Phase II Geologic Characterization Data Acquisition

Surface Geologic Mapping of the Rocky Flats Plant and Vicinity, Jefferson and Boulder Counties, Colorado

Final Report

March, 1992

U.S. Department of Energy
Rocky Flats Plant
Golden, Colorado

EG&G Rocky Flats, Incorporated

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Surface Geologic Mapping of the Rocky Flats Plant and Vicinity Jefferson and Boulder Counties, Colorado

Prepared for

EG&G Rocky Flats, Inc.
P.O. Box 464
Golden, Colorado 80402-0464

Prepared by

The EBASCO Team

The S.M. Stoller Corporation
5700 Flatiron Parkway
Boulder, Colorado 80301
(303) 449-7220

and

Ebasco Services Incorporated
143 Union Boulevard, Suite 1010
Lakewood, Colorado 80228
(303) 988-2202

March 1992

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LIST OF ABBREVIATIONS

BFI	Browning Ferris Industries
CDH	Colorado Department of Health
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
CSM	Colorado School of Mines
D&RGW	Denver and Rio Grande Western Railroad
DOE	U.S. Department of Energy
DQO	data quality objective
ER	Environmental Restoration
EPA	U.S. Environmental Protection Agency
GSA	Geological Society of America
M&O	Managing and Operating
mm	millimeter
NPL	National Priorities List
OU	operable unit
PARCC	precision, accuracy, representativeness, comparability, completeness
QA	quality assurance
QC	quality control
RCRA	Resource Conservation and Recovery Act
RFP	Rocky Flats Plant
RMAG	Rocky Mountain Association of Geologists
SOP	Standard Operating Procedure
USGS	U.S. Geological Survey

1.0 <u>INTRODUCTION</u>

1.1 BACKGROUND

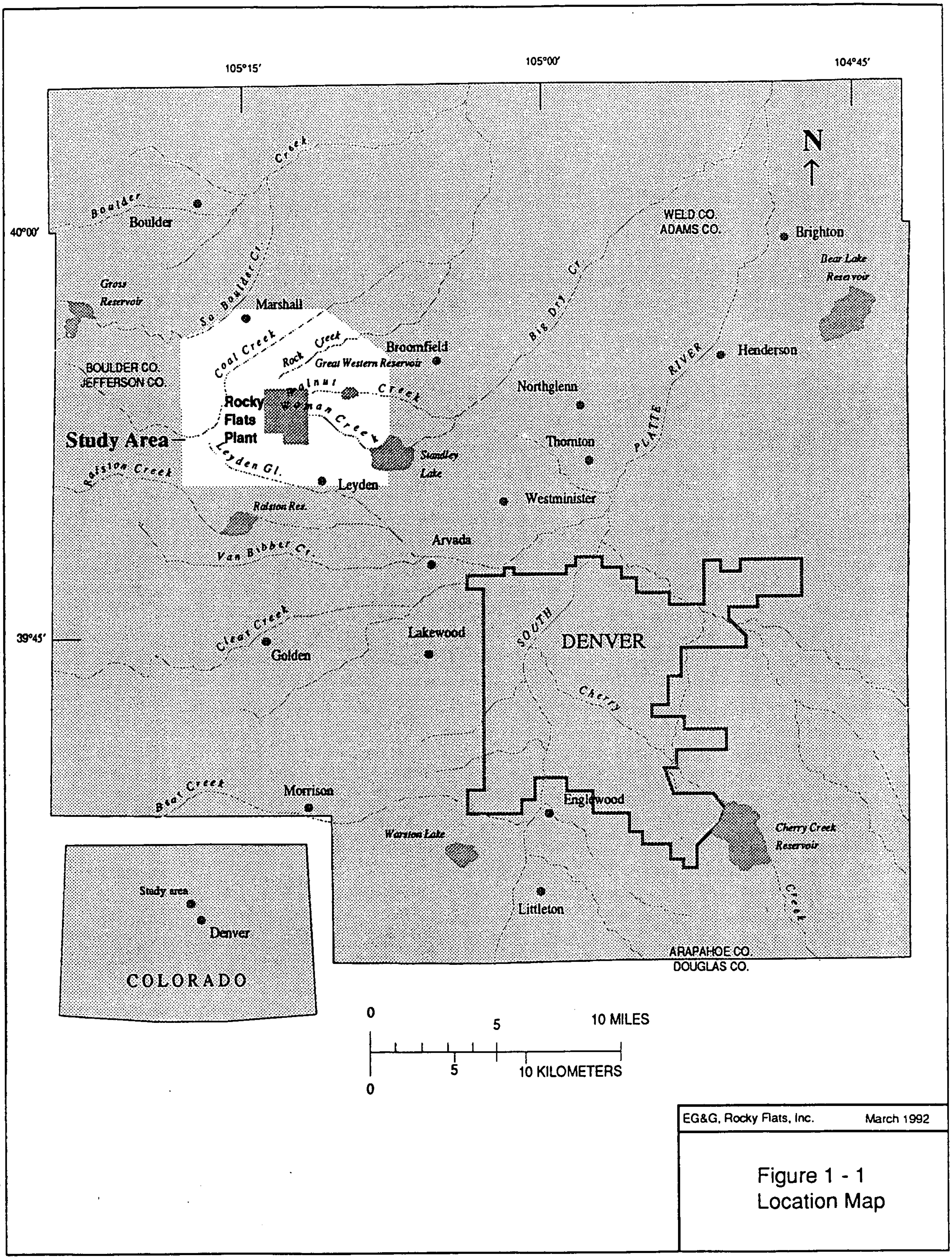
The U.S. Department of Energy (DOE) Rocky Flats Plant (RFP) is located approximately 16 miles northwest of Denver, Colorado, in northern Jefferson County (Figure 1-1). The plant site lies 4 miles east of the Front Range section of the southern Rocky Mountains along the western edge of the Colorado Piedmont section of the Great Plains physiographic province (Spencer, 1961).

RFP is a government-owned, contractor-operated facility that has been in operation since 1952. EG&G is the primary operating contractor. RFP is involved in the manufacture of the "pit assembly" plutonium component of nuclear weapons, reprocessing scrap and plutonium from dismantled weapons, conducting laboratory research on properties of nuclear materials, and fabrication of other metals such as steel and beryllium. Wastes produced include hazardous wastes, low-level and transuranic radioactive wastes, and mixed wastes. Historically, these wastes have been either disposed onsite, stored in containers onsite, or disposed offsite. RFP was proposed for inclusion on the Superfund National Priorities List (NPL) in 1984 and was included on the NPL in the October 4, 1989, *Federal Register*. Cleanup is being conducted under the Resource Conservation and Recovery Act (RCRA) and the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA). The U.S. Environmental Protection Agency (EPA), DOE, and the Colorado Department of Health (CDH) are involved in assessment and cleanup roles at the plant.

1.2 PURPOSE

The geology of RFP and the surrounding area has strong influence on the interaction and movement of groundwater and surface water and, consequently, potential contaminant transport pathways. The purpose of this study was to characterize the geology of RFP and vicinity. The study was conducted under the Environmental Restoration (ER) program at RFP as Task 6 of the Phase II Geologic Characterization Data Acquisition.

The objectives of this investigation were to (1) produce a detailed surface geologic map of the RFP area, (2) describe the Upper Cretaceous geologic formations underlying



EG&G, Rocky Flats, Inc. March 1992

Figure 1 - 1
Location Map

RFP and develop criteria for their identification in the surface and subsurface, (3) identify and characterize deformational structures that may affect the geometry of stratified bedrock beneath the plant site, and (4) resolve inconsistencies among previously published geologic maps with regard to stratigraphic and structural interpretations. Specific areas of interest targeted in this study were fault blocks within the Marshall area, the Eggleston Fault at Eggleston Reservoir, and stratigraphic sequences exposed at Pine Ridge, Eggleston Reservoir, Leyden Gulch, Eldorado Canyon, and the clay pits west of RFP.

A 60-square-mile area surrounding and including RFP was mapped in order to relate the plant site geology to the broader local and regional geologic setting. The map area extended a minimum of 2 miles from the boundaries of RFP and is bounded by the town of Marshall to the north, Leyden Gulch to the south, Standley Lake and Great Western Reservoir to the east, and the edge of the foothills to the west (Figure 1-1). The map area includes the communities of Marshall, Superior, and Leyden and the major drainages South Boulder Creek, Coal Creek, Rock Creek, Walnut Creek, Woman Creek, and Leyden Gulch (Figure 1-1).

The geologic mapping program was designed and implemented for field collection of new geologic data and to supplement existing geologic data available from previous geologic investigations at RFP. A two-person team of geologists with extensive surface mapping experience worked 55 days in the field between November 1990 and April 1991. More than 350 surface outcrops and areas with bedrock float were examined and described. The data collected in the field were synthesized on a geologic map and in the following descriptive report.

1.3 METHODS

The methodology employed in this task was a combination of observational, comparative analysis, and field measurement techniques, which collectively constitute classical surface geologic mapping. Methods were standardized to the maximum extent possible, and several visits were made to outcrops or other field areas for the purposes of comparative analysis or supplemental data gathering. The classical geologic approach of multiple working hypotheses was followed in the field and during compilation to help prevent potentially biased observations and to facilitate data collection and interpretation.

Methods used to map and describe bedrock geologic units, based on standard procedures in Compton (1962), included (1) field inspection of outcrops and bedrock float where outcrop was not present, (2) microscopic inspection of hand samples collected from outcrop locations across the field area, (3) measurement of fault plane attitudes where possible, (4) description of detailed measured sections from select locations, and (5) stratigraphic correlation with subsurface drill cores. The basic field and analytical methods used during this task as well as the quality assurance procedures followed are discussed in the following section. Data quality objectives (DQOs) and how they were met are also explained.

1.3.1 Field Mapping

A geologic map (1:12,000 scale) of RFP and the vicinity was produced using evidence from aerial photographs, surface outcrops, and subsurface geologic data. Aerial photographs (1:8,400 scale) were used to identify outcrop locations, large-scale structural features, and recent landslides.

Field inspections of outcrops were conducted across the entire map area. At each outcrop location, textural, mineralogical, and structural descriptions were recorded and the outcrop was preliminarily assigned to a geologic map unit based on lithologic descriptions from previously published work in the area. Lithologic characteristics of the Fox Hills Sandstone and Laramie Formation are described in detail by Spencer (1961) for the Louisville quadrangle and by Weimer (1976) for the Golden area. Van Horn (1957, 1972) and Weimer (1976) described the Laramie and Arapahoe Formations within the Golden quadrangle. Thus, field decisions were guided by relevant, previously published studies of the map area. In a few cases, outcrops were revisited and changes to the map were made on the basis of additional field or petrographic evidence.

Bedrock outcrops indicated on previously published geologic maps were examined and described. Additional bedrock outcrops were located, recorded, and described in field notes and were marked in place on base maps consisting of U.S. Geological Survey (USGS) 7.5-minute topographic quadrangles. The outcrop locations of stratigraphic contacts, where observed, were also recorded on the topographic base map. Lithologic field descriptions based on bedrock logging procedures in RFP Standard Operating Procedure (SOP) GT.01, "Logging Alluvial and Bedrock Material," included rock type, color (using the Geological Society of America [GSA, 1984] "Rock Color Chart"), grain size, degree of sorting, degree of rounding, porosity, cementation, friability, composition, fossils, bedding, sedimentary structures, fractures and slickensides, and weathering characteristics.

Outcrops are rare, and most were found along road cuts and other excavations or in drainages. Information from sparse outcrops was supplemented by detailed mapping of float material using recognizable lithologic beds or marker horizons. Float mapping was most useful on colluvial slopes. Other means of tracing poorly exposed contacts included identifying rock fragments in animal burrows; noting changes in composition, color, and texture of the soil; observing changes in vegetation or slope breaks; and projecting contact surfaces on the basis of nearby strike and dip measurements (Compton, 1962, p. 61-62).

Two primary objectives of this task were to (1) develop criteria for the recognition and delineation of stratigraphic units underlying RFP and (2) resolve stratigraphic inconsistencies among previously published geologic maps in the RFP vicinity. In order to achieve these objectives, locations of type sections or typical exposures were researched in the literature and visited where possible. This approach was followed for developing criteria for recognition and delineation of the crucial Laramie-Arapahoe contact. Also, as mapping progressed, additional site-specific criteria for discriminating the upper Laramie Formation from the basal Arapahoe Formation were developed.

Many outcrops were revisited by the mapping team as additional site-specific mapping criteria were developed and as the multiple working hypotheses were refined to ensure that all pertinent geologic observations were made. In addition, weekly field review trips were held with experienced supervisory personnel and other advisory personnel to validate field observations and interpretations and to fully develop the multiple working hypotheses approach.

1.3.2 Petrography

Field descriptions of lithologic units were supplemented by microscopic analyses of hand samples collected in the field. Sample locations for all 239 samples collected were marked on topographic base maps (see Appendix A) and are described in field logs. Ninety outcrop samples and nine RFP drill core samples were examined using a binocular microscope. Descriptions of these samples included rock type, color, texture, composition, and classification. Analysis of these descriptions was useful in confirming the distinguishing characteristics of the map units. These characteristics were noted in the field and also identified by microscopic examination. Hand-sample descriptions for each of these samples are included in Appendix A. More than 100 samples were also collected for grain-size analysis. Results of grain-size analyses are available for 20 of those samples (Appendix C).

In addition, 19 thin sections of selected outcrop samples and 23 thin sections of RFP drill core representing the Fox Hills Sandstone, Laramie Formation, Arapahoe Formation, and a Tertiary igneous intrusion were examined using a petrographic microscope. Thin sections were examined to enhance descriptions of the lithologic characteristics of the map units and to test discriminating criteria for each unit. Detailed descriptions of the map units are provided in Section 4.3 and include the results of hand-sample and thin-section analyses. Photomicrographs of these samples are also included in the descriptive narrative.

1.3.3 Structural Geology

Structural relationships were investigated in the field by recording the attitude (strike and dip) of bedding surfaces and exposed stratigraphic contacts. The attitude of bedding surfaces was measured using a Brunton compass, recorded in field notes, and marked on topographic base maps using appropriate symbols. Orientations of joint surfaces and slickensides were measured, and fracture patterns were described. Faults were mapped where (1) rock unit contacts were offset, (2) rock units were repeated, (3) rock units or subunits within the stratigraphic section were missing, (4) bedding attitudes changed abruptly, and/or (5) linear features were observed on aerial photographs, and offset was confirmed in outcrop following methods in Compton (1962, p. 67-69). Where evidence of movement along fault surfaces was present, the attitude of the fault plane was measured and recorded; the type of fault (normal, reverse, thrust, or strike-slip) and the sense of movement along the fault were also noted and recorded on the base map. Efforts were made to trace fault planes along strike to determine the areal extent of associated displacement.

Subsurface geologic and geophysical data were obtained by examining 63 RFP drill cores and through discussion with project geophysicists regarding past and current seismic surveys and data interpretations. Previous drill-core logs and photographs were used as a guide in selecting the cores to be examined. Cores were examined to help determine the structural elevation of the Laramie-Arapahoe contact beneath RFP. Geophysical data were used to help determine the regional dip, define channels in the upper Laramie and lower Arapahoe Formations, and investigate stratigraphic discontinuities and possible structures.

1.3.4 Stratigraphy

A total of nine stratigraphic sections were measured at seven different locations in the map area (Figure 1-2). Selection of measured section locations was limited to some extent by the poor bedrock exposure across most of the map area. Most measured sections were of the Fox Hills Sandstone and lower Laramie Formation because they are more commonly exposed in outcrop and in unreclaimed coal mines and clay pits. One section of the upper Laramie and lower Arapahoe Formations was measured in a road cut along McCaslin Boulevard. Sections were measured using the Brunton-and-tape method or the Jacob's staff method as appropriate. Measured section descriptions include thickness, rock type, texture, composition, internal sedimentary structures, and weathering characteristics following the methods in Compton (1962, p. 235-240) and in RFP SOP GT.01, "Logging Alluvial and Bedrock Materials." Measured sections are illustrated and discussed in Section 4.2.

Drill cores from 63 boreholes on the RFP site were also examined (see Appendix A, Table A-4). Selected intervals were examined and described in order to make lithologic and stratigraphic correlations between surface exposures of bedrock and the subsurface drill cores. The selection of boreholes was based on their location relative to known surface exposures and their total depth and on previous descriptions of sandstone intervals in the cores.

1.3.5 Data Quality Objectives

The DQOs for this task are described in the Phase II Geologic Characterization Data Acquisition Work Plan (EG&G, 1991c). DQOs are expressed in terms of precision, accuracy, representativeness, comparability, and completeness (PARCC). Because data collection associated with geologic mapping is both observational and interpretive, it is difficult to quantify all data collection methods. DQOs were achieved where possible and included (1) taking duplicate compass readings of bedding attitudes and joint and slickenside orientations at a rate of approximately 20 percent daily; (2) checking declination settings and needle rotation on Brunton compasses and calibrating the altimeter to known elevations twice daily for accuracy; (3) reviewing outcrop and hand-sample descriptions from site to site weekly and comparing them to SOP requirements for representativeness; (4) comparing and contrasting data collected (e.g., lithologic descriptions, bedding attitudes, outcrop locations, fault trace locations) with previously published data for comparability; and (5) assessing, characterizing, and documenting that task requirements were in accordance with the SOPs and assessing quality control (QC) information for completeness. All specific objectives of the study were achieved, surpassing the 90 percent target for activity completion.

Appropriate quality assurance/quality control (QA/QC) measures were implemented for this task, as specified in the Work Plan (EG&G, 1991c), to ensure that (1) the information and data collected are valid and of appropriate quality, (2) activities were monitored, (3) personnel were adequately trained, (4) documentation was reviewed and controlled, and (5) project files were maintained and secured.

Four areas were monitored for appropriate QA/QC: (1) sampling, storage, and transport; (2) instrument and equipment calibration; (3) documentation; and (4) document control. Selected samples were sent offsite for thin-section preparation and grain-size analysis. Field instruments (Brunton compasses and altimeter) were calibrated when appropriate. The magnetic declination was set at the beginning of the project and was checked periodically to ensure its accuracy. All observations, measurements, and descriptions were recorded in field logbooks under the appropriate station number corresponding to the location of the outcrop. All samples and photographs were sequentially recorded in field logbooks. Field personnel were responsible for the security of logbooks on a daily basis, and field notes were stored in the contractor offices. Field notes and maps were periodically reviewed for completeness by the Task Manager and Work Order Manager.

