



Sedimentology, provenance, and paleotectonic significance of the cretaceous Newark Canyon Formation, Cortez Mountains, Nevada
by James David Suydam

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

Exposures of Cretaceous Newark Canyon Formation strata in east-central Nevada provide key sedimentologic data for the interpretation of depositional systems and tectonic setting of the poorly understood hinterland of the Sevier orogenic belt. The Newark Canyon Formation in the Cortez Mountains consists of up to 740 m of interbedded conglomerate, sandstone, and mudstone with minor limestone. An Albian to Maastrichtian age is constrained by biostratigraphic data, indicating temporal equivalence with other exposures of Newark Canyon Formation and Sevier foreland basin deposits. Lithofacies analysis suggests deposition by gravelly anastomosing, wandering gravel-bed, and braided fluvial systems. Anastomosing fluvial systems resulted in isolated, lenticular, fining-upward channel bodies encased in overbank fines; tabular channel sequences with abundant interbedded fine-grained lithofacies were deposited by wandering gravel-bed and perhaps gravelly braided fluvial systems. An upward trend from anastomosed to wandering gravel-bed and braided fluvial deposits may reflect possible tectonic or local climatic controls.

Paleocurrent data support a southward direction of transport for sediment deposited in Newark Canyon Formation basins. Source areas were composed of dominantly Mississippian to Permian Antler foreland basin and overlap sequence rocks and Jurassic volcanics. lower Paleozoic miogeoclinal and eugeoclinal rocks, and upper Paleozoic rocks of the Golconda allochthon may have been minor sources. Separate basins of deposition for Newark Canyon Formation strata in east-central Nevada are supported by differences in composition and fluvial style.

Newark Canyon Formation basins developed in response to uplift and sedimentation associated with Eureka thrust belt deformation. Deposition was localized by thrust loading, and between anticlinal flexures in gently deformed late Paleozoic rocks east of the Eureka thrust belt and west of the Sevier thrust belt. Newark Canyon Formation basins developed coeval with but geographically distinct from the Sevier foreland basin.

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ABSTRACT

Exposures of Cretaceous Newark Canyon Formation strata in east-central Nevada provide key sedimentologic data for the interpretation of depositional systems and tectonic setting of the poorly understood hinterland of the Sevier orogenic belt. The Newark Canyon Formation in the Cortez Mountains consists of up to 740 m of interbedded conglomerate, sandstone, and mudstone with minor limestone. An Albian to Maastrichtian age is constrained by biostratigraphic data, indicating temporal equivalence with other exposures of Newark Canyon Formation and Sevier foreland basin deposits. Lithofacies analysis suggests deposition by gravelly anastomosing, wandering gravel-bed, and braided fluvial systems. Anastomosing fluvial systems resulted in isolated, lenticular, fining-upward channel bodies encased in overbank fines; tabular channel sequences with abundant interbedded fine-grained lithofacies were deposited by wandering gravel-bed and perhaps gravelly braided fluvial systems. An upward trend from anastomosed to wandering gravel-bed and braided fluvial deposits may reflect possible tectonic or local climatic controls.

Paleocurrent data support a southward direction of transport for sediment deposited in Newark Canyon Formation basins. Source areas were composed of dominantly Mississippian to Permian Antler foreland basin and overlap sequence rocks and Jurassic volcanics. Lower Paleozoic miogeoclinal and eugeoclinal rocks, and upper Paleozoic rocks of the Golconda allochthon may have been minor sources. Separate basins of deposition for Newark Canyon Formation strata in east-central Nevada are supported by differences in composition and fluvial style.

Newark Canyon Formation basins developed in response to uplift and sedimentation associated with Eureka thrust belt deformation. Deposition was localized by thrust loading, and between anticlinal flexures in gently deformed late Paleozoic rocks east of the Eureka thrust belt and west of the Sevier thrust belt. Newark Canyon Formation basins developed coeval with but geographically distinct from the Sevier foreland basin.

INTRODUCTION

Geologic Setting

The tectonic and depositional histories of the Sevier orogenic belt and associated foreland basin have been the subject of considerable investigation and are reasonably well understood. Sevier deformation is expressed by Proterozoic to Mesozoic rocks in Montana, Idaho, Wyoming, Utah, and southern Nevada that are displaced a minimum of 140 km on west-dipping thrust faults which sole into a regional decollement (Armstrong and Oriel, 1965; Armstrong, 1968; Fleck, 1970; Royse and others, 1975). Deformation is thought to have begun during Late Jurassic time (Allmendinger and Jordan, 1981) and continued until the Eocene (Dorr and others, 1977; Wiltschko and Dorr, 1983). Thrust loading and concomitant sedimentation resulted in the accumulation of thick sequences of Cretaceous to early Tertiary strata in the Rocky Mountain foreland basin (Jordan, 1981). Subsidence studies of Heller and others (1987) indicate the earliest synorogenic deposits of the foreland basin were deposited in response to thrust plate-induced subsidence beginning in Aptian time. Numerous sedimentologic and stratigraphic studies of coarse-grained deposits adjacent to the thrust belt have helped bracket the timing of Sevier deformation and characterize the types of depositional systems that operate in an actively subsiding foreland basin (for example, Lawton, 1983; Dickinson and others, 1986; Schmitt and Kohout, 1986; DeCelles and others, 1987).

Despite the large volume of knowledge concerning the Sevier orogenic belt and foreland basin, comparatively little work has been done in the hinterland, defined by Armstrong (1968) as the region west of the Sevier thrust belt and east of the Sierra Nevada magmatic arc (Figure 1). Studies in the hinterland have been hampered by complex structural relations and a paucity of Cretaceous strata. Several

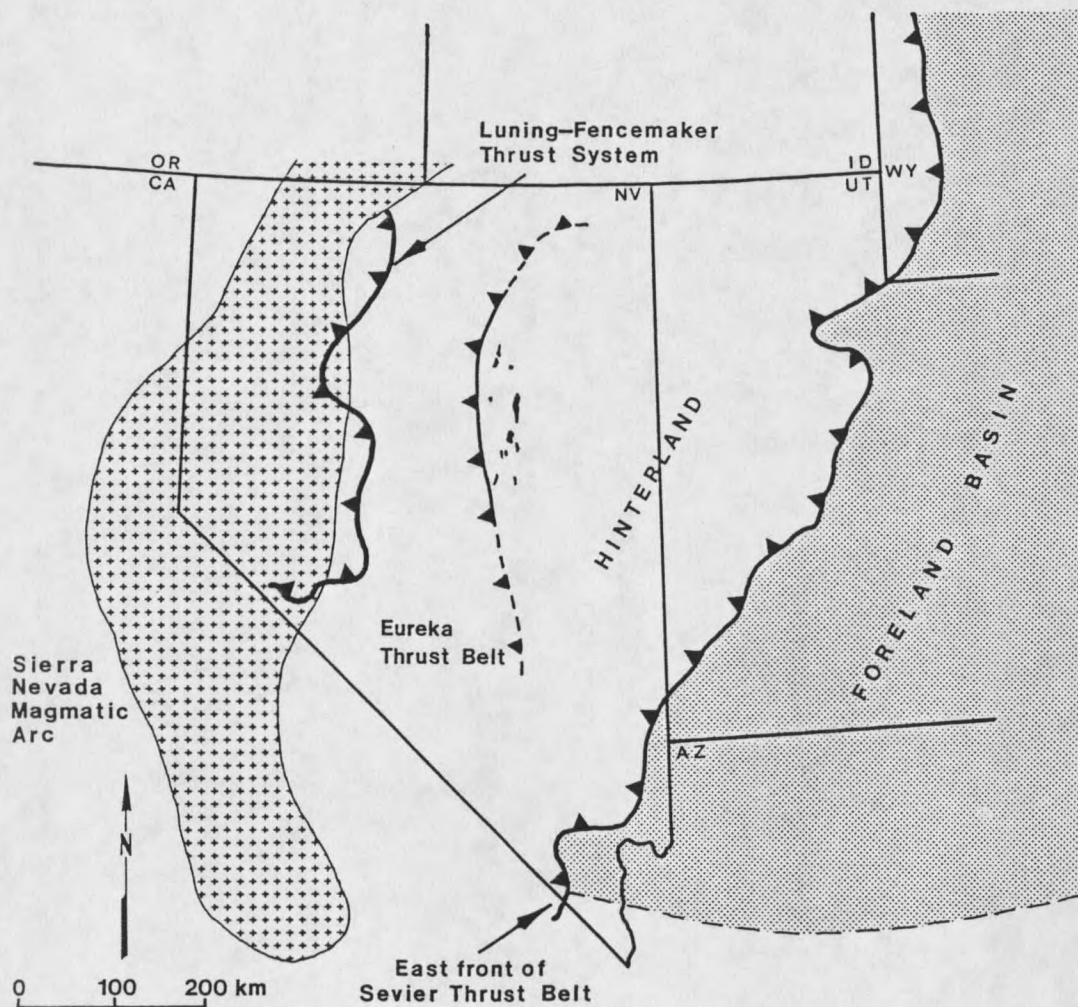


Figure 1. Regional map of the central western U.S. Cordillera showing late Mesozoic tectonic features in relation to exposures of Cretaceous Newark Canyon Formation (solid pattern). Data from Stewart (1980), Speed (1983), Allmendinger and others (1987), Little (1987), and Bartley (personal communication, 1988).

workers have interpreted distinct belts of shortening within the hinterland (Ketner and Smith, 1974; Allmendinger and Jordan, 1981; Coats and Riva, 1983; Speed, 1983; Oldow, 1984; Bartley and others, 1987); however, the magnitude and extent of these are largely obscured by late Tertiary extension and volcanism. Coney and Harms (1984) suggest the hinterland was an elevated plateau created by lower crustal thickening and was therefore not a favorable site for late Mesozoic to early Tertiary sedimentation. A detailed sedimentologic and provenance study of Cretaceous basin-fill in the hinterland is a vital link in discerning the tectonic history and depositional systems of this poorly understood region.

The distribution of Cretaceous rocks in Nevada is limited to a discontinuous belt of exposures in east-central Nevada that have been assigned to the Newark Canyon Formation (see Figure 1). The type area for the Newark Canyon Formation was defined by Nolan and others (1956) for exposures of Cretaceous rocks in the southern Diamond Mountains near Eureka, Nevada (Figure 2). Cretaceous rocks in the southern Fish Creek Range have also been mapped as Newark Canyon Formation (Hose, 1983). Smith and Ketner (1976b) recognized the Newark Canyon Formation in the Cortez Mountains and Pinon Range south of Carlin, Nevada (Figure 2). Scattered exposures also occur in the Pinon Range (Smith and Ketner, 1976b) and Simpson Park Range (Stewart and Carlson, 1978).

Objectives of Study

The primary objective of this study is to conduct detailed sedimentologic and provenance analyses of the Cretaceous Newark Canyon

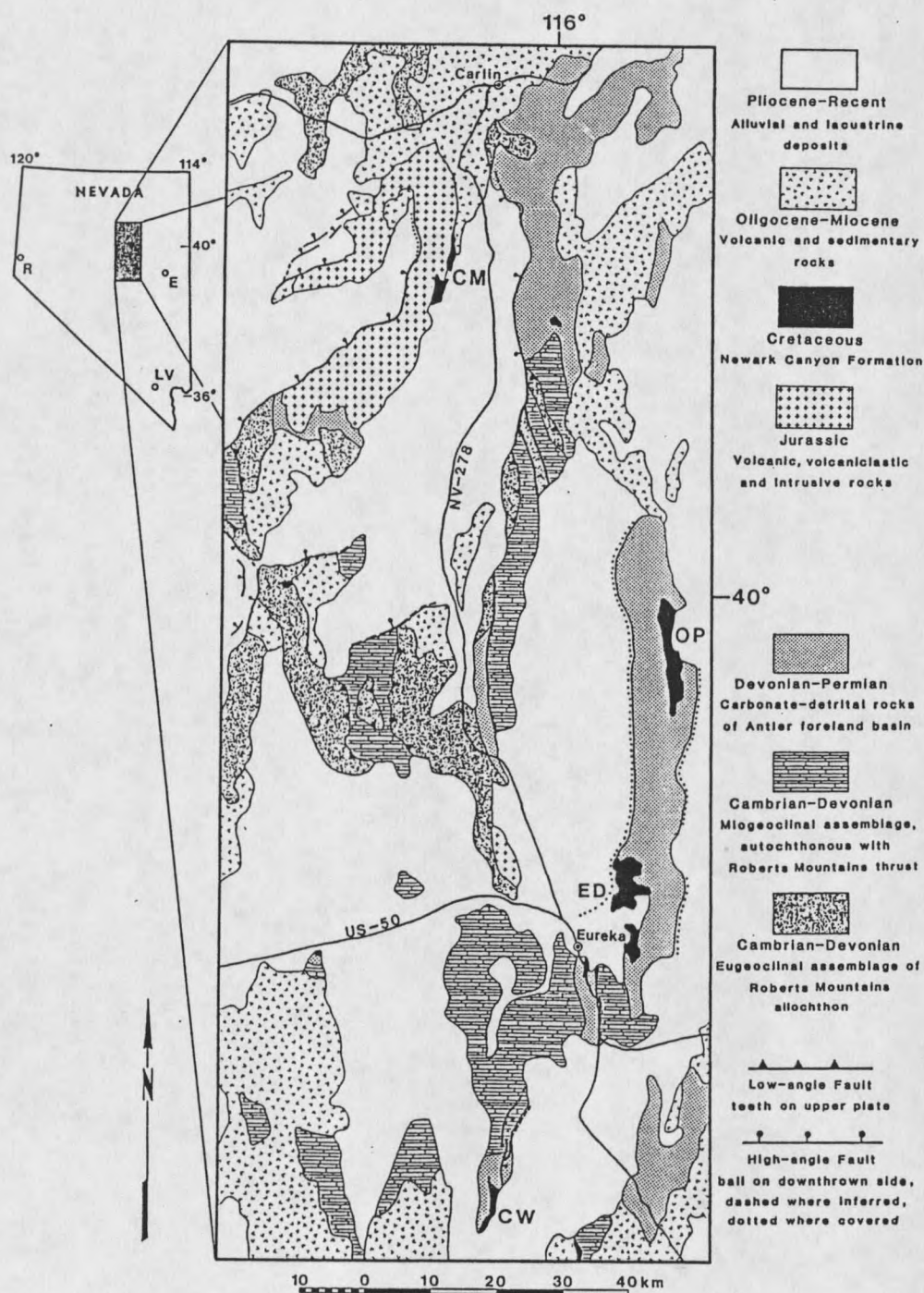


Figure 2. Generalized geologic map of part of east-central Nevada showing the distribution of Newark Canyon Formation. CM=Cortez Mountains exposures of this study; OP=Overland Pass, ED=Eureka District, and CW=Cockalorum Wash exposures studied by Vandervoort (1987). Geology from Stewart and Carlson (1978).

Formation in the Cortez Mountains of east-central Nevada. More specifically, data gathered from the rocks will be analyzed in light of the following questions:

- 1) What depositional system(s) were responsible for sedimentation in Newark Canyon Formation basins?
- 2) What do paleoflow directions and composition of terrigenous units indicate about geographic position and lithology of source areas?
- 3) Can a paleogeographic setting for the Newark Canyon Formation basin(s) be documented by synthesizing the results of this study with those of Vandervoort (1987)?
- 4) What can lateral and vertical variations in lithology and facies suggest about the paleotectonic setting of Newark Canyon Formation basins?

Answers to the above questions will contribute to a better understanding of hinterland tectonics and the nature of non-marine depositional systems in hinterland basins.

Study Area

The area of study encompasses exposures of Newark Canyon Formation in a belt 11 km long and up to 2 km wide on the east flank of the Cortez Mountains, approximately 30 km south of Carlin, Nevada (see Figure 2). Outcrops are well preserved in canyons which cut across the regional strike and although the mudstone units are deeply weathered and poorly exposed, represent some of the best exposures of Newark Canyon Formation in east-central Nevada (Figure 3). The study area is accessible by several ranch roads which wind up canyons in the Cortez Mountains from State Highway 278 in the center of Pine Valley. The northern outcrop area is more easily accessed than the southern by an improved dirt road that traverses the Cortez Mountains.

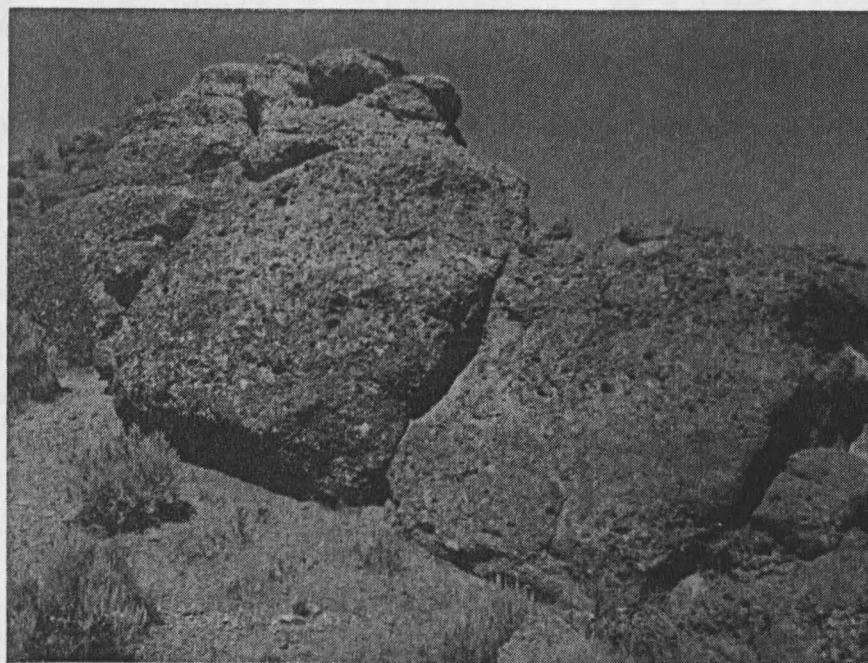


Figure 3. Representative exposures of Newark Canyon Formation conglomerates from measured section CM6 on the east flank of the Cortez Mountains.

Methodology

Field Methods

Eight stratigraphic sections comprising nearly 4 km of Newark Canyon Formation were measured with a Jacob's staff at locations deemed suitable for sampling and lithofacies descriptions (Appendix A). Lithofacies were described using the classification scheme developed by Miall (1977; 1978) and appended by Rust (1978). The measured stratigraphic sections and lateral profiles constructed from field sketches and photographs contributed to a lithofacies analysis stressing vertical and horizontal facies associations (Miall, 1985). Representative sandstone units were sampled for thin-sectioning and

petrographic analysis. The average size of the ten largest clasts in each conglomerate unit was recorded to determine general grain-size trends.

Clast identification counts were performed on pebble-cobble conglomerates to determine compositional trends and clast provenance. A minimum of 250 clasts were counted at each locality using a fixed grid exceeding the mean observed clast size. Paleoflow data were gathered from conglomerate and sandstone trough axes by direct measurement where exposures permitted or by estimation (DeCelles and others, 1983) for two-dimensional exposures. The strike and dip of platy clasts and long-axis orientation of elongate clasts in conglomerates were measured to determine paleoflow as well.

Laboratory Methods

Thin-sections of 43 Newark Canyon Formation sandstones were examined with a research petrographic microscope. Each thin-section was counted on a fixed-grid spacing for a minimum of 400 framework grains (points). Although only fine- to medium-grained sandstones were used to facilitate point-counting, modal grain sizes were visually estimated for each sample. Compositional data were plotted on QFL and Q_mFL_t ternary diagrams to discern possible petrofacies and provenance (Dickinson and Suczek, 1979). Clast imbrication/orientation and trough axes were rotated on an equal-area stereonet to correct for post-depositional tectonism. These data were then plotted as rose diagrams with calculated vector means and magnitudes (Potter and Pettijohn, 1977, p.259-271).

NEWARK CANYON FORMATION

The name Newark Canyon Formation was originally applied by Nolan and others (1956) to exposures of heterogeneous rocks of Cretaceous age near Eureka, Nevada. Strata in the northern Diamond Range near Overland Pass were mapped as Permian by Larsen and Riva (1963), but have since been renamed Newark Canyon Formation (Larsen, personal communication, in Stewart, 1980). Exposures of Cretaceous strata in the southern Fish Creek Range have also been mapped as Newark Canyon Formation (Hose, 1983). Vandervoort (1987) recently completed a detailed sedimentologic investigation of these areas which he referred to as the Eureka District, Overland Pass, and Cockalorum Wash (see Figure 2).

The Newark Canyon Formation in the Diamond Mountains and Fish Creek Range varies from approximately 200 to 700 m in thickness and consists of interbedded conglomerate, sandstone, mudstone, and limestone which unconformably overlie or are in fault contact with Ordovician through Permian strata. Vandervoort (1987) concluded through lithofacies and provenance analyses that the Newark Canyon Formation was deposited by east to southeast flowing gravelly and sandy braided fluvial systems. Furthermore, he determined the composition of source areas from clast suites to have been Mississippian Antler foreland basin and Paleozoic miogeoclinal strata.

