pre-date development of the Eureka thrust belt, which may pre-date deposition of the Newark Canyon Formation in areas to the south. Conversely, folds in the Newark Canyon Formation in the Eureka District show apparently eastward vergence suggesting that east-west compression might have occurred after Newark Canyon Formation deposition in the Eureka District. This suggests that the Overland Pass section could have been deformed after Eureka District Newark Canyon Formation deposition.

Another problem is the significance of Newark Canyon Formation deposition in relation to sedimentation in the foreland basin of the Sevier thrust belt. Although the spatial distribution of syntectonic sedimentation in the Sevier thrust belt is well understood, timing of sedimentation in response to active thrust faulting and source of sediment in the foreland basin is controversial. Shortening within the Sevier thrust belt is classically inferred to have begun in latest Jurassic time and to have continued through earliest Tertiary time (Armstong and Oriel, 1965; Armstong, 1968; Wiltschko and Dorr, 1983); however, the timing of initial deformation has never been well documented.

Dating of synorogenic clastic sediments along the Utah sector of the Sevier thrust belt indicates that deformation and concomitant sedimentation of the earliest synorogenic clastic sediments (Indianola Group) was probably no older than late Early Cretaceous (Albian) in age (Figure 35) (Standlee, 1982; Lawton.1985)). Additionally, subsidence curves of Heller and others (1986) indicate that foreland basin subsidence due to thrust loading in this region could not have occurred earlier than middle Cretaceous (Aptian-Cenomanian) time (Figure 35). The age of the Newark Canyon Formation is Barremian to early Albian, approximately 15 Ma older than foreland basin subsidence and sedimentation (Figure 35).

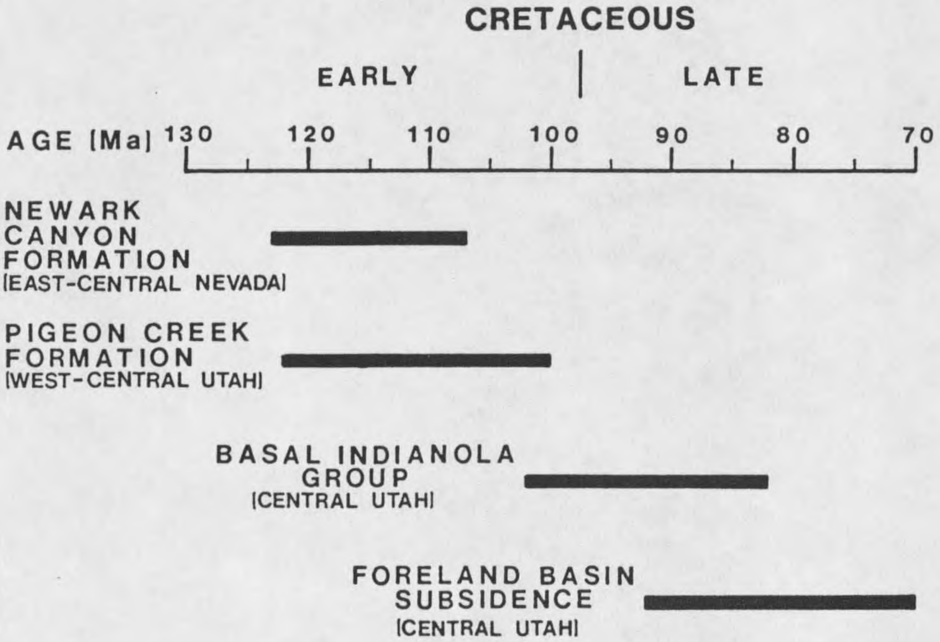

Figure 37. Chart showing the ages of sedimentary and tectonic events from west (Newark Canyon Formation) to east (foreland basin subsidence). Note eastward transgression of sedimentary/tectonic events. Data from Fouch and others (1979), Schwans (in prep), Standlee (1982), Lawton (1985), and Heller and others (1986).