2.0 REGIONAL SETTING

2.1 SURFACE TOPOGRAPHY

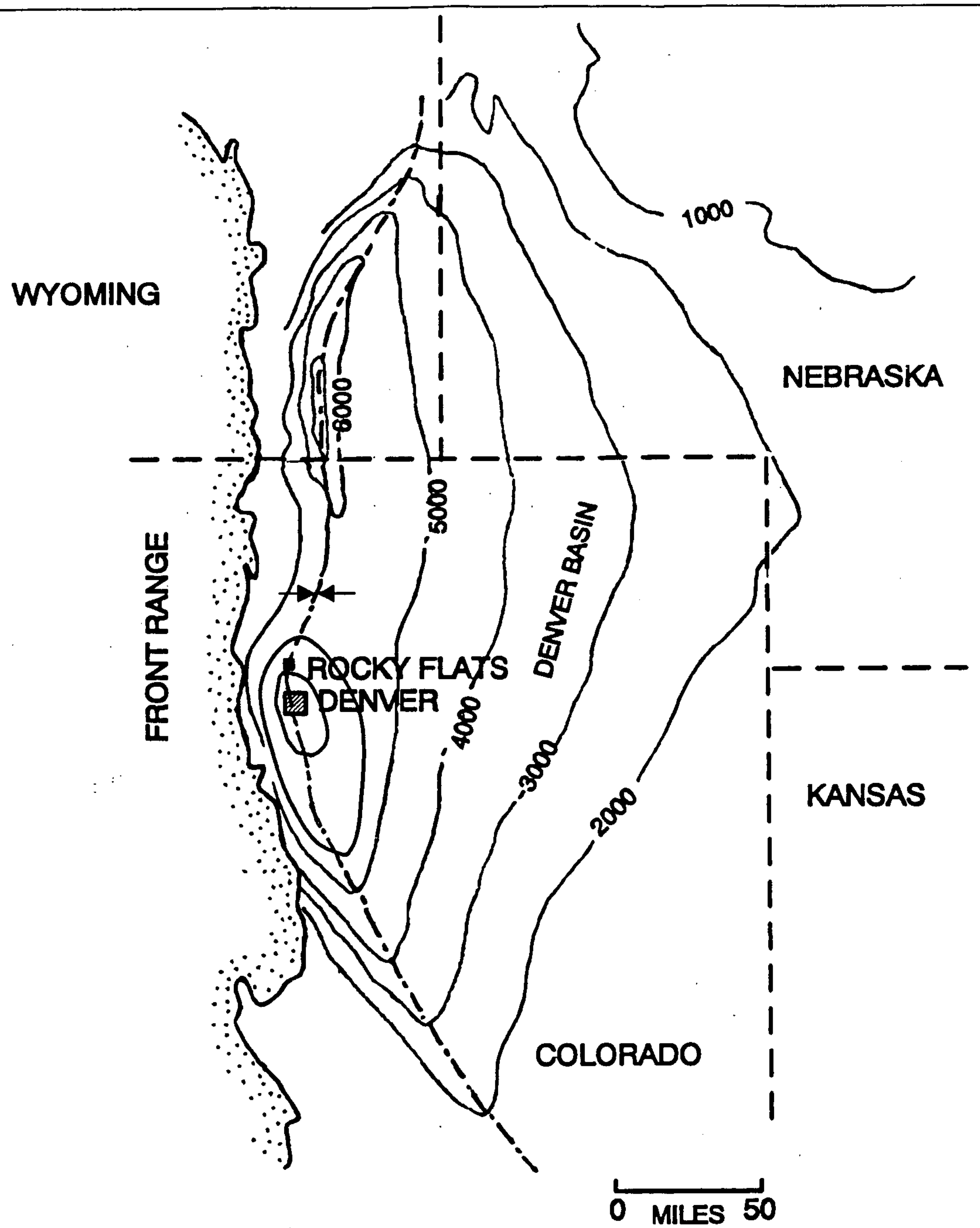
The map area extends from the edge of the Front Range foothills on the western boundary across the Pleistocene alluvial fans, which form gently sloping uplands, to the plains along the South Platte River valley on the eastern boundary. The dominant features in the area are the alluvial fans that have been locally dissected and reworked by fluvial processes. These processes have formed moderately steep hill slopes adjacent to the intermittent streams that drain the area.

Two major tributaries of the South Platte River, South Boulder Creek and Coal Creek, emerge from the foothills and flow through the northern portion of the map area (Figure 1-1). Their drainage basins and stream bottoms follow a northeast trend, and streams flow northeast. Intermittent streams originating from upland areas in the northern portion of the map area (e.g., Rock Creek) also follow northeast trends. The central and southern portions of the map area are drained by tributaries of Clear Creek and Big Dry Creek. These are primarily ephemeral streams and include Walnut Creek, South Walnut Creek, Woman Creek, and Barbara Gulch. These streams flow generally due east from the foothills and uplands.

Altitudes within the map area range from 5550 feet (above mean sea level) at Standley Lake to 7650 feet near Ralston Buttes. The upland alluvial fan altitudes range from 5900 to 6300 feet. The land slope of these upland fans is approximately 2 degrees east. Hill slopes along the stream courses are generally mantled with colluvial deposits. Landslide and slump deposits are common along hill slopes adjacent to stream drainages.

2.2 GEOLOGIC SETTING

The RFP site is located along the eastern edge of the Southern Rocky Mountain region. The map area is bounded on the west by the Colorado Front Range and is underlain by the Denver Basin (Figure 2-1). The Denver Basin contains more than 10,000 feet of Pennsylvanian to Upper Cretaceous sedimentary rocks that have been locally folded and faulted. Sedimentary bedrock is unconformably overlain by Quaternary alluvial gravels that cap pediment surfaces of several distinct ages (Scott, 1965). The Rocky



Basin Axis

Structure contours on top of Precambrian basement (in feet below mean sea level)

Modified from: Rockwell International, 1986, RCRA Part B Permit Application

EG&G Rocky Flats Plant, Inc.	March, 1992
Figure 2-1 Geologic Setting and Structural Features of the Denver Basin	

Mountain region has a history of episodic structural deformation and stable cratonic sediment accumulation.

The formation of the ancestral Rocky Mountains during the Pennsylvanian was followed by deposition of Pennsylvanian through Cretaceous sediments. Deposition of mid-Pennsylvanian clastics was followed by deposition of Permian sandstones, claystones, and limestones. These are unconformably overlain by Jurassic sandstones, claystones, and shales. Lower Cretaceous sandstones grade upward into Upper Cretaceous calcareous and noncalcareous shales. The Upper Cretaceous stratigraphy is dominated by nearshore marine and deltaic sandstones, siltstones, claystones, and shales. Detailed descriptions of the regional stratigraphy are provided in Section 4.1. The Phanerozoic sequence of sedimentary rocks reflects the changes in depositional environments and source areas that occurred in this region in response to large-scale tectonic forces.

The tectonic framework of the southern Rocky Mountain region is dominated by subsidence of large basins and the rise of areally less extensive uplifts (e.g., Front Range and Sawatch Range). These uplifts were formed predominantly during Laramide time (late Cretaceous to early Tertiary) during regional compression related to movement of the North American plate over a gently dipping subducted slab (Hamilton, 1981). Some Laramide structures, as well as some sedimentation patterns, were strongly influenced by basement anisotropy induced by Precambrian deformation.

Laramide deformation is responsible for most of the major structural elements in the region. Consensus has not been reached as to the geometry of Laramide structures, and two distinct models are generally discussed. In the first, low-angle thrust faults induced by horizontal compression dominate the tectonics (Hamilton, 1981). In the second general model, structural relief along the Rocky Mountain foreland results from vertical tectonics. Fault blocks are bounded by steeply dipping structures in this model. High-angle fault surfaces and basement-cored fold structures in the northern Front Range appear to support models for vertical tectonism (Stearns, 1971; Matthews and Work, 1978). However, recently collected seismic reflection data indicate that Precambrian rocks have been thrust over Phanerozoic sediments (Jacob, 1983; Lowell, 1983; Stone, 1985). Erslev et al. (1988) have recently presented field evidence that supports the seismic data and strengthens horizontal compression models for Laramide deformation in the Front Range north of RFP. Based on the most recent data collected, most investigators agree that Laramide deformation of the Rocky Mountain foreland is temporally related to subduction processes along the west coast of North America and that the regional compressional stress field in the foreland led to reverse, thrust, and strike-slip faults.

The Denver Basin has a steeply inclined western flank that abuts the southern Front Range Uplift along a zone of related boundary faults (Figure 2-1). Questions remain as to the geometry of these bounding faults, but there is increasing acceptance of the view that these are west-dipping reverse faults with variable dip angles (Curtis, 1986). In northern Jefferson County, the trend of the western flank of the Denver Basin changes abruptly from north-northwest to nearly due north. The location of this shift is coincident with pre-existing structural trends, such as the northeast-trending Idaho Springs-Ralston Shear Zone. This structural feature extends for nearly 23 miles from a location near Georgetown, Colorado, to the eastern edge of the Front Range Uplift at Coal Creek. The degree to which pre-existing structures in the Precambrian basement rock control the style and extent of local Laramide deformation is not known.

3.0 PREVIOUS WORK

Previous geologic characterizations of the RFP area include five distinct types of investigations: (1) USGS geologic reports and maps (Malde, 1955; Spencer, 1961, 1986; Sheridan et al., 1967; Wells, 1967; Van Horn, 1957, 1972), (2) USGS hydrologic investigations (Hurr, 1976), (3) reports prepared for RFP by private consultants (e.g., Dames and Moore, 1981), (4) reports prepared for RFP by the Managing and Operating (M&O) contractor (e.g., EG&G, 1990a-b, 1991a-d), and (5) published research regarding the sedimentology and depositional environments of Cretaceous strata on the west flank of the Denver Basin (e.g., Weimer, 1976). Clearly, a large body of previous work exists that describes the geologic setting of RFP. However, each of the above investigations was conducted with significantly different objectives, and none of the previous reports or investigations specifically targeted the objectives of this study. The key problems revealed by previous work and addressed in this study are (1) inconsistencies in the designation and nomenclature of stratigraphic units, particularly the Laramie and Arapahoe Formations and the location of their mutual contact and (2) interpretation of fault geometries. These problems are briefly described below.

Lithologic descriptions of the bedrock and surficial geologic units within the RFP area have been summarized in a number of geologic quadrangle maps published by the USGS. Portions of five published maps cover the study area (Malde, 1955; Spencer, 1961; Sheridan et al., 1967; Wells, 1967; Van Horn, 1972). In adjacent or overlapping areas of these published maps, numerous inconsistencies exist in the designation and nomenclature of bedrock units. For example, in Spencer's (1961) map of the Louisville quadrangle, no differentiation is made between the Laramie and Arapahoe Formations and all of the Upper Cretaceous strata overlying the Fox Hills Sandstone are included in and mapped as the Laramie Formation. In contrast, Van Horn (1972) separates the Arapahoe from the Laramie, and his geologic map of the Golden quadrangle shows a contact between these two units south of RFP. Malde (1955) concentrated on the surficial geologic units and made no differentiation among any of the Upper Cretaceous bedrock units.

In a hydrogeologic study of the RFP site, Hurr (1976) concluded that the Arapahoe aquifer receives recharge primarily where it is in angular discordance with the overlying Rocky Flats Alluvium in the western portion of RFP. A geologic map accompanying Hurr's report shows a low-angle, east-dipping contact between the Laramie and Arapahoe Formations, striking approximately north-south and located immediately west of RFP. This contact was not observed by previous workers (Spencer, 1961; Van Horn, 1972). The same geologic map depicts the Eggleston Fault to extend southeast into the RFP site.

The sitewide Geologic Characterization Report, prepared for DOE by EG&G (1991d), develops the most current conceptual geologic model for RFP using evidence from 1986, 1987, and 1989 drill cores, borehole geophysical logs, and reprocessed seismic data. The report presents site-specific descriptions of the upper Laramie and Arapahoe Formations and descriptions of structural geology and includes several interpretive maps of the subsurface geology. Preliminary correlations of the site stratigraphy with offsite locations were made by comparing geophysical logs from two offsite wells (Johnson F.H. and C.R. Co. No. 1 well, section 7, T3S, R69W; Public Service No. 2 well, section 27, T2S, R70W) with logs from RFP wells and boreholes. The contact surface between the Laramie and Arapahoe Formations is described as a 1 to 2 degree, east-dipping surface that lies 150 feet below the ground surface in the central portion of the plant site. The report names five individual sandstone intervals (Numbers 1, 2, 3, 4, and 5 sandstones) within the Arapahoe Formation, all of which dip 1 to 2 degrees east at distinct subsurface elevations. A bedrock elevation contour map (EG&G, 1991d; Appendix B, Map 5) shows the elevations of the top of the bedrock where it is overlain by younger alluvial and colluvial deposits. A prominant bedrock "step" of 30 feet is present on the contour map immediately east of the plant's inner east gate.

Dames and Moore (1981) conducted a detailed seismologic and geologic investigation of the RFP site and surrounding areas to the south near Golden and as far north as Eggleston Reservoir. The primary purpose of that investigation was to assess the seismic hazard at RFP by describing the style and extent of Laramie and younger fault deformation at and around the RFP site. The results of the investigation indicated no compelling evidence for Recent tectonic activity on Laramide fault structures in the RFP area and no evidence for current seismic hazards at RFP. Test pits and trenching excavations near the Eggleston Reservoir did not encounter evidence of the Eggleston Fault in the subsurface. Dames and Moore (1981) concluded that "the Eggleston Fault does not exist."

Shallow, high-resolution seismic reflection surveys have been conducted at RFP primarily to acquire subsurface stratigraphic information. Therefore, seismic data were processed to enhance flat-lying stratigraphic features. However, the results of shallow seismic surveys (EG&G, 1991a) do show evidence for structural displacement within the Laramie Formation; reprocessing of the data to enhance dipping events is required in order to confirm the presence of structural offsets. Rockwell (1989) identified four east- to northeast-trending paleochannels in bedrock beneath Operable Unit (OU) 2 (the 903 Pad, Mound, and East Trenches areas) at RFP. EG&G (1990b) reprocessed and reinterpreted approximately 3.5 miles of seismic data, originally acquired by the Colorado School of Mines (CSM) in 1975, that extend from RFP 4 miles north to Marshall. Thrust faults were identified on two of the lines, one in the northwest portion of the buffer zone and the other in the central portion of the plant. EG&G (1991d) related these two features and a fault on the deep seismic line to a single structure at depth, a west-dipping, west to east thrust fault that offsets the Pierre Shale beneath RFP. EG&G (1991a) identified and mapped three sandstone channels in bedrock beneath OU 2; combined borehole and seismic data were used in the same study to identify an approximately 30-foot drop, or "step", in the depth to the top of bedrock under the younger alluvial gravels in the OU 2 area. Several sandstone channels were also identified east of RFP on the Indiana Street seismic lines (EG&G, 1991b). A south-dipping structure and a possible fault have also been identified on one of the Indiana Street seismic profiles. A north-south-trending syncline has been identified on the West Spray Field seismic line. Beds on the west limb of this fold have an apparent dip of 45 degrees east, and beds on the east limb of the fold, which extends beneath RFP, have an apparent dip of 2 to 3 degrees east.

R.J. Weimer and co-workers at CSM have compiled the most detailed lithologic descriptions of the Upper Cretaceous strata (Benton Shale through Arapahoe Formation) in the RFP area and have proposed depositional models for their origin (e.g., Weimer, 1973; Weimer, 1976; Weimer et al., 1972; Weimer and Tillman, 1980). In general, the three main Upper Cretaceous stratigraphic units cropping out in the RFP area (the Fox Hills Sandstone, Laramie Formation, and Arapahoe Formation) are interpreted as representing the last shoreline regression of the Cretaceous interior seaway.

Several structural models specific to the western Denver Basin have been proposed by previous workers using observed field relationships and subsurface drill-core and coal mine data from the map area of this study. A series of northeast-trending faults identified in the Boulder-Weld coalfield was first interpreted to be nearly vertical and forming a series of horsts and grabens (Spencer, 1961). These faults were thought to extend to a depth of approximately 4000 feet, where they died out in the Pierre Shale. The horst-graben system was termed a product of right-lateral strike-slip movement along the Idaho Springs-Ralston Shear Zone. In contrast, Davis and Weimer (1976) interpreted these faults as syndepositional growth faults formed within the deltaic environment represented by the Pierre Shale, Fox Hills Sandstone, and Laramie Formation. They estimated that these growth faults extend to depths of 5000 feet.

Spencer (1986) conducted a detailed study of seven coal beds in the Boulder-Weld coalfield. In this study, Spencer interpreted the faults as predominantly high-angle normal faults of dip-slip origin that formed a series of horsts and grabens. Spencer (1986) related their origin to movement along the Idaho Springs-Ralston Shear Zone. His study also demonstrated that the thicknesses of coal beds were not related to the fault structures and placed doubt on a growth-fault interpretation of those faults.

In a recent study of subsurface data from the Boulder-Weld coalfield, Kittleson (1991) showed that the Upper Cretaceous strata in the area had been displaced to the southeast. He concluded that this deformation was probably produced by gravity sliding of sedimentary rocks along easily deformed sedimentary strata (e.g., Pierre Shale) during emergence of the Front Range Uplift. In addition, Kittleson concluded that alternative kinematic models may be invoked that can also explain the structural deformation in that area.

4.0 STRATIGRAPHY

The 19 stratigraphic units recognized in the map area are described in Section 4.1. Detailed descriptions of the upper three bedrock formations (the Fox Hills Sandstone, Laramie Formation, and Arapahoe Formation) are presented in Sections 4.2 and 4.3.

4.1 GEOLOGIC MAP UNITS

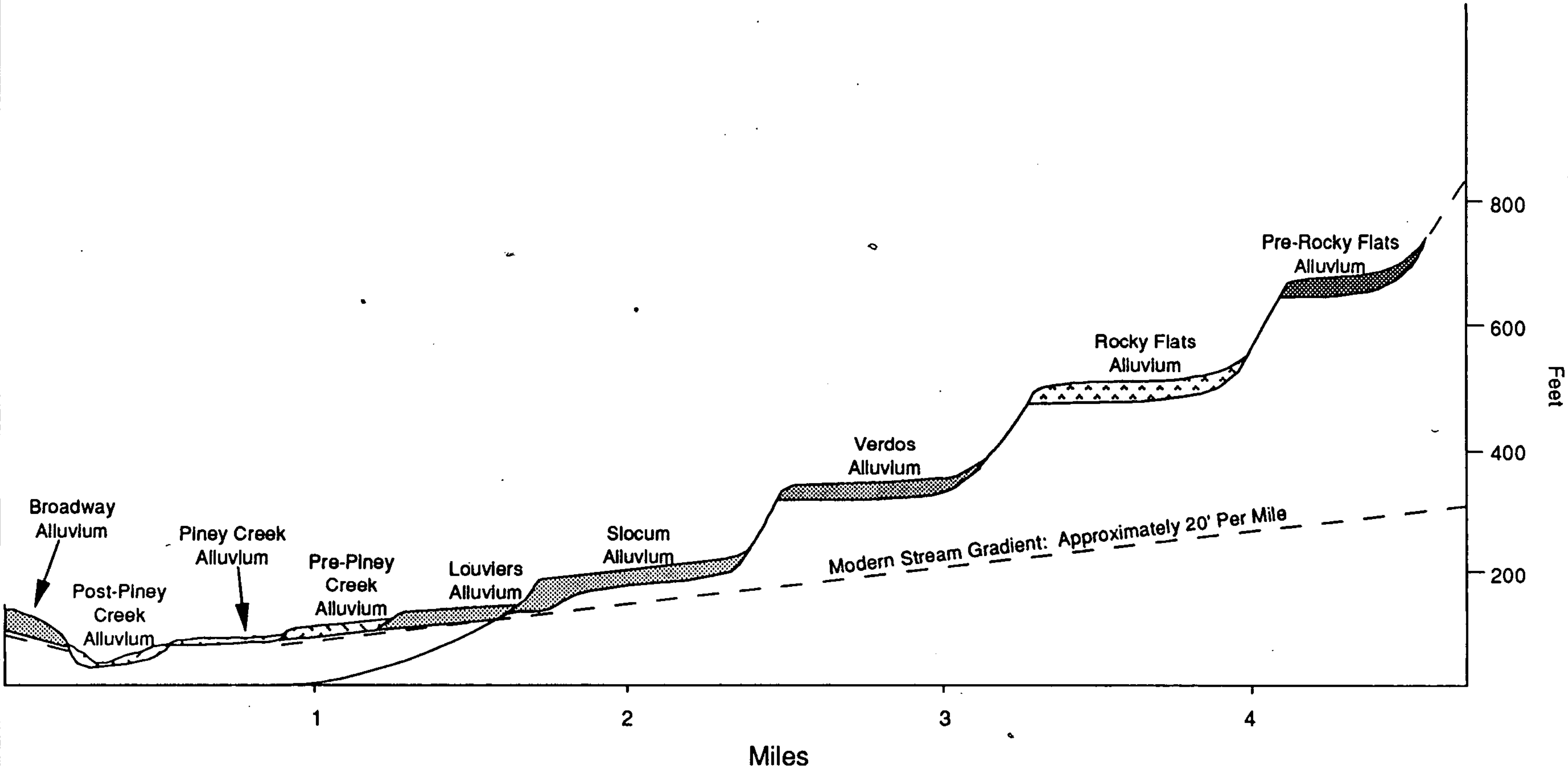
Geologic map units are divided into surficial and bedrock units. Surficial units include Recent landslide and alluvial deposits and Pleistocene alluvial gravels of several distinct ages (Figure 4-1). Bedrock units range from Precambrian gneiss through Upper Cretaceous sedimentary rocks, as illustrated in a general stratigraphic column in Figure 4-2. Surficial and bedrock units are described in sequence from youngest to oldest. Descriptions are taken from the literature and supplemented with field data collected during this study. These descriptions are intended to accompany and describe the geologic map (Plate I). Sections 4.2 and 4.3 provide more detailed stratigraphic and petrographic descriptions of the upper three bedrock formations.