An Early Cretaceous (Aptian-Albian) age is assigned to the Newark Canyon Formation in the Eureka District based on the presence of nonmarine mollusks, ostracodes, fish, charophytes, and palynomorphs

(MacNeil, 1939; David, 1941; Nolan and others, 1956; Fouch and others, 1979) (Figure 4). Vandervoort (1987) collected an unidentifiable dinosaur bone fragment as well. MacNeil (1939) interpreted these rocks to be equivalent to the lower part of the Blairmore Group of Alberta, Canada on the basis of nonmarine mollusks. Ostracodes and palynomorphs identified from the Newark Canyon Formation at Cockalorum Wash indicate a Barremian to early Albian age (Tschudy, written communication, in Fouch and others, 1979). Strata at Cockalorum Wash are temporally

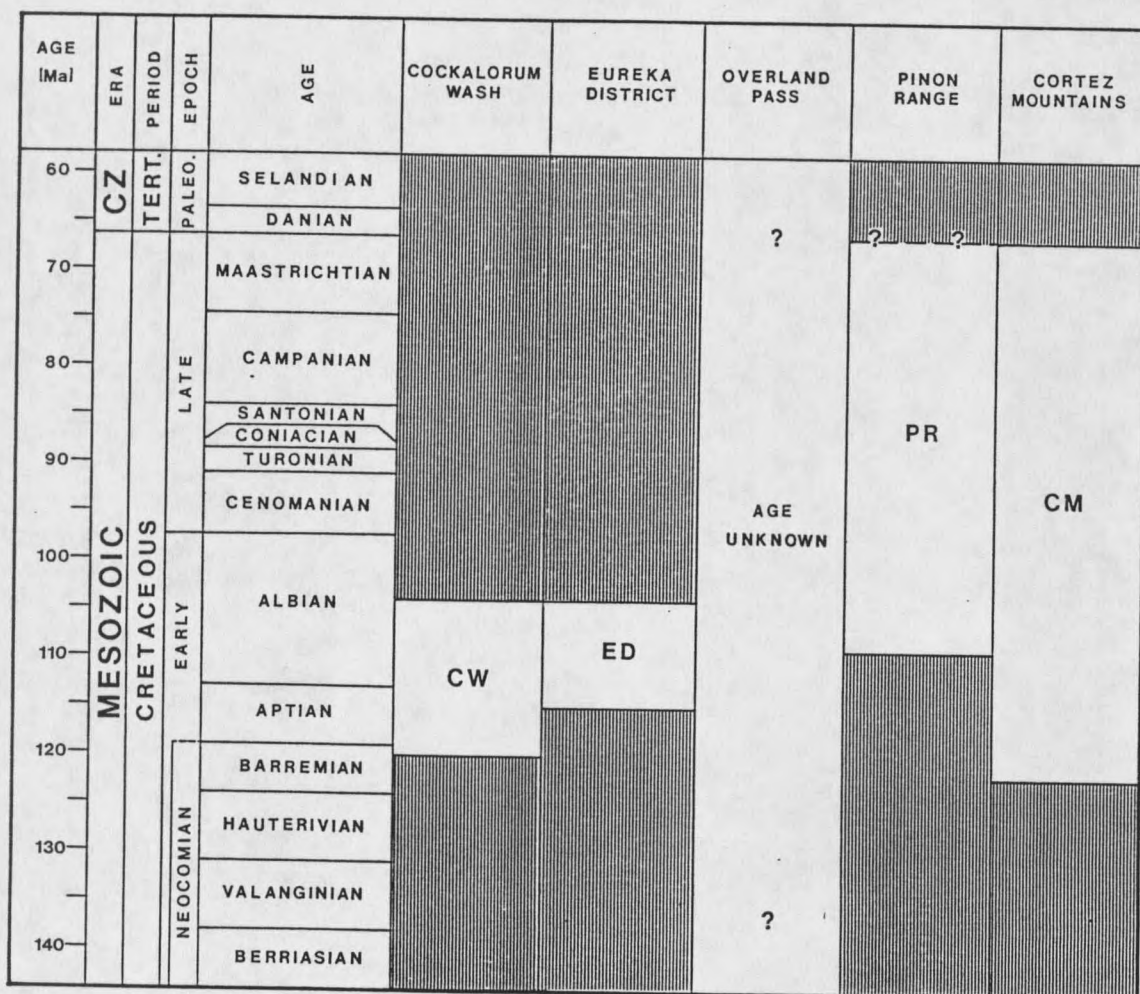


Figure 4. Correlation chart of Newark Canyon Formation exposures in east-central Nevada. Refer to Figure 2 for locations. Data from Smith and Ketner (1976b), and Fouch and others (1979).

equivalent to Eureka District strata (see Figure 4) and partially correlative with the Lakota, Burro Canyon, and Cedar Mountain Formations of the Rocky Mountains (Tschudy, written communication, in Fouch and others, 1979; Fouch and others, 1979). Furthermore, the Newark Canyon Formation in the Eureka District and Cockalorum Wash are partly equivalent to recently recognized nonmarine rocks of the Pigeon Creek Formation in central Utah (Schwans, in press). Strata at Overland Pass lack identifiable fauna and are assigned to the Newark Canyon Formation based on lithologic similarities (Dott, 1955; Larsen, personal communication, in Stewart, 1980).

Smith and Ketner (1976b) assigned nonmarine rocks from the east flank of the Cortez Mountains and central Pinon Range to the Newark Canyon Formation (refer to Figure 2). Age of the Newark Canyon Formation in the Cortez Mountains is based on the identification of reptile bones and teeth, fossil plants, ostracodes, and palynomorphs and can be best constrained as latest Early to Late Cretaceous (Smith and Ketner, 1976b). During this study, abundant petrified wood with stumps as large as 50 cm in diameter were observed in the upper part of the section. Additionally, unidentifiable dinosaur bone fragments were collected from the basal mudstone unit in the northern outcrop area. Strata in the Pinon Range contain an ostracode fauna indicative of Early Cretaceous to Paleocene age (Sohn, 1969; Fouch and others, 1979) (see Figure 4). A recent stratigraphic and sedimentologic study by Biglow (1986) concentrated on the Cortez Mountains exposures; however, more detailed field, petrographic, and lithofacies data collected as a part of this investigation suggests reinterpretations are needed.

The scope of this study was limited to the exposures in the Cortez Mountains as they were deemed the most significant in contributing towards lithofacies and provenance analyses. The strata on the east flank of the Cortez Mountains attain a maximum thickness of 740 m and unconformably overlie the Jurassic Frenchie Creek Rhyolite member of the Pony Trail Group, a volcanic unit consisting of rhyolite-andesite flows, tuffs, and volcanoclastic sandstones. The basal contact is not well exposed but outcrop relations along the extent of the exposures suggest topographic relief existed on the Frenchie Creek prior to Newark Canyon Formation deposition. The section typically grades upward from a poorly exposed basal mudstone unit with thin lenticular conglomerate and sandstone to a sequence of interbedded conglomerate, sandstone, mudstone, and minor limestone (Figure 5). The Newark Canyon Formation is unconformably overlain by Oligocene ash-flow tuff, Plio-Pleistocene fluvial and lacustrine deposits, and Quaternary gravels.

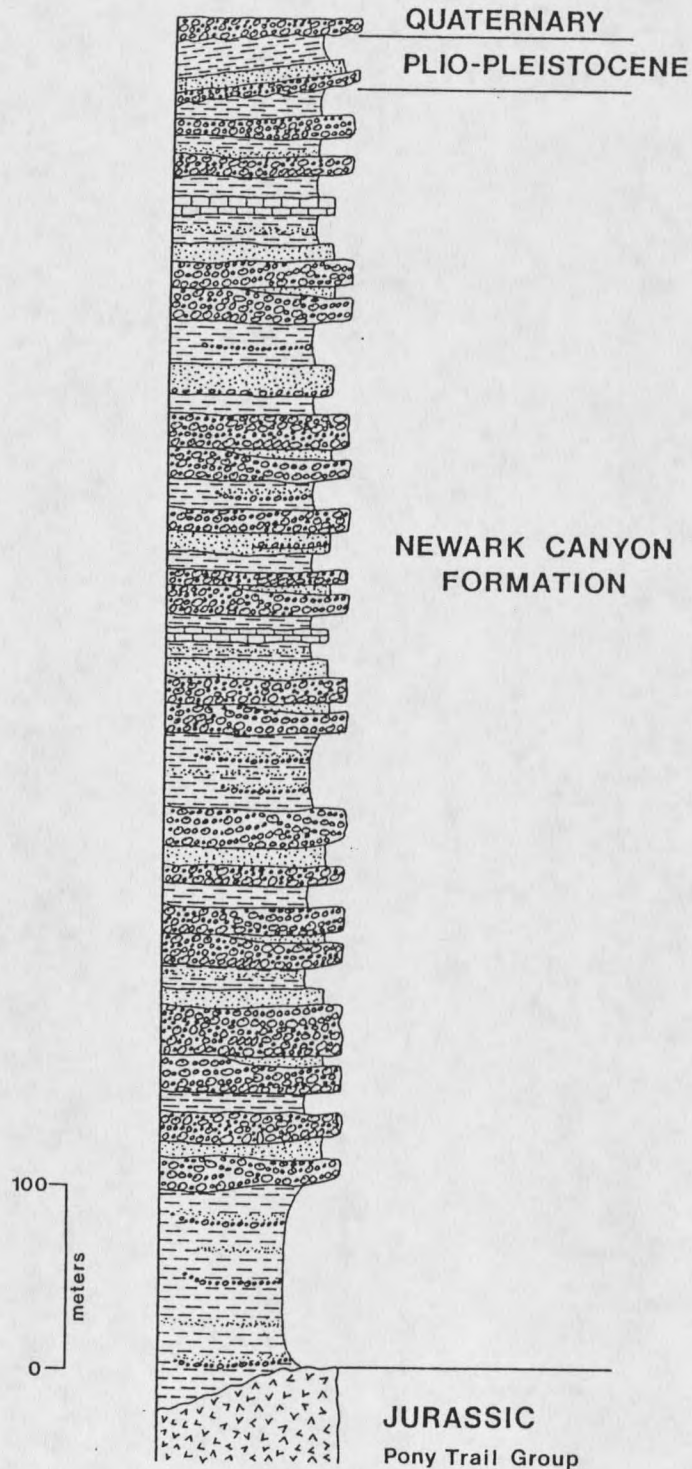


Figure 5. Generalized, schematic vertical profile of the Newark Canyon Formation in the Cortez Mountains, east-central Nevada. Thicknesses of individual units are approximate.

LITHOFACIES

The Newark Canyon Formation in the Cortez Mountains contains conglomerate, sandstone, mudstone, and minor carbonate lithologies. Lithofacies are distinguished on the basis of texture, fabric, and sedimentary structures and assigned a one or two letter code (Miall, 1977, 1978; Rust, 1978). The following discussion addresses each lithofacies separately giving : 1) a description of physical characteristics followed by, 2) a genetic interpretation based on modern and ancient examples.

Massive or Crudely Bedded Conglomerate (Gm)

Description

Massive or crudely bedded conglomerate (Gm) consists of organized and disorganized clast-supported conglomerate. Organized Gm has pebble- to cobble-size framework clasts and medium to very coarse sand-size matrix which locally shows normal grading. Normal grading is apparent in a few units; however, clast-size trends are generally lacking. Lithofacies of this type are characterized by poor to moderate sorting, angular to rounded clasts, and closed-framework packing. When present, crude horizontal bedding is defined primarily by differences in clast size (Figure 6). Contact clast imbrication and preferential orientation of clasts is rare due to the paucity of platy and elongate clasts. Units of organized Gm occur as individual beds less than 1 m thick with irregularly scoured basal surfaces or as sequences of several stacked

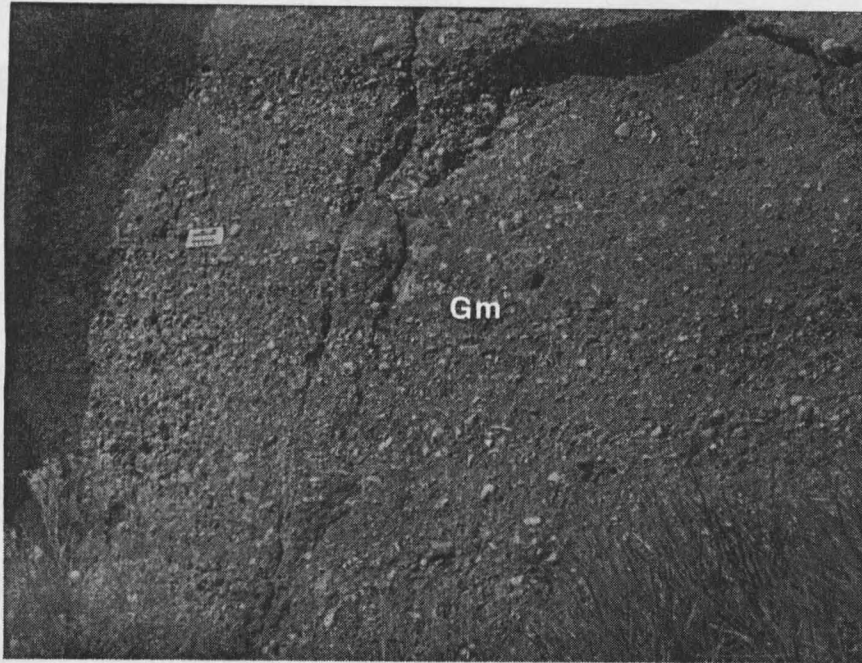


Figure 6. Organized, massive, pebble to cobble conglomerate (Gm) with crude horizontal bedding. Scale is approximately 14 cm long.

beds and are typically scoured into and truncated by lithofacies Gt. Channel geometries with lateral dimensions of tens of meters are most prevalent, while other units are apparently tabular.

Disorganized clast-supported conglomerate is massive and more poorly-sorted than organized Gm. Framework clasts range from pebble to boulder size with a matrix consisting of poorly-sorted sand, pebbles, and a small percentage (< 5%) of mud (Figure 7). Normal grading is poorly developed in some units. When present, platy and elongate clasts display apparently random orientations. Units of disorganized Gm are typically less than 2 m thick and occur as channelized, laterally discontinuous bodies.

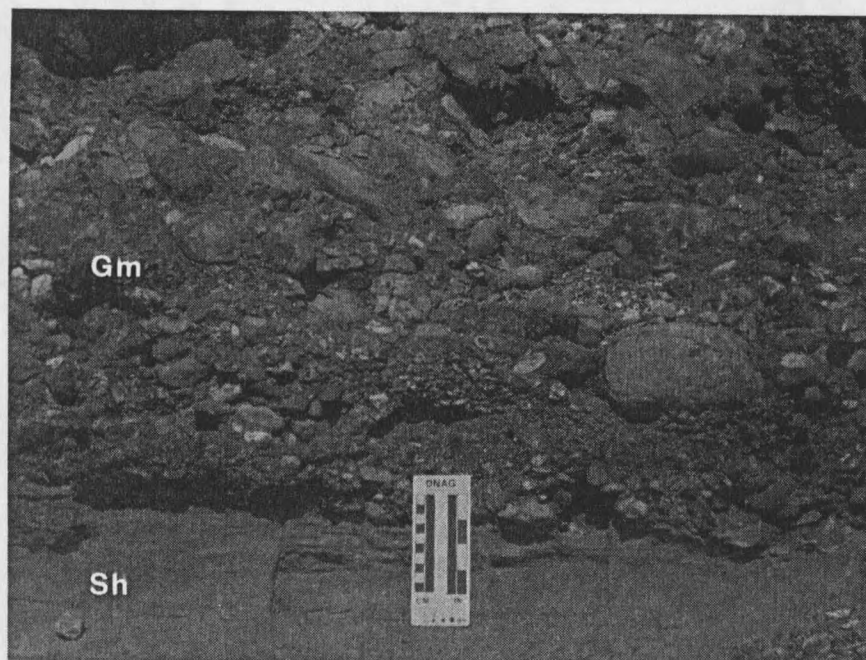


Figure 7. Very poorly-sorted, disorganized, massive conglomerate (Gm) scoured into fine-grained, horizontally-laminated sandstone (Sh).

Interpretation

Organized, clast-supported, massive and crudely bedded conglomerate (Gm) is interpreted as the deposit of longitudinal gravel bars. Longitudinal bars develop and migrate during periods of high discharge in braided fluvial systems (Rust, 1972; Smith, 1974). At high flow, gravel bedload is mobilized as diffuse gravel sheets only a few clasts in thickness (Hein and Walker, 1977). Waning flow as a result of waning flood, diurnal variation, bed roughness, and channel obstructions causes deposition of coarse bedload which then acts as a nucleus for further bar development during periods of higher flow. Crude horizontal stratification is produced by such discharge fluctuations (Miall, 1977). The lack of angle-of-repose foresets (lithofacies Gp), formed by the slip-face migration of high relief gravel bars, indicate vertical

accretion of gravel sheets was not sufficient to develop high relief bars. Hein and Walker (1977) suggest horizontally stratified or massive gravel is deposited under conditions of high sediment and fluid discharge when the majority of coarse bedload is deposited on the downstream side of low amplitude bars. Furthermore, the presence of irregular basal contacts and truncation by lithofacies Gt (discussed below) support the extensive erosional modification of preexisting bars. Sandy matrix accumulated in the interstices of originally openwork gravel during lower flow stages (Enyon and Walker, 1974; Smith, 1974). Normal grading of granules to medium sand within the matrix indicates a significant flow deceleration (Rust, 1984).

Disorganized, massive, clast-supported conglomerate (Gm) was deposited by processes intermediate between pure, turbulent stream flow and laminar, cohesive debris flow. Beverage and Culbertson (1964) used the term 'hyperconcentrated stream flow' for suspensions with sediment concentrations between 40 and 80 wt%. Since sediment concentration is impossible to determine from deposits, Smith (1986) introduced a related term, 'hyperconcentrated flood flow', to describe high discharge flows representing extreme flood events. The texture and fabric of disorganized Gm described in this study are consistent with previously interpreted hyperconcentrated flood flow gravels (Smith, 1986; Schmitt and Olson, 1986) and sheetflood conglomerates (Ballance, 1984; Wells, 1984), and similar to strata deposited by the 'pseudoplastic debris flows' of Shultz (1984). Rapid traction and suspension deposition is suggested by the overall poor sorting, normal grading, and long-axis orientations of clasts both transverse to and parallel with paleoflow

(Smith, 1986). Turbulence acts as the dominant sediment-support mechanism; however, a fine-grained suspended load can contribute to the suspension of larger clasts by increasing the fluid viscosity and thus decreasing sediment fall velocity (Simons and others, 1963).

Trough Crossbedded Conglomerate (Gt)

Description

Trough crossbedded conglomerate (Gt) represents 70 % of the Newark Canyon Formation conglomerates in the study area. Lithofacies Gt consists of distinctly stratified pebble-cobble conglomerate texturally similar to organized Gm. Individual troughs are broad, shallow features 30 cm to 1.5 m deep and ranging from several meters to almost 10 m in lateral extent. True dimensions are probably greater, as troughs are typically truncated by others both laterally and vertically. Each trough is characterized by a concave-up erosional base, typically overlain by a lag of pebbles or cobbles which are coarser than the trough-fill. Trough-fill strata commonly conform to the basal scour surface and as a result, dip less than 15° (Figure 8). Less commonly, trough-fill strata consist of normally graded foresets up to 10 cm thick with dips of 20 to 25° (Figure 9). Cosets consisting of several individual troughs are most common, but solitary sets associated with lithofacies Gm and within sandstone lithofacies are also present.

Interpretation

Trough crossbedded conglomerate (Gt) represents the deposition of gravel in major channels during flood-stage and waning flow and in minor

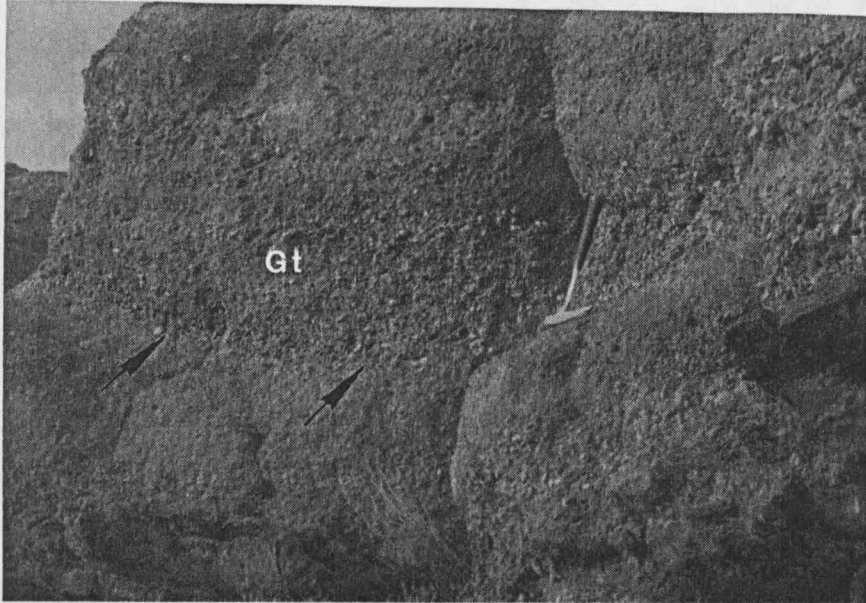


Figure 8. Well-developed trough set within poorly defined trough crossbedded conglomerate (Gt). Arrows point to base of prominent trough.