The present geographical separation of Newark Canyon Formation exposures and the earliest Sevier synorogenic clastic sediments in central Utah is about 380 km. Utilizing a province-wide average of 40% extension for Basin and Range extension based on equations of Wernicke and Burchfiel (1982), this yields a pre-Basin and Range geographic seperation of Newark Canyon Formation exposures and earliest Sevier synorogenic conglomerates of about 230 km. Admittedly, the amount of geographic seperation between these two areas could be modified by: 1) early Tertiary extension involving Cordilleran metamorphic core complexes

(Coney and Harms, 1984), and 2) crustal shortening due to Sevier deformation (Royse and others, 1975). However, this approach yields reasonable results representative of the pattern of crustal conditions at a Cordilleran scale (Coney and Harms, 1984).

On the basis of a geographic separation of 230 km and the presence of large-scale, east-flowing, fluvial systems during Newark Canyon Formation deposition, it is suggested here that Newark Canyon Formation sediments represent through-flowing paleodrainage systems that were draining the Sevier hinterland and transporting sediment to the nascent Sevier foreland basin. Indeed, 230 km of fluvial drainage is not an unreasonable distance for large-scale river systems to flow through upland terrains and have aggradational reaches along the fluvial system. Schwans (in prep) also notes the presence of Neocomian to late Albian fluvial sediments in west-central Utah (Pigeon Creek Formation), which are roughly contemporaneous with Newark Canyon Formation deposition and also pre-date foreland basin subsidence and sedimentation (Figure 35) (Heller and others, 1986). Perhaps these sediments represent reaches of the early Cretaceous paleodrainage which was transporting sediment from the hinterland uplands to the nascent Sevier foreland basin. The Newark Canyon Formation represents a fortuitously preserved proximal portion of this paleodrainage system.

CONCLUSIONS

The Newark Canyon Formation is characterized by different lithofacies assemblages and depositional architecture at each of the areas examined. The Overland Pass Newark Canyon Formation is spatially unrelated to Newark Canyon Formation strata in the Eureka District and at Cockalorum Wash; the temporal relationship between the Overland Pass section and exposures to the south remains uncertain. Temporal equivalence of the Eureka District and the Cockalorum Wash sequences has been established (Fouch and others, 1979); similarities in lithofacies assemblages suggest that strata at these two locations are lithostratigraphic equivalents.

Newark Canyon Formation strata were deposited by a variety of fluvial, fluvio-lacustrine, and lacustrine depositional systems. Crossbed and cobble orientation data indicate the presence of east-flowing fluvial systems, suggesting that highland source terrains were to the west.

Clast composition and sandstone framework grain composition data indicate that highland source terrains consisted of Paleozoic sedimentary strata. Limestone and most chert clasts originated from late Paleozoic miogeoclinal strata. Red and green chert clasts had their source either as recycled clasts from Antler foreland basin clastic deposits, or have a primary source in Roberts Mountains allochthon bedded cherts. White quartzite clasts have their source in the Ordovician Eureka Quartzite.

Sandstone framework modes reveal two separate and distinct petrofacies. Differences in composition between Overland Pass and Eureka District/Cockalorum Wash sandstones suggest that these areas had different provenances.

The Newark Canyon Formation was deposited in response to topographic relief and basin susidence created by poorly documented late Mesozoic tectonism. Clasts of Ordovician quartzite indicate that strata as old as Ordovician were exposed to erosion.

Deposition of the Newark Canyon Formation in the Eureka District and at Cockalorum Wash pre-dates the timing of deposition of the earliest synorogenic conglomerates in the Sevier foreland basin and the timing of initiation of foreland basin subsidence. Presence of large-scale, east-flowing, fluvial systems in the Newark Canyon Formation and the pre-Basin and Range extension proximity of Newark Canyon Formation exposures to the Sevier foreland basin suggest that Newark Canyon strata represent fortuitously preserved deposits of fluvial systems which were denuding the hinterland uplands and transporting sediment to the nascent Sevier foreland basin.