4.1.1 Landslide Deposits

Landslide deposits are late Recent and consist of small slumps on oversteepened slopes and along the banks of creeks and ponds. Slumps commonly occur in claystones in the upper Laramie and Arapahoe Formations and involve downward and outward movement along curved slip planes. They are recognized by a curved scarp at the top, a coherent mass of material downslope that may be rotated back toward the slip plane, and hummocky topography at the base. Areas of creep are expressed in weakly consolidated, grass-covered slopes as bulges or low, wavelike swells.

4.1.2 Valley-Fill Alluvium

Valley-fill alluvium consists of channel and terrace deposits in and along South Boulder Creek, Rock Creek, Coal Creek, Walnut Creek, Woman Creek, and Leyden Gulch. This designation includes the pre-Piney Creek Alluvium of Scott (1960), Piney Creek Alluvium of Hunt (1954), and post-Piney Creek Alluvium of Malde (1955). Valley-fill alluvial deposits are early Recent to late Recent (Sheridan et al., 1967). Lithologically, valley-fill deposits are composed of light brown to brownish gray humic



LEGEND

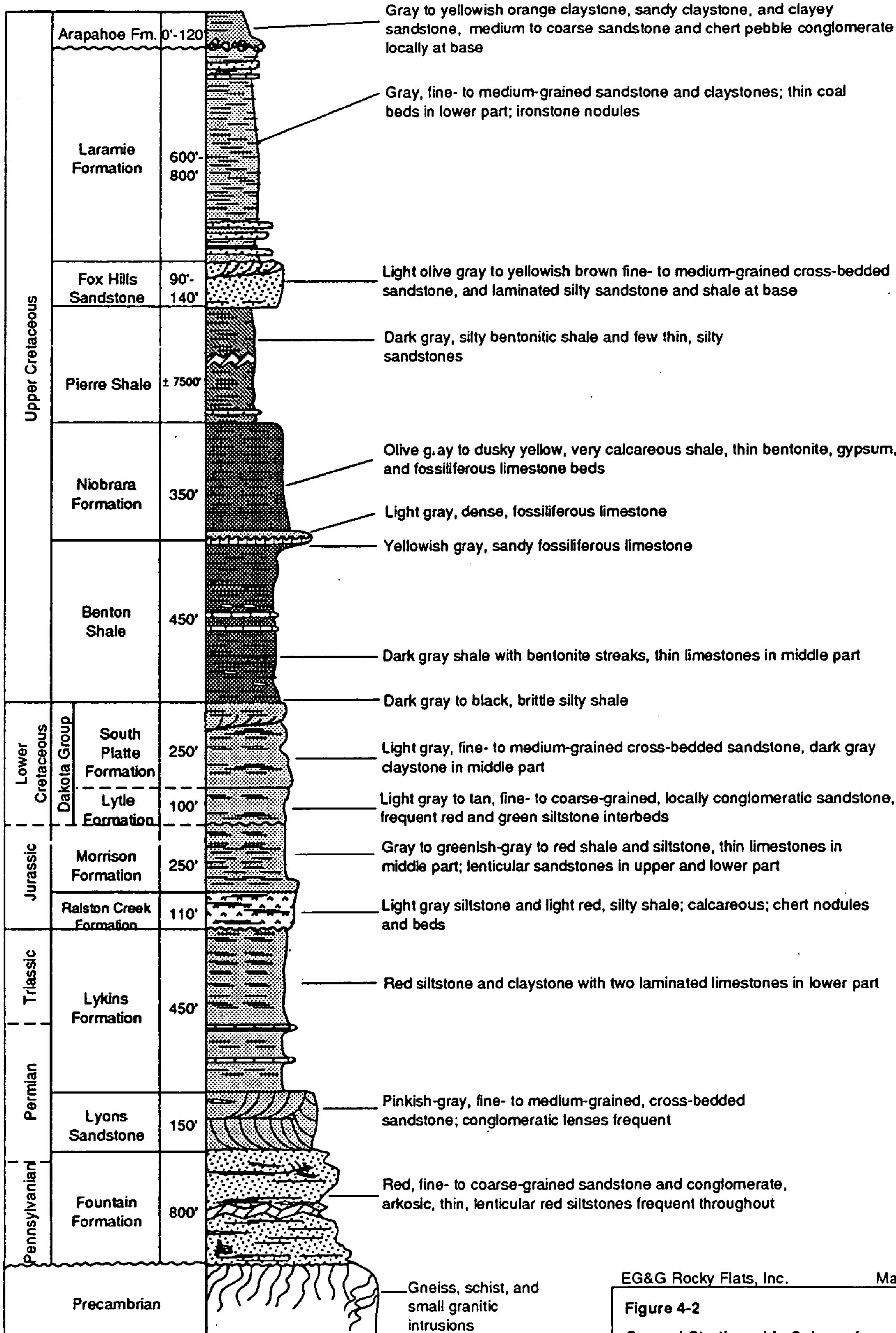
Qpr	Pre-Rocky Flats Alluvium
Qrf	Rocky Flats Alluvium
Qta	Undifferentiated Terrace Alluvium
Qa	Valley-Fill Alluvium

EG&G Rocky Flats, Inc. March 1992

Figure 4-1

Quaternary Stratigraphic Relationships in the Vicinity of the Rocky Flats Plant

Reference: Scott (1963)



EG&G Rocky Flats, Inc. March 1992

Figure 4-2

General Stratigraphic Column for the Rocky Flats Plant Vicinity

Modified from LeRoy and Weimer (1971)

clay, silt, sand, and pebbly sand with silty and cobbly gravel lenses. Pebbles and cobbles are most commonly composed of quartzites. Granite, gneiss, and sandstone pebbles and cobbles are less common. Valley-fill alluvial deposits vary from less than 10 feet to more than 40 feet in thickness and occur as much as 25 feet above the level of modern streams (Scott, 1965; EG&G, 1991d).

4.1.3 Post-Rocky Flats Undifferentiated Terrace Alluvium

Post-Rocky Flats undifferentiated terrace alluvium consists of alluvial material deposited on pediments topographically below the Rocky Flats Alluvium but higher than channel and terrace deposits in modern streams. This designation includes the Verdos (Kansan or Yarmouth), Slocum (Illinoisan or Sangamonian), Louviers (early Wisconsin), and Broadway (late Wisconsin) alluviums of Scott (1960). These undifferentiated alluvial deposits are composed of light to moderate brown, clayey coarse gravel and coarse sand. Pebbles and cobbles are most commonly composed of quartzite. Weathered granite, gneiss, sandstone, and schist pebbles and cobbles are less common. Undifferentiated terrace alluvial deposits range from 10 to 50 feet in thickness and occur from 25 to 250 feet above the level of modern streams (Scott, 1960; EG&G, 1991d).

4.1.4 Rocky Flats Alluvium

The Rocky Flats Alluvium is an alluvial fan deposit that occupies an extensive erosional surface. The alluvial deposit has a fanlike form, with its apex near the mouth of Coal Creek Canyon. The slope of the pediment near the apex is approximately 140 feet per mile in the western portion of the map area (Malde, 1955). In the southern portion of the map area, near Leyden Gulch, the pediment surface slopes east and southeast at approximately 50 feet per mile. Scott (1960) interpreted the Rocky Flats Alluvium to be of Nebraskan or Aftonian age, based on its topographic position with respect to the Verdos Alluvium. The thickness of the Rocky Flats Alluvium ranges from 1 to 100 feet (Malde, 1955; EG&G, 1991d; this study). The thinnest deposits occur on top of bedrock ridges or hogbacks, and the thickest deposits occur as local channel fills in scoured bedrock or behind bedrock ridges. The Rocky Flats Alluvium is composed of yellowish brown to reddish brown, angular to subrounded, poorly sorted, coarse, bouldery gravel in a sand matrix with lenses of clay, silt, and sand and varying amounts of caliche. Pebbles, cobbles, and boulders are composed primarily of quartzite but include lesser amounts of schist, gneiss, granite, pegmatite, sandstone, and siltstone. Pebbles range from 2 to 4 inches in diameter. Boulders as much as 2 feet in diameter are common. Deposits of Rocky Flats Alluvium occur from approximately 250 to 380 feet above the level of modern streams (Scott, 1965; EG&G, 1991d).

4.1.5 Pre-Rocky Flats Alluvium

Pre-Rocky Flats Alluvium consists of alluvial gravel deposits in the western portion of the map area in sections 5, 6, 7, 8 (Station 173), and 29, T2S, R70W. The pre-Rocky Flats Alluvium caps the highest erosional surface in the area; its topographic position indicates that it is older than the Rocky Flats Alluvium. Although not named on previous maps of this area (Wells, 1967; Sheridan et al., 1967), pre-Rocky Flats alluvial gravels may be correlative with the Nussbaum alluvial gravels (Scott, 1965) that are best preserved in the Colorado Springs area. Because the pre-Rocky Flats Alluvium is closely associated with the Rocky Flats Alluvium, Van Horn (1967) suggested that it is most likely of early Nebraskan age. The thickness of the pre-Rocky Flats Alluvium varies from 30 feet in section 7, T2S, R70W near its apex to 10 feet near its eastern terminus. The slope of the pediment is steep, approximately 1400 feet per mile, near the apex but flattens out to the east to approximately 200 feet per mile (Wells, 1967). Pre-Rocky Flats alluvial deposits are composed of moderate reddish brown, subangular to rounded, poorly sorted, silty or clayey sand matrix containing cobbles and boulders that are primarily quartzite but include decomposed granitic rocks. Sizes of individual boulders range from 8 inches to 6 feet in diameter (Van Horn, 1967). Pre-Rocky Flats alluvial deposits occur 40 to 100 feet above the Rocky Flats pediment and 290 to 480 feet above the level of modern streams.

4.1.6 Igneous Intrusive Rocks

Two medium-grained, alkalic basalt sills locally intrude the Fort Hayes Limestone Member of the Niobrara Formation northeast of Ralston Buttes along the southwestern edge of the map area (Station 181). The sills are approximately 1500 feet long and less than 10 feet wide. These rocks have silica contents characteristic of basalt or basaltic andesite (54.0 to 51.4 weight percent silica, Larson and Hoblitt, 1973). A sample was collected for petrographic analysis from the southern portion of section 29, T2S, R70W, south of Fireclay (Station 24-5). The alkalic basalt is porphyritic with phenocrysts of augite and sanidine and lesser amounts of olivine, magnetite, and apatite. Van Horn (1967) described the same intrusive sills as mafic monzonites.

Radiometric age determinations have been obtained from several mafic intrusions at or near Ralston Reservoir between Golden and Clear Creek. These range from 64.6 ($\pm$ 2.4) millions years ago (Ma) to 58.7 Ma (Sheridan et al., 1967; Larson and Hoblitt, 1973). All of the mafic intrusions appear to be temporally related and have similar ages at or around 64 Ma.

4.1.7 Arapahoe Formation

The Upper Cretaceous Arapahoe Formation is approximately 200 feet thick in the Golden area (Weimer, 1976), but this study indicated that only portions of the lowermost 120 feet are exposed in the map area. The Arapahoe Formation is composed primarily of sandstones and claystones that are very similar to those in the underlying Laramie Formation. This similarity between the upper Laramie and Arapahoe has resulted in confusion distinguishing these two units.

South of the map area, near Golden, the lower part of the Arapahoe Formation has been described as one of the most distinctive lithologic units in the area (Weimer, 1976). The lower 80 feet of the formation in the CSM clay pits area consist of trough cross-bedded conglomerate and conglomeratic sandstone. Most of the pebbles in the conglomerate are composed of gray to black chert, which led earlier workers to call this lower conglomerate the "flint-chert phase" (Weimer, 1976). The base of the Arapahoe, as described by Van Horn (1957), is marked by a thick, discontinuous conglomerate with pebbles composed principally of chert with some granite, gneiss, and schist pebbles. Where this basal conglomerate is absent, sandstone beds near the base of the Arapahoe commonly contain pebbles composed of ironstone (Van Horn, 1972). Within the map area, the base of the Arapahoe is only locally exposed, but where bedrock exposures are present, the base is marked by the presence of medium-grained to conglomeratic sandstones. This marker bed of the Arapahoe Formation is similar to the one described by Weimer (1976) and can be readily distinguished from upper Laramie sandstones in the field. Within the map area, these marker beds are composed of well-rounded and frosted, medium to coarse quartz sand grains that often include pebbles of chert, rock fragments, and ironstone. Bedrock exposures used in this study to define the contact between the Laramie and Arapahoe are shown on the accompanying geologic map (Plate I).

Conglomeratic sandstones in the Arapahoe Formation are composed of variable proportions of sand and gravel. Near Standley Lake (Stations 32-9, 33-1) the coarsest sandstones contain pebbles and cobbles ranging from 0.25 inch to 12 inches in lengthwise diameter. The conglomeratic sandstones also contain very large, irregularly shaped clay intraclasts as much as 2 feet in diameter and a few partially devitrified volcanic rock fragments.

Other sandstones in the Arapahoe Formation are light gray to olive gray, very fine to medium-grained, calcareous, quartzose sandstones. Iron-oxide staining is common and results in a yellowish orange to yellowish brown color on the weathered surface.

Sedimentary structures include trough and planar cross-stratification and discontinuous parting lineations (Figure 4-3). Claystones and silty claystones are dusky red to medium olive-gray and weather dark yellowish orange. They are primarily massive and blocky breaking and contain organic material. Some outcrops are wavy-laminated or fissile. A more detailed description of the petrology, contact relationships, and vertical sequence stratigraphy of the Arapahoe Formation is provided in Sections 4.2.4 and 4.3.4.

4.1.8 Laramie Formation

The Upper Cretaceous Laramie Formation conformably overlies the Fox Hills Sandstone and is approximately 600 to 800 feet thick (EG&G, 1991d; this study). Steeply dipping to slightly overturned beds in the lower part of the Laramie form a prominent north-south-trending hogback in the western portion of the map area (Figure 4-4). Open-pit kaolinitic clay mines are common along the lower Laramie hogback near Leyden Gulch, along the Denver and Rio Grande Western (D&RGW) Railroad cut, and at RFP. Coal has also been mined from the lower Laramie in the Leyden Gulch, Marshall, and Superior areas. Subsidence above the old coal mines has left much of the Marshall area pock-marked with large subsidence craters or depressions. Exposures of the lower Laramie are best along the D&RGW Railroad cut (Station 22-1), in the clay pits west of RFP (Stations 18-1, 18-2, 18-4), and at Pine Ridge.

Figure 4-3. Arapahoe Formation Outcrop (Station 33-1). Friable conglomeratic sandstones interbedded with medium-grained sandstones and claystones exposed on deeply incised wall of gully leading to Standley Lake.

Figure 4-4. Laramie Formation Outcrop (Station 48). Sandstones in the lower portion of the Laramie Formation form a hogback at Coal Creek.

The lower part of the Laramie Formation is 300 feet thick at the D&RGW Railroad cut. This is the most continuous lower Laramie exposure in the map area. The base of the Laramie is placed at the base of a thin, blocky, grayish brown, carbonaceous claystone that overlies the light olive brown Fox Hills Sandstone. Above this claystone is a series of thin- to thick-bedded, ripple-laminated to trough cross-bedded, very fine to fine-grained yellowish gray sandstone. Some thick sandstones contain channel lag deposits. Sandstones are interbedded with blocky, brownish gray claystones, grayish black carbonaceous shales, and black coals.

Fragments of oyster shells (*Ostrea*) are abundant in a sandstone bed near the base of the Laramie Formation that is locally exposed along the southeastern shore of Marshall Lake (Station 71, Figure 4-5). Fossil leaf and bark imprints are abundant, and ripple marks are prominent on the upper bounding surfaces of some sandstones.

The Laramie Formation is informally subdivided into lower and upper members. The upper Laramie is generally distinguished from the lower Laramie where the formation becomes dominantly composed of fine-grained sedimentary rocks (primarily claystones) with no thick sandstone beds. The upper part of the Laramie Formation is approximately 300 to 500 feet thick and consists primarily of olive-gray and yellowish orange claystones with large ironstone nodules. A few thin coal beds occur in the upper Laramie, but they are discontinuous (Spencer, 1961). Lenticular beds of platy laminated or friable, calcareous, fine-grained, light olive-gray sandstones are also present and occur with greater frequency at higher levels in the section. These sandstones are very similar to fine-grained sandstones in the overlying Arapahoe Formation. A more detailed description of the petrology and vertical sequence stratigraphy in the lower and upper Laramie Formation is included in Sections 4.2.2, 4.2.3, 4.3.2, and 4.3.3.

4.1.9 Fox Hills Sandstone

The Upper Cretaceous Fox Hills Sandstone conformably overlies the Pierre Shale. Exposures of the Fox Hills Sandstone are best along the D&RGW Railroad cut and at Pine Ridge (Figure 4-6). The thickness of the Fox Hills Sandstone ranges from 90 feet at the D&RGW Railroad measured section in the southern portion of section 21, T2S, R70W (this study) to 140 feet along Community Ditch in the northwestern portion of section 28, T1S, R70W (Spencer, 1961). Spencer (1961) reports thicknesses of the

Figure 4-5. Fossiliferous sandstone in the Laramie Formation (Station 71). Lag deposit of oyster shells (*Ostrea*) in a silty sandstone matrix along east shore of Marshall Lake.

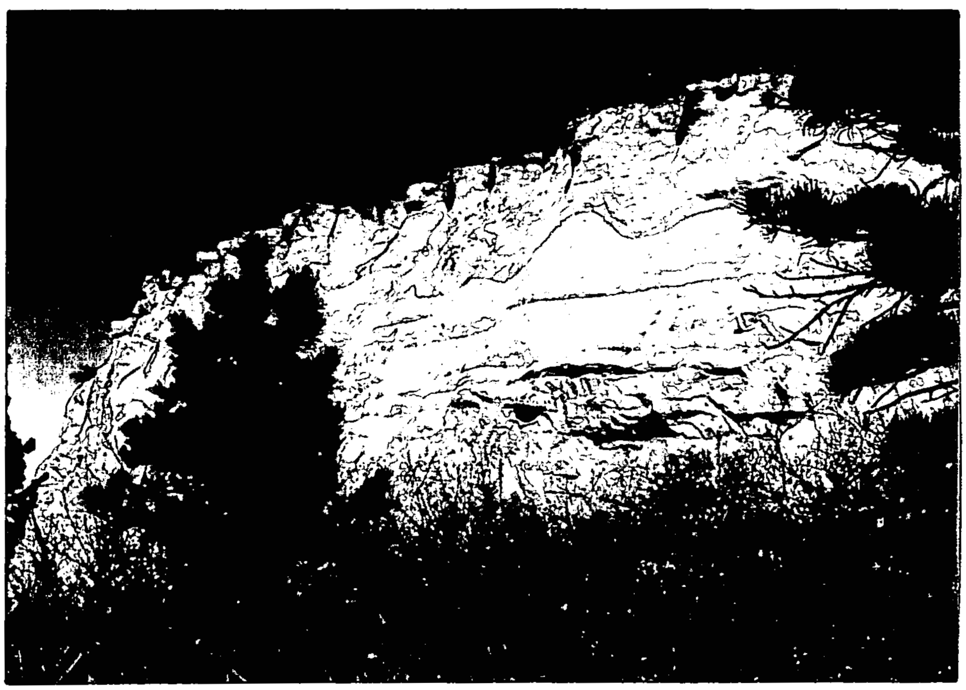


Figure 4-6. Fox Hills Sandstone Outcrop (Station 1-15). Thick-bedded to massive sandstones in the upper part of the Fox Hills at Pine Ridge are resistent to weathering and form cliffs.