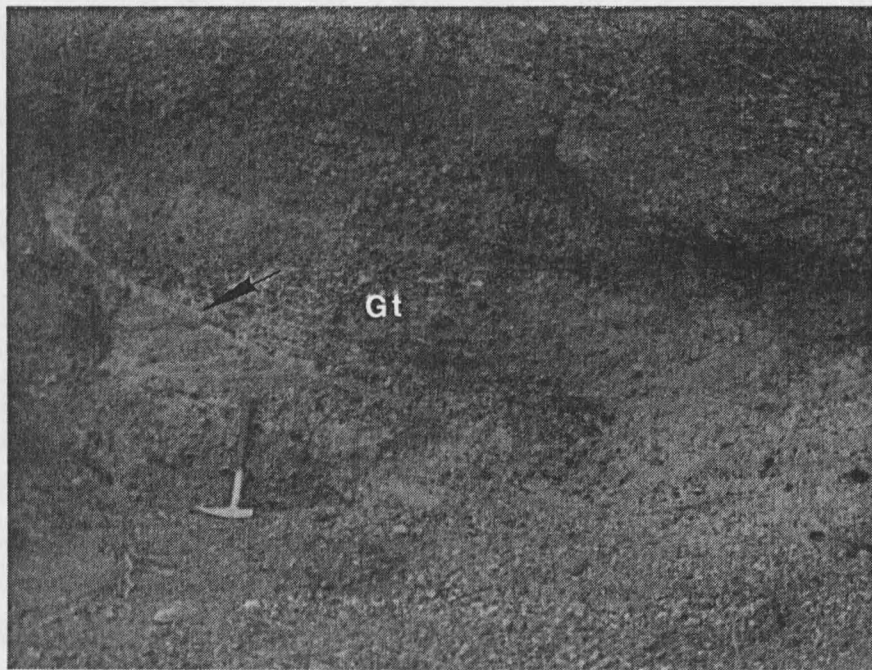


Figure 9. Trough crossbedded conglomerate (Gt) with well-developed, angle-of-repose foresets. Arrow is oriented parallel to foresets and points to base of trough.

bar top scours in braided streams (Miall, 1977). Major channels develop by avulsion during high-stage whereas smaller channels and scours are largely produced by waning flow modification of bar surfaces and margins (Williams and Rust, 1969). Deposition during upper flow regime plane-bed conditions is suggested by gravelly-trough fill that conforms to the basal scour surfaces of troughs (Miall, 1977). The nature of trough-fill stratification, geometry of individual troughs, and association with lithofacies Gm suggest the majority of trough crossbedded conglomerate was generated as broad scours and channels were filled by successive diffuse gravel sheets. The remainder of lithofacies Gt, consisting of troughs with high-angle foresets (20 to 25°), was deposited by gravel dunes (Enyon and Walker, 1974). Bedforms of this type were probably similar to those observed by Galay and Neill (1967) in the North Saskatchewan River. Cosets of trough crossbedded conglomerate represent channel-fill sequences characterized by repeated scour-and-fill or migrating gravel bedforms (Rust, 1978).

Trough Crossbedded Sandstone (St)

Description

Trough crossbedded sandstone (St) commonly consists of cosets of mutually cross-cutting troughs (Figure 10) and to a lesser extent, solitary troughs scoured into underlying lithofacies (Miall, 1977). Isolated troughs are likely lithofacies Ss (asymmetrical scour facies of Cant and Walker (1976)); however, they are included here with lithofacies St because the two could not be confidently distinguished in the field. Individual sets range from 5 to 70 cm in thickness and up to

1.5 m wide. Each trough is an elongate, scoop-shaped scour aligned parallel with local flow directions (DeCelles and others, 1983). Troughs are filled with curved foreset strata that merge tangentially with the basal scour surface and plunge down-current. Lithofacies St is comprised of very coarse- to medium-grained, moderately- to poorly-sorted sandstone; granules and small pebbles are locally abundant directly above the lower bounding surfaces of some troughs. Sets generally decrease in size from the base to top of cosets. Lithofacies St commonly grades upward from trough crossbedded conglomerate (Gt) and is overlain depositionally by lithofacies Sr, Sm, or Fm.

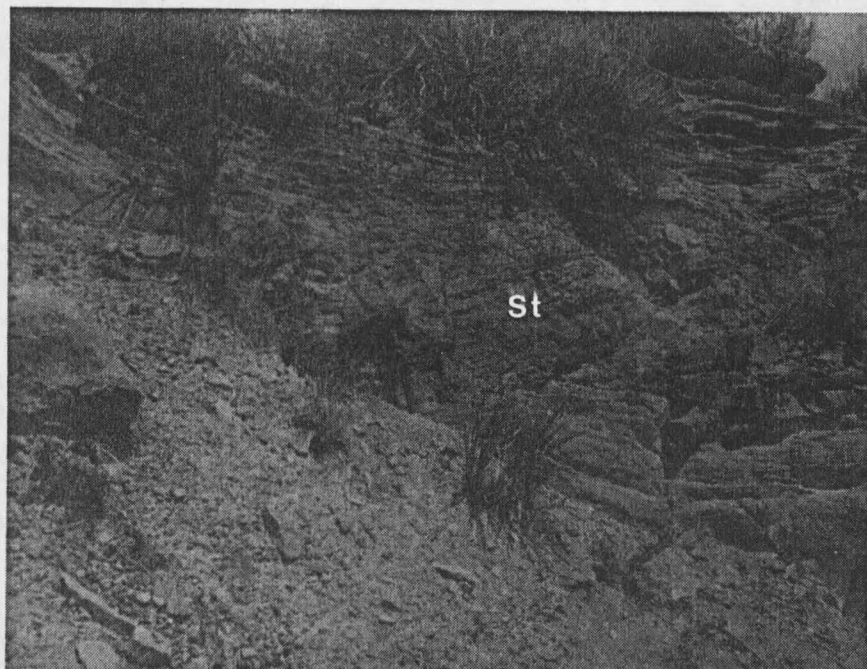


Figure 10. Large coset of trough crossbedded sandstone (St). Note lateral and vertical truncation of individual troughs.

Interpretation

Trough crossbedded sandstone (St) is interpreted as the deposits of sinuous-crested dunes which form and migrate in the lower flow regime (Harms and Fahnestock, 1965; Harms and others, 1982). Isolated troughs and small cosets associated with facies Gm and Gt represent migrating dunes and/or scour-fill in bar top channels and scours during waning flow and low-stage conditions (Enyon and Walker, 1974; Boothroyd and Ashley, 1975). Renewed higher stage flow likely obliterated many sandy bedforms, preserving only those deposited in the topographically lower areas of bar surfaces. Large cosets of trough cross-strata are channel-fill sequences deposited by dunes on the floor of channels as a result of waning flood or perhaps avulsion of the main channel. The latter is supported by the presence of thick St sequences which are laterally equivalent in outcrop-scale with conglomeratic units.

Horizontal and Low-Angle Stratified Sandstone (Sh/Sl)

Description

Horizontal (Sh) and low-angle stratified sandstone (Sl) are composed of fine- to very coarse-grained sandstone which are otherwise texturally similar to lithofacies St. Lithofacies Sh and Sl are grouped together here as they commonly grade into one another and, as is discussed below, are formed under similar conditions. Horizontally stratified sandstone (Sh) occurs as laminated, tabular beds 10 cm to 1.8 m in thickness (Figure 11), and several meters wide to laterally continuous in outcrop-scale. Parting lineation may or may not be present on bedding plane surfaces. Low-angle stratified sandstone (Sl)

consists of solitary or groups of several sets of broad, shallow scours which grade into lithofacies Sh or are laterally truncated by other scours. Scours are filled with conformable, low-angle ($< 10^{\circ}$) strata generally 0.5 to 1 cm thick (Figure 11). Fragmented plant material and mudstone intraclasts are locally abundant in both lithofacies. Lithofacies Sh and Sl typically overlie lithofacies Gm, Gt, and St and are either erosionally scoured by conglomerate lithofacies or overlain by St, Sr, or Fm.

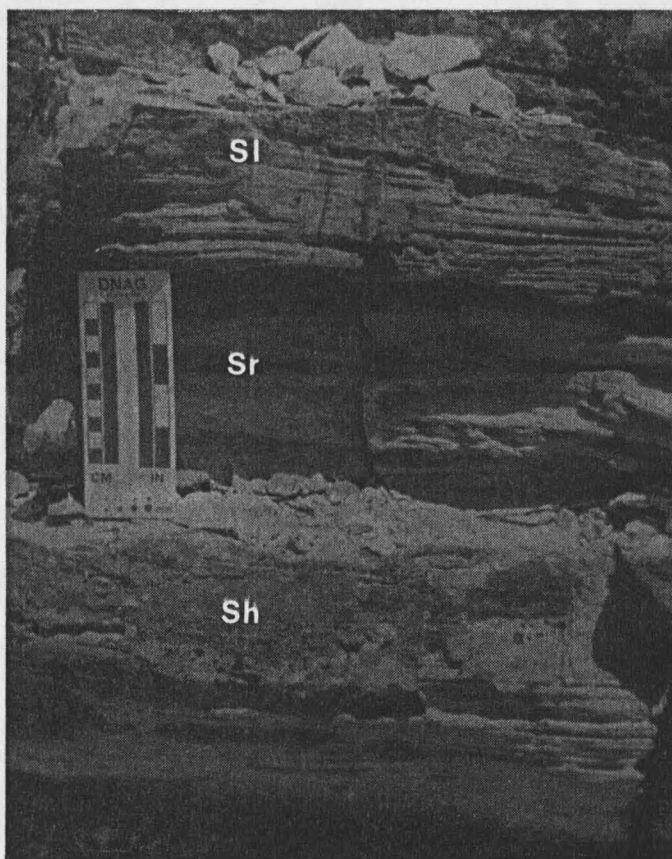


Figure 11. Fine- to coarse-grained, horizontal (Sh), ripple (Sr), and low-angle (Sl) stratified sandstone.

Interpretation

Horizontally stratified sandstone (Sh) was deposited in upper and lower plane-bed conditions associated with waning flow on bar surfaces and low-water accretion in channels. Shallow flow over bars during waning flow sustained upper flow regime velocities conducive to traction deposition of fine sand (Harms and Fahnestock, 1965). The presence of parting lineations in some units supports upper plane-bed deposition (Harms and others, 1982); however, this structure is either absent or unrecognizable in the majority of lithofacies Sh. In these instances, horizontally laminated sandstones (Sh) may have been deposited by low-stage accretion in channels. Harms and others (1982) showed that plane-bed deposition of coarse to very coarse sand occurs for a narrow range of velocities in the lower flow regime. Furthermore, in water depths of less than a centimeter and low flow velocities, very low amplitude bedforms develop sub-horizontal lamination in fine sand (Smith, 1971).

Low-angle stratified sandstone (Sl) is interpreted to form from upper plane-bed deposition of sand in very shallow scours (Cant and Walker, 1976). Upper flow regime conditions are suggested by conformable laminae in scours and lateral gradation with lithofacies Sh of known high-energy flow origin.

Massive Sandstone (Sm)

Description

Massive sandstone (Sm) characterized by extensive floral and faunal pedoturbation is the most abundant sandstone lithofacies. Grain sizes range from very fine to medium sand; faint horizontal (Sh) and ripple

(Sr) laminations are rare. Disseminated carbonaceous material and small mudstone intraclasts are common. Evidence of basal scouring is locally developed in units overlying lithofacies Fm and Fl. Massive sandstone occurs as tabular beds generally less than 1 m thick and is typically interbedded with fine-grained lithofacies (Fm, Fl) (Figure 12), or other sandstone lithofacies (St, Sh).

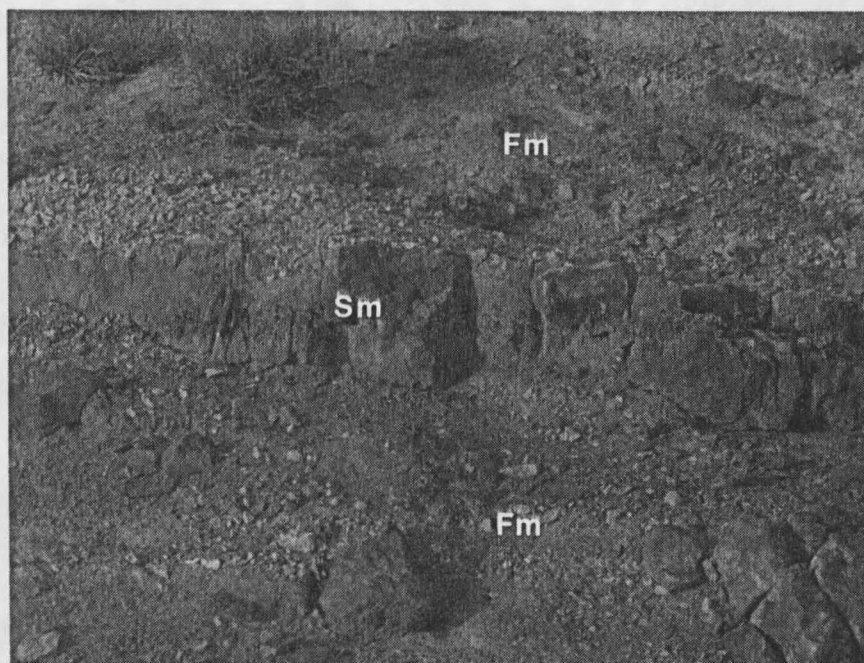


Figure 12. Thin unit of massive sandstone (Sm) within poorly exposed, massive mudstone (Fm). Rock hammer in left center of photograph is 35 cm long.

Interpretation

Massive sandstone (Sm) is interpreted as the deposits of sheetfloods (Bull, 1972) in overbank areas. Similar facies relationships were recognized in the Cretaceous Sphinx Conglomerate of southwestern Montana by DeCelles and others (1987) who interpreted

massive, tabular sandstone bodies and fine-grained strata as flood deposits on inactive areas of an alluvial plain. Lithofacies Sm was deposited from suspension as flood waters spread into overbank areas and lost competence. Evidence of basal scouring and faint horizontal and ripple lamination in some units suggests traction transport, perhaps in crevasse splays proximal to active channels. McKee and others (1967) recognized similar features in flood deposits characterized by predominantly fine-grained sediments. The abundance of pedoturbation (burrows and rootlets) indicates rapid colonization of overbank areas and extended periods of inactivity (DeCelles and others, 1987). When associated with channel-fill sequences, lithofacies Sm represents low flow accretion or flood deposition in abandoned channels.

Ripple Cross-Laminated Sandstone (Sr)

Description

Ripple cross-laminated sandstone (Sr) consists of climbing or stacked sets of migrating ripple cross-strata (Figure 13). Grain sizes range from very fine- to medium-size sand. Beds of lithofacies Sr are rare and occur as outcrop-scale exposures 10 to 30 cm thick. Ripple cross-strata are small-scale (< 2 cm) troughs filled with inclined laminae which dip 20 to 30°. Lithofacies Sr typically overlies lithofacies St, Sh, or Sl with a planar contact and is commonly overlain by Fm or Fl. Units of Sr are commonly burrowed and in some cases grade into massive sandstone (Sm).

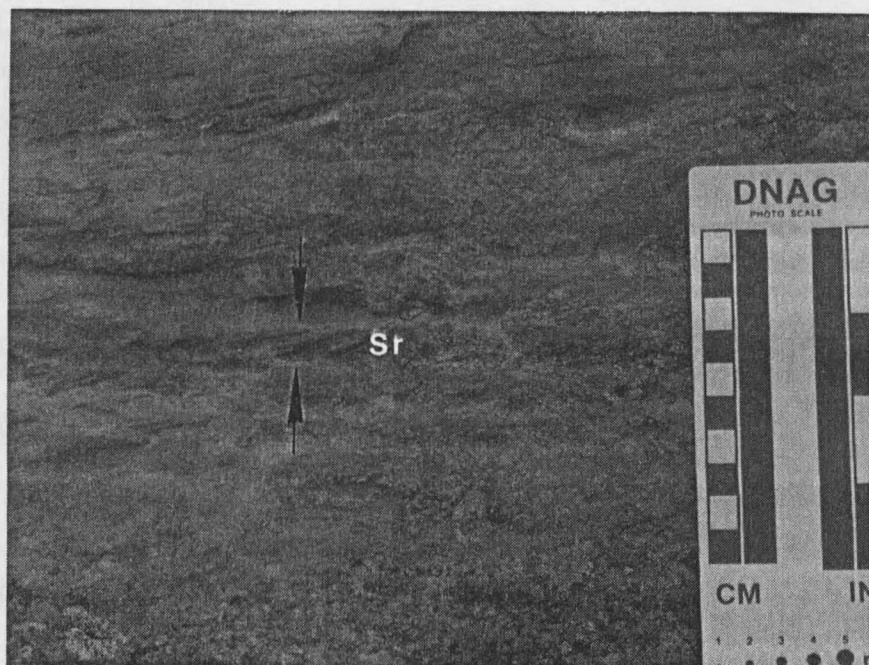


Figure 13. Stacked sets of fine-grained, ripple cross-laminated sandstone (Sr); arrows define one set. Unit grades upward from horizontally bedded sandstone (Sh) and is overlain by massive mudstone (Fm).

Interpretation

Ripple cross-laminated sandstone (Sr) represents deposition of sand by migrating, asymmetric ripples during lower flow regime conditions in minor bar top channels and swales (Harms and Fahnestock, 1965; Miall, 1977). The rarity of lithofacies Sr may be due to lack of formation, destruction during flood events, or destruction by bioturbation. The gradation between lithofacies Sr and massive sandstone (Sm) supports the latter.

Fine-Grained Lithofacies (Fm/F1)Description

Fine-grained lithofacies include red, brown, gray, and black massive mudstone (Fm) and lesser laminated siltstone and mudstone (F1). Wavy bedding, rootlets, and bioturbation are common in lithofacies F1. Silicified wood, including stumps up to 50 cm in diameter, and thin beds (< 1 m) of nodular micrite are locally abundant in fine-grained units. Smith and Ketner (1976) found dinosaur teeth and bone fragments in the thick basal mudstone unit. Fine-grained lithofacies are deeply weathered and poorly exposed, thus a detailed facies analysis was not possible. A few fortuitous exposures revealed small-scale interbedding of fine-grained (Fm/F1) lithofacies with Sm and Sh (Figure 14).

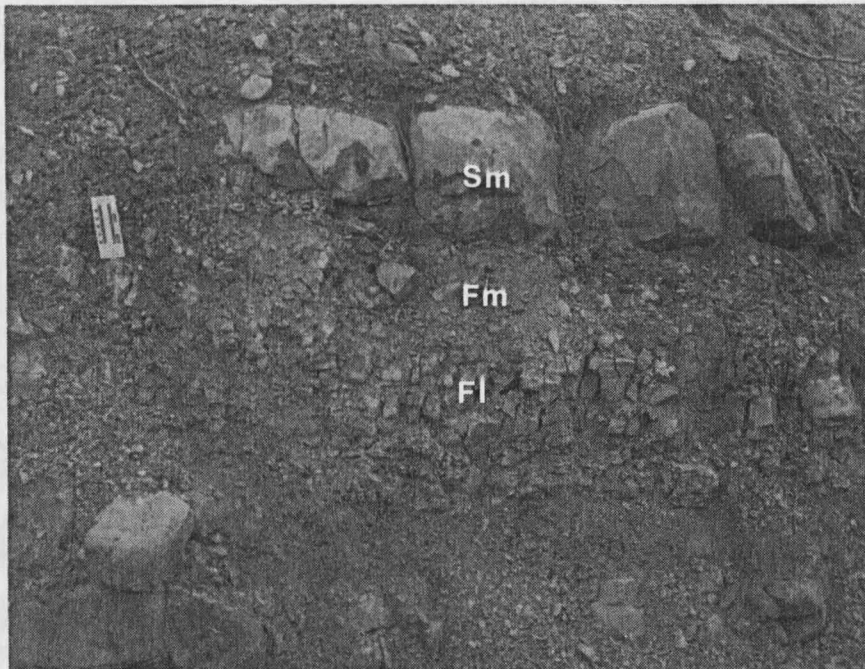


Figure 14. Fine-grained unit of interbedded laminated siltstone (F1), massive mudstone (Fm), and massive sandstone (Sm).

Interpretation

Lithofacies Fm and Fl represent deposition of fines from suspension during waning flood in overbank areas and abandoned channels (Miall, 1977). Rust (1972) observed that fine-grained sediments deposited in overbank areas of the Donjek River are originally horizontally laminated. The pervasively massive character of fine-grained lithofacies in this study is attributed to bioturbation and thixotropic deformation while the sediment was still wet (Williams and Rust, 1969; Rust, 1978). Associated wood and micritic soil horizons indicate overbank areas were inactive for extended periods of time. The paucity of fine-grained lithofacies within gravelly or sandy channel-fill sequences suggests low preservation potential during subsequent flood flow (Rust, 1984).

Carbonate Lithofacies (L/P)

Description

Carbonate lithofacies constitute a small fraction of Newark Canyon Formation strata. Lithofacies of this type occur as nodular micrite (P) and laminated micrite (L). Lithofacies P consists of gray to purple-gray, massive, nodular, silty micrite exposed in thin, laterally discontinuous beds less than 1 m thick. Nodular micrite (P) is entirely interbedded with fine-grained lithofacies (Figure 15). Lithofacies L includes gray, silty micrite and biomicrite which weather to light gray or tan. Silty micrite is composed of silt-sized, angular quartz grains dispersed uniformly in pure carbonate mud. Biomicrite contains varying amounts of ostracodes and charophytes; some layers are ostracodal hash.

Both types are moderately-rich in organic material. Lithofacies L occurs in beds usually less than 1 m thick or as units of interbedded L and Fl as thick as 5 m; lateral dimensions are in tens-of-meters.