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APPENDICES

APPENDIX A

SECTION LOCATIONS

Overland Pass

OP1 - NE1/4 SW1/4 S32 T24N R55E; north side of Overland Pass in northeast trending gully at elevation 7600'.

OP2-A - SW1/4 SE1/4 S5 T23N R55E; south side of Overland Pass on northeast trending spur of Diamond Range.

Eureka District

CS1 - Cherry Spring: NE1/4 SE1/4 S25 T19N R55E; north side of Highway 50, east side of pullout opposite Windfall Canyon.

CS2-A - Cherry Spring: SW1/4 SW1/4 S24 T19N R53E; opposite side of hollow east of top of CS1.

CS2-B - Cherry Spring: NW1/4 SW1/4 T19N R53E; in trees 1/4 mile north of CS2-A.

CS3 - Cherry Spring: NE1/4 SW1/4 S24 T19N R53E; prominent conglomerate ledge at top of CS2-B.

HC1 - Hildebrand Canyon: NE1/4 SE1/4 S21 T20N R54E; 1/4 mile east of Palmer Ranch.

HC2 - Hildebrand Canyon: SE1/4 NW1/4 S22 T20N R54E; narrow part of canyon, vertical section on north side of road.

NC1 - Newark Canyon: SE1/4 SE1/4 S11 T19N R54E; 1/4 mile up prominent gully on north side of road, east from Pt. 7875'.

NC3 - Newark Canyon: SE1/4 NW1/4 S14 T19N R54E; south side of canyon, northeast facing steep slope at narrow part of canyon.

NC4 - Newark Canyon: NE1/4 NW1/4 S14 T19N R54E; prominent conglomerate ledges on north side of canyon.

GC1 - Green Canyon: NW1/W SE1/4 S14 T19N R54E near top of gully on southwest side of cuesta.

PCS1 - Pinto Creek Spring: SW1/4 NW1/4 S24 T19N R54E; northeast side of canyon, start at proninent boulder conglomerate ledge at base of canyon.

PCS2 - Pinto Creek Spring: SE1/4 NW1/4 S26 T19N R54E; south side of broad slope opposite Mud Springs.

Cockalorum Wash

CW1-A - SE1/4 NW1/4 S33 T15N R52E; east side of north trending gully, prominent boulder conglomerate.

CW1-B - NW1/4 NW1/4 S4 T14N R54E; east side of gully above large talus block.

CW2-A to CW2-D - E1/2 W1/2 S33 T15N R54E; scattered outcrops along east side of prominent conglomerate ridge.

CW3-A - SW1/4 SE1/4 S33 T15N R52E; prominet east dipping ledges 1/4 mile east of broad saddle in conglomerate ridge.

CW3-B - SW1/4 SW11/4 S27 T15N R52E; south side of Cockalorum Wash, low saddle west of knob of Sheep Pass Formation.

APPENDIX B

CLAST COMPOSITION DATA

Table 2. Field clast lithology count data.

LOCATION	TOTAL	GY CHT	BK CHT	RD CHT	GRN CHT	BRN CHT	WT QTZTE	SS	LS
OP-BASE	1198	867	51	100	5	5	124	25	21
CS-BASE	1049	523	111	118	51	25	105	47	69
HC-BASE	1018	110	45	13	4	8	63	32	743
NC-BASE	1858	1206	247	37	67	22	184	75	24
PCS-BASE	1107	74	73	41	0	8	16	70	825
CS-UPPER	1191	710	212	12	0	9	184	32	32
HC-UPPER	1036	132	47	12	0	5	54	63	723
NC-UPPER	2026	1069	400	37	8	33	365	75	39
PCS-UPPER	1188	774	246	19	0	34	95	16	4
CW-BASE	2441	1244	551	29	48	203	193	101	72

KEY

GY CHT - grey chert
BK CHT - black chert
RD CHT - red chert
GRN CHT - green chert
BRN CHT - brown chert
SS - sandstone
BUFF QTZTE - buff quartzite
LS - limestone