Fox Hills Sandstone of 225 feet near Superior and 484 feet in a drill hole near Marshall Lake. Small variations in thickness are attributed to the gradational nature of the contact, as the Fox Hills Sandstone is interfingered with the underlying Pierre Shale. Large variations in thickness, such as in the Marshall Lake area, are attributed to faulting (Spencer, 1961). Stratigraphic sections measured at Pine Ridge, Eldorado Springs Drive, and Eggleston Reservoir have incomplete sections of the Fox Hills Sandstone and cannot be used to determine thickness.

The lower part of the Fox Hills Sandstone is composed of laminated to thin-bedded, very fine to fine-grained, light olive-gray to yellowish gray silty sandstone that weathers light olive-brown to moderate yellowish brown. It contains trace fossils and hard, iron-stained calcareous sandstone concretions that are ovoid in shape and as much as 2 feet in diameter. Oxidation occurs only on the outer rim of the concretions; the sandstone inside is unoxidized. The upper part of the Fox Hills Sandstone is composed of thick-bedded to massive, planar-laminated to cross-bedded, very fine to medium-grained, light olive-gray to yellowish gray silty sandstone that weathers white to dark yellowish orange and contains polygonal fracture patterns. This part of the formation is fairly resistant to weathering and forms ledges and cliffs (Figure 4-6).

4.1.10 Pierre Shale

The Pierre Shale is approximately 7500 feet thick and is late Cretaceous in age. The base of the formation is placed at the contact between the grayish yellow shale of the Niobrara Formation and the dark gray claystone overlying it. Exposures of the Pierre Shale are scattered and are best along roadcuts on State Highway 93 (Figure 4-7) and on the D&RGW Railroad cut (Station 158). The lower 1725 feet of the formation is composed of massive to thin-bedded, dark gray weathering dusky yellow, silty bentonitic claystone with a few very thin, moderate brown, noncalcareous siltstone beds. The upper 5225 feet of the formation is composed of thin-bedded to massive, dark gray to olive-gray, silty, bentonitic shale (Figure 4-7) with a few limestone concretions and thin, poorly cemented sandstone beds (Wells, 1967). The formation from 1725 to 2275 feet is called the Hygiene Sandstone Member, composed of thinly laminated to massive, gray to dusky yellow calcareous sandstone and sandy siltstone containing pelecypods and ammonites. The best exposures of the Hygiene Sandstone Member occur in the railroad cut near Arena Siding (Stations 171, 172).

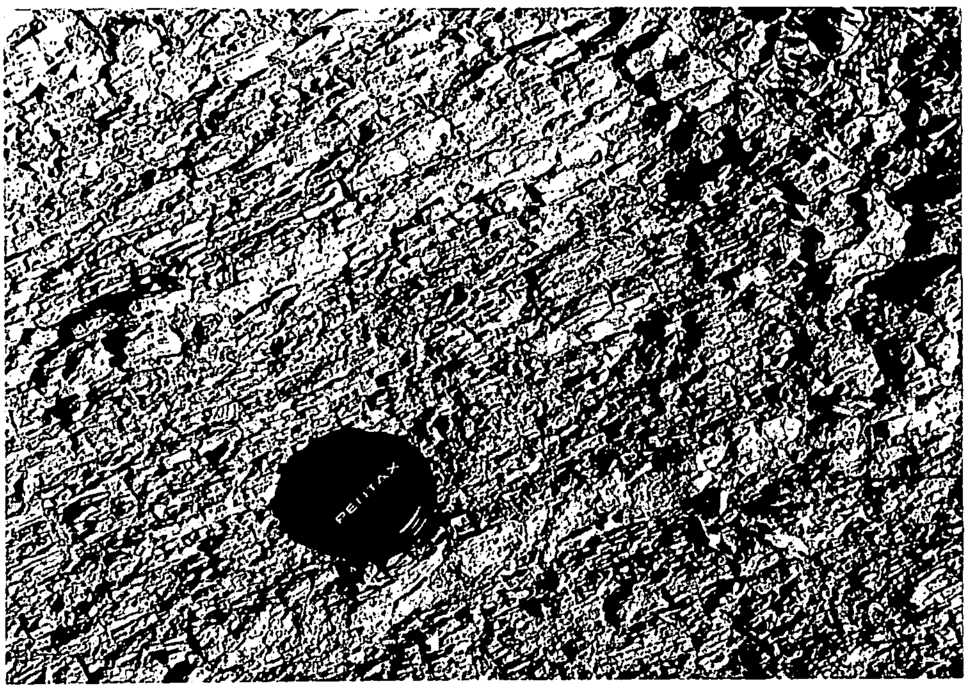


Figure 4-7. Pierre Shale Outcrop (Station 7-7). Thin-bedded olive-gray shale interbedded with poorly cemented sandstones on Highway 93 road cut south of Coal Creek.

4.1.11 Niobrara Formation

The Upper Cretaceous Niobrara Formation unconformably overlies the Benton Shale and is approximately 350 feet thick. The Fort Hayes Limestone Member, which is approximately 30 feet thick, comprises the lower part of the Niobrara Formation. Exposures of the Fort Hayes Member are best along Brook Creek near Eldorado Springs (Station 236) and in the drainages and road cuts near Fireclay in the southwest corner of the map area (Stations 180, 181). The Fort Hayes Member is composed of thick-bedded, medium gray to yellowish gray, medium crystalline limestone with foraminifera and pelecypod (*Inoceramus*) fragments and medium dark gray calcareous shale.

The Smokey Hill Shale Member, which is approximately 320 feet thick, overlies the Fort Hayes Member and comprises the upper part of the Niobrara Formation. Exposures of the Smoky Hill Shale Member are limited. The Smoky Hill Shale Member is composed primarily of light gray, olive-gray, and dusky-yellow calcareous shale, with a few thin beds of bentonite and gypsum and two light gray to grayish yellow chalky limestone beds with abundant foraminifera and mollusk fragments (Van Horn, 1967; Wells, 1967).

4.1.12 Benton Shale

The Upper Cretaceous Benton Shale conformably overlies the Dakota Group, and the contact between them is gradational. The thickness of the Benton Shale ranges from 450 to 500 feet in the map area. The Benton Shale has been subdivided into the Graneros Shale Member, the Greenhorn Limestone Member, and the Carlile Shale Member equivalents in the Ralston Reservoir area (Van Horn, 1967); however, because exposures are limited, the Benton Shale has been mapped as one unit in this report. Lithologically, the Benton Shale is composed of dark gray to black, fissile, calcareous and noncalcareous shale interbedded with very light gray to yellowish orange bentonite, dark gray wavy-laminated to cross-bedded siltstone, and yellowish gray earthy to crystalline limestone. Limestones contain fragments of oyster shells (*Ostrea*) and pelecypods (*Inoceramus*).

4.1.13 Dakota Group

The Dakota Group of early Cretaceous age unconformably overlies the Morrison Formation and varies in thickness and lithology across the western portion of the map area. Thicknesses range from 300 feet in the southwestern corner of the map area, where the Dakota Group forms the crest of the easternmost hogback (Station 175), to 350 feet between Rainbow Cut and Eldorado Springs, where the Dakota sandstone crops out on the eastern slope of the hogback (Stations 238, 239, 240). Lithologies vary from gray to tan, coarse-grained conglomeratic cross-bedded sandstone and conglomerate interbedded with varicolored shale in the lower part, which corresponds to the Lytle Formation of Waage (1955), to light gray, fine- to medium-grained, cross-bedded and ripple marked quartzose sandstone interbedded with light to dark gray siltstone and dark gray claystone in the upper part, which corresponds to the South Platte Formation of Waage (1955). In this report, the Lytle and South Platte Formations of the Dakota Group are mapped as a single unit. Sandstones in the upper part of the Dakota contain dinosaur tracks, fish scales, plant fragments and poorly preserved clasts of pelecypods (Van Horn, 1967).

4.1.14 Morrison Formation

The Morrison Formation of Jurassic age generally conformably overlies the Ralston Creek Formation, although in some locations, the basal sand of the Morrison Formation was deposited in a channel cut into the upper part of the Ralston Creek Formation. The thickness of the Morrison in the map area is approximately 250 feet, and exposures are limited. The base of the Morrison is marked by a light gray, cross-bedded, fine- to medium-grained sandstone that is 10 to 40 feet thick. Overlying this is a sequence of greenish gray, dusky red, and dark gray claystones and mudstones interbedded with light to dark gray siltstones. Thin limestone beds occur in the lower part of the Morrison Formation, and several thin beds of fine-grained sandstone occur in the upper part (Van Horn, 1967).

4.1.15 Ralston Creek Formation

The Ralston Creek Formation of Jurassic age unconformably overlies the Lykins Formation and is approximately 110 feet thick. The type section for the Ralston Creek Formation, as described by LeRoy (1946), is immediately south of the map area and north of Ralston Reservoir along Ralston Creek. Exposures are good at the type section and are generally limited elsewhere. The Ralston Creek Formation is composed of varicolored claystone, limestone, and calcareous siltstone with small scattered nodules and thin layers of red, white, and gray chert. Claystones are silty and generally calcareous and vary in color from grayish red or orange to pale green or light gray. Limestones are light gray to grayish orange and have a rough, weathered surface. Siltstones occur primarily in the lower part of the formation and are light gray to grayish red in color (Van Horn, 1967).

4.1.16 Lykins Formation

The Lykins Formation unconformably overlies the Lyons Sandstone and is approximately 450 feet thick. Permian *Dascyclad* algal fragments give a lower age limit to the Lykins Formation; however, the upper age limit, although probably Triassic, is not known (Van Horn, 1967). Exposures are limited. The Lykins consists of grayish red, irregularly bedded, calcareous mudstone with a few thin beds of light gray, finely crystalline, slightly dolomitic limestone. LeRoy (1946) subdivided the Lykins into five members, from oldest to youngest: the Harriman Shale, Falcon Limestone, Bergen Shale, Glennon Limestone, and Strain Shale. For this report and map, the Lykins Formation is mapped as a single unit.

4.1.17 Lyons Sandstone

The Permian Lyons Sandstone conformably overlies the Fountain Formation and is approximately 150 feet thick. Best exposures occur near the crest of the hogback north of Ralston Buttes in the southwestern corner of the map area. The Lyons Sandstone is composed of light gray to grayish orange and pinkish gray, fine- to medium-grained, cross-bedded, quartzose sandstone (Van Horn, 1967). Claystone, siltstone, and conglomerate interbeds occur in the upper 50 feet of the formation.

4.1.18 Fountain Formation

The Fountain Formation is approximately 800 feet thick and forms the crest of the hogback at Ralston Buttes in the southwestern corner of the map area. The Fountain unconformably overlies Precambrian metamorphic rocks and is middle Pennsylvanian to early Permian age. It is composed of pink to reddish orange, coarse-grained, conglomeratic, cross-bedded arkosic sandstone and conglomerate interbedded with indurated, dark reddish brown, micaceous silty mudstones (Van Horn, 1967). Pebbles and cobbles are composed primarily of quartz and pink feldspar and are up to 7 inches in diameter. The upper 30 feet of the Fountain Formation contains a few lenticular beds of pinkish gray, fine-grained, cross-bedded, quartzose sandstone that resemble beds in the overlying Lyons Sandstone.

4.1.19 Precambrian Rocks

Precambrian rocks crop out in the southwestern corner of the map area and extend to the west, where they form the core of the Front Range Uplift. Rocks in the map area consist of microcline gneiss with varying amounts of amphibolite, hornblende gneiss, layered calc-silicate gneiss, biotite gneiss, and quartz gneiss (Sheridan et al., 1967). The microcline gneiss is composed of fine- to medium-grained microcline, quartz, plagioclase, and biotite. It ranges in color from light orange-pink and pinkish gray to dark gray and is characterized by a granitic appearance and a conspicuous foliation. Discontinuous, dark-colored layers of amphibolite, hornblende gneiss, and biotite gneiss and light-colored layers of calc-silicate gneiss and quartz gneiss are complexly interlayered with the microcline gneiss.

4.2 SEDIMENTARY PETROLOGY OF UPPER CRETACEOUS SANDSTONES

Detailed descriptions of sandstones in the Upper Cretaceous Fox Hills Sandstone, Laramie Formation, and Arapahoe Formation are presented below. Sandstones of these units may resemble each other in the field, but they can be distinguished from each other on the basis of textural and compositional characteristics. Petrography has been useful in assigning rocks to the appropriate formation. The correct identification of these units is critical to stratigraphic and structural interpretations in this area.

Ninety samples from outcrops of Upper Cretaceous sandstones plus 23 samples from RFP drill core were examined with a binocular microscope and described in detail. The individual sample descriptions are presented in Appendix A. Forty-two thin sections (19 from outcrop samples and 23 from RFP drill core) were examined to help identify textural relationships, rock fragment types, and accessory minerals. Textures and compositions of Fox Hills, Laramie, and Arapahoe sandstones, based on microscopic examination of rock samples, are summarized in Table 4-1 and described in detail below. Sieve analyses were performed on 20 rock samples in order to quantify grain-size distribution of Upper Cretaceous sandstones. Hydrometer tests were also conducted to determine percentages of silt and clay. Raw data and cumulative curves showing grain-size distribution are presented in Appendix C. Characteristics that can be used to distinguish Fox Hills sandstones from Laramie sandstones and Laramie sandstones from Arapahoe sandstones are summarized in Table 4-2.

Textural and compositional characteristics of the Fox Hills, Laramie, and Arapahoe sandstones are used to make preliminary interpretations of the provenance or source-area lithology, method of transport, and depositional environment of the sandstones (Folk, 1974). Grain size depends largely on the energy of the depositional environment and the size of the available particles. Sorting is a function of the size range of the material supplied, the type of deposition (rapid dumping or current reworking), current characteristics (current strength and persistence), and time. Roundness is a function of the internal properties of the source rock, the processes operating in the environment of deposition, and time. Rounded grains, especially quartz grains, may have frosted or dull surfaces. This may be caused by chemical etching, incipient quartz overgrowths, or aeolian abrasion, where the frosting is due to minute percussion marks caused by impact with other sand grains.

Table 4-1 - Texture and Composition of Upper Cretaceous Sandstones

	Fox Hills Sandstone	Lower Laramie Formation	Upper Laramie Formation		Araphoe Formation			
			Fine Sandstone	Medium Sandstone	Fine Sandstone	Medium Sandstone	Conglomeratic Sandstone	Med-Coarse Frosted Sandstone
Number of Samples	18	28	4	6	6	8	12	8
Number of Thin Sections	2	3	10	2	4	4	13	3
Texture								
Modal grain size	Fine grained	Fine grained	Fine grained	Medium grained	Fine grained	Medium grained	Coarse grained	Medium grained
Sorting	Well	Moderate	Well	Moderate	Well	Moderate	Poor	Moderate
Roundness	Subangular	Subangular-Subrounded	Subangular	Subangular-Subrounded	Subangular	Subangular-Subrounded	Subangular-Well-rounded	Well-rounded
Frosting	Unfrosted	Unfrosted	Unfrosted	Unfrosted-Frosted	Unfrosted	Unfrosted-Frosted	Frosted	Frosted
Average Porosity	20%	10%	10%	15%	10%	20%	10%	20%
Matrix (estimated)	13% silt, 8% clay	10% silt, 4% clay	7% silt, 8% clay	5% silt, 3% clay	10% silt, 5% clay	6% silt, 2% clay	4% silt, 5% clay	3% silt, 2% clay
Cement	Rare	Silica	Calcite, siderite, clay	Calcite, siderite	Calcite, pyrite	Calcite	Calcite, siderite, clay	Calcite
Average Composition								
Quartz	85%	96%	93%	93%	85%	90%	80%	97%
Rock fragments	7%	3%	5%	5%	12%	8%	18%	2%
Feldspar	2%	1%	1%	2%	3%	2%	2%	1%
Other	Biotite, glauconite	Claystone rip-up clast, carbonaceous fragments	Carbonaceous fragments, biotite	Carbonaceous fragments, chert	Chert	Chert, biotite	Chert, ironstone pebbles, volcanic rock fragments	Chert

Table 4-2 - Distinguishing Characteristics of Upper Cretaceous Sandstones

Fox Hills Sandstone	Lower Laramie Formation
Thick bedded to massive	Thin to thick bedded
Rounded, concave weathering	Blocky weathering
Usually friable	Usually non-friable
Few Plant imprints	Abundant plant imprints
<95% quartz	>95% quartz
>5% rock fragments	<5% rock fragments

Upper Laramie Formation	Arapahoe Formation
Trace rounded, frosted quartz grains	Predominantly well-rounded and frosted quartz grains
Few rock fragments (<6%)	Ironstone and chert pebbles plus volcanic fragments
Few coarse sandstones	Many coarse sandstones

According to Folk (1974), as sediments are subjected to a greater input of mechanical energy through the abrasive and sorting action of waves or currents, they pass sequentially through four stages of textural maturity: immature, submature, mature, and supermature. Immature sediments have a matrix composed of more than 5 percent terrigenous clay, and the sand grains are usually angular and poorly sorted. Submature sediments have a matrix composed of less than 5 percent terrigenous clay, and the sand grains are subangular to subrounded but still poorly sorted. Mature sediments contain little or no clay. Sand grains are subangular to subrounded and are moderately to well sorted. Supermature sediments contain no clay. Sand grains are subrounded to well rounded and are well sorted. When determining textural maturity, clay content is most important, sorting is next most important, and roundness is least important.

Clay may be deposited mechanically, form by weathering of constituent grains, or occur as authigenic pore filling. Clay coats are typically formed by the accumulation of colloidal material onto sand grains (Galloway, 1979) but may also form by authigenesis. The accumulation of clay onto sand grains reduces the primary porosity. Cementation, chemical replacement, and recrystallization are other means of porosity reduction.

Pettijohn (1957) discussed the importance of heavy mineral studies in determining provenance and noted their usefulness in pinpointing the timing of major tectonic events. An influx of minerals not recognized in sediments deposited before a tectonic event or a new heavy mineral zone could mark the initiation of a tectonic event such as the Laramide orogeny. Studying the varietal characters of one mineral species is useful in delineating heavy mineral zones exposed by denudation after a tectonic event. Making varietal counts on one or two heavy mineral species within the same size range is also useful in determination of provenance or source area lithology. A few heavy minerals were tentatively identified in hand samples and thin sections using a binocular or petrographic microscope. However, no systematic heavy mineral study was conducted as a part of this investigation.

4.2.1 Fox Hills Sandstone

Most of the samples collected for petrographic analysis are from the upper part of the Fox Hills Sandstone, briefly described in Section 4.1.9 as a thick-bedded to massive, planar-laminated to cross-bedded, light gray to yellowish gray, silty sandstone.

Eighteen outcrop samples and two thin sections were described in detail and are summarized in the section below. Sieve analyses and hydrometer tests were conducted on five outcrop samples.

4.2.1.1 Texture

Description

The Fox Hills Sandstone is a very fine to medium-grained (mode is fine-grained), well-sorted, angular to subrounded, immature to submature sandstone with a matrix composed of 5 to 20 percent silt and 2 to 15 percent clay (Figure 4-8 and Table 4-1). Figure 4-9 is a cumulative curve representative of sandstones in the Fox Hills.