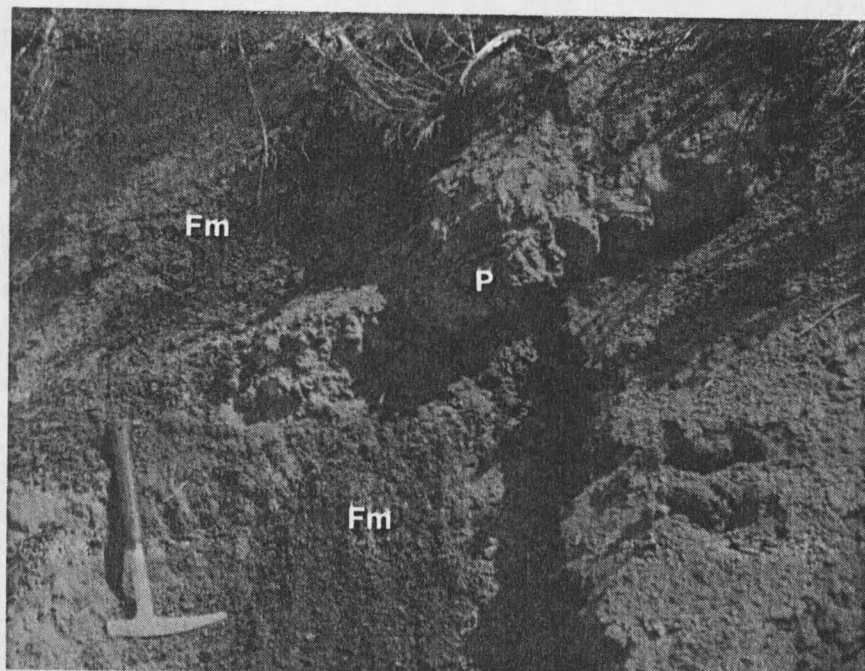


Figure 15. Thin unit of nodular micrite (P) within massive mudstone (Fm).

Interpretation

Nodular micrite (P) is interpreted as pedogenic carbonate (Miall, 1977; Rust, 1978) formed in soil horizons on inactive areas of an alluvial plain. Laminated micrite (L) was deposited in ponds or small, freshwater lakes which developed in low areas of the floodplain. The abundance of ostracodal biomicrite suggests ponds were shallow but perennial (Glass and Wilkinson, 1980). The proximity of large, silicified stumps, identified as a type of conifer (Smith and Ketner,

1976b), with lithofacies L further supports the presence of stable areas on the floodplain.

DEPOSITIONAL SYSTEMS

On the basis of lithofacies assemblage, vertical profiles, and lateral lithofacies relations, Newark Canyon Formation strata in the Cortez Mountains are interpreted as the deposits of gravel-dominant, anastomosing and wandering gravel-bed fluvial systems. The strata resemble the Donjek type, braided fluvial model of Miall (1977) and facies assemblage G_{III} of Rust (1978), also based on the proglacial Donjek River in the Yukon Territory, Canada. The Upper Member of the Carboniferous Cannes de Roche Formation in eastern Quebec (Rust, 1978) is a suitable ancient analog. Fluvial systems were characterized by several important processes including: longitudinal bar formation, hyperconcentrated flood flow, channel scour and fill, low water accretion, and sedimentation in overbank areas.

Longitudinal bars, represented by massive, organized conglomerate (G_m), formed by vertical accretion of diffuse gravel sheets during periods of high flow in active channels (Hein and Walker, 1977). Disorganized conglomerate (G_m) was deposited in laterally discontinuous, channelized bodies by hyperconcentrated flood flows (Smith, 1986). Such high concentration dispersions could have been generated by bank slumping during flood events. The majority of conglomeratic units consist of trough crossbedded gravel (G_t), interpreted as broad, shallow scours or channels filled by successive diffuse gravel sheets. Trough crossbedded sandstone (S_t) was deposited by sinuous-crested dunes, and low-angle (S_l) sandstone by scour-and-fill in minor channels. Low water

accretion in bar top scours and minor channels resulted in the deposition of horizontal (Sh) and ripple stratified (Sr) sandstone. Abundant fine-grained sediments (Fm/Fl) and thin, tabular sand bodies (Sm) were deposited during flood events in interchannel areas. Extensive floral and faunal pedoturbation indicates that floodplains were rapidly colonized. Carbonate soil horizons (P) developed frequently on floodplain surfaces. Laminated micrite (L) was deposited in small, freshwater ponds capable of sustaining an invertebrate fauna. The lithofacies recognized in Newark Canyon Formation strata support deposition by gravel-bed streams with large inactive areas between main channel tracts.

Refined interpretations of Newark Canyon Formation depositional systems are possible through a distillation of data gathered from measured stratigraphic sections (Plate I), and field observations of lateral lithofacies relationships. Conglomerate and sandstone packages represent gradual filling of active channel complexes. Typical channel-fill sequences fine-upward and are encased in fine-grained units (Figure 16). Channel-fill strata are dominantly lithofacies Gt (Figure 16), generated by repeated scour-and-fill in broad, shallow channels. When present, massive conglomerate (Gm) is usually truncated and scoured by lithofacies Gt, suggesting fluvial systems were characterized by flashy discharge of insufficient magnitude and duration for bar development (Smith, 1974; Hein and Walker, 1977). Thick, fining-upward sequences attributable to a single depositional episode are further evidence for a flashy or episodic nature of Newark Canyon Formation fluvial systems (Figure 17). Continued aggradation resulted in deposition of sandy

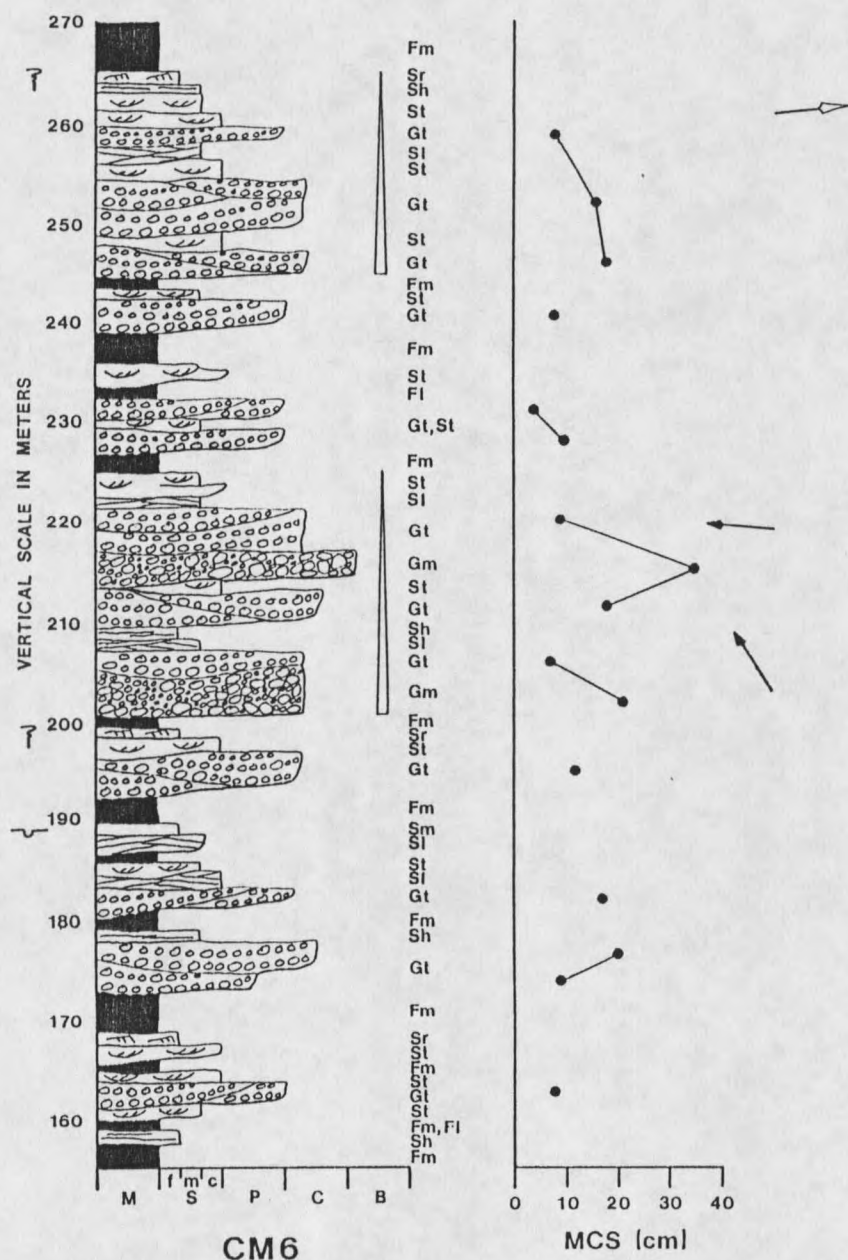


Figure 16. Part of measured stratigraphic section CM6 showing fining-upward channel-fill sequences encased in overbank fines. Arrowheads to right of column denote channel sequences. Solid arrows=paleoflow direction from imbricated clasts in lithofacies Gm, open arrows=paleoflow direction from sandstone trough axes. Refer to Appendix A for section location, and Plate I for a description of lithofacies symbols and complete measured section.

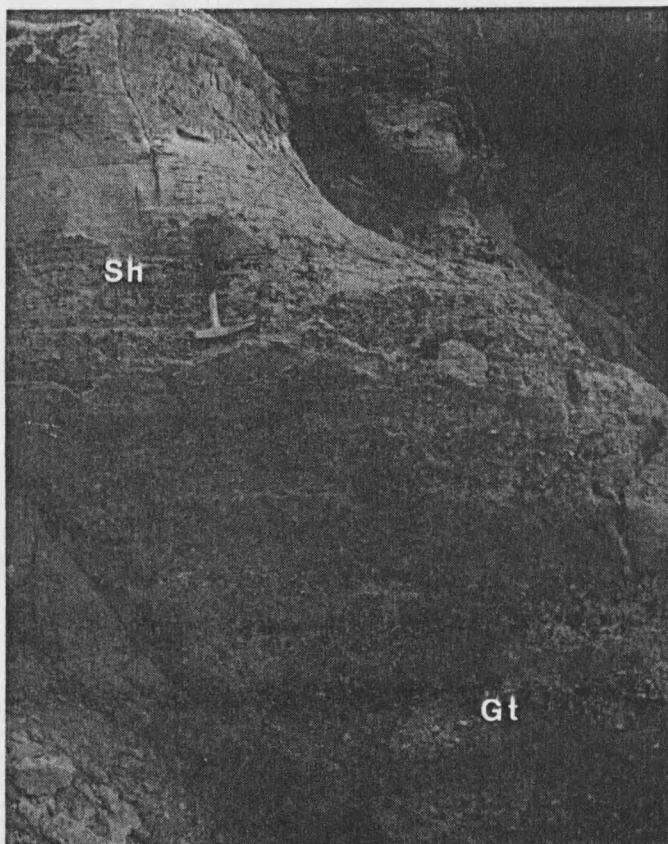


Figure 17. Thick, normally-graded unit consisting of trough crossbedded pebble conglomerate (Gt) overlain by horizontally bedded, medium- and fine-grained sandstone (Sh).

bedforms (St, Sl, Sh, and Sr) as the active channel migrated to another area of the floodplain. Other channel sequences lack a complete fining-upward sequence and consist of entirely trough crossbedded (Gt) with lesser massive (Gm) conglomerate. Minor channels within braided channel complexes were filled by migrating sand dunes (St) and sandy bedforms (Sh, Sr) typical of low velocity flow conditions (Harms and others, 1982) (Figure 18).

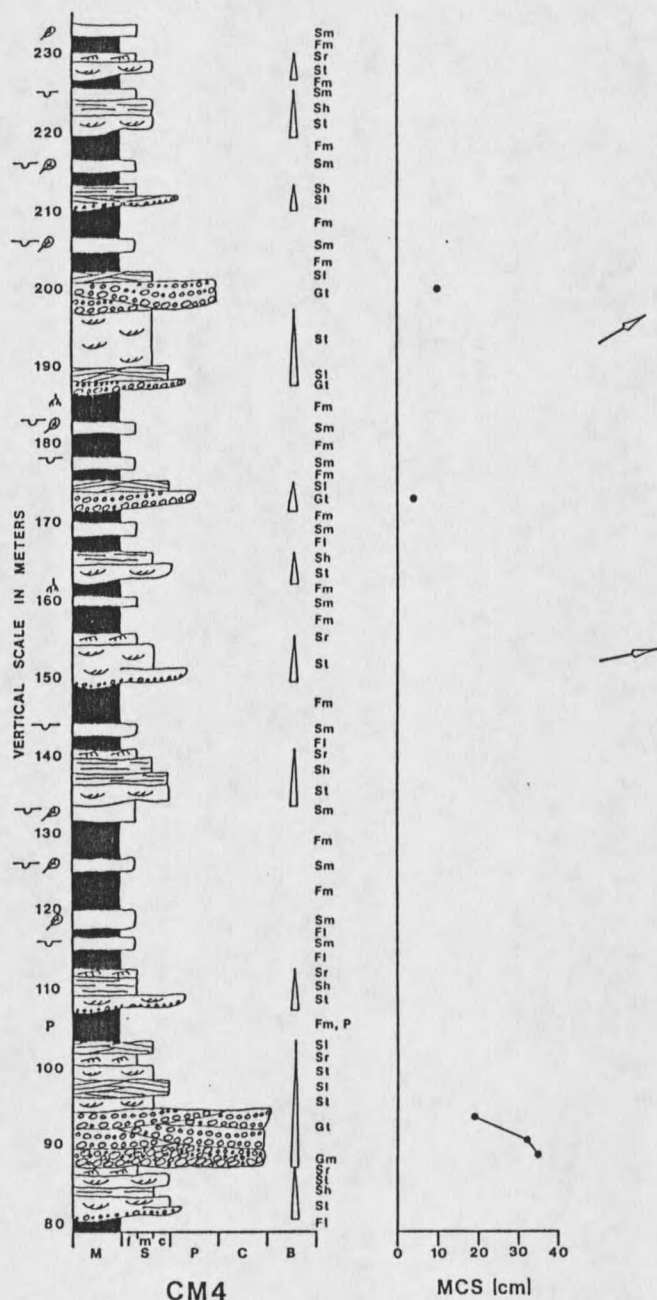


Figure 18. Part of measured stratigraphic section CM4 showing several upward-fining sandstone channel sequences within abundant overbank fines (Fm, Fl). Arrowheads to right of column denote channel-fill sequences. Open arrows in far right column=paleoflow direction from sandstone trough axes. Refer to Appendix A for section location, and Plate I for a description of lithofacies symbols and complete measured section.

Thick fine-grained units (Fm/Fl) were deposited in interchannel areas during flood events. Thin, tabular sandstones (Sm) are interpreted as sheetflood deposits which were quickly vegetated and burrowed between flood events. Soil horizons, represented by thin layers of nodular micrite (P), suggest certain areas of the floodplain remained inactive for extended periods. In fact, laminated micrite (L) and abundant silicified wood indicate the floodplain occasionally supported trees and small, freshwater ponds.

The abundance of fine-grained lithofacies (Fm/Fl) and fining-upward channel sequences are suggestive of meandering streams (Jackson, 1978); however, the preponderance of gravel lithofacies and lack of lateral accretion surfaces indicate another origin for Newark Canyon Formation strata. Channel-fill architecture ranges from tabular units typical of wide, braided channels to laterally discontinuous, lenticular bodies which rapidly grade into overbank lithofacies (Figure 19). The latter are more prevalent in the basal part of the section and are interpreted as the deposits of anastomosing channels. Anastomosing streams form in areas of rapid aggradation as a result of elevated local base level or basin subsidence coupled with high sediment influx (Smith and Smith, 1980; Smith and Putnam, 1980). Stable channels avulse rather than migrate laterally because of intervening vegetated or cohesive overbank material (Smith, 1976; Rust, 1981). Therefore, deposits of anastomosed streams result in disconnected channel elements encased in overbank fines (Smith and Smith, 1980) (Figure 20).

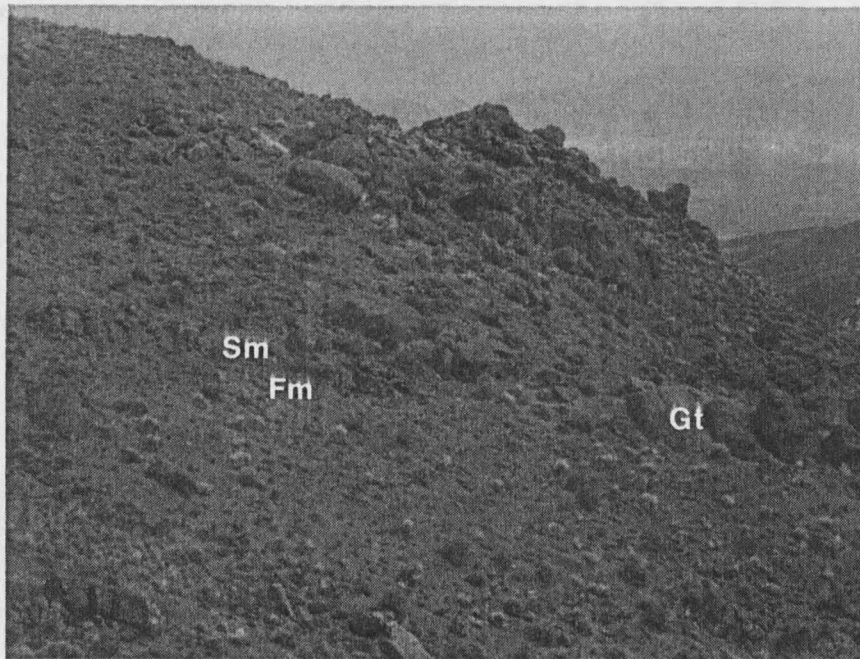


Figure 19. Photograph showing lateral gradation from lenticular channel-fill sequence composed of trough crossbedded conglomerate (Gt) to fine-grained overbank lithofacies (Sm, Fm).

Fluvial architecture in the upper part of the Newark Canyon Formation is characterized by more tabular channel body geometries with intervening units of fine-grained lithofacies. Major channels are dominantly fining-upward, gravelly sequences (Gm, Gt, Sl, Sh), and fine-grained units (Fm, Fl) commonly contain thin interbeds of pebbly to fine-grained, horizontally stratified (Sh) and massive sandstone (Sm) (see Figure 16). Facies assemblages of this type are recognized in modern, wandering gravel-bed rivers (Bluck, 1971; Forbes, 1983; Desloges and Church, 1987). Wandering gravel-bed rivers have irregularly sinuous channels and extensive interchannel floodplains. Deposition of channel gravel is by lateral accretion, thus producing tabular geometries

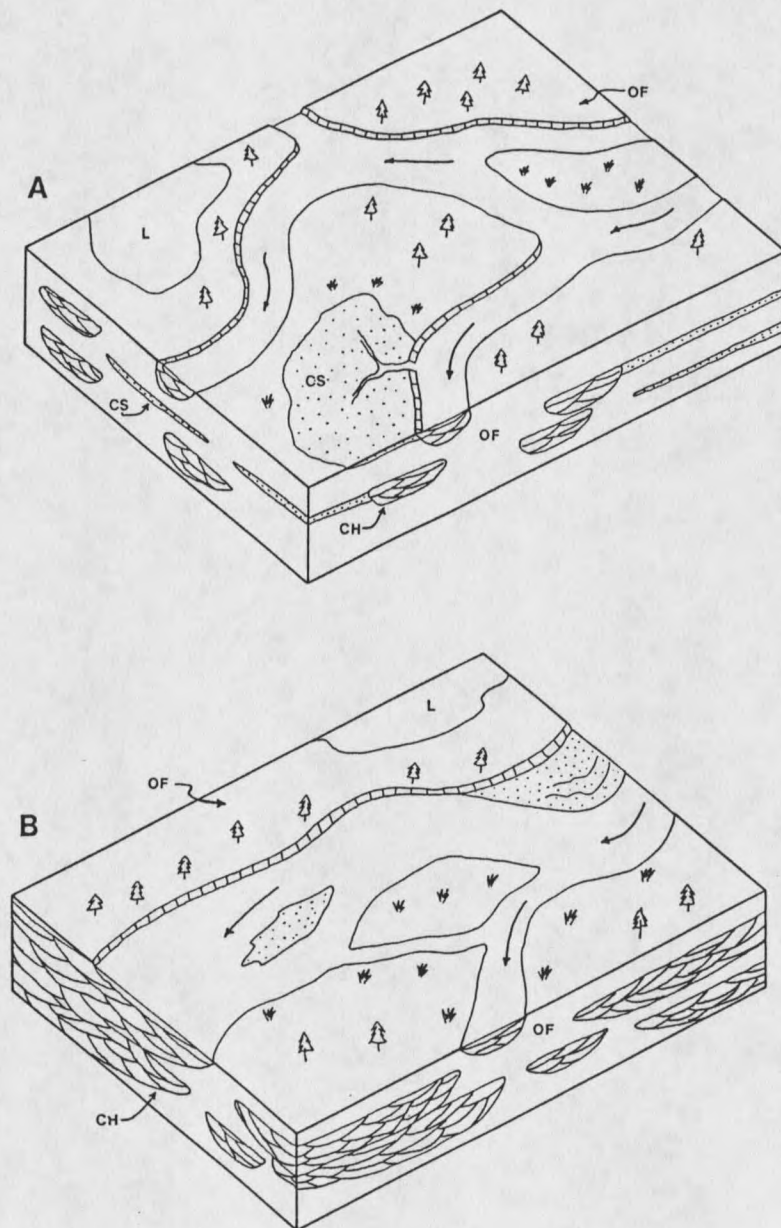


Figure 20. Schematic block diagrams illustrating Newark Canyon Formation depositional systems. A) anastomosing fluvial systems typical of the lower part of the section which resulted in isolated channel bodies within abundant overbank fines. B) wandering gravel-bed and braided fluvial systems common in the upper part of the formation characterized by tabular channel bodies and large interchannel areas. CH=channel bodies, CS=crevasse splays, OF=overbank fines, and L=lacustrine. Architectural element codes modified from Miall (1985).

(Desloges and Church, 1987) (see Figure 20). However, lateral accretion surfaces were not discernible in Newark Canyon Formation conglomerates because of the complex scour-and-fill nature of gravel deposition. Floodplains accumulate fine sediment by vertical accretion, and in areas proximal to active channels, may contain thin splay deposits of pebbly to fine-grained, horizontally stratified sandstone (Desloges and Church, 1987).