OP - Overland Pass, central Diamond Mountains
CS - Cherry Spring, Eureka District
HC - Hildebrand Canyon, Eureka District
NC - Newark Canyon, Eureka District
PCS - Pinto Creek Spring, Eureka District
CW - Cockalorum Wash, southern Fish Creek Range

APPENDIX C

SANDSTONE DETRITAL MODES

Table 3. Sandstone point count data

SAMPLE NO.	GR. SZ.	TOTAL	Q	Qm	Qp	F	L	Lt	Ls
OP1-8A	c	418	379	276	103	24	15	108	15
OP1-9	f	404	363	256	107	23	18	125	18
OP1-10	f	505	448	315	133	34	23	156	23
OP1-11	m	415	360	280	80	25	30	116	30
OP1-13	f	407	351	274	77	31	25	102	25
OP1-14	m	409	359	274	85	23	27	112	27
OP1-15	f	400	354	273	81	19	27	108	27
OP1-16	m	415	358	275	83	25	22	105	22
OP1-17	f	399	355	283	72	27	17	89	17
GC-BFR9	m	424	356	229	127	4	64	191	64
NC4-3	m	416	354	193	161	6	36	197	36
NC2-4	m	414	339	137	202	2	73	275	73
GC-BFR4	m	432	380	152	228	3	59	287	59
GC-BFR12	c	425	368	128	240	2	55	295	55
NC2-1	c	426	369	243	126	4	53	179	53
NC4-15	f	418	372	247	125	6	40	165	40
NC4-6	m	437	373	132	241	3	61	302	61
GC-BFR11	c	416	342	233	109	1	73	182	73
GC-BFR7	m	411	356	169	187	0	55	237	55
GC-BFR6	c	401	343	137	206	2	56	262	56
GC-BFR1	c	427	382	178	204	4	41	245	41
NC2-10	m	412	375	208	167	7	30	197	30
NC4-12	m	430	345	103	242	0	85	327	85
NC4-2	m	412	375	205	170	1	36	206	36
GC1-4	c	389	346	163	183	3	40	223	40
CS1-11	c	435	403	137	266	6	32	298	32
CS2-3	m	405	387	221	166	2	16	182	16
CS1-17	m	402	385	268	117	0	27	134	27
CS1-13	f	403	385	252	133	1	18	151	18
FC1-6	f	399	348	211	137	7	44	178	44
FC1-7	m	410	374	217	157	8	28	185	28
FC1-12	c	402	376	229	147	6	20	167	20
FC1-13	f	418	386	260	126	5	27	153	27
FC1-17	f	400	345	166	179	10	45	224	45
FC1-18	c	448	426	208	218	2	20	248	20
FC1-27	m	468	435	197	238	6	27	265	27
FC1-29	f	410	381	230	151	5	24	175	24
FC1-30	m	335	308	196	112	3	24	136	24

Q = total quartzose grains (Qm + Qp)
Qm = monocrystalline quartz
Qp = polycrystalline quartz
F = feldspar grains
L = nonquartzose lithic grains
Lt = total lithic grains (Qp + L)