Median grain size, read from the cumulative curve, is fine-grained sand. The slope of the cumulative curve is fairly steep, which indicates that Fox Hills sandstones are well sorted. All samples are friable because of their high porosity and low cement content. Porosity ranges from 5 to 25 percent and averages approximately 20 percent. Calcite and siderite cement occur in scattered nodules.

Interpretation

The material supplied during deposition of the Fox Hills was fine grained and includes silt- and clay-sized material, which may indicate that initial deposition was rapid and that little or no winnowing occurred after deposition (Folk, 1974). The presence of both angular and subrounded grains within the same size grade suggests that the grains come from multiple sources originally or that sediments from two different environments were mixed. The angular grains suggest that little or no rounding occurred in the last environment of deposition and indicate a low-energy environment. Sand grains in the Fox Hills Sandstone have clay coats, which are rinds of clay oriented parallel to the grain surface, that reduce porosity. Calcite and siderite cements are restricted to concretions in the lower part of the formation. The Fox Hills sandstones range from immature to submature, as evidenced by the amount of clay matrix and the angularity of sand grains, indicating rapid deposition and/or deposition in a low-energy environment.

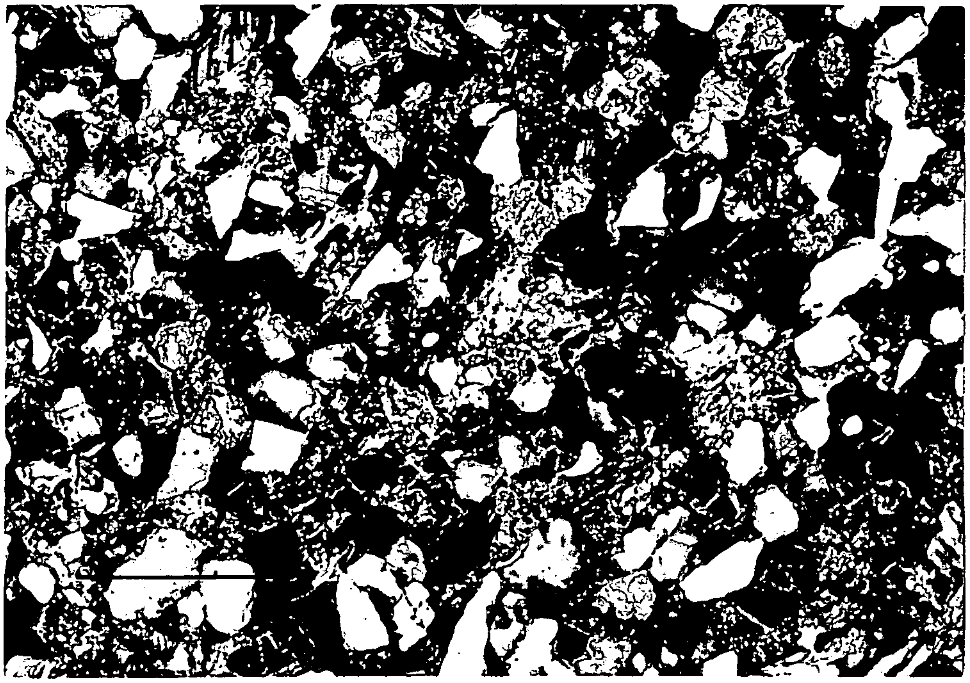


Figure 4-8(a). Photomicrograph Showing Texture of Fox Hills sandstones. (MV4-N, Station 15). Fox Hills sandstones are typically fine grained, well sorted, subangular, and texturally immature, with some rock fragments and a trace biotite. Crossed Nicols. Magnification equals 50X. Scale bar is 400 micrometers.

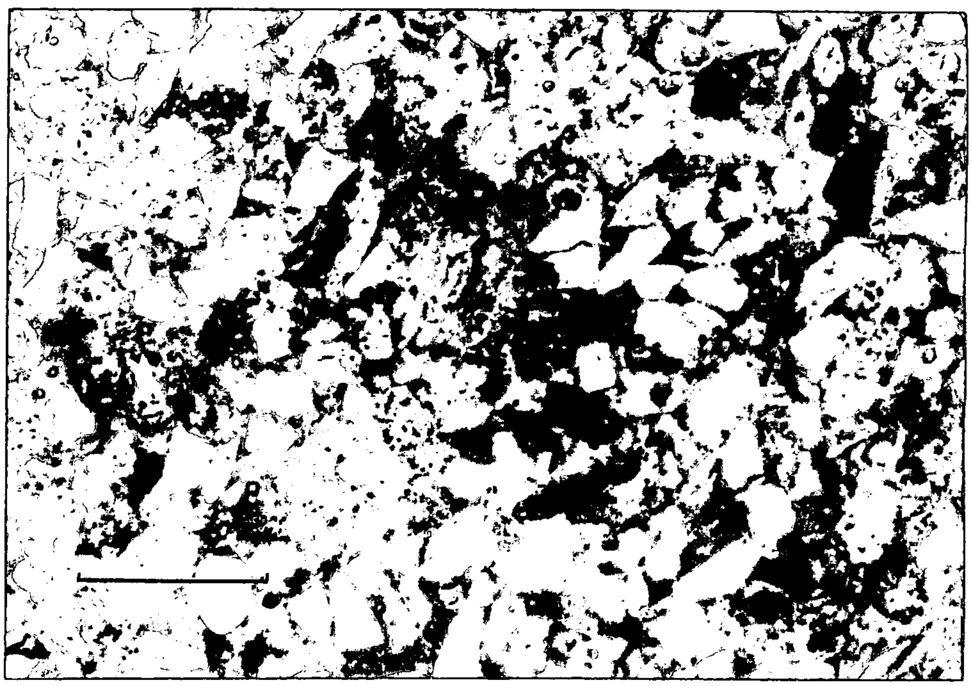


Figure 4-8(b). Same as above (MV4-N, Station 15). Plane polarized light. Magnification equals 50X. Scale bar is 400 micrometers.

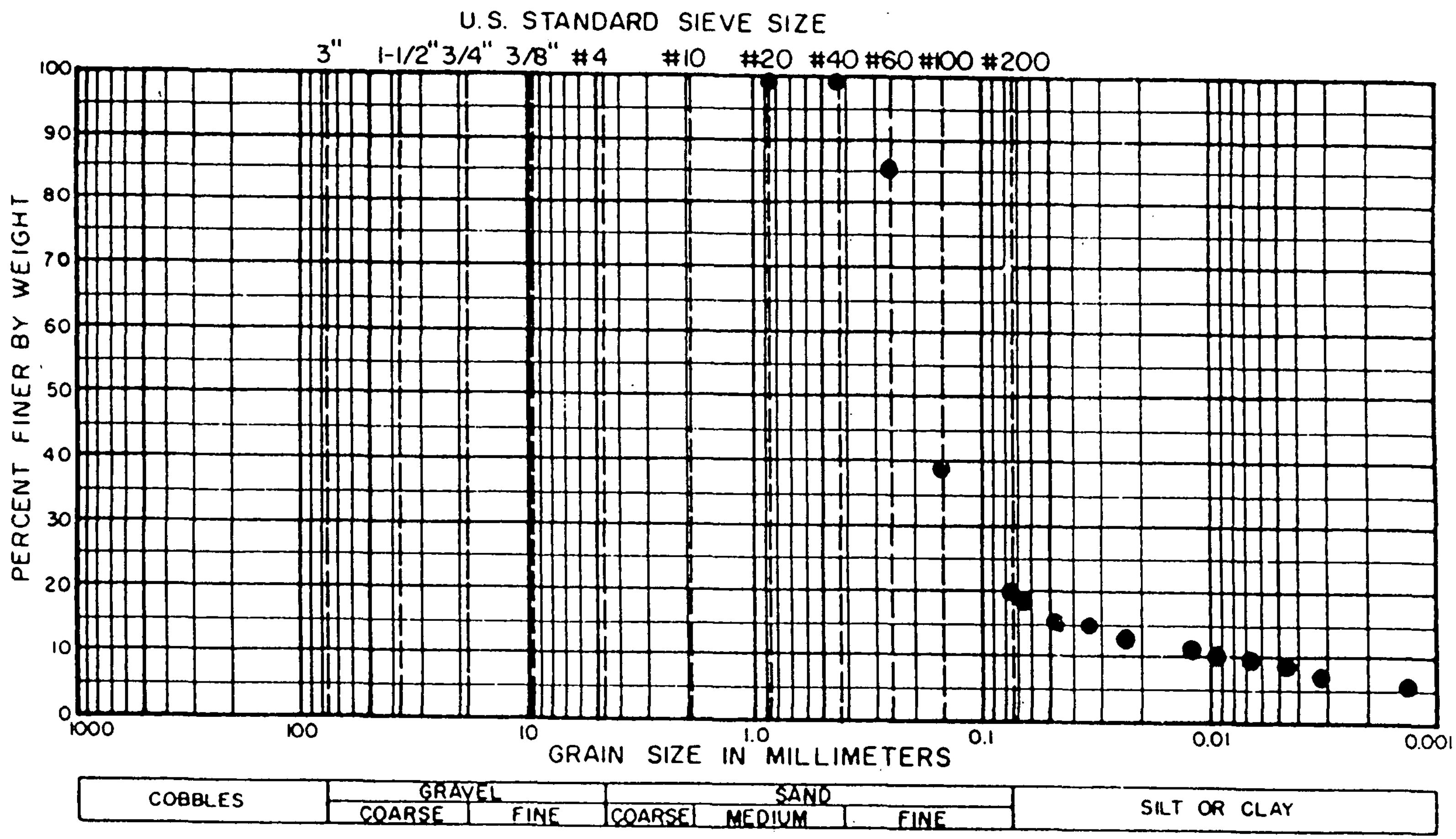


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Figure 4-9 Size Frequency Distribution of Fox Hills Sandstones.
Representative sample is from Pine Ridge near Marshall (KT6-N).

4.2.1.2 Composition

Description

The Fox Hills Sandstone varies from 80 to 90 percent quartz, 3 to 10 percent rock fragments, 0 to 10 percent carbonaceous fragments, 1 to 5 percent chert, trace to 3 percent biotite, trace to 2 percent glauconite and feldspar, trace to 1 percent muscovite, and traces of tourmaline, garnet, and zircon (Figure 4-8). Most of the quartz grains are common plutonic quartz with subequant, xenomorphic grains that display straight to slightly undulose extinction, some vacuoles, and a few microlites. A few grains are recrystallized metamorphic quartz with a mosaic of equant interlocking grains that have straight to slightly undulose extinction and some vacuoles. Other grains are stretched metamorphic quartz with a mosaic of lenticular grains with crenulated or granulated boundaries that have strongly undulose extinction, some vacuoles, and a few microlites.

Metamorphic and sedimentary rock fragments are the most common types of lithic fragments and include quartzites, siltstones, and claystones. Some of the rock fragments are altered to chlorite or to iron oxides such as limonite. Carbonaceous fragments are rare except in the Eldorado Springs Drive outcrop (Station 10-1). Reworked detrital chert composed of microcrystalline quartz is generally black, whereas chalcedonic quartz is typically white. Biotite, glauconite, and microcline and plagioclase feldspars are rare. Heavy minerals are present, but their identification is difficult in hand samples. Tentative identifications include rounded and euhedral zircon, tourmaline, and garnet.

The Fox Hills Sandstone is classified as a sublitharenite (Folk, 1974), based on the average abundance of essential constituents, which include quartz, feldspar plus granite and gneiss fragments, and all other rock fragments (including chert), recalculated to 100 percent. Individual rock descriptions and their assignments into Folk's (1974) sandstone classification are presented in Appendix A. Quartz is the most abundant constituent at 88 percent of the rock volume. Rock fragments, which include sedimentary and metamorphic fragments plus chert, are next most abundant at 10 percent of the rock volume. Feldspar makes up only 2 percent of the rock volume.

Interpretation

Provenance controls the mineral composition of sandstone (Folk, 1974). Because sedimentary and metamorphic rock fragments are mechanically weak, their presence in the Fox Hills Sandstone indicates a relatively local supracrustal provenance. The high quartz content and restrictive lithic fragment content, coupled with a lack of feldspar, suggests that the Fox Hills Sandstone originated from the denudation of a sedimentary terrane.

Color of individual mineral grains in sandstone is an environmental indicator (Folk, 1974). Chert's black color is due to inclusions of organic material. Biotite varies from brown to yellow in color, and the yellow color indicates that iron has been leached during weathering. Glauconite is green in color and is indicative of deposition in a marine environment under mildly oxidizing to mildly reducing conditions.

4.2.2 Lower Laramie Formation Sandstones

Most of the samples collected for petrographic analysis are from the lower part of the Laramie Formation. Sandstone beds in the lower Laramie are more laterally extensive and more resistant to weathering than sandstone beds in the upper Laramie and form better outcrop exposure. The lower Laramie is characterized by thin- to thick-bedded, ripple-laminated to trough cross-bedded, yellowish gray sandstone with abundant plant remains. Twenty-eight lower Laramie sandstone outcrop samples and three thin sections were described in detail. Sieve analyses and hydrometer tests were conducted on four outcrop samples.

4.2.2.1 Texture

Description

Sandstones in the lower part of the Laramie are very fine to medium grained (mode is fine), moderately sorted, subangular to subrounded, immature to submature with a matrix composed of 5 to 15 percent silt and 0 to 8 percent clay (Figure 4-10 and Table 4-1). Figure 4-11 is a cumulative curve representative of lower Laramie sandstones. The cumulative curve is flatter than the curve for the Fox Hills (Figure 4-9), which

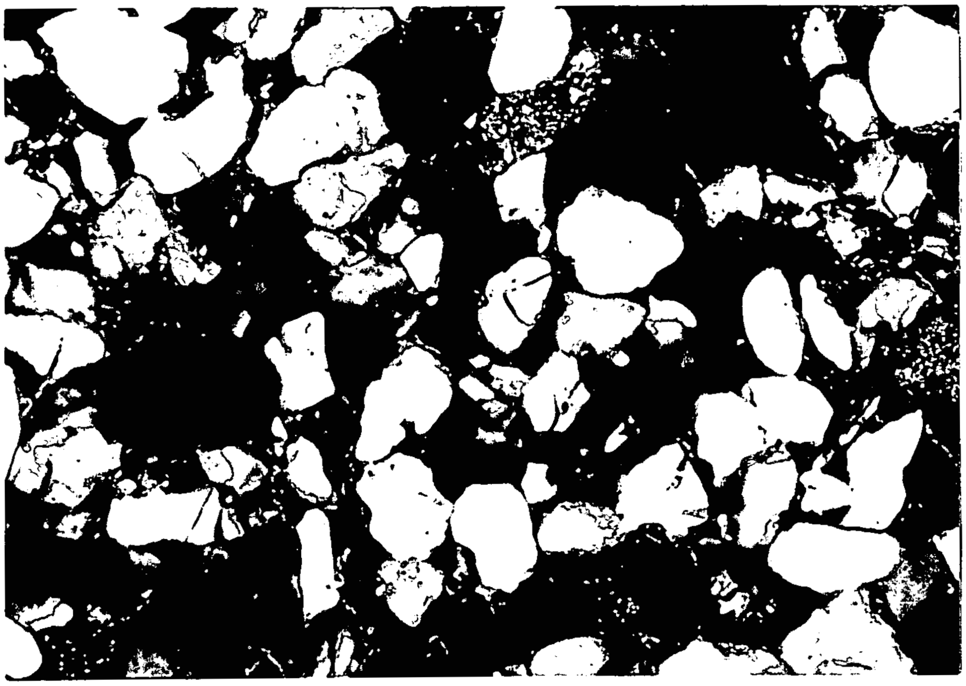

Figure 4-10(a). Photomicrograph Showing Texture of Lower Laramie Sandstones (KT13-W, Station 20-1). Laramie sandstones are typically fine grained, moderately sorted, subangular to subrounded, texturally immature to submature, and quartz rich, with a trace carbonaceous fragments. Crossed Nicols. Magnification equals 50X. Scale bar is 400 micrometers.

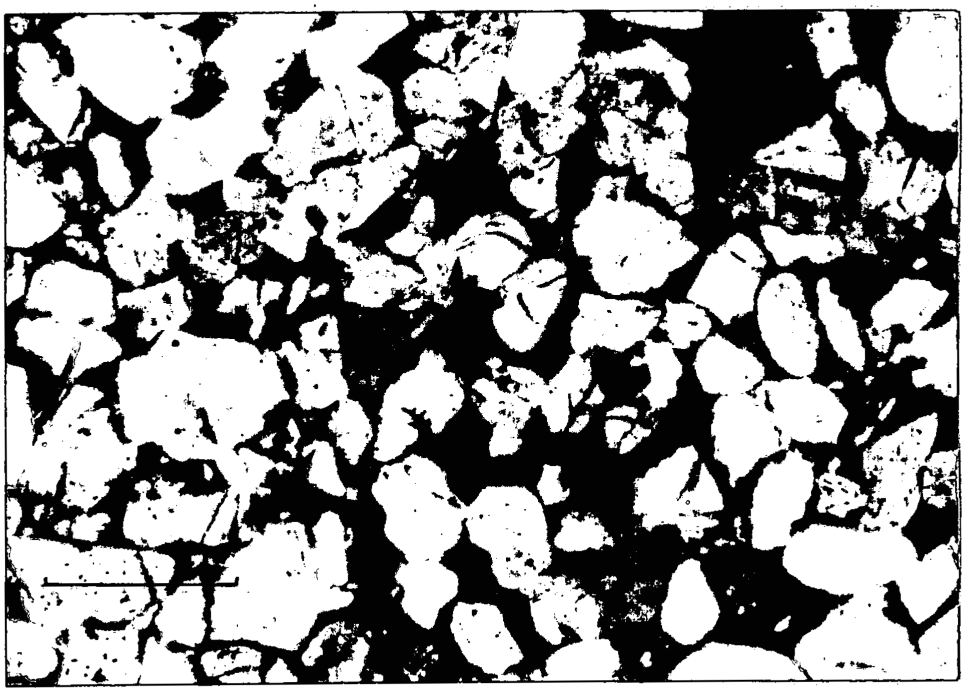

Figure 4-10(b). Same as above (KT13-W, Station 20-1). Plane polarized light. Magnification equals 50X. Scale bar is 400 micrometers.