Tabular channel geometries may have also been produced by gravel-dominant, braided fluvial systems. Modern, gravelly, braided streams (ie. Donjek River) are characterized by coarse-load deposition in wide channels but typically lack significant fine-grained sediment (Rust, 1978; see also Morison and Hein, 1987). The Donjek River, however, is confined to a glacial valley and therefore overbank deposits are constantly being reworked (Rust, 1978). The occurrence of extensive fine-grained lithofacies and associated tabular channel bodies could have resulted from braided channels migrating across an unconfined alluvial plain. Braided systems differ from wandering gravel-bed systems in that the channels have low sinuosity. The distinction between braided and wandering gravel-bed fluvial systems is problematic, and would involve greater three-dimensional control in order to determine channel sinuosity.

The upward trend from anastomosing to braided or wandering gravel-bed fluvial systems in the Newark Canyon Formation may reflect a tectonic or climatic signal. Changes in fluvial architecture have been related to rates of basin subsidence through computer modelling (Allen, 1979; Bridge and Leeder, 1979). Given a constant sediment supply, a

decrease in subsidence rate would result in greater channel body interconnection, whereas increased subsidence would produce isolated channel bodies within overbank fines. The upward trend from lenticular to tabular channel bodies in Newark Canyon Formation strata may reflect a decrease in subsidence rate. Conversely, if subsidence was constant, the observed trend might indicate an increase in sediment supply. Increased sediment supply may have been triggered by active uplift of source areas or perhaps by local climatic change. Given the lack of good biostratigraphic data, accurate determination of climatic control on Newark Canyon Formation deposition is not possible.

PALEOCURRENTS

Paleocurrent data from Newark Canyon Formation strata in the Cortez Mountains include trough axis orientations and pebble imbrication. For the most part, the orientation of trough axes from sandstone and conglomerate units were measured directly from three-dimensional exposures. A small percentage of two-dimensional exposures required visual estimation, but are likely accurate to within 25° of true paleoflow direction (DeCelles and others, 1983). Pebble imbrication in lithofacies Gm is the a(t)b(i) type defined by Harms and others (1982), where the long (a) axes of platy clasts are transverse to flow and the intermediate (b) axes are inclined upstream. Collection of pebble imbrication data was hampered by the scarcity of plate-shaped clasts.

Trough orientations in conglomerate and sandstone units are variable, but show a preferential direction of transport to the south and east (Figure 21). Gravel troughs are well-exposed in the conglomeratic units, and are considered the most reliable indicator of paleoflow direction for the Newark Canyon Formation. Sandstone trough axes are typically more variable as they are formed in minor channels which often trend oblique to primary flow directions. Figure 21 shows an apparent change in gravel trough axis orientations from a west-southwest transport direction in the lower part of the section to south-southeast in the upper part. This change in paleoflow direction through time may reflect tectonically-induced changes in paleodrainage patterns, or directional variability inherent in the braided and anastomosing

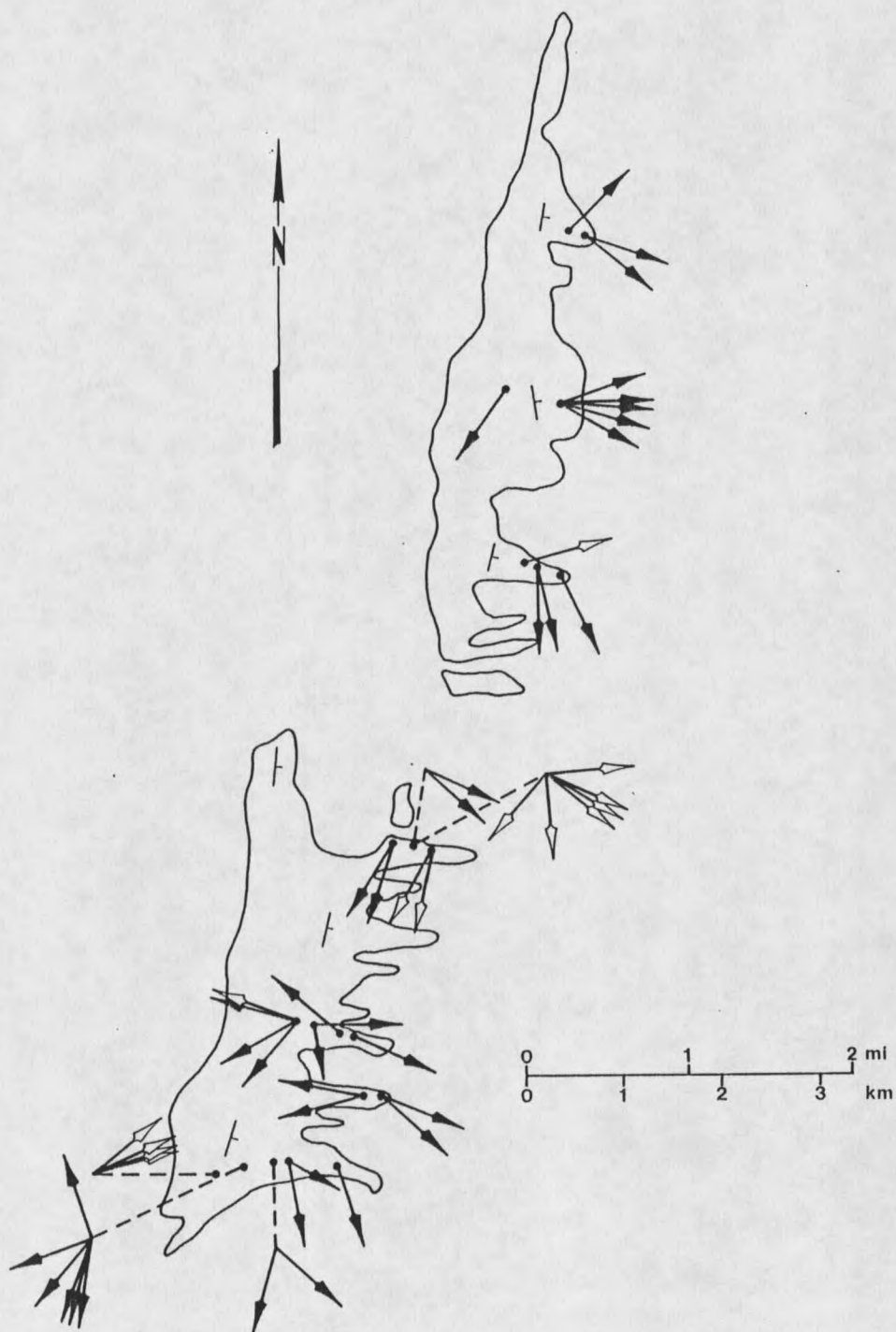


Figure 21. Trough axis orientations for crossbedded conglomerates and sandstone units in the Newark Canyon Formation of this study. Each arrow represents a single trough axis. Solid arrows=conglomerate troughs, open arrows=sandstone troughs.

fluvial systems responsible for Newark Canyon Formation deposition. Local flow variation in modern braided channels is produced by flow divergence around and over the tops of longitudinal bars, back-flow in the lee of large-scale bedforms, and flow out of the main channel during flood events (Williams and Rust, 1969; Rust, 1972; Smith, 1974).

Pebble imbrication data show a dominantly north to northwest paleoflow direction (Figure 22). All but one sample ($I=45\%$) were determined to be preferentially oriented at the 95% confidence interval using the Rayleigh test of significance (Curry, 1956). However, pebble imbrication orientations do not support paleoflow trends observed for trough axes and in most cases are 180° apart. The variability may be due to flow divergence during waning flood on the tops of longitudinal bars (Billi and others, 1987), or the result of false imbrication data. Imbrication data might produce an incorrect picture of flow direction if the imbrication reflects the axis orientation of shallow troughs which are difficult to recognize in outcrop. Imbrication data in Figure 22 indicate a south to southeast dip direction of clasts which, if produced by gravel scour-fill, is comparable to trough axis orientations (see Figure 21).

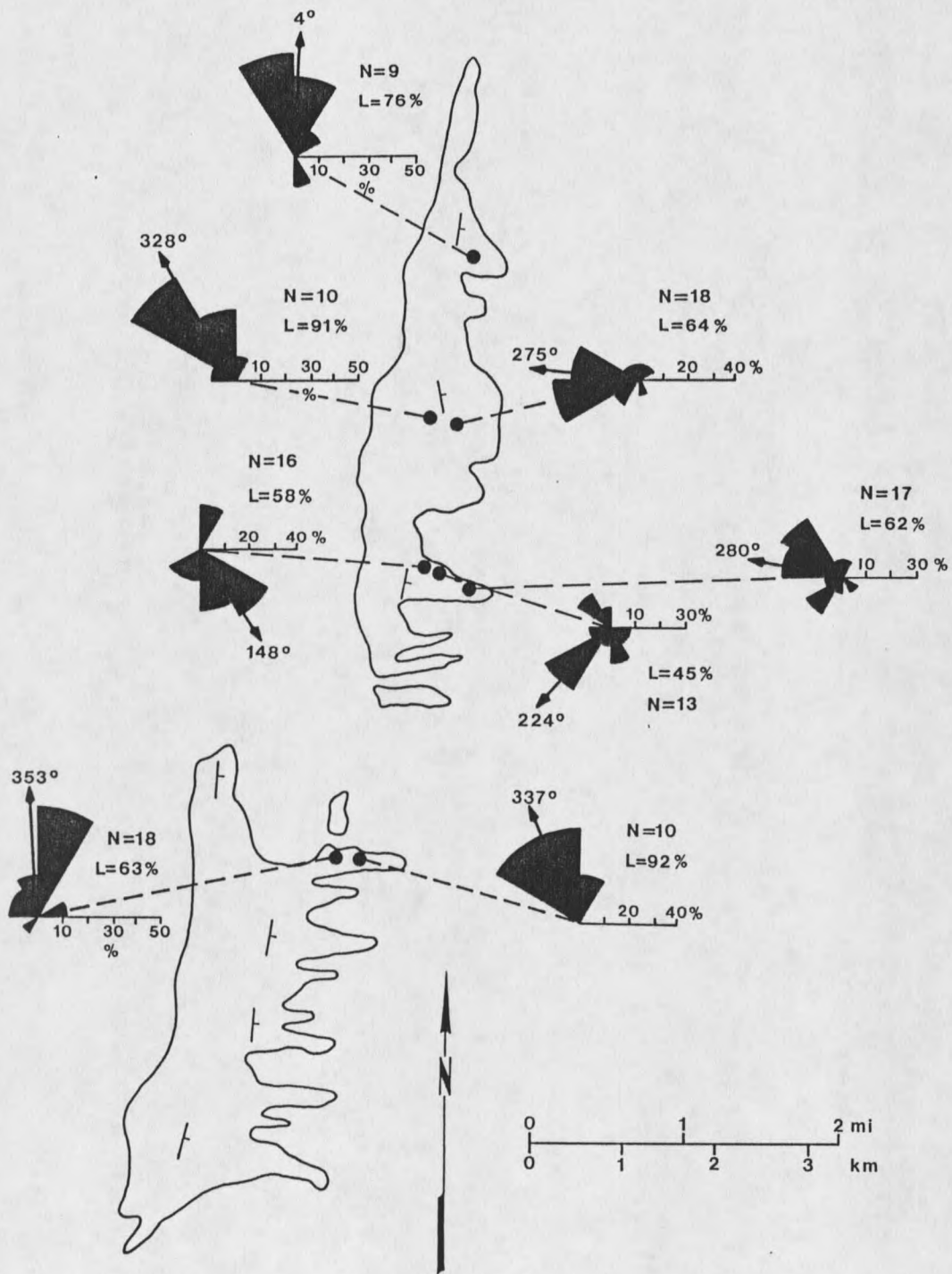


Figure 22. Rose diagrams showing paleoflow direction from imbricated clasts in massive conglomerates. L=magnitude of resultant vector expressed in percentage of total readings.

PETROGRAPHY

Conglomerate

Composition

Coarse-grained units within the Newark Canyon Formation are primarily chert-pebble and -cobble conglomerates; boulder conglomerates are scarce. A few conglomerates are characterized by an abundance of limestone or volcanic clasts and lesser chert. Clast types recognized in Newark Canyon Formation conglomerates include brown, gray, red, black, and green chert, sandstone, conglomerate, limestone, and volcanic rock fragments. Chert, sandstone, and conglomerate clasts are durable, subangular to rounded, and equant to bladed in shape. Limestone and volcanic clasts are less durable, subrounded to well-rounded, and usually bladed or prolate. Platy and elongate clasts are rare, therefore imbrication or any preferred fabric is uncommon. A discussion of the characteristics of individual clast lithologies follows.

In hand samples, chert of all types is mostly massive and lacks recognizable primary textures. Faint laminations are distinguishable in a few clasts of brown and black chert; red chert occasionally shows a brecciated texture. Red, gray, and brown chert are commonly encased within a thin (1-3 mm) white rind produced by surface chemical weathering, a characteristic of reworked detrital chert (Folk, 1980, p.80). Gray and brown chert contain abundant sponge spicules. A shallow water carbonate origin is supported for gray chert by the

presence of relict crinoid columns, corals, and fusulinids. Sandstone clasts include a wide variety of tan to brown, red, and gray to black, fine- to very coarse-grained litharenites and sublitharenites. The sandstones are composed almost entirely of subangular to well-rounded quartz and chert grains, are poor to very well-sorted, and generally quartz-cemented. Included with the sandstone clasts but in minor amounts is white, fine-grained, well-sorted and rounded, silica-cemented quartzarenite. Conglomerate clasts within Newark Canyon Formation conglomerates are clast-supported and composed of subangular to rounded, brown, green, black, and red chert granules and pebbles. Boulders of conglomerate up to 35 cm in diameter comprise the majority of clasts in the coarsest conglomeratic units. Limestone clasts consist of light to medium gray, massive and laminated sparite. Most are fossiliferous and contain abundant brachiopods, crinoids, fusulinids, and bryozoans which are commonly silicified. Volcanic clasts include white to gray silicic ash flow tuff, purple tuff, and reddish brown and green volcanoclastic sandstone. Silicic ash flow tuff contains phenocrysts of biotite and potassium feldspar in an aphanitic groundmass of quartz and feldspar. Clasts of this type are somewhat more durable than other volcanics and are as large as 15 cm in the basal part of the section. Clasts of purple tuff consist of potassium feldspar phenocrysts in a groundmass extensively altered to clay minerals. Volcanoclastic sandstones are medium- to coarse-grained, poorly-sorted, and composed of quartz, feldspar (K-spar and plagioclase), and aphanitic volcanic fragments.

Clast Composition Modes

Relative clast percentages for conglomeratic units in the Newark Canyon Formation are displayed in Figure 23 as histograms of the total clasts per measured section, and of individual clast counts in Figures 24 and 25. Over 7,600 clasts were counted throughout the study area to determine source area lithology and illuminate any compositional trends. Appendix B contains a tabulation of the clast count data. The following discussion addresses the distribution of clast types and compositional trends in Newark Canyon Formation conglomerates.

Gray chert, brown chert, and sandstone account in combination for more than two-thirds of the total clasts in Newark Canyon Formation conglomerates (Figure 23). Red chert represents a significant fraction of the clasts in certain units but is otherwise present in small amounts (Figures 24 and 25). Black and green chert are volumetrically insignificant and absent altogether in many units (Figures 24 and 25). Conglomerate clasts account for a small percentage but are present in most units whereas limestone clasts show a very sporadic distribution (Figures 24 and 25). Volcanic clasts are the dominant clast-type in four basal conglomeratic units and absent elsewhere (Figures 24 and 25).

The most prevalent compositional trend observable in Newark Canyon Formation conglomerates is the distribution of volcanic clasts. Four basal conglomeratic units (Figures 24 and 25) contain abundant volcanic clasts with subordinate amounts of other types. The remainder of the section throughout the study area is devoid of volcanic clasts. In general, all other clast types appear in significant numbers with the disappearance of volcanic clasts and show no preferred vertical or

lateral trends (Figures 24 and 25). Possible controls on the distribution of volcanic and limestone clasts are discussed in the subsequent chapter.

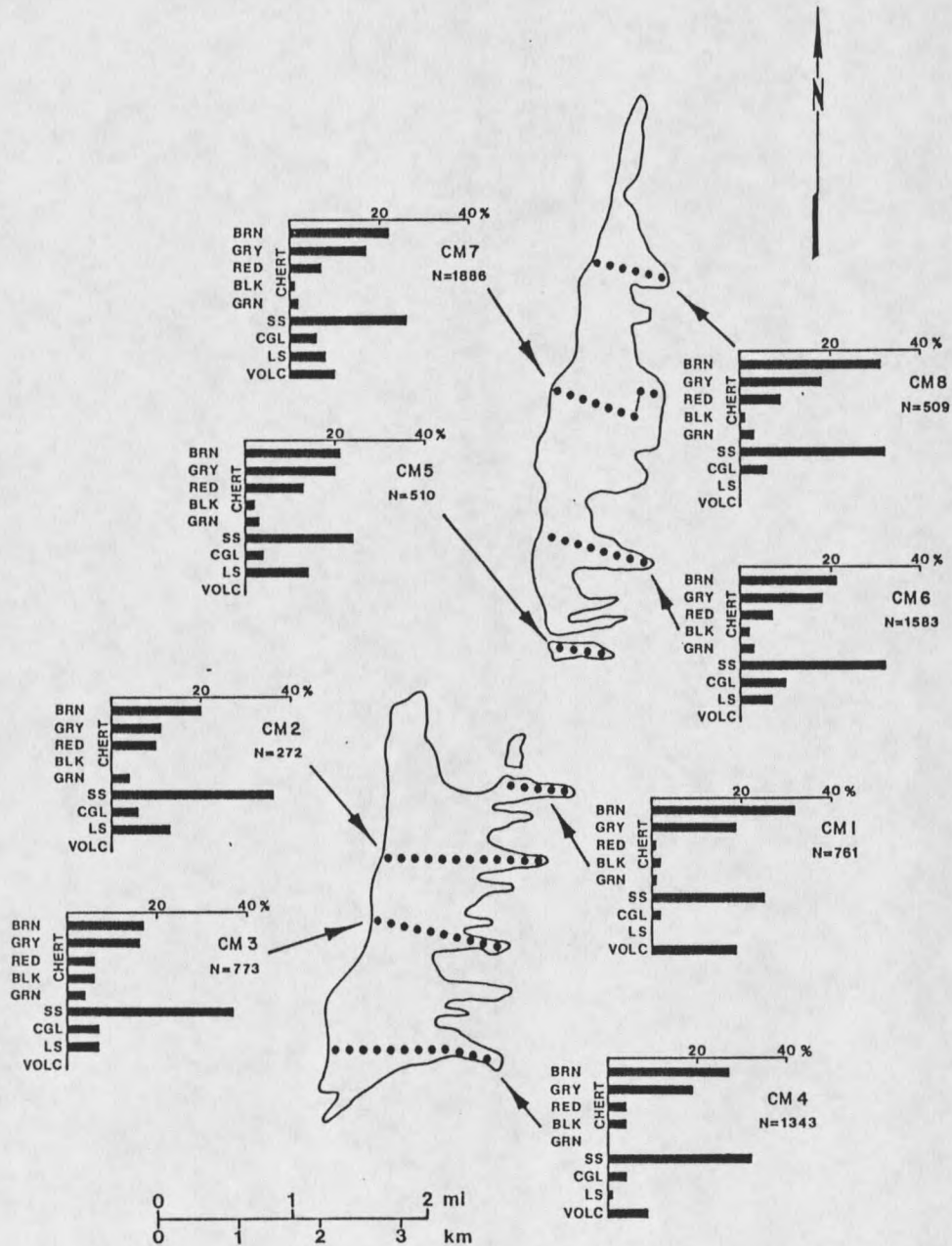


Figure 23. Histograms illustrating relative percentages of clast lithologies for each measured section of Newark Canyon Formation in the Cortez Mountains.