APPENDIX D

MEASURED STRATIGRAPHIC SECTIONS

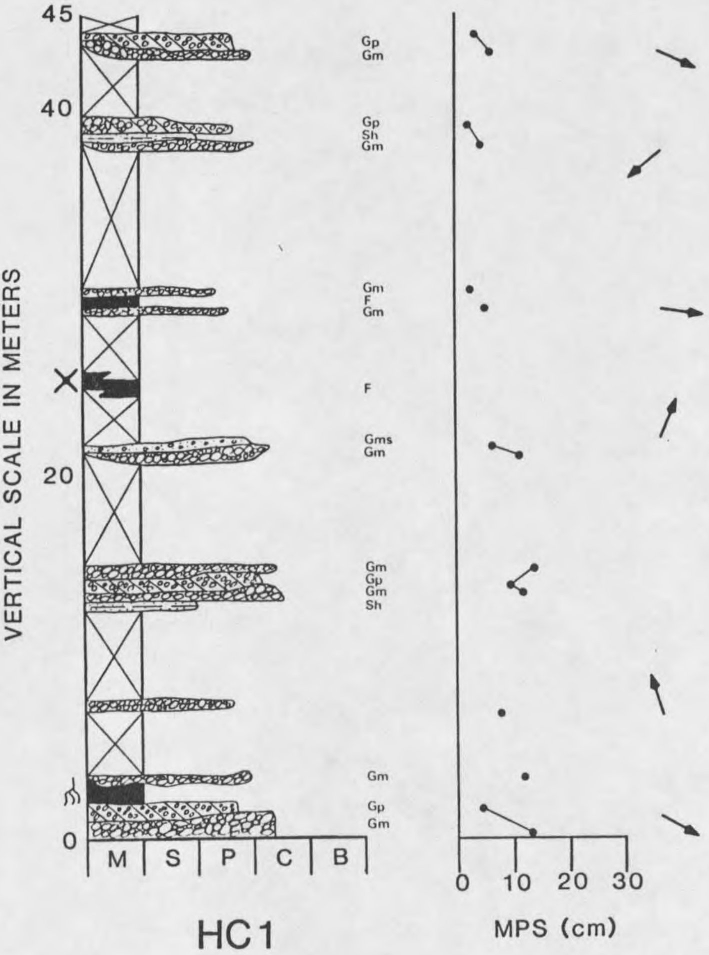

Figure 38. Measured stratigraphic section of the Eureka District Basal Conglomerate/Mudstone at Hildebrand Canyon. Refer to Figure 7 for key to lithofacies symbols and to Appendix A for section location.