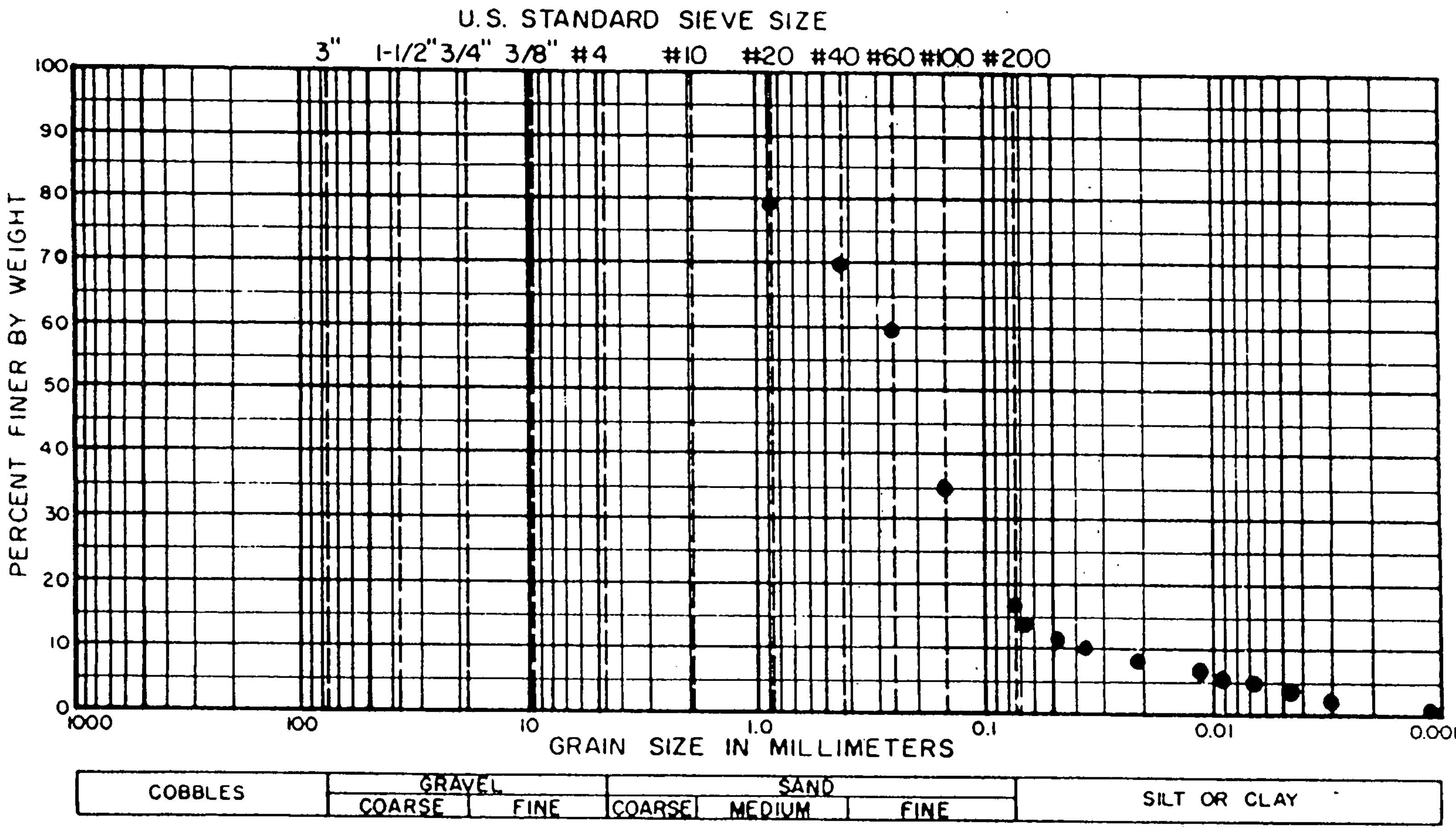

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Figure 4-11 Size Frequency Distribution of Lower Laramie Formation Sandstones. Representative sample is from the Denver and Rio Grande Western railroad cut (KT32-W).

indicates that the sandstone is not as well sorted. Median grain size read from the cumulative curve is also slightly larger, although it is still a fine-grained sand. Samples vary from indurated to moderately friable, depending on the amount of porosity and pore-filling cement. Porosity ranges from 0 to 20 percent and averages approximately 10 percent. Silica cement content also ranges from 0 to 20 percent. Silica cement occurs as microquartz and partially to completely occludes intergranular and fracture porosity. Siderite cement occurs in small, scattered nodules but tends to occlude some intergranular porosity in the surrounding sandstone.

Interpretation

Because silt and clay are fairly common, deposition may have been rapid with little reworking occurring after deposition (Folk, 1974). The presence of both subangular and subrounded grains within the same size grade suggests that the grains were from multiple sources or that sediments from two different environments were mixed. The existence of subangular grains may indicate that little rounding took place in the most recent environment of deposition. Lower Laramie sandstones are texturally immature, as evidenced by the amount of clay matrix and the angularity of sand grains. This is indicative of rapid deposition or deposition in a low-energy environment.

Sand grains in the lower Laramie are coated with rinds of clay oriented parallel to the grain surface (Figure 4-10). As in the Fox Hills Sandstone, clay coats form as colloidal material on sand grains (Galloway, 1979) or by authigenesis. It is possible that pore-filling clay is a pseudo-matrix composed of squashed rock fragments rather than mechanically deposited material. Clay accumulation appears to reduce porosity in the lower Laramie to a lesser extent than in the Fox Hills Sandstone, as determined from visual inspection of thin sections (Figure 4-8). Cementation by silica, and to a lesser extent siderite, accounts for most of the porosity reduction in the lower Laramie Formation.

4.2.2.2 Composition

Description

Lower Laramie Formation sandstones vary in composition from 92 to 99 percent quartz, 1 to 5 percent rock fragments, trace to 3 percent feldspar, 0 to 3 percent chert and carbonaceous fragments, trace to 1 percent muscovite and biotite, and traces of magnetite, tourmaline, and zircon (Figure 4-10). Virtually all of the quartz grains are common plutonic quartz with subequant, xenomorphic grains that exhibit straight to slightly undulose extinction, some vacuoles, and a few microlites. The composition of local lag deposits, discussed in more detail in Section 4.3.2, varies from 67 to 80 percent quartz, 20 to 30 percent rock fragments, 0 to 2 percent chert, and 1 percent feldspar. The difference between typical lower Laramie Formation sandstones and sandstone lag deposits is due primarily to the abundance of siltstone and claystone rip-up clasts (classified as rock fragments) and carbonaceous fragments found in the lag deposits.

Metamorphic and sedimentary rock fragments are common and include quartzites, siltstone, and claystone. Fossil leaf and stem imprints are common, but there are few carbonaceous fragments. Most of the organic material has been oxidized, and siderite and various iron oxides produced during oxidation have converted to limonite and goethite. Reworked detrital chert is composed of microcrystalline quartz and is brown, gray, or black in color. Feldspar, muscovite, and biotite are rare. Tentative identification of heavy minerals includes magnetite, zircon, and tourmaline.

Based on the average abundance of essential constituents, most of the lower Laramie sandstones are quartzarenites (Folk, 1974). Individual rock descriptions and their assignment into Folk's (1974) sandstone classification are presented in Appendix A. Quartz is the most abundant constituent at 96 percent of the rock volume. Rock fragments, including sedimentary and metamorphic fragments plus chert, are next most abundant at 3 percent of the rock volume. Feldspar makes up the final 1 percent. A few samples have more rock fragments and less quartz, resulting in borderline sublitharenites (Folk, 1974). Lag deposits with 67 to 80 percent quartz and 20 to 30 percent rock fragments are classified as sublitharenites and litharenites (Folk, 1974).

Interpretation

Mineral composition of lower Laramie sandstones is controlled by provenance or source-area lithology (Folk, 1974). Quartzarenites and borderline sublitharenites are mature and require compositionally mature source rocks. Typical lower Laramie sandstones may have originated from multiple sources of pre-existing, fairly mature sandstone. Sandstone lag deposits contain siltstone and claystone fragments. Because these rock types tend to abrade over time, their presence indicates that transport time was brief. Claystone fragments often show smearing along the edges of the clasts, suggesting that the claystone was not fully lithified when it was entrained by the supporting sandstone. Sandstone lag deposits, although compositionally mature, are texturally immature and may represent local erosion and deposition within a single channel.

4.2.3 Upper Laramie Formation Sandstones

The upper Laramie Formation is composed primarily of olive-gray and yellowish orange claystones with beds of fine- to medium-grained, platy-laminated to ripple-laminated, friable to indurated, calcareous, light olive-gray sandstone. Sandstones can be further subdivided on the basis of grain size into fine-grained and medium-grained subunits of the upper Laramie Formation. Ten outcrop samples were described in detail (four from fine-grained sandstones and six from medium-grained sandstones). Twelve thin sections (ten from fine-grained sandstones and two from medium-grained sandstones) were also described. Nine of the ten thin sections of fine-grained sandstones are from RFP drill core. Sieve analyses and hydrometer tests were conducted on six outcrop samples.

4.2.3.1 Texture

Description

Fine-grained sandstones of the upper Laramie Formation are very fine to medium grained (mode is fine), well sorted, subangular, and texturally immature with a matrix of 3 to 12 percent silt and 3 to 13 percent clay (Figure 4-12 and Table 4-1). Figure 4-13 is a cumulative curve typical of fine-grained upper Laramie Formation sandstones. Median grain size read from the cumulative curve is very fine grained sand. The slope of the cumulative curve is fairly steep, which indicates that these very fine grained sandstones are well sorted. Porosity ranges from 5 to 20 percent and averages approximately 10 percent. Calcite and siderite occur as pore-filling cement.

Although fine-grained sandstones predominate, the upper Laramie Formation also has locally occurring medium-grained, moderately sorted, subangular to subrounded,

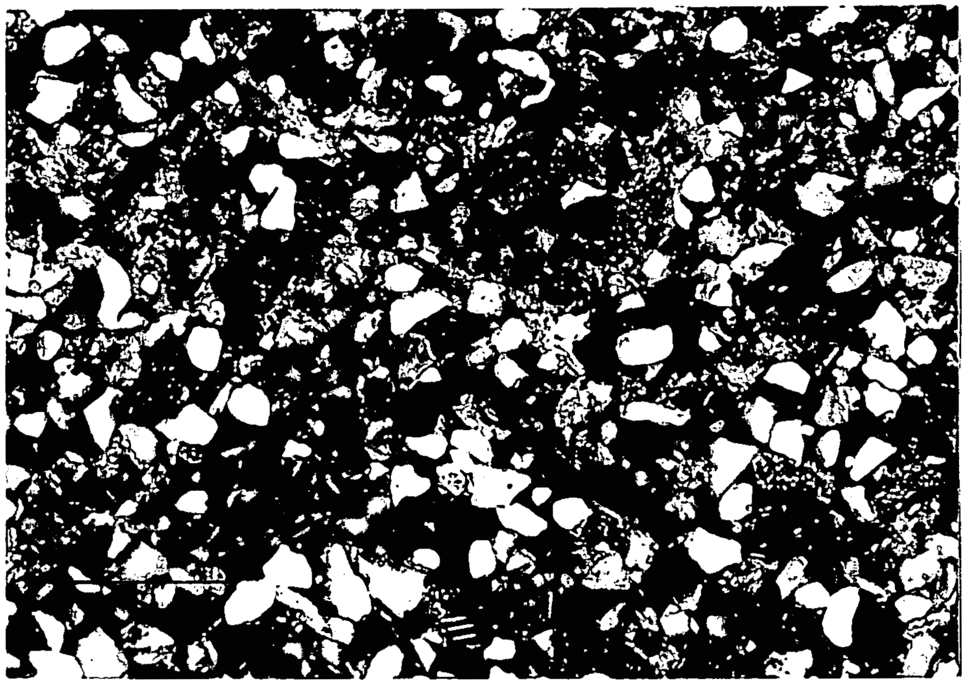

Figure 4-12(a). Photomicrograph Showing Texture of Upper Laramie Fine-Grained Sandstones (KT33-N, Station 14-5). Sandstones are typically well sorted, subangular, and texturally immature, with some carbonaceous fragments. Crossed Nicols. Magnification equals 50X. Scale bar is 400 micrometers.

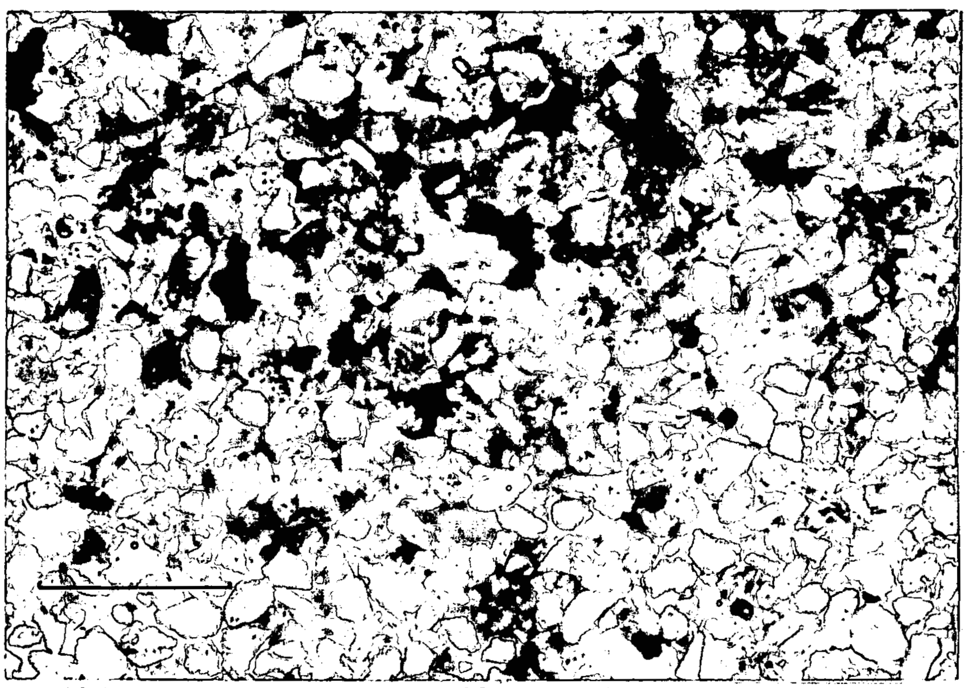

Figure 4-12(b). Same as above (KT33-N, Station 14-5). Plane polarized light. Magnification equals 50X. Scale bar is 400 micrometers.

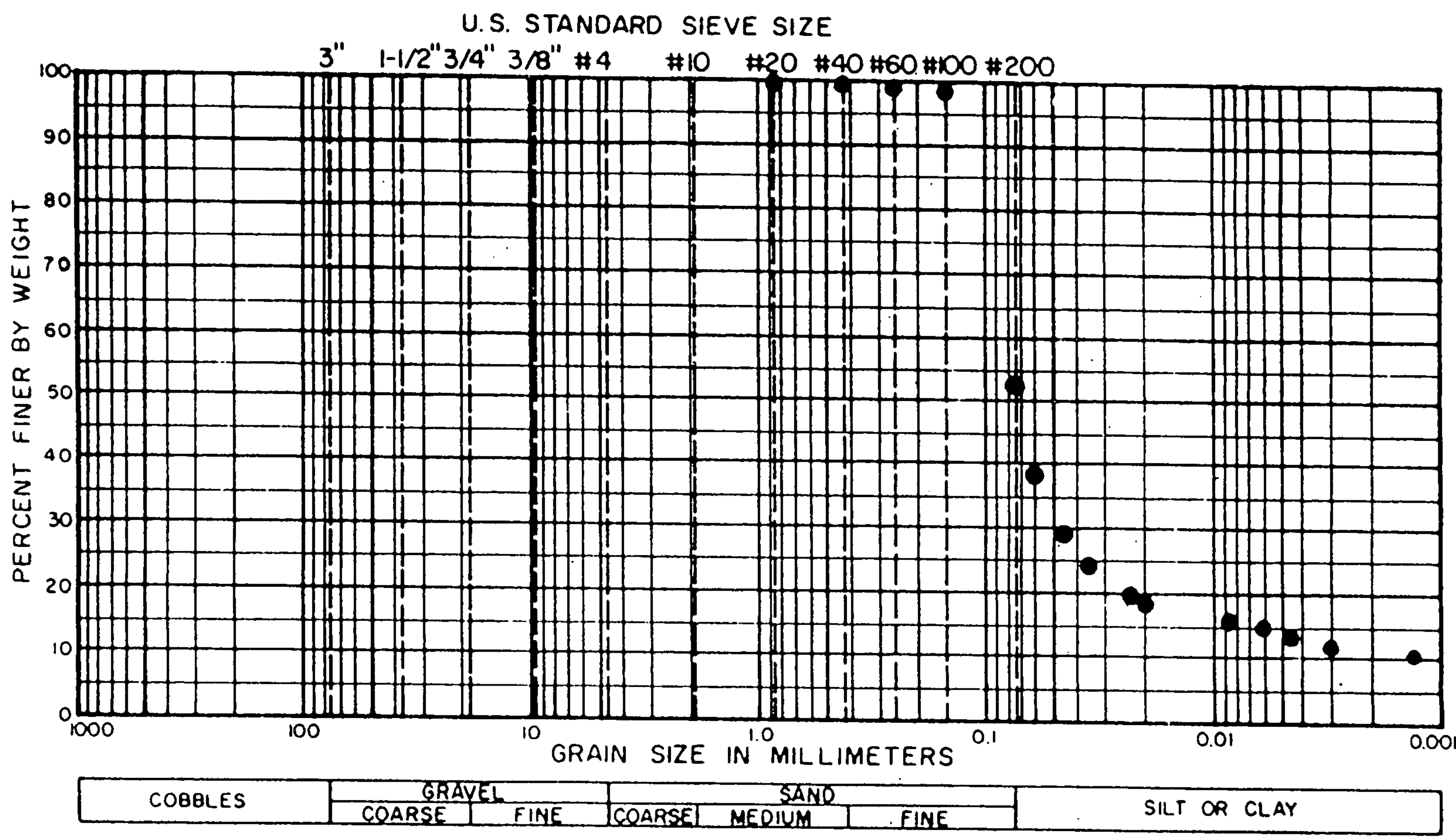

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Figure 4-13 Size Frequency Distribution of Upper Laramie Fine-Grained Sandstones. Representative sample is from a roadcut on State Highway 36 (KT33-N, Station 14-5).

submature sandstones with a matrix of 5 percent silt and 3 percent clay (Figure 4-14 and Table 4-1). Subrounded quartz grains rarely have frosted surfaces. Grain-size distribution of a typical medium-grained upper Laramie Formation sandstone is shown in Figure 4-15. The slope of the cumulative curve is much flatter than the one shown in Figure 4-13 because the sandstones are not as well sorted. Median size read from the cumulative curve is medium-grained sand. Porosity ranges from 5 to 25 percent and averages 15 percent. Calcite and siderite occur as pore-filling cement.

Interpretation

The upper Laramie is composed of predominantly fine-grained, subangular, immature sandstones. The fine grain size indicates that deposition may have occurred in a low-energy depositional environment (Folk, 1974). Because silt and clay are fairly common, deposition was probably rapid and there was little reworking after deposition. Periods of more rapid deposition may be indicated by local occurrences of medium-grained sandstones. The presence of subangular and rounded grains within the same size grade in these sandstones suggests that the grains were from multiple sources or that sediments from two different environments were mixed. The inclusion of subangular grains within the upper interval may mean that little rounding took place in the most recent environment of deposition. The sandstones are submature, which indicates that they may have been deposited fairly rapidly or in a moderate-energy environment.

The fine-grained upper Laramie sandstone's reduced porosity is due to interstitial clay. Cementation by calcite, and to a lesser extent siderite, accounts for most of the porosity reduction in medium-grained upper Laramie sandstones (Figure 4-16). Calcite cement partially to completely occludes intergranular porosity. Siderite cement occurs less often. Iron oxide and hydroxide (limonite and goethite) cements occur in large, scattered nodules and thick siltstone beds referred to as ironstones. Limonite and goethite often form by diagenetic alteration of siderite (Berry and Mason, 1959).