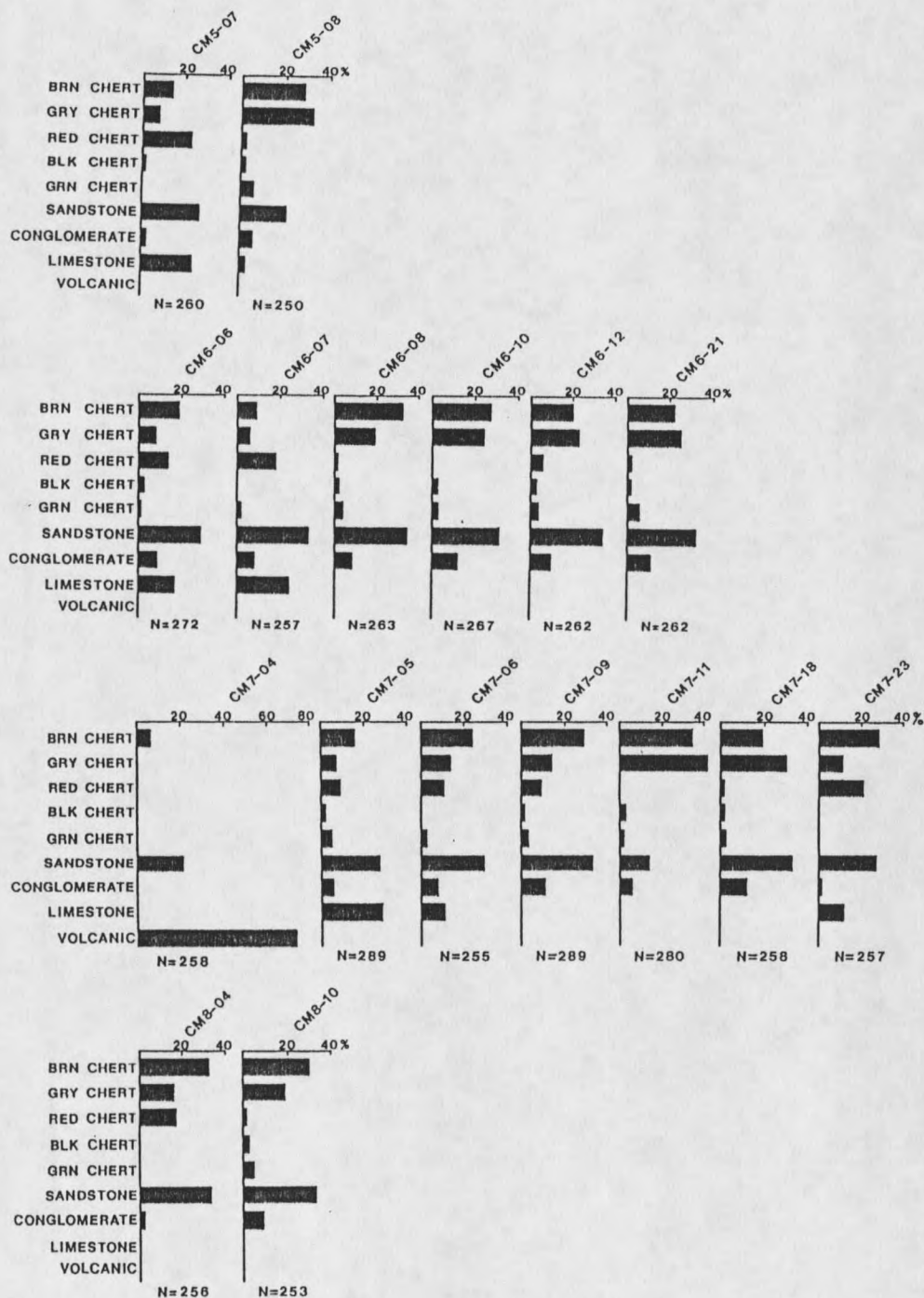


Figure 24. Histograms showing relative percentages of clast lithologies for each unit counted from the northern exposures of Newark Canyon Formation in the Cortez Mountains. See text for a discussion of clast distributions.

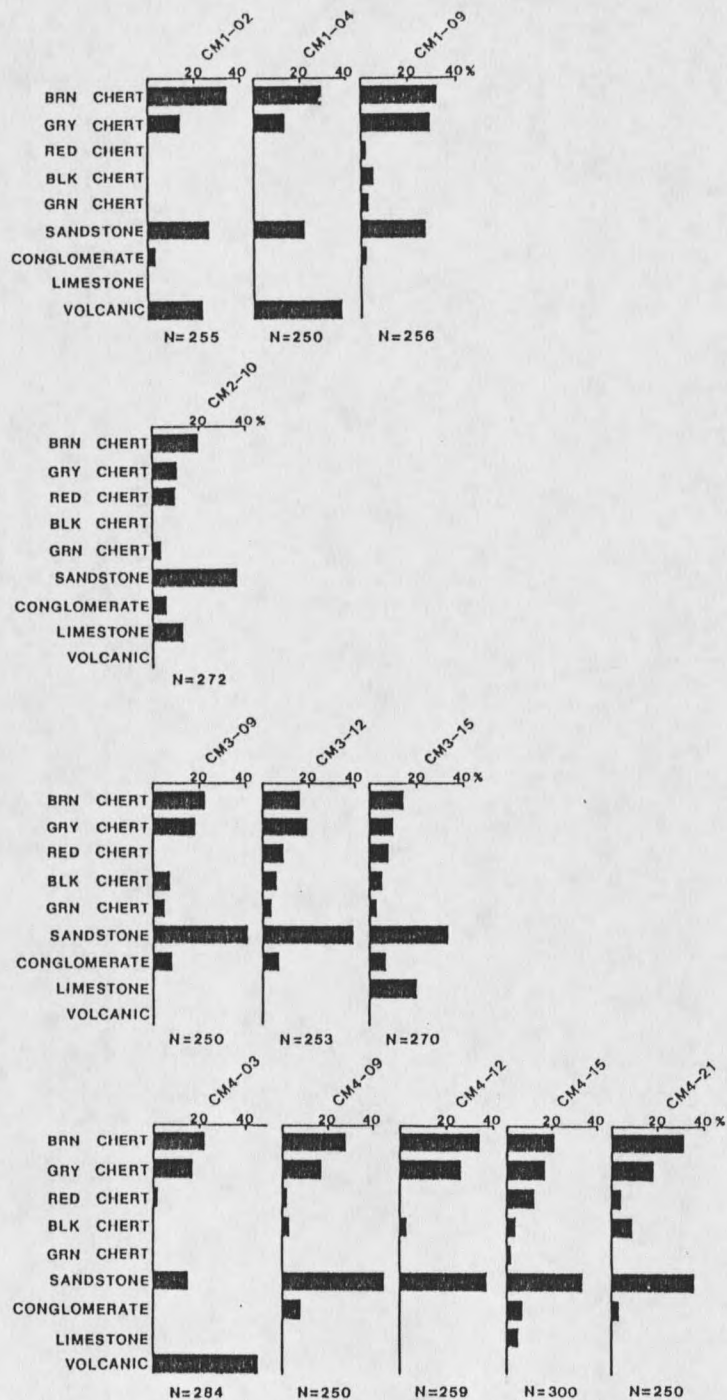


Figure 25. Histograms showing relative percentages of clast lithologies for each unit counted from the southern exposures of Newark Canyon Formation in the Cortez Mountains. See text for a discussion of clast distributions.

Sandstone

Texture

Newark Canyon Formation sandstones in the Cortez Mountains are characterized by extreme textural diversity. Vandervoort (1987) reported similar variability for Newark Canyon Formation sandstones in the Diamond Mountains and Fish Creek Range. Grain sizes from very fine to very coarse sand are present although the majority of sandstone units are comprised of the fine to medium sand fraction. Relative percentage of terrigenous clay matrix, size sorting, and grain roundness are all variable and result in texturally immature to mature sandstones. In particular, all sandstones examined contain varying proportions of angular and rounded grains in the same sample (Figure 26), and are indicative of a complex source area (Folk, 1980, p.14). Grain contacts are primarily tangential, long, and concavo-convex.

The post-burial history of Newark Canyon Formation sandstones involves a complex sequence of diagenetic processes including cementation, and dissolution, replacement, and alteration of framework grains. Preferential diagenetic trends were not discerned; however, the following is a brief description of observed textural modifications. Cementation by : 1) silica in the form of quartz overgrowths and to a lesser extent chert pore-filling, 2) poikilotopic sparry calcite, 3) kaolinite, and 4) intergrown hematite/clay are all significant. Dissolution of volcanic rock fragments, feldspar, and carbonate grains has created secondary porosity in some sandstones. Calcite commonly replaces framework grains; in some instances silicification of framework

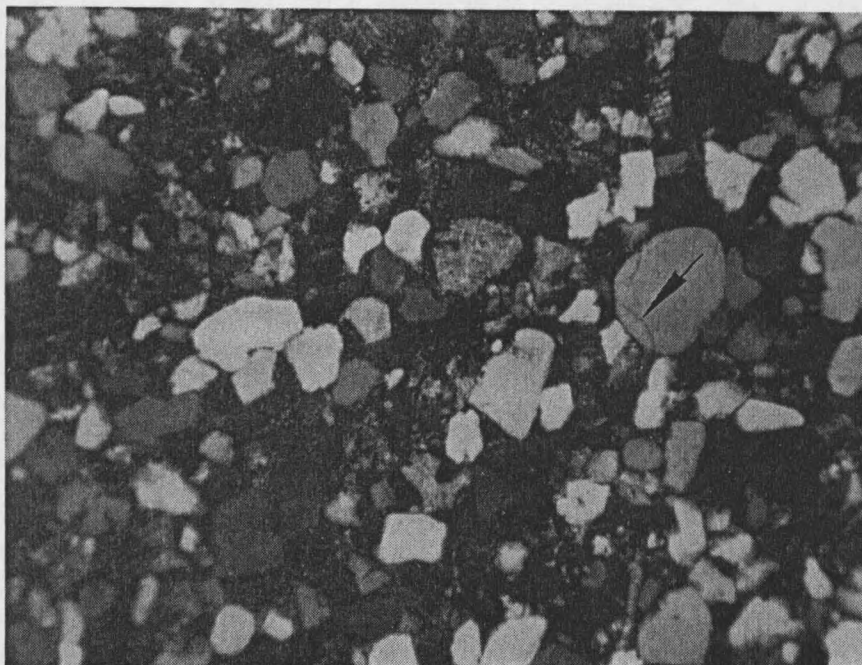


Figure 26. Photomicrograph of typical, immature Newark Canyon Formation sandstone. Note the presence of both rounded and very angular quartz grains. Arrow points to abraded quartz overgrowth on large, rounded quartz grain.

grains may be a post-burial effect, but is difficult to distinguish from reworked silicified grains. The majority of volcanic rock fragments and feldspar grains are partially altered to clay minerals and could often be recognized on that basis.

Framework Grains

Framework grains in thin-sections of Newark Canyon Formation sandstones were identified and described based on the methods of Folk (1980, p.62-89) and Pettijohn and others (1972, p.29-47). The primary framework grain parameters developed by Dickinson (1970) are recognized here and include monocrystalline quartz (Qm), polycrystalline quartz

(Op), feldspar (F), and lithic fragments (L). Additionally, total quartzose grains (Q) were calculated from the sum of mono- and polycrystalline quartz, and total lithic fragments (Lt) from the sum of polycrystalline quartz grains and lithic fragments. Compositional modes of Newark Canyon Formation sandstones involving relative percentages of the above parameters are discussed under a subsequent heading. The original modal point-count data are presented in Appendix C.

Monocrystalline Quartz (Qm). Quartz consisting of single crystal units with straight to slightly undulose extinction, common vacuoles, and occasional microlites and rutile inclusions comprises the majority of grains in Newark Canyon Formation sandstones. Grains with strong undulose extinction and weakly polygonized semi-composite quartz are rare. Reworked sedimentary quartz is common and recognized by abraded authigenic quartz overgrowths (see Figure 26). Volcanic quartz characterized by clear, idiomorphic grains is present in small amounts.

Polycrystalline Quartz (Op). Polycrystalline quartz of several types including chert, chalcedonic chert, and composite quartz are present. Chert grains are by far the most abundant type and consist of microcrystalline quartz in the form of equidimensional grains usually less than 10 microns in diameter. Relict sponge spicules (Figure 27), silt, and clay minerals are common impurities. Chalcedonic chert occurs in subordinate amounts and is recognized by its radiating, fibrous crystal structure. Composite quartz grains are composed of a mosaic of equant, interlocking crystals with straight boundaries and as grains of

smooth or sutured, elongate crystal units. Composite quartz comprises the smallest fraction of polycrystalline quartz at usually less than 5%.

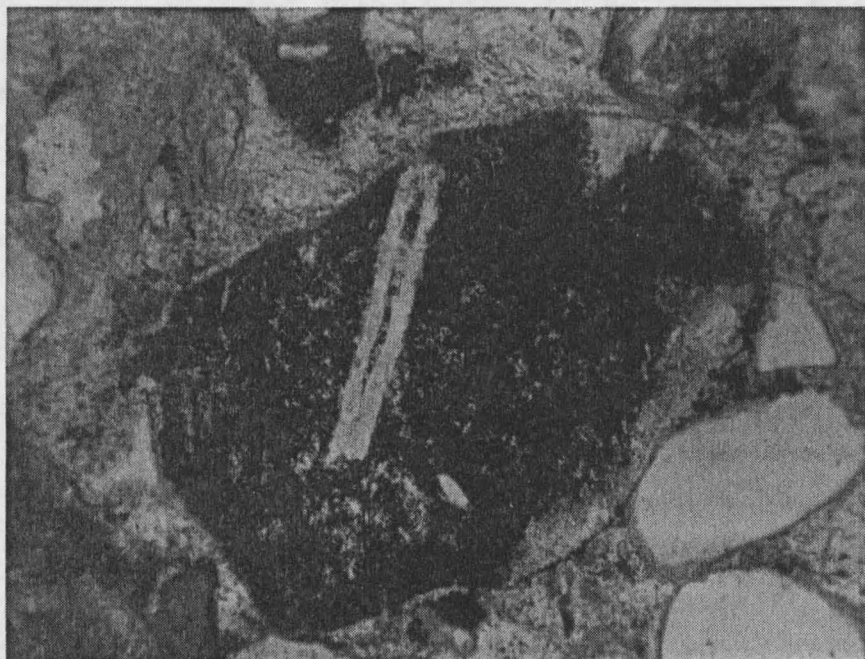


Figure 27. Photomicrograph of a sponge spicule within a phosphatic chert grain.

Feldspar (F). Feldspar grains in Newark Canyon Formation sandstones are predominantly potassic feldspar with subequal proportions of orthoclase and microcline. Plagioclase of indeterminable composition is present in trace amounts. Thin sections were unsuccessfully stained for potassium feldspar and as a result, differentiation between monocrystalline orthoclase and quartz was subject to some error. Orthoclase was distinguished from quartz by the presence of cleavage, cloudy appearance due to clay mineral alteration, sericitization, and biaxial negative optic sign.

Lithic Fragments (L). Lithic fragments include various sedimentary and volcanic types. Siliceous mudstone, siltstone, and siliceous siltstone comprise the recognizable sedimentary rock fragments. The siliceous types are very similar to chert and were distinguished from chert by the presence of clay minerals (Dickinson, 1970); however, a gradational relationship is likely and therefore a margin of error in point-counting is expected. Non-siliceous siltstone is often distorted and impacted by adjacent grains. Volcanic rock fragments are felsitic and composed of either an anhedral mosaic of quartz and feldspar phenocrysts or feldspar phenocrysts in a microcrystalline groundmass. Volcanic fragments were most easily identified under plane light where the lathwork texture is readily apparent (Figure 28).



Figure 28. Photomicrograph of volcanic lithic fragment (Lv) showing feldspar laths within an aphanitic groundmass of unknown composition.

Sandstone Composition Modes

Point-counts of 43 Newark Canyon Formation sandstones utilizing relative percentages of the above framework grain parameters plot as a linear cluster on compositional ternary diagrams (Figure 29).

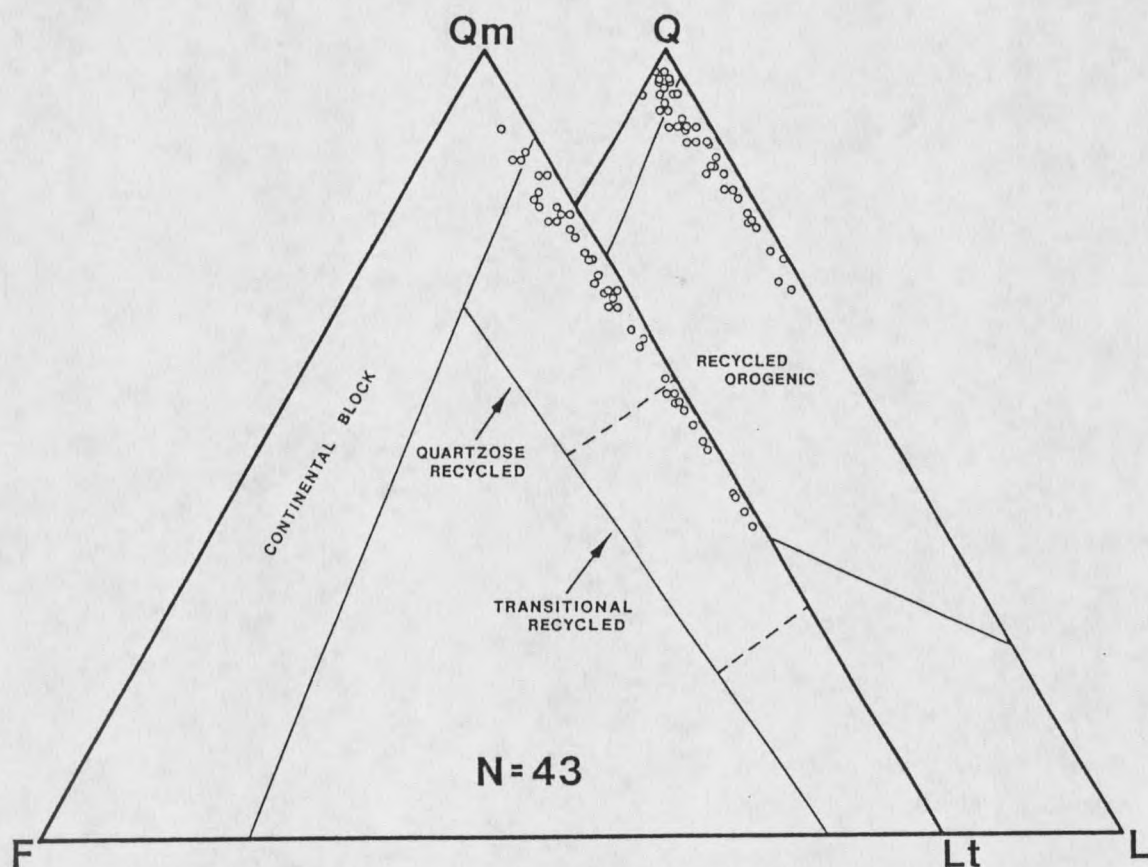


Figure 29. QFL and QmFLt ternary diagrams illustrating composition and provenance of Newark Canyon Formation sandstones in the Cortez Mountains. Provenance fields after Dickinson and others (1983a).

Sandstones are uniformly low in feldspar (less than 5%) and range in composition from low-quartzose litharenites to sublitharenites. Litharenites are predominantly chertarenites characterized by subequal monocrystalline quartz and total lithic fragments ($Q_m=59\%$, $Lt=40\%$).

Lithic fragments include variable amounts of polycrystalline quartz ($Qp=12-51\%$), sedimentary rock fragments ($Ls=0-28\%$), and volcanic rock fragments ($Lv=0-26\%$). Figure 30 is a photomicrograph of a typical chertarenite containing sedimentary lithic fragments and Figure 31 shows chertarenite with subordinate volcanic fragments. Sublitharenites contain abundant quartzose grains ($Q=93\%$) which are mostly monocrystalline quartz ($Qm=84\%$) (Figure 32). Total lithics comprise a small fraction ($It=16\%$) and consist of polycrystalline quartz ($Qp=6-21\%$) with trace amounts of sedimentary and volcanic rock fragments ($Ls=0-5\%$, $Lv=0-11\%$).

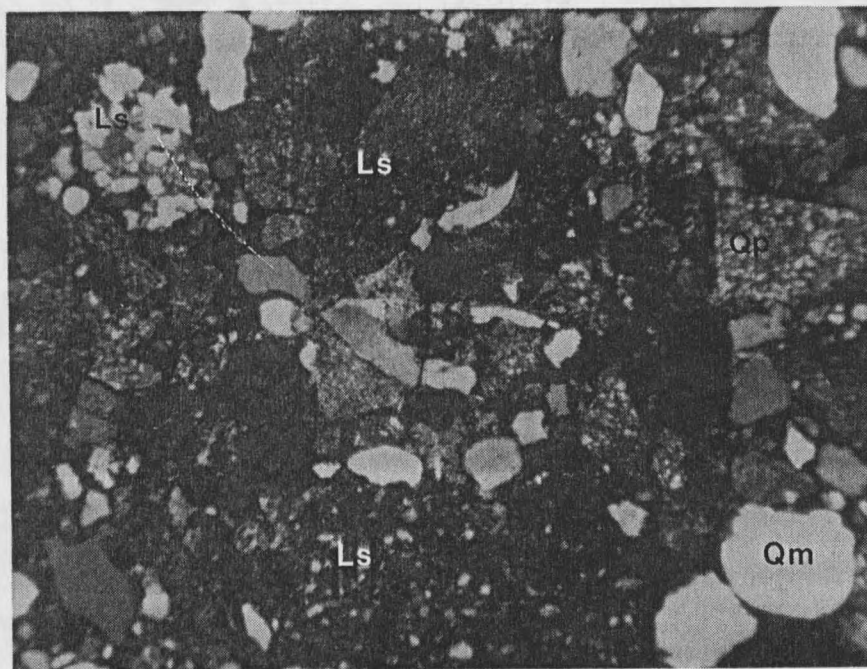


Figure 30. Photomicrograph of Newark Canyon Formation chertarenite with subordinate sedimentary lithic fragments (Ls) consisting of siliceous mudstone and siltstone. Qm =monocrystalline quartz, Qp =chert.

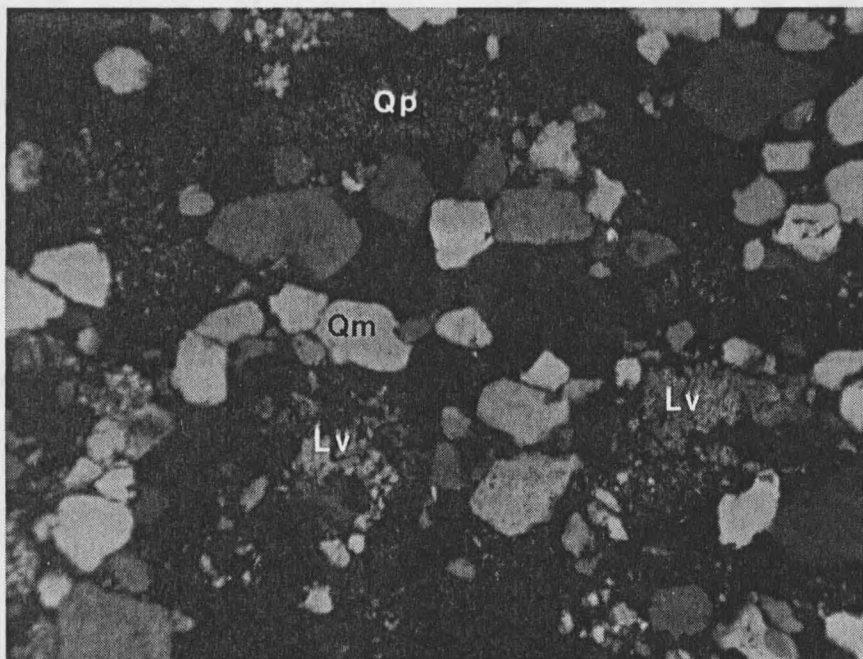


Figure 31. Photomicrograph of Newark Canyon Formation chertarenite with subordinate volcanic lithic fragments (Lv). Qm=monocrystalline quartz, Qp=chert.