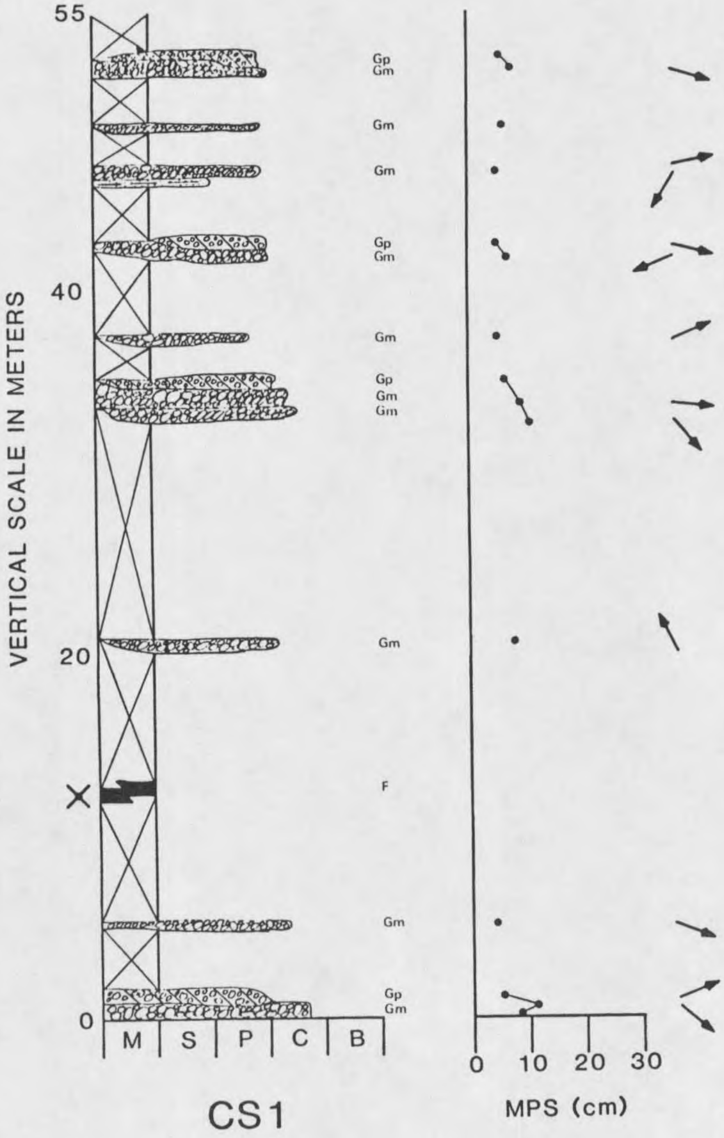

Figure 39. Measured stratigraphic section of the Eureka District Basal Conglomerate/Mudstone at Cherry Spring. Refer to Figure 7 for key to lithofacies symbols and to Appendix A for section location.

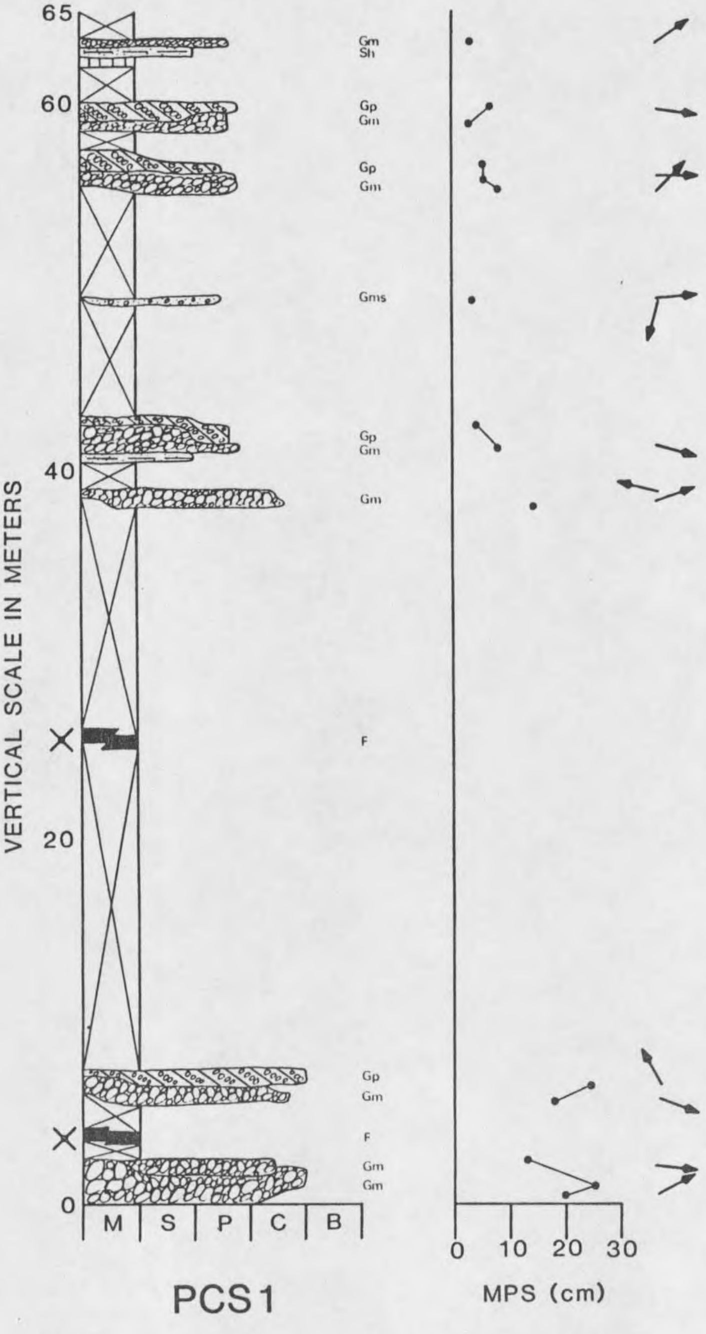

Figure 40. Measured stratigraphic section of the Eureka District Basal Conglomerate/Mudstone at Pinto Creek Spring. Refer to Figure 7 for key to lithofacies symbols and to Appendix A for section location.