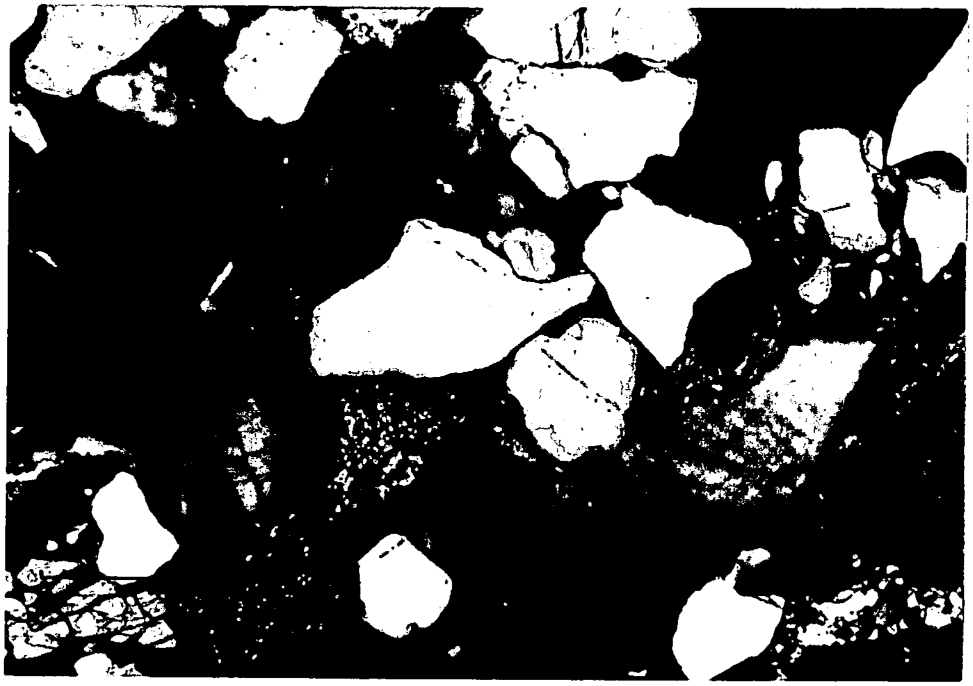

Figure 4-14(a). Photomicrograph Showing Texture of Upper Laramie Medium-Grained Sandstones (KT60-N, Station 28-7). Sandstones are typically moderately sorted, subangular to rounded, and texturally submature, with carbonaceous fragments and chert. Crossed Nicols. Magnification equals 50X. Scale bar is 400 micrometers.

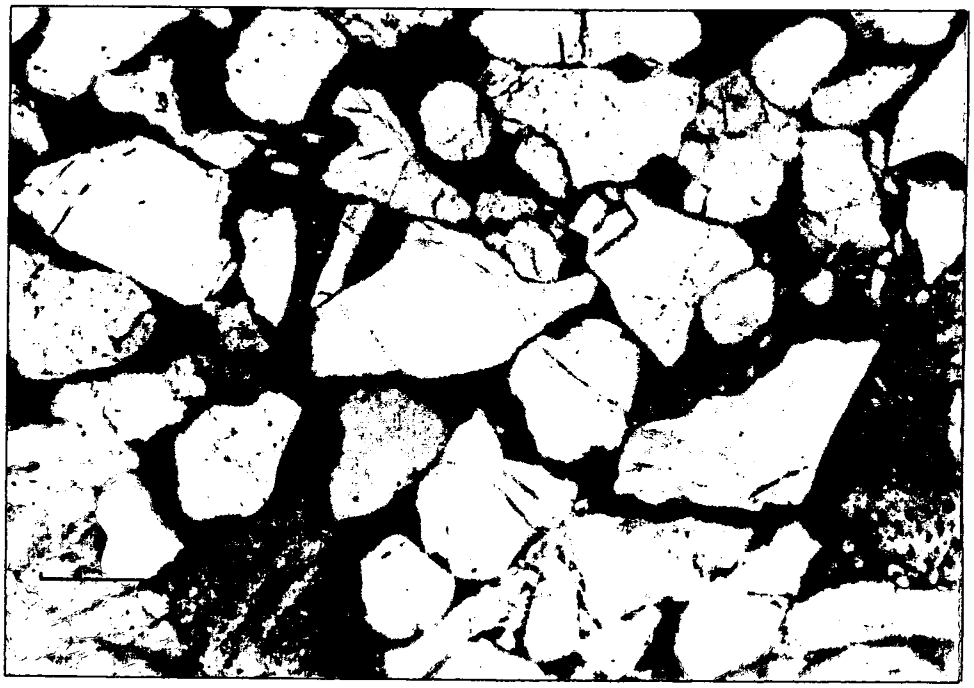

Figure 4-14(b). Same as above (KT60-N, Station 28-7). Plane polarized light. Magnification equals 50X. Scale bar is 400 micrometers.

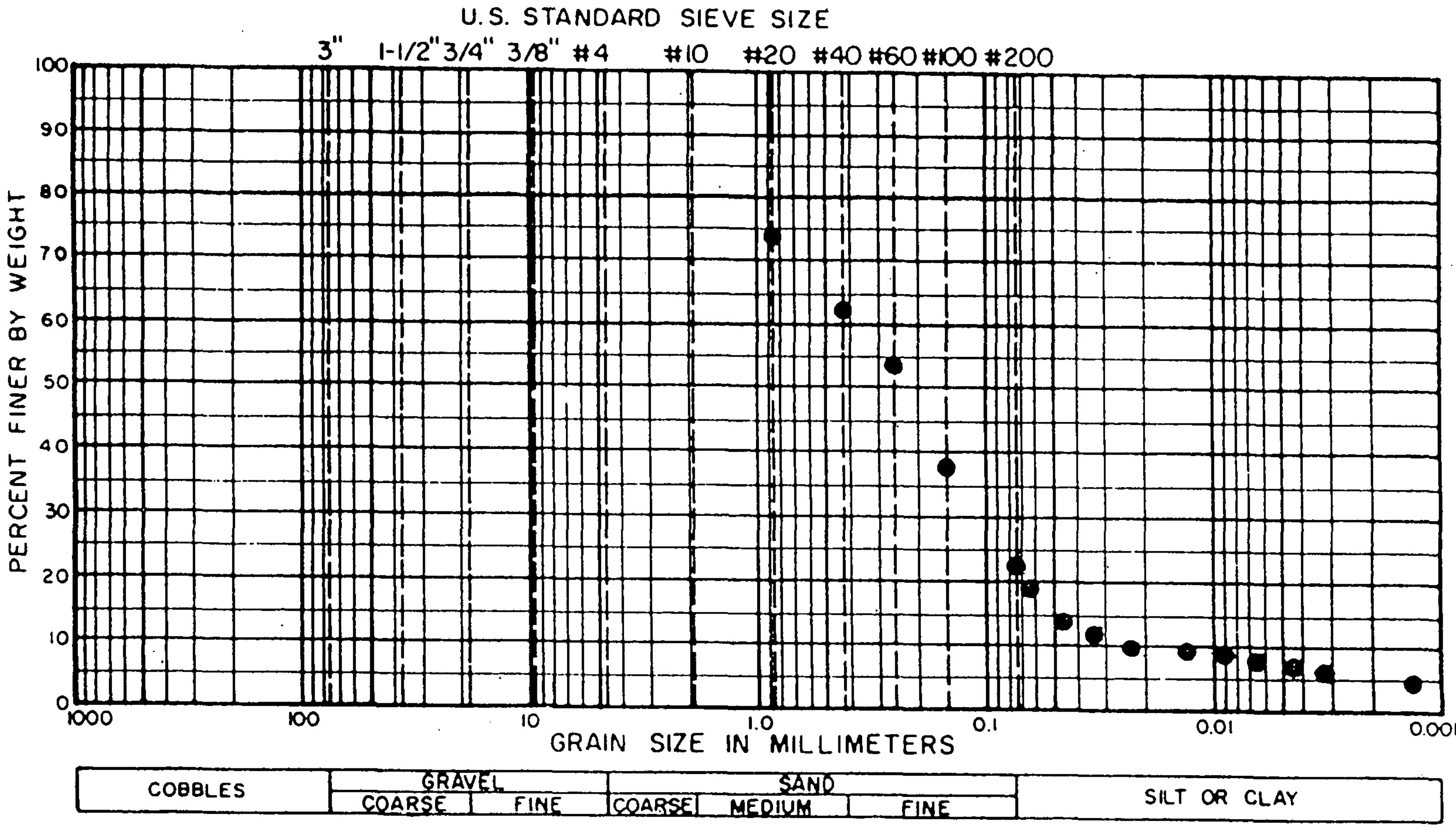

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Figure 4-15 Size Frequency Distribution of Upper Laramie Medium-Grained Sandstones. Representative sample is from a roadcut on McCaslin Boulevard (KT61-N, Station 28-7).

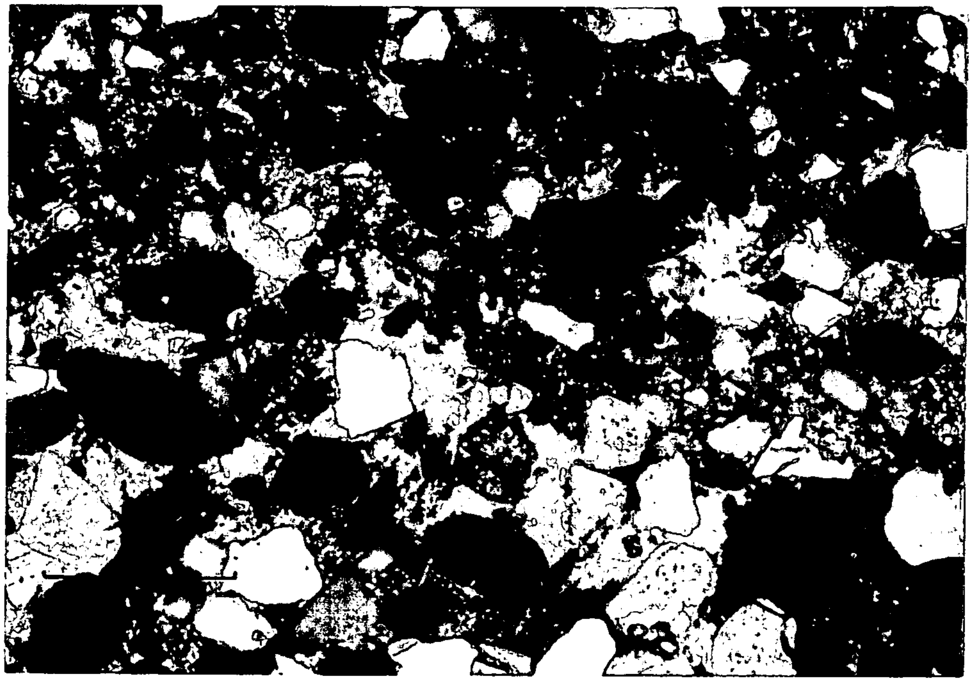

Figure 4-16(a). Calcite Cement in Upper Laramie Sandstone (KT61-N, Station 28-7). Calcite cement occurs in two large crystals seen as tan (upper right) and brown (lower left). Crossed Nicols. Magnification equals 50X. Scale bar is 400 micrometers.

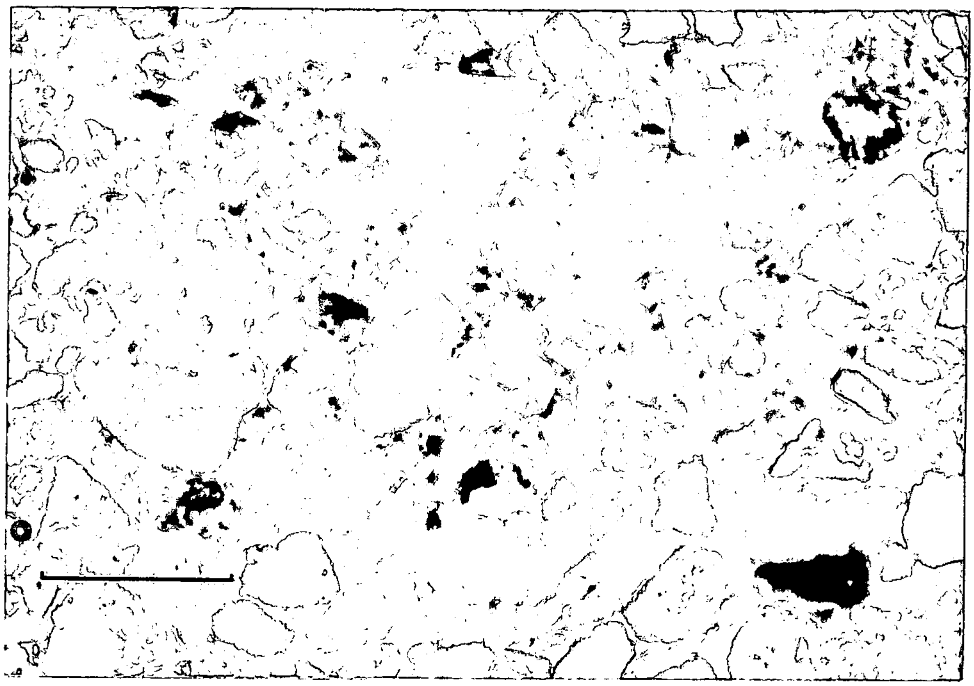

Figure 4-16(b). Same as above (KT61-N, Station 28-7). Plane polarized light. Magnification equals 50X. Scale bar is 400 micrometers.

4.2.3.2 Composition

Description

Upper Laramie sandstones vary in composition from 85 to 98 percent quartz, 1 to 10 percent rock fragments, trace to 6 percent chert, trace to 5 percent carbonaceous fragments, trace to 3 percent feldspar, trace to 2 percent biotite, and a trace of muscovite and magnetite. Organic material is common and occurs as laminae in very fine grained sandstones and as carbonaceous fragments in coarser sandstone lag deposits. Most of the quartz grains are common plutonic quartz with subequant, xenomorphic grains that exhibit straight to slightly undulose extinction, some vacuoles, and a few microlites. A few grains are recrystallized metamorphic quartz with a mosaic of equant interlocking grains that exhibit straight to slightly undulose extinction and some vacuoles. Metamorphic and sedimentary rock fragments are most common and include quartzites, siltstones, and claystones. Feldspars are rare. Other accessory minerals such as reworked detrital chert, biotite, and muscovite are also rare. Tentative identification of heavy minerals was restricted to magnetite.

Based on the average abundance of essential constituents, most of the upper Laramie sandstones are sublitharenites (Folk, 1974). Individual rock descriptions and their assignment into Folk's (1974) sandstone classification are presented in Appendix A. Quartz is the most abundant constituent at 93 to 94 percent of the rock volume. Rock fragments, including sedimentary and metamorphic fragments plus chert, are next most abundant at 5 percent of the rock volume. Feldspar makes up the final 1 to 2 percent.

Interpretation

Mineral composition of upper Laramie sandstones is controlled by provenance (Folk, 1974). Sublitharenites are compositionally submature and require conditions that produce and deposit relatively stable material. The upper Laramie may have originated from multiple sources of pre-existing, fairly mature sandstone. Medium-grained sandstones with large carbonaceous fragments and siltstone and claystone fragments may represent local erosion and deposition.

4.2.4 Arapahoe Formation Sandstones

With the exception of the marker bed, the Arapahoe Formation is composed of olive-gray to yellowish orange claystones with beds of fine- to medium-grained, platy-laminated to ripple-laminated, friable to indurated, calcareous or pyritic, light olive-gray sandstones similar to those in the underlying upper Laramie Formation. Fourteen outcrop samples were described in detail, six from the fine grained sandstones and eight from the medium-grained sandstones. Eight thin sections, four from fine-grained sandstones and four from medium grained sandstones, were also described. Five of the eight thin sections are from RFP drill core. A sieve analysis and hydrometer test were conducted on one outcrop sample.

Texture and composition of fine-grained Arapahoe Formation sandstones are illustrated in Figure 4-17 and are summarized in Table 4-1. Texturally, the fine-grained Arapahoe sandstones are almost identical to those in the upper Laramie Formation (Figure 4-12), but compositionally, they have a higher percentage of chert and rock fragments (12 percent versus 5 percent) and a lower percentage of quartz (85 percent versus 93 percent) than those in the upper Laramie Formation. The fine-grained Arapahoe sandstones are also locally pyritic.

Texture and composition of medium-grained Arapahoe Formation sandstones are shown in Figure 4-18 and are summarized in Table 4-1. Texturally, the medium-grained Arapahoe sandstones exhibit better rounding and have slightly higher porosity (20 percent) than those in the upper Laramie Formation (15 percent) (Figure 4-14). Compositionally, they are almost identical. Interpretations on depositional and diagenetic environments are similar to those in Section 4.2.3.1, and information on provenance corresponds to that presented in Section 4.2.3.2.

The marker bed is a lithologically distinctive, thick-bedded, planar-laminated to trough cross-bedded, yellowish gray to dark yellowish orange, calcareous sandstone with an abundance of well-rounded, frosted quartz sand grains that varies laterally from a medium-grained frosted sandstone to a conglomeratic sandstone. Twenty outcrop samples, (12 of pebbly sandstones and 8 of frosted sandstones) and 16 thin sections (13 of pebbly sandstones and 3 of frosted sandstones) were described in detail (see Appendix A). Nine of the 16 thin sections are from RFP drill core. Sieve analyses and hydrometer tests were conducted on five outcrop samples.

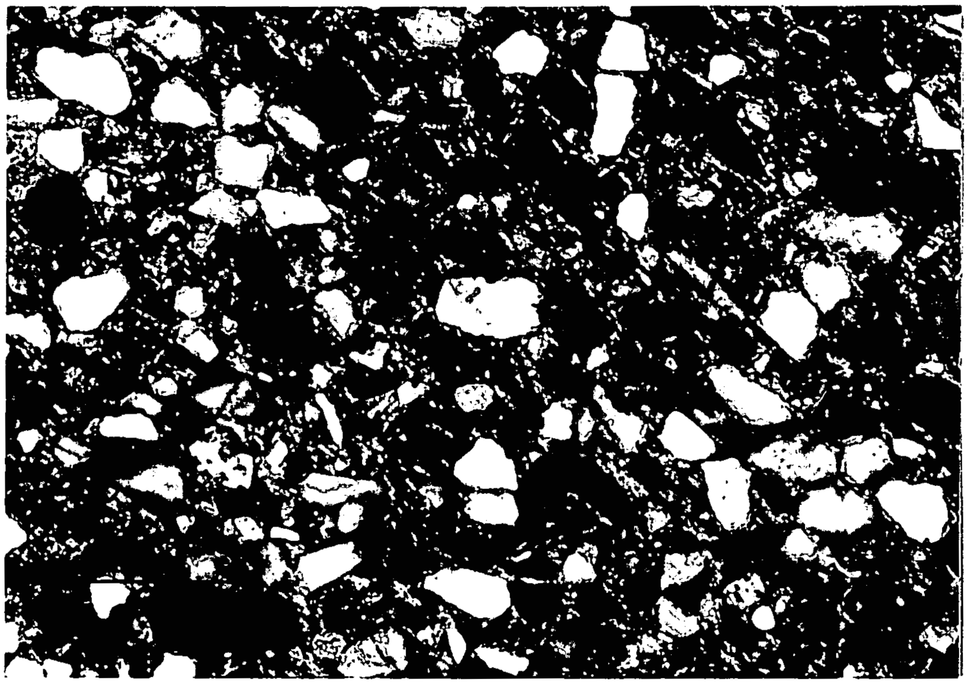

Figure 4-17(a). Photomicrograph Showing Texture of Arapahoe Fine-Grained Sandstones (Core 6286, 55.3 ft). Sandstones are typically well sorted, subangular, and texturally immature, with carbonaceous fragments and chert. Note clay coats around sand grains. Crossed Nicols. Magnification equals 50X. Scale bar is 400 micrometers.