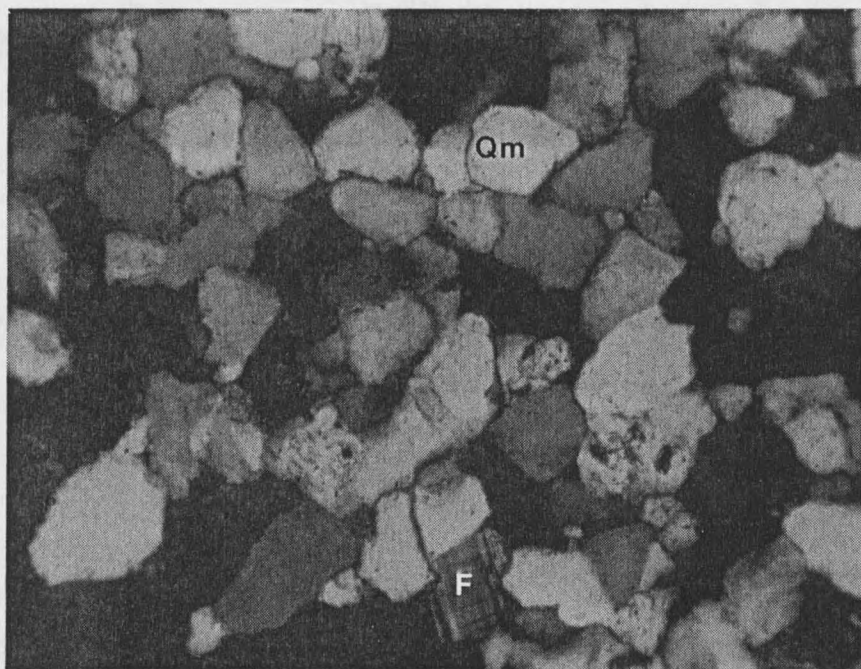


Figure 32. Photomicrograph of Newark Canyon Formation sublitharenite characterized by abundant monocrystalline quartz (Qm). Note microcline (F) grain in lower center of photo.

The samples used in this analysis were obtained from a detailed sampling of all measured sections and are representative of Newark Canyon Formation sandstones throughout the study area. Despite certain patterns in conglomerate clast suites, neither spatial nor temporal trends were observed in the composition of sandstone units.

PROVENANCE

Compositional data from conglomerates and sandstones suggest the Newark Canyon Formation in the Cortez Mountains was locally derived from source terrains composed of Paleozoic sedimentary and Jurassic volcanic rocks. Paleozoic strata in the region are assigned to several widely recognized major tectono-stratigraphic assemblages (Stewart and Carlson, 1978). Rocks of the eastern carbonate and transitional assemblages consist of shelf carbonates and clastics deposited in the late Precambrian to Devonian miogeocline along the western margin of North America (Stewart and Poole, 1974). The western siliceous assemblage includes coeval deep-water rocks of the Roberts Mountains allochthon which were thrust eastward over shelf rocks during the Late Devonian-Early Mississippian Antler orogeny (Roberts and others, 1958). Sediment produced from erosion of the Roberts Mountains allochthon accumulated to form the Mississippian to Lower Pennsylvanian Antler foreland succession in a narrow trough east of the thrust front (Brew, 1971; Poole, 1974). The Antler overlap sequence consists of late Paleozoic rocks deposited on the Roberts Mountains allochthon as the foreland basin filled (Roberts and others, 1958). The final assemblage is represented by the Havallah sequence, late Paleozoic deep-water rocks emplaced by the Golconda thrust onto coeval Antler overlap rocks during the Permian-Triassic Sonoma orogeny (Silberling and Roberts, 1962). Jurassic volcanic and volcanoclastic rocks of the Pony Trail Group (Muffler, 1964) underlie the Newark Canyon Formation and mark the onset of

nonmarine deposition in the area. In the following discussion, provenance of the Newark Canyon Formation is addressed through examination of conglomerate clast and framework grain compositions, and paleocurrent data.

Many of the clast types in Newark Canyon Formation conglomerates are indicative of specific formations within the above assemblages, while the origin of others is not as well constrained (Table 1). Conglomerate clasts consisting of brown, green, black, and red chert pebble conglomerate are attributable to coarse clastics of the Antler foreland succession, Antler overlap sequence, or both. The Mississippian Diamond Peak Formation (Brew, 1971; Poole, 1974) and Tonka Formation (Dott, 1955), a coarse-grained equivalent of the Diamond Peak in the area of this investigation, contains conglomeratic units which could have supplied clasts to the Newark Canyon Formation. Additionally, the Tomera and Strathearn formations of the Pennsylvanian to Permian Antler overlap sequence have conglomerates with similar compositions (Dott, 1955; Smith and Ketner, 1976a). Limestone clasts further support source areas composed of late Paleozoic Antler foreland succession and overlap rocks. Brachiopod- and fusulinid-bearing limestone is characteristic of post-Antler carbonate sequences (Stewart, 1980). More specifically, fusulinids are diagnostic of limestone units in the Pennsylvanian to Permian Antler overlap sequence (Smith and Ketner, 1976a). The sporadic nature of limestone clast distribution in Newark Canyon Formation conglomerates is likely the result of lithologically complex source terrains and/or their preferential destruction during fluvial transport. The final definitive clast type

Table 1. Provenance of clasts from Newark Canyon Formation conglomerates.

CONGLOMERATE

- Mississippian Diamond Peak and Tonka Formations (Antler foreland succession)
- Pennsylvanian to Permian Tomera and Strathearn Fms (Antler overlap sequence)

LIMESTONE

- Mississippian Diamond Peak Formation (Antler foreland succession)
- Pennsylvanian to Permian Moleen, Tomera, and Strathearn Fms (Antler overlap sequence)

VOLCANICS

- Jurassic Pony Trail Group

GRAY AND BROWN CHERT

- bedded chert from:
 - 1) Antler foreland succession (uPz)
 - 2) Antler overlap sequence (uPz)
 - 3) Western assemblage (lPz)
- second-cycle clasts from:
 - 1) Antler foreland succession (uPz)
 - 2) Antler overlap sequence (uPz)

BLACK, GREEN, AND RED CHERT

- bedded chert from:
 - 1) Western assemblage (lPz)
 - 2) Havallah sequence (uPz)
- second-cycle clasts from:
 - 1) Antler foreland succession (uPz)
 - 2) Antler overlap sequence (uPz)

SANDSTONE

- bedded sandstones and second-cycle clasts from:
 - 1) Antler foreland succession (uPz)
 - 2) Antler overlap sequence (uPz)
- Eastern assemblage "quartzites" (ie. Ordovician Eureka Quartzite)
- "quartzite" from Ordovician Valmy Formation (Western assemblage)

includes felsic volcanic clasts, derived solely from the Jurassic Pony Trail Group. The occurrence of volcanic clasts in only the basal part of the section suggests that either volcanic rocks originally comprised a small fraction of the source area, or were gradually covered by deposition of the Newark Canyon Formation.

The most abundant clast types in Newark Canyon Formation conglomerates, chert and sandstone, are not indicative of specific source terrains (Table 1). Gray and brown chert containing sponge spicules are diagnostic of Antler foreland succession and overlap

sequence carbonate units (Stewart, 1980); however, spicules are not ubiquitous in gray and brown chert clasts. Smith and Ketner (1976a) have recognized gray and brown chert in Ordovician and Silurian rocks of the Roberts Mountains allochthon. Furthermore, gray and brown chert clasts are common in post-Antler coarse clastics (Brew, 1971; Poole, 1974; Smith and Ketner, 1976a). Black, green, and red chert clasts are equally nondiagnostic for provenance determination. Chert of these colors is well-known from western siliceous assemblage rocks in the Roberts Mountains allochthon (Roberts and others, 1958) and Havallah sequence in the upper plate of the Golconda thrust (Silberling and Roberts, 1962). Additionally, conglomerates in the Antler foreland succession and overlap sequence, interpreted to have been derived from the Roberts Mountains allochthon (Brew, 1971; Poole, 1974; Smith and Ketner, 1976a), contain abundant clasts of black, green, and red chert.

Sandstone clast types in Newark Canyon Formation conglomerates are diverse, and may have been derived from a number of sources. Sandstone beds in the Mississippian Diamond Peak Formation and Pennsylvanian to Permian overlap sequence, as well as sandstone clasts within conglomeratic units, may have been sources. Other potential sources are "quartzites" from eastern assemblage rocks of the lower Paleozoic miogeocline, including the Ordovician Eureka Quartzite (Ketner, 1968), and "quartzite" from the Ordovician Valmy Formation in the Roberts Mountains allochthon (Roberts, 1964).

The presence of conglomerate, limestone, and volcanic clasts favors a source terrain for the Newark Canyon Formation characterized by upper Paleozoic, Antler-derived clastic and shallow-marine sequences with

lesser Jurassic volcanic rocks. Chert and sandstone clasts are not indicative of specific source terrains; however, they are suggestive of contributions from lower Paleozoic eastern and western assemblage rocks. While Newark Canyon Formation conglomerates offer convenient insight into the lithology of source terrains, sandstone framework compositions are equally revealing.

Newark Canyon Formation sandstones plot in the quartzose and transitional recycled orogenic provenance fields of Dickinson and others (1983a) (see Figure 29), thus supporting derivation from an uplifted sedimentary source terrain. Indeed, upper Paleozoic Antler-derived sandstones are chert-rich, subquartzose litharenites and plot in the transitional recycled field (Dickinson and others, 1983a, 1983b). The more quartzose Newark Canyon Formation sandstones reflect recycling of upper Paleozoic lithic sandstones from Antler foreland and overlap sequences.

Volcanic rock fragments and plagioclase grains, present in significant amounts in many sandstones, indicate the Jurassic Pony Trail Group supplied sediment to Newark Canyon Formation sandstones. Volcanic grains include identifiable fragments of ash-flow tuff and rhyolite exposed adjacent to Newark Canyon Formation exposures in the Cortez Mountains (Muffler, 1964; Smith and Ketner, 1976b). Plagioclase grains were likely derived from plagioclase phenocrysts in the Sod House Tuff of the Pony Trail Group (Muffler, 1964). Furthermore, thin-section analysis uncovered a textural bimodality of quartz grains in some sandstone units. Very angular quartz associated with predominantly

subangular to rounded quartz grains are interpreted to have been derived from the silicic volcanics of the Pony Trail Group.

Microcline comprises the largest percentage of feldspar in Newark Canyon Formation sandstones, but its source is not well constrained. Granitic intrusions associated with the Jurassic Pony Trail Group volcanics are a potential source of microcline (Muffler, 1964). If the Jurassic intrusives are the source, this would indicate pre-Newark Canyon Formation erosion was sufficient to erode through the volcanic cover. The upward depletion of volcanic clasts in Newark Canyon Formation conglomerates supports this hypothesis. Another source of microcline may be late Precambrian to mid-Devonian miogeoclinal and eugeoclinal sandstones. Framework modes for these sandstones are of the transitional continental provenance type (Dickinson and others, 1983a). Microcline is an important constituent in miogeoclinal sandstones of Middle and Late Cambrian age (Rowell and others, 1979) and Silurian sandstones of the western siliceous assemblage (Gilluly and Gates, 1965).

Paleoflow data from conglomerates and sandstones are variable but suggest a southwest to southeast direction of transport for Newark Canyon Formation sediments (see Figure 21). Conglomerate clast and sandstone framework compositions favor a source terrain composed of predominantly Mississippian to Permian Antler foreland and overlap sequence rocks, Jurassic volcanic rocks, and perhaps minor lower Paleozoic eastern and western assemblage rocks. It is suggested that late Paleozoic rocks of the Antler foreland succession and overlap sequence, along with Jurassic volcanic rocks associated with crustal

intrusions, were widespread prior to Cretaceous time and supplied the majority of sediment to Newark Canyon Formation basins.

IMPLICATIONS

Cretaceous Newark Canyon Formation strata represent a significant link in understanding the late Mesozoic paleogeography and paleotectonics of the Sevier hinterland. Sedimentologic data from this study, and the work of Vandervoort (1987) in the Diamond Mountains and Fish Creek Range, suggest the Newark Canyon Formation was deposited in isolated, topographic basins which formed in response to late Mesozoic tectonism. Vandervoort (1987) concluded, on the basis of petrographic and lithofacies dissimilarities, that the strata at Overland Pass were deposited in a separate basin from Eureka District and Cockalorum Wash strata (see Figure 2 for locations). Newark Canyon Formation strata in the Eureka District and Cockalorum Wash are similar in most respects; however, evidence for a single or distinct basins of deposition is present (Vandervoort, 1987). The Newark Canyon Formation in the Cortez Mountains is in part temporally equivalent with the strata in the Eureka District and Cockalorum Wash (see Figure 4), but clast suites are markedly different and suggest a lithologically distinct source area. If Newark Canyon Formation strata were deposited in a single basin, a mixing of clast suites would be expected. Additionally, extensive lacustrine deposits in the upper part of the section in the Eureka District and Cockalorum Wash suggest restricted-basin conditions (Vandervoort, 1987).

Numerous folds and thrust faults mapped in east-central (Nolan and others, 1971; 1974) and northeastern Nevada (Ketner and Smith, 1974)

have folded rocks of Ordovician through Jurassic age and partly involve Newark Canyon Formation strata (Vandervoort, 1987). In Hildebrand Canyon along the west flank of the Diamond Mountains, the Newark Canyon Formation has been folded into an east-verging, syncline/overtaken anticline pair (Schmitt, personal communication, 1988). Deformational features include east-verging, open folds and thrusts with displacements of several kilometers. These structures define a belt of deformation named the Eureka thrust belt by Heck and others (1986) which was probably active from latest Jurassic through Cretaceous time (Ketner and Smith, 1974; Speed, 1983). Structures assigned to the Eureka thrust belt may be a northward extension of Cretaceous (?) folds and thrust faults mapped in the Quinn Canyon Range and Worthington Mountains by Bartley and others (1987) (see Figure 1). Furthermore, Little (1987) recognized south-verging folds and imbricate thrusts in a belt trending east-west in the vicinity of Mountain City, Nevada (see Figure 1). Deformation there is Jurassic (Little, 1987) and could represent an eastward extension of the Luning-Fencemaker thrust system in western Nevada or a splay of the Eureka thrust belt.

Deformation in the Eureka thrust belt was contemporaneous with the Sevier thrust belt to the east (Allmendinger and Jordan, 1981; Wiltschko and Dorr, 1983), and Luning-Fencemaker thrust system in western Nevada (Oldow, 1984) (see Figure 1). Based on this temporal correlation and similar, eastward shortening directions, Speed (1983) suggests the three Mesozoic thrust belts were genetically linked and may have shared a common decollement. Orientations and displacements of the belts of deformation are consistent with late Mesozoic stress regimes created by

left oblique subduction of the Farallon plate (Oldow, 1984). The enclaves between thrust belts were essentially flats, referred to as "meganappes" by Speed (1983), and characterized by only gently folded Paleozoic strata (Armstrong, 1968; Hose and Blake, 1976).

The documentation of late Mesozoic compressional structures proximal to and involving exposures of Newark Canyon Formation suggests sedimentation occurred in response to tectonism. Basins developed by thrust loading, and between anticlinal flexures in the late Paleozoic rocks east of the Eureka thrust belt and west of the Sevier thrust belt (Figure 33). Additionally, by restoring Tertiary extension using a province-wide average of 40% (Wernicke and Burchfiel, 1982; Coney and Harms, 1984), the Sevier and Eureka thrust belts are found to have been separated by only 250 km. If the two thrust belts shared a common decollement, the Newark Canyon Formation was deposited in allochthonous, "piggyback basins" similar to the Fossil basin in southwestern Wyoming (Iamerson, 1982).

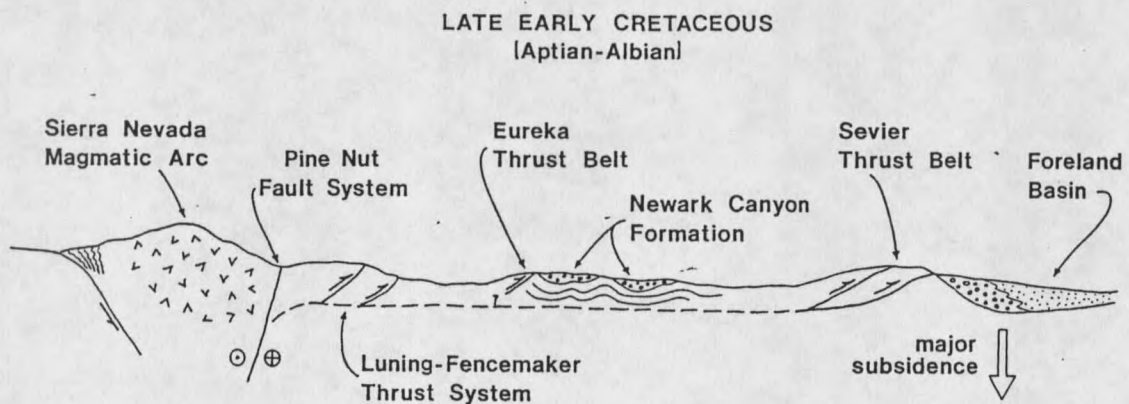


Figure 33. Diagrammatic cross-section illustrating the interpreted late Mesozoic structural setting of Newark Canyon Formation basins and relationship between the Eureka and Sevier thrust belts. Modified from Schmitt and Vandervoort (1987).

The relationship between deposition of the Newark Canyon Formation and sedimentation in the Sevier foreland basin is uncertain and probably indeterminable. Subsidence curves of Heller and others (1986) indicate initial foreland basin subsidence due to thrust plate loading occurred no earlier than Aptian time. Synorogenic conglomerates of the Indianola Group in central Utah (Standlee, 1982; Lawton, 1985), and Willow Tank Formation in southern Nevada (Bohannon, 1983) contain an Albian and younger fauna. Furthermore, recently recognized fluvial deposits of the Pigeon Creek Formation in central Utah have been assigned a Neocomian to late Albian age (Schwans, in press). These ages are correlative with the Neocomian to Albian age determined for the Newark Canyon Formation in the Eureka District and Fish Creek Range (Fouch and others, 1979), and late Early to Late Cretaceous age for exposures in the Cortez Mountains and Pinon Range (Smith and Ketner, 1976b; Fouch and others, 1979).

Based on the temporal equivalence and pre-Tertiary proximity of Newark Canyon Formation and early Sevier foreland basin deposits, it is possible that Newark Canyon Formation depositional systems were at times transporting sediment to the nascent foreland basin (Vandervoort, 1987). However, studies of early foreland basin clastics suggest deposition occurred in structurally partitioned basins during incipient Sevier thrusting (DeCelles, 1986; Schwans, in press) (Figure 34). Therefore, Newark Canyon Formation basins are interpreted to have developed coeval with, but geographically distinct from the Sevier foreland basin.

APTIAN PALEOGEOGRAPHY

119 - 113 Ma

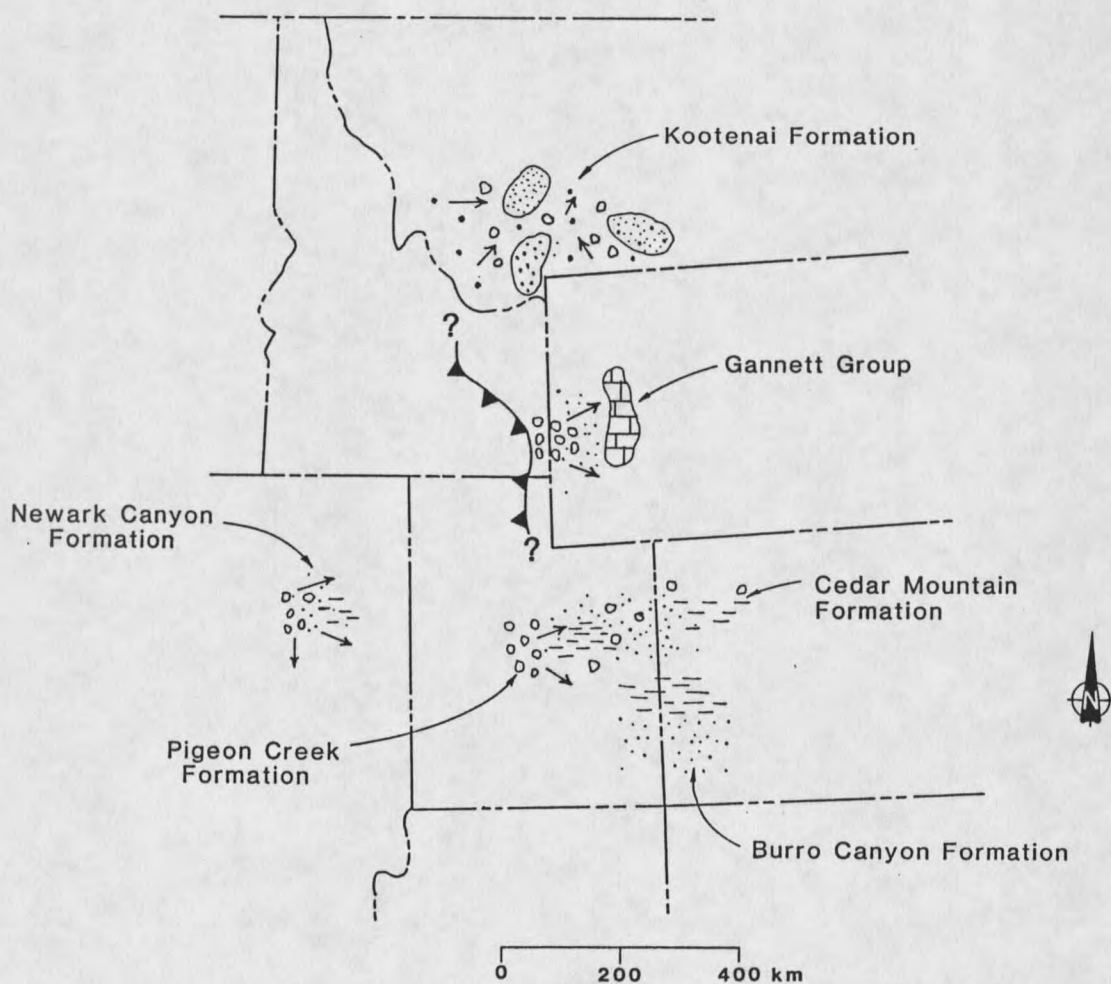


Figure 34. Interpreted Early Cretaceous paleogeography of the western U.S. Cordillera. The Newark Canyon Formation is shown to have been deposited geographically distinct from the structurally partitioned basins which developed during incipient Sevier thrusting. Modified from Schwans (in press).