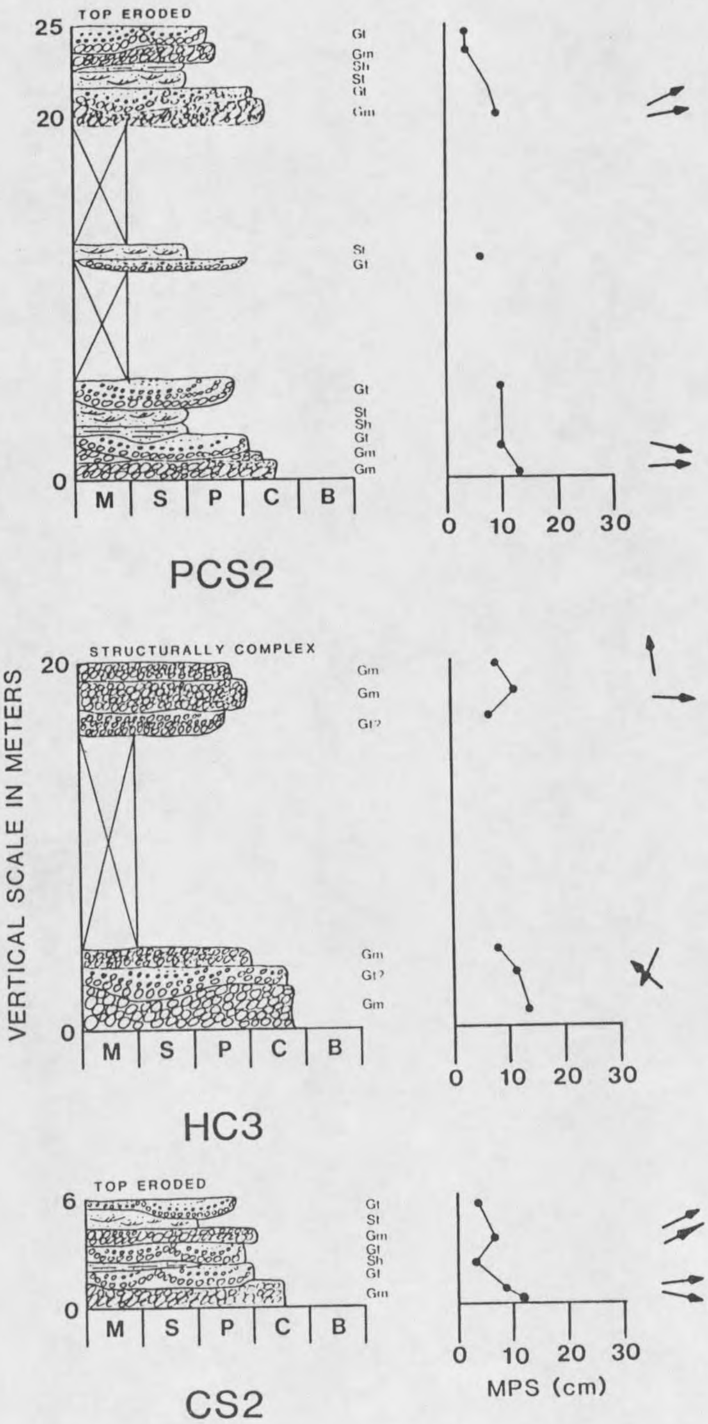

Figure 41. Measured stratigraphic sections of the Eureka District Upper Conglomerate at Pinto Creek Spring, Hildebrand Canyon, and Cherry Spring. Refer to Figure 7 for key to lithofacies symbols and to Appendix A for section locations.