CONCLUSIONS

Sedimentologic and provenance analyses of the Newark Canyon Formation in the Cortez Mountains of east-central Nevada suggest the following conclusions concerning hinterland depositional systems, paleogeography, and tectonic setting:

1. The Cretaceous Newark Canyon Formation in the Cortez Mountains was deposited by anastomosing, wandering gravel-bed, and braided fluvial systems. Anastomosing systems were characterized by stable channels which produced isolated channel bodies within extensive overbank fines. Wandering gravel-bed systems consisted of irregularly sinuous channels and large interchannel areas, and resulted in facies assemblages dominated by tabular, gravelly channel-fill and subordinate fine-grained lithofacies. Similar sequences could have been produced by gravelly, braided channels migrating across an unconfined alluvial plain. Trends in fluvial architecture may reflect tectonic or local climatic controls.

2. Composition of Newark Canyon Formation conglomerates and sandstones indicate source areas were composed of predominantly Mississippian to Permian Antler foreland and overlap sequence rocks, Jurassic volcanics, and perhaps minor lower Paleozoic eastern and western assemblage rocks. Upper Paleozoic rocks were probably widespread prior to Cretaceous time and would have provided the bulk of sediment to Newark Canyon Formation basins. Paleocurrent data are variable but suggest a southwest to southeast transport direction for Newark Canyon Formation depositional systems.

3. The Newark Canyon Formation accumulated in isolated basins in response to Eureka thrust belt deformation. Differences in clast suites and fluvial architecture between exposures of Newark Canyon Formation strata in east-central Nevada are evidence for more than one distinct basin of deposition. Basins developed by thrust loading and between anticlinal flexures in late Paleozoic rocks east of the Eureka thrust belt and west of the Sevier thrust belt.

4. Newark Canyon Formation basins developed concurrently with but geographically distinct from the incipient Sevier foreland basin.

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APPENDICES

APPENDIX A
LOCATIONS OF MEASURED SECTIONS

Cortez Mountains, Eureka County, Nevada

- CM8 (northernmost) - Sec.11 T30N R51E; begins approximately 500 m northeast of the center of Sec.11, follows gully to the southeast then along south side of creek to the center of the E 1/4 Sec.11.
- CM7 - Sec.14 T30N R51E; begins in the SW 1/4 NW 1/4 Sec.14, continues southeast along north side of creek to approximately 500 m east of the center of Sec.14, moves north along strike to the adjacent gully, and continues eastward to the SE 1/4 NE 1/4 Sec.14.
- CM6 - Sec.23 T30N R51E; begins in the SW 1/4 NW 1/4 Sec.23, proceeds southeastward along north side of creek to the center of the N 1/2 SE 1/4 Sec.23.
- CM5 - Sec.26 T30N R51E; begins in the SW 1/4 NW 1/4 Sec.23 and continues eastward along the north side of the creek to the SE 1/4 NW 1/4 Sec.23.
- CM1 - Sec.34 and 35 T30N R51E; begins in the SW 1/4 NE 1/4 Sec.34 and proceeds eastward along north side of creek to the SW 1/4 NW 1/4 Sec.35.
- CM2 - Sec.33 and 34 T30N R51E and Sec.3 T29N R51E; begins in the SE 1/4 SE 1/4 Sec.33, continues eastward along north side of creek and then in creek bottom to the extreme NE 1/4 NE 1/4 Sec.3.
- CM3 - Sec.3 and 4 T29N R51E; begins in the center of the NE 1/4 Sec.4 and continues southeastward along north side of creek to the center of the SE 1/4 Sec.3.
- CM4 (southernmost) - Sec.9 and 10 T29N R51E; begins at approximately the center of Sec.9, proceeds along the north side of creek to prominent bend, then continues along south side of creek to approximately 200 m east of the center of Sec.10.

APPENDIX B

CONGLOMERATE CLAST COMPOSITION DATA

Table 2. Clast-count data from Newark Canyon Formation conglomerates.

<u>UNIT #</u>	<u>TOTAL</u>	<u>BRN</u> <u>CHT</u>	<u>GRY</u> <u>CHT</u>	<u>RED</u> <u>CHT</u>	<u>BLK</u> <u>CHT</u>	<u>GRN</u> <u>CHT</u>	<u>SS</u>	<u>OGL</u>	<u>LS</u>	<u>VOL</u>
CM8-04	256	82	42	44	0	0	82	6	0	0
CM8-10	253	76	48	3	7	13	83	23	0	0
CM7-04	258	16	0	0	0	0	54	0	0	188
CM7-05	289	47	20	27	7	13	78	17	80	0
CM7-06	255	60	35	29	1	7	75	19	29	0
CM7-09	289	85	39	27	3	8	94	33	0	0
CM7-11	280	93	116	0	9	5	39	18	0	0
CM7-18	258	48	77	2	6	8	86	31	0	0
CM7-23	257	73	28	53	0	0	69	2	32	0
CM6-06	272	51	23	39	7	3	78	24	47	0
CM6-07	257	23	16	45	1	4	86	20	62	0
CM6-08	263	85	51	2	5	10	89	21	0	0
CM6-10	267	71	65	0	8	8	83	32	0	0
CM6-12	262	52	60	14	9	10	89	27	1	0
CM6-21	262	57	65	6	5	17	83	29	0	0
CM5-07	260	37	21	59	2	1	70	7	63	0
CM5-08	250	70	79	6	6	15	52	15	7	0
CM1-02	255	88	36	0	0	0	67	9	0	55
CM1-04	250	73	32	0	0	0	52	0	0	93
CM1-09	256	82	74	5	12	7	70	6	0	0
CM2-10	272	54	31	26	0	11	99	16	35	0
CM3-09	250	52	46	0	18	12	101	21	0	0
CM3-12	253	40	49	23	16	9	99	17	0	0
CM3-15	270	38	28	21	13	8	89	18	55	0
CM4-03	284	62	48	3	0	0	43	0	0	128
CM4-09	250	68	43	3	7	0	110	19	0	0
CM4-12	259	89	68	0	7	0	95	0	0	0
CM4-15	300	61	52	35	13	4	100	22	13	0
CM4-21	250	77	44	11	22	0	89	7	0	0

BRN CHT = brown chert

GRY CHT = gray chert

RED CHT = red chert

BLK CHT = black chert

GRN CHT = green chert

SS = sandstone

OGL = conglomerate

LS = limestone

VOL = volcanics

APPENDIX C
SANDSTONE COMPOSITION DATA

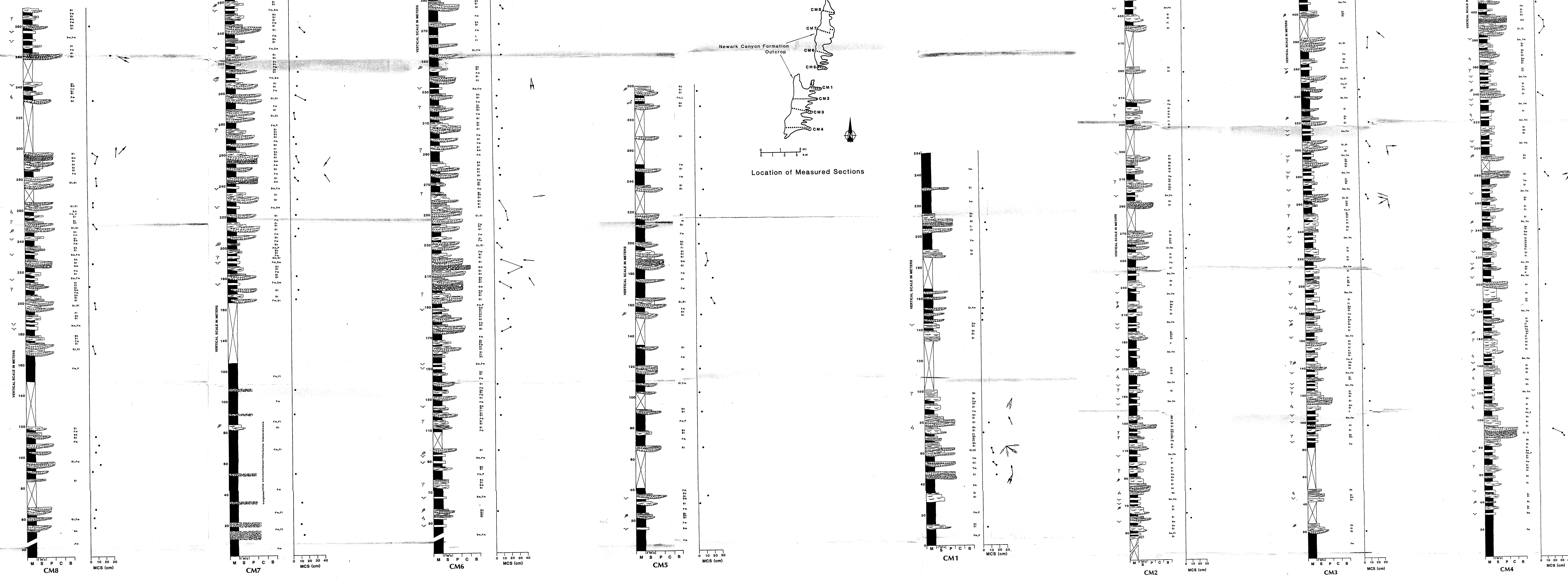
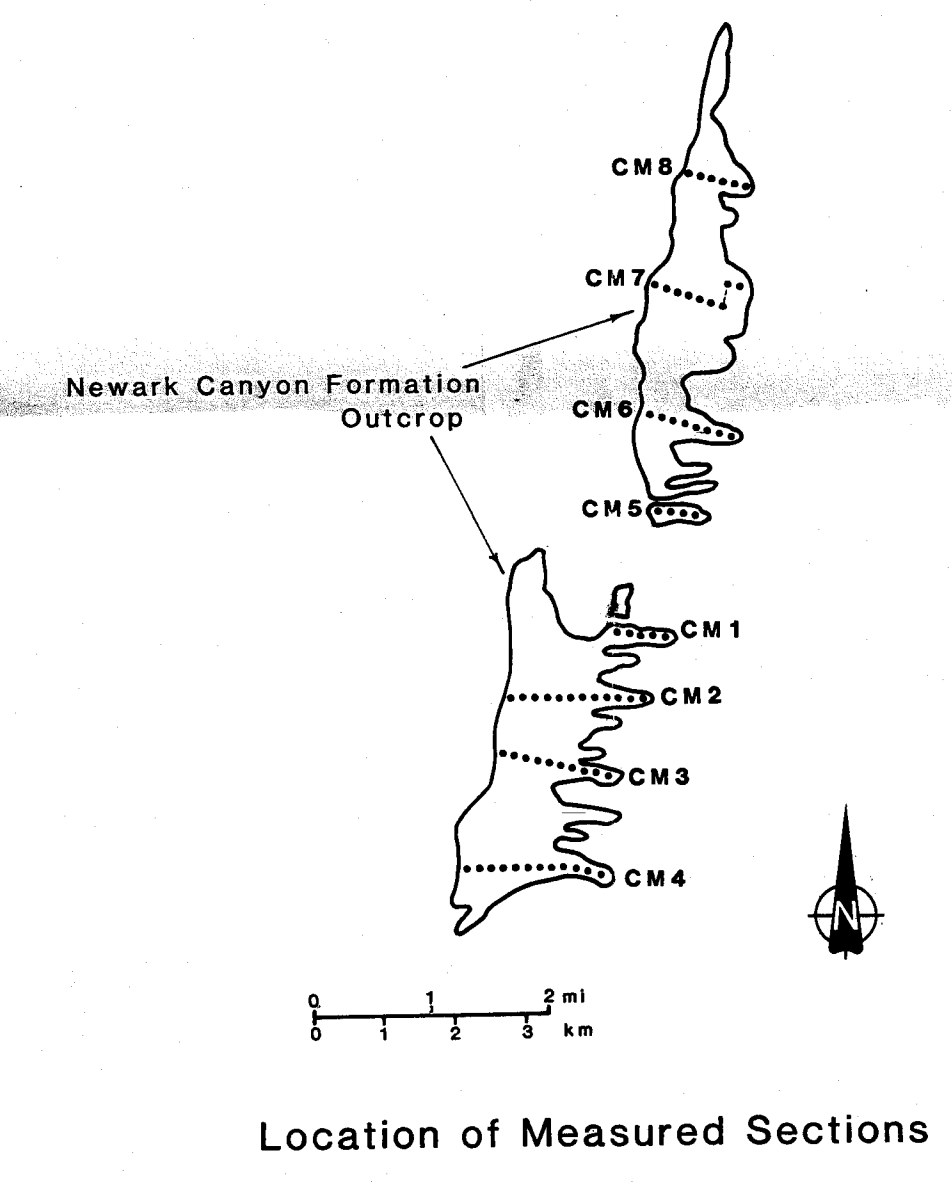
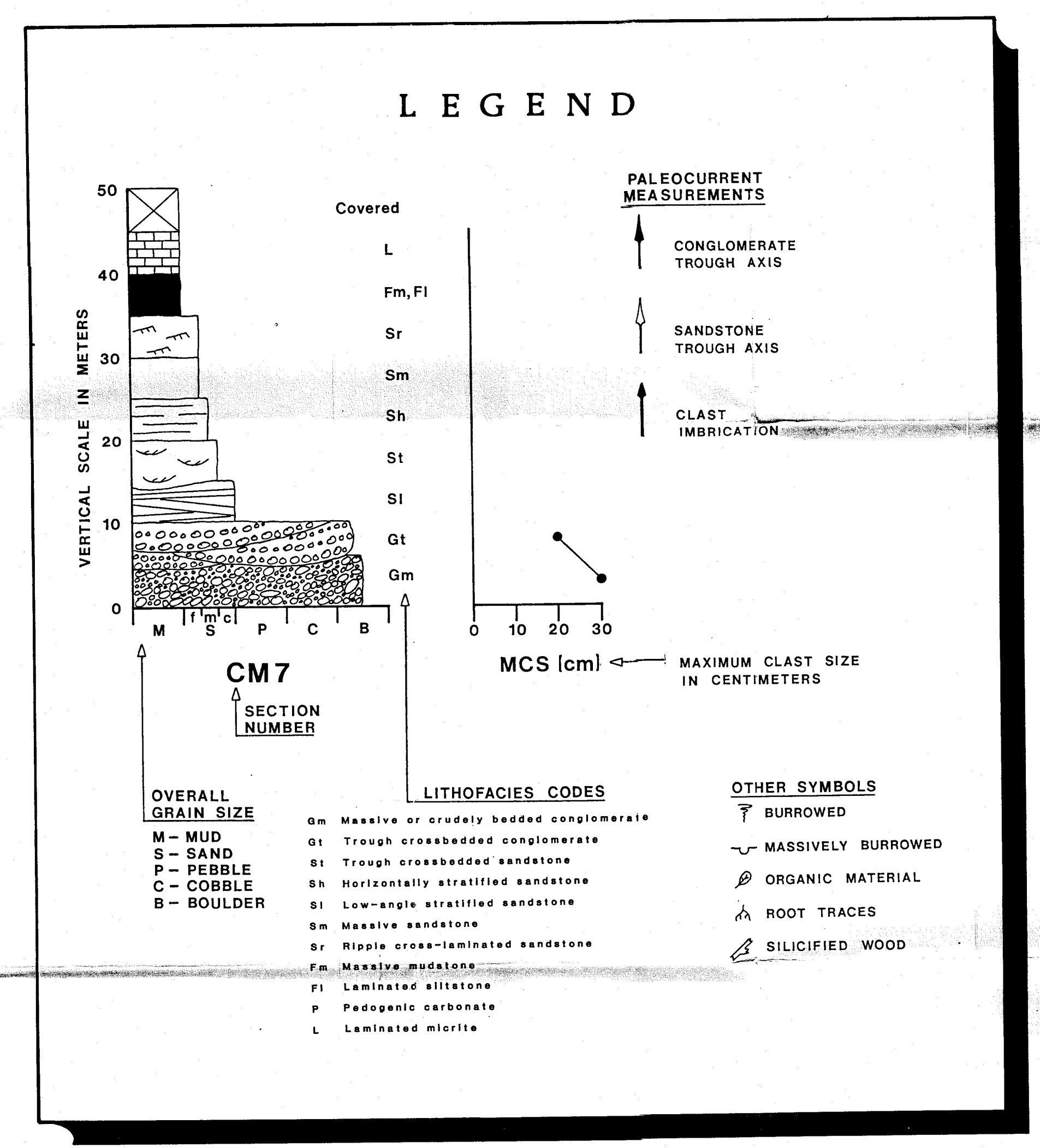
Table 3. Point-count data from Newark Canyon Formation sandstones.

<u>SAMPLE #</u>	GR <u>SZ</u>	<u>TOTAL</u>	<u>O</u>	<u>Om</u>	<u>Op</u>	<u>F</u>	<u>Lt</u>	<u>L</u>	<u>Is</u>	<u>Iv</u>
CM1-01b	f	400	357	271	86	11	118	32	10	22
CM1-01t	m	434	419	319	100	9	106	6	0	6
CM1-03	f	481	458	374	84	22	85	1	0	1
CM1-06	m	442	434	255	179	4	183	4	4	0
CM2-01	f	419	399	262	137	5	152	15	4	11
CM2-02t	f	420	411	324	87	9	87	0	0	0
CM2-04t	f	421	413	292	121	7	122	1	1	0
CM2-11t	m	419	374	162	212	3	254	42	35	7
CM2-12	vf	408	399	353	46	8	47	1	1	0
CM2-13	f	429	414	276	138	7	146	8	4	4
CM2-15	f	429	416	342	74	7	80	6	6	0
CM2-16b	f	421	408	291	117	5	125	8	8	0
CM3-02t	f	418	369	307	62	6	105	43	12	31
CM3-03	m	409	377	290	87	7	113	26	12	14
CM3-06b	f	442	402	338	64	7	97	33	14	19
CM3-08t	f	413	375	330	45	15	68	23	6	17
CM3-10t	m	420	382	333	49	6	81	32	16	16
CM3-13	f	417	390	344	46	13	60	14	14	0
CM3-18	f	415	396	350	46	4	61	15	15	0
CM4-04b	m	429	320	267	53	7	155	102	27	75
CM4-05b	f	414	354	329	25	7	78	53	9	44
CM4-07b	f	433	368	337	31	15	81	50	20	30
CM4-08b	f	415	385	355	30	16	44	14	1	13
CM4-13t	f	417	398	374	24	12	31	7	1	6
CM4-16b	f	422	366	232	134	4	186	52	50	2
CM4-17m	f	407	369	285	84	11	111	27	18	9
CM5-01b	f	411	381	354	27	15	42	15	2	13
CM5-06	f	435	362	244	118	7	184	66	61	5
CM5-10b	f	402	385	337	48	9	56	8	3	5
CM6-02t	m	430	383	289	94	13	128	34	34	0
CM6-05	f	431	335	185	150	4	242	92	92	0
CM6-06m	f	434	356	218	138	4	212	74	74	0
CM6-11m	f	409	329	221	108	3	185	77	77	0
CM6-20	m	410	302	175	127	2	233	106	105	1
CM6-21t	m	421	334	220	114	3	198	84	84	0
CM7-01m	f	422	300	290	10	10	122	112	0	112
CM7-02b	m	415	376	335	41	18	62	21	1	20
CM7-08	m	406	284	165	119	4	237	118	112	6
CM7-13t	vf	429	368	315	53	10	104	51	49	2
CM7-18	f	424	331	235	96	4	185	89	64	25
CM8-03t	f	407	337	199	138	3	205	67	55	12
CM8-05b	f	418	354	234	120	5	179	59	50	9
CM8-08m	vf	412	376	276	100	9	127	27	18	9

N378
Su 9745

North

South



MEASURED STRATIGRAPHIC SECTIONS OF THE CRETACEOUS NEWARK CANYON FORMATION
CORTEZ MOUNTAINS, NEVADA

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