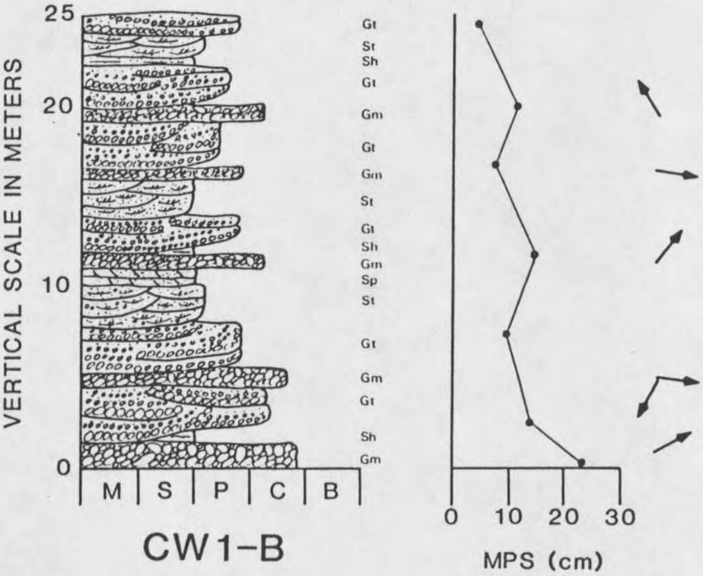

Figure 42. Measured stratigraphic section of the Cockalorum Wash Basal Conglomerate. Refer to Figure 7 for key to lithofacies symbols and to Appendix A for section location.

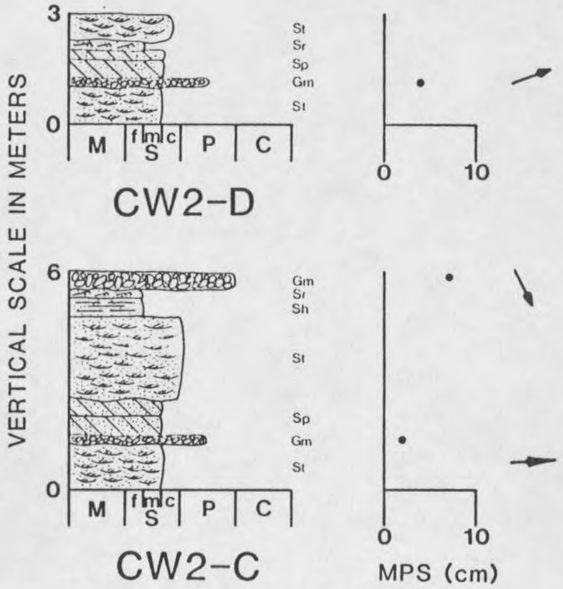

Figure 43. Measured stratigraphic sections of the Cockalorum Wash Lower Sandstone. Refer to Figure 7 for key to lithofacies symbols and to Appendix A for section locations.

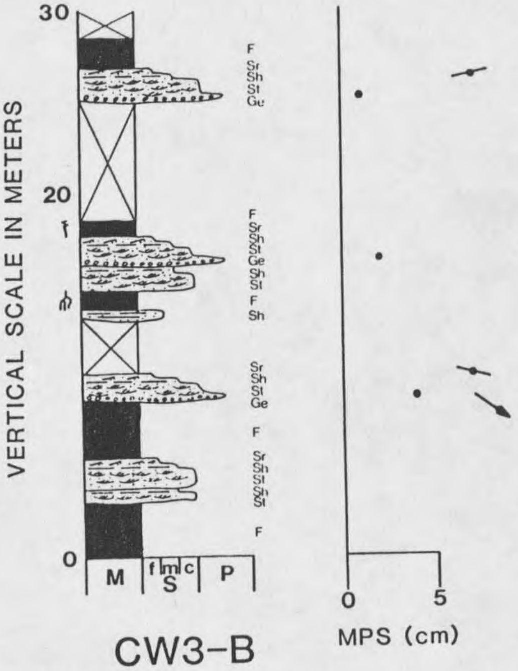

Figure 44. Measured stratigraphic section of the Cockalorum Wash Upper Sandstone. Refer to Figure 7 for key to lithofacies symbols and to Appendix A for section location.