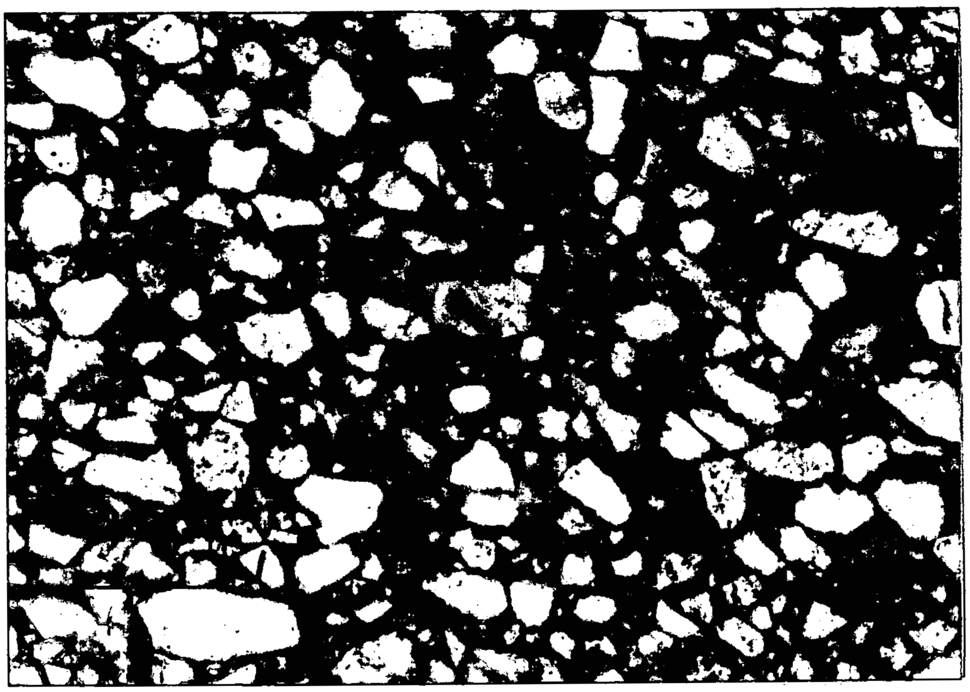

Figure 4-17(b). Same as above (Well 6286, 55.3 ft). Plane polarized light. Magnification equals 50X. Scale bar is 400 micrometers.

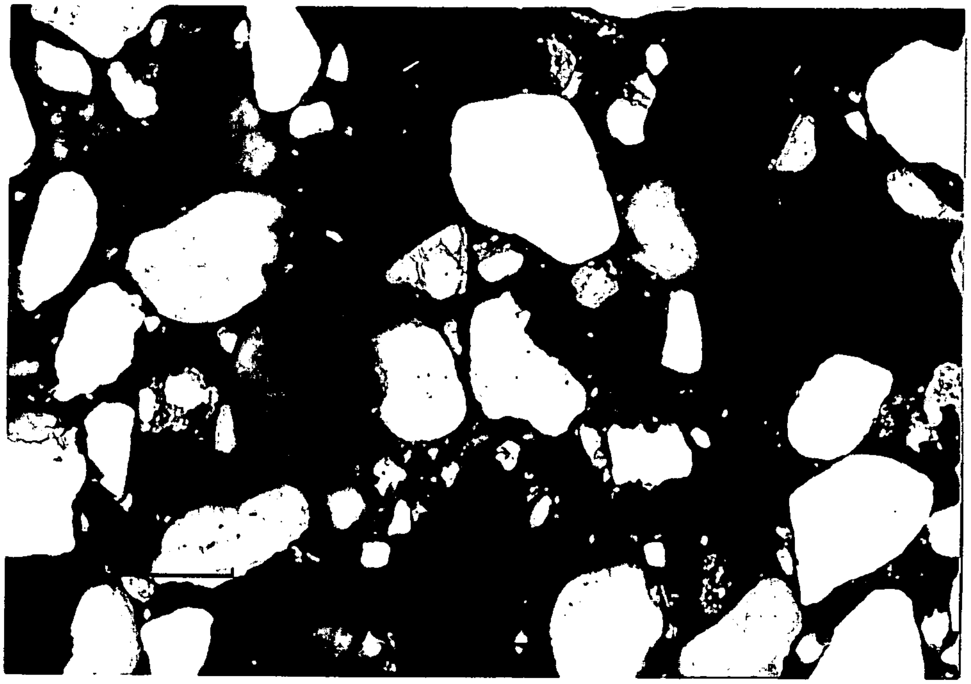

Figure 4-18(a). Photomicrograph Showing Texture of Arapahoe Medium-Grained Sandstones (Core 1487BR, 20 ft). Sandstones are typically moderately sorted, subangular to rounded, texturally submature, and quartz rich. Crossed Nicols. Magnification equals 50X. Scale bar is 400 micrometers.

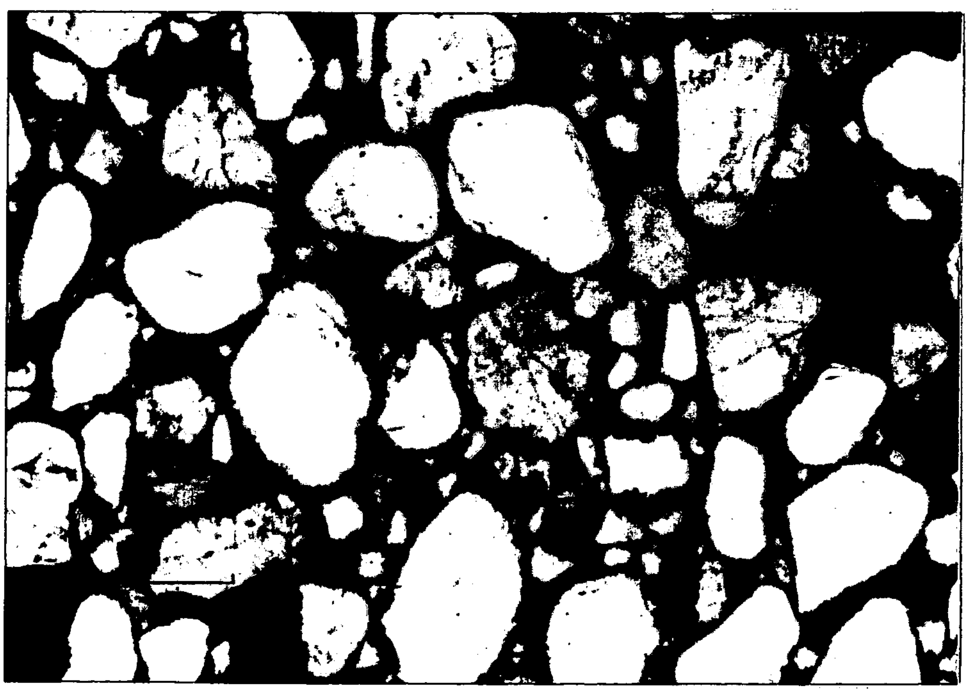

Figure 4-18(b). Same as above (Core 1487BR, 20 ft). Plane polarized light. Magnification equals 50X. Scale bar is 400 micrometers.

4.2.4.1 Texture

Description

The Arapahoe Formation marker bed grain size ranges from medium sand to coarse sand and fine pebble. Medium-grained frosted sandstones are moderately sorted, subangular to well rounded, and mature with a matrix of 0 to 5 percent silt and 0 to 3 percent clay (Figure 4-19 and Table 4-1). Figure 4-20 is a cumulative curve typical of frosted sandstones at the base of the Arapahoe Formation. Median grain size read from the cumulative curve is medium-grained sand. The slope of the cumulative curve is fairly steep but flattens out, which indicates that sorting is moderate. Rounded and well-rounded quartz grains typically have frosted surfaces. Porosity ranges from 0 to 25 percent and averages approximately 20 percent. Calcite occurs as pore-filling cement.

Grain size in the conglomeratic sandstones ranges from fine sand to coarse pebble, and the conglomeratic sandstones are moderately to poorly sorted, subangular to well rounded, and immature to submature (Figure 4-21 and Table 4-1). Rounded and well-rounded quartz and chert grains typically have frosted surfaces. Figure 4-22 is a cumulative curve typical of conglomeratic sandstones. Median grain size read from the cumulative curve is coarse-grained sand. The slope of the cumulative curve is fairly shallow and has a tail on the right side, which indicates that sorting is poor. Samples vary from indurated to highly friable, depending on the amount of porosity. Highly friable samples have 20 to 25 percent porosity, a matrix composed of 1 to 8 percent silt and 0 to 20 percent clay, and 5 percent calcite cement. Indurated samples have 0 to 5 percent porosity, a matrix composed of 3 to 6 percent silt and 0 to 7 percent clay, and 15 to 25 percent calcite and siderite cement.

Many of the individual sand grains exhibit shattering (Figure 4-21). In some cases, the fractures have been healed; in other cases, they have been occluded with pore-filling calcite cement. Figure 4-23 shows pervasive calcite cementation with detrital sand grains held together by a large, single calcite crystal (poikilotopic cementation), as evidenced by the uniformity of calcite extinction. Calcite cement may also occur in discrete nodules or random patches. Siderite cement is concentrated in small, scattered

Figure 4-19(a). Photomicrograph Showing Texture of Arapahoe Medium-Grained Frosted Sandstones (MV28-E, Station 276). Sandstones are typically medium grained, moderately sorted, well rounded, and texturally mature, with some chert. Crossed Nicols. Magnification equals 50X. Scale bar is 400 micrometers.

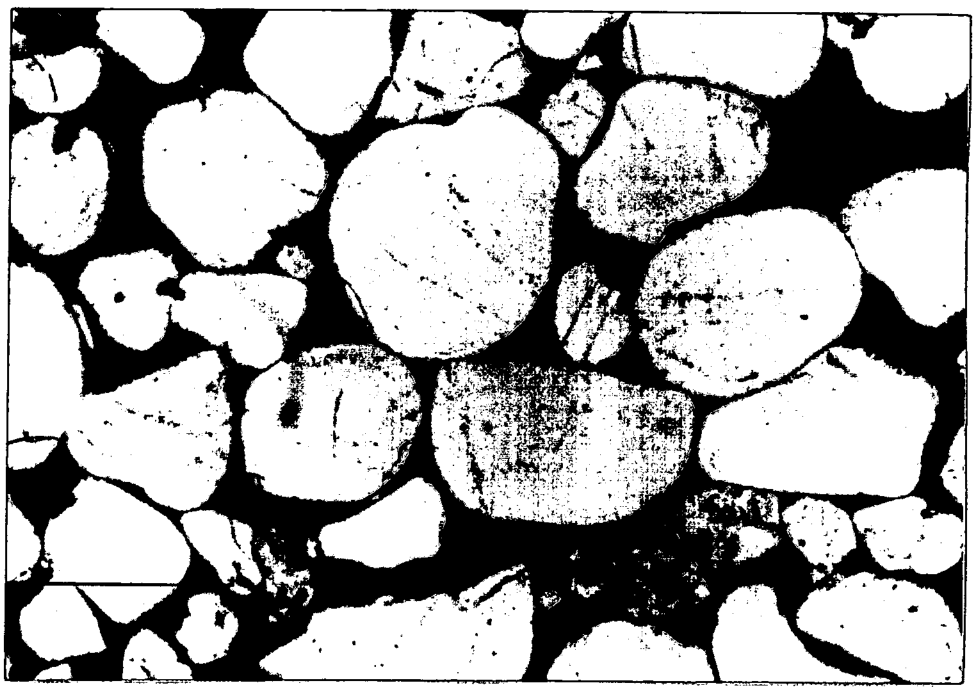

Figure 4-19(b). Same as above. (MV28-E, Station 276) Plane polarized light. Magnification equals 50X. Scale bar is 400 micrometers.

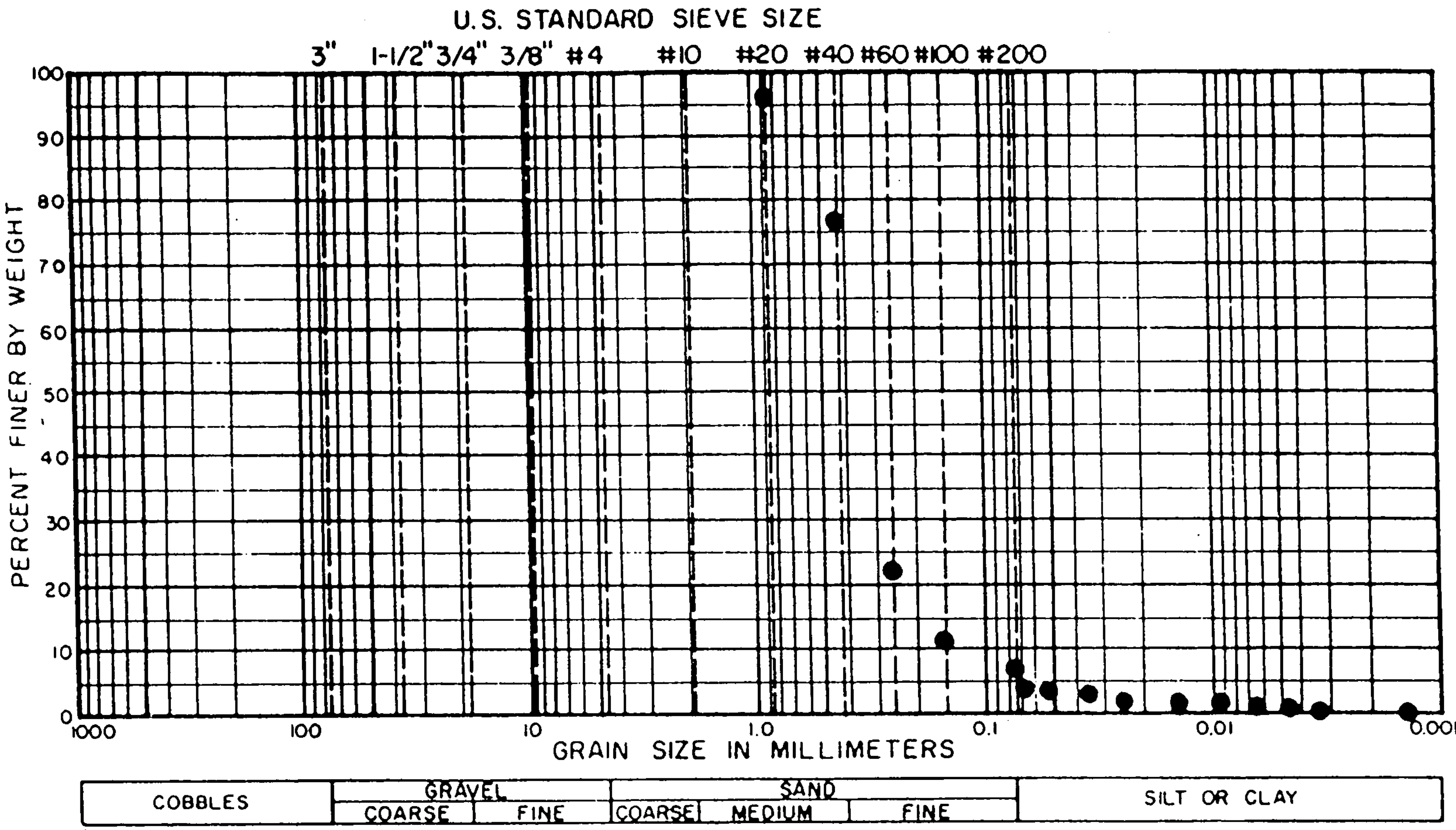

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Figure 4-20 Size Frequency Distribution of Arapahoe Medium-Grained Frosted Sandstones. Sample typical of key bed in the lower Arapahoe Formation is from a roadcut on Indiana Street (MV28-E, Station 276).

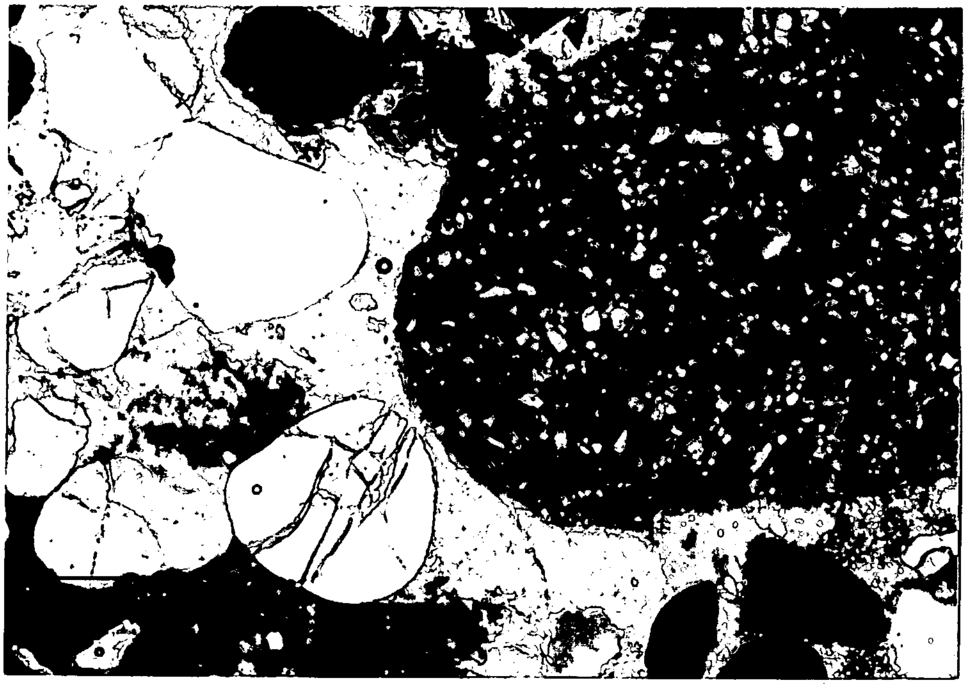

Figure 4-21(a). Photomicrograph Showing Texture of Arapahoe Conglomeratic Sandstones (KT56-N, Station 29-3). Sandstones are typically coarse grained, poorly sorted, well rounded, and texturally submature, with frosted quartz grains, chert, and rock fragments. Intergranular pores are filled with calcite cement. Note the shattered quartz grains and the large rock fragment at upper right. Crossed Nicols. Magnification equals 50X. Scale is 400 micrometers.

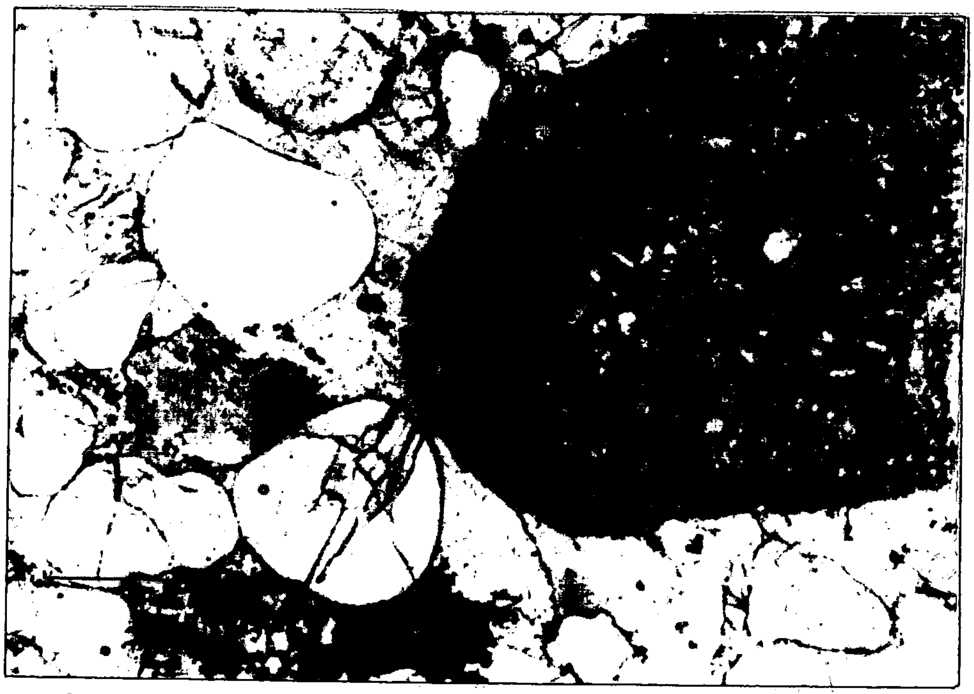

Figure 4-21(b). Same as above (KT56-N, Station 29-3). Plane polarized light. Magnification equals 50X. Scale bar is 400 micrometers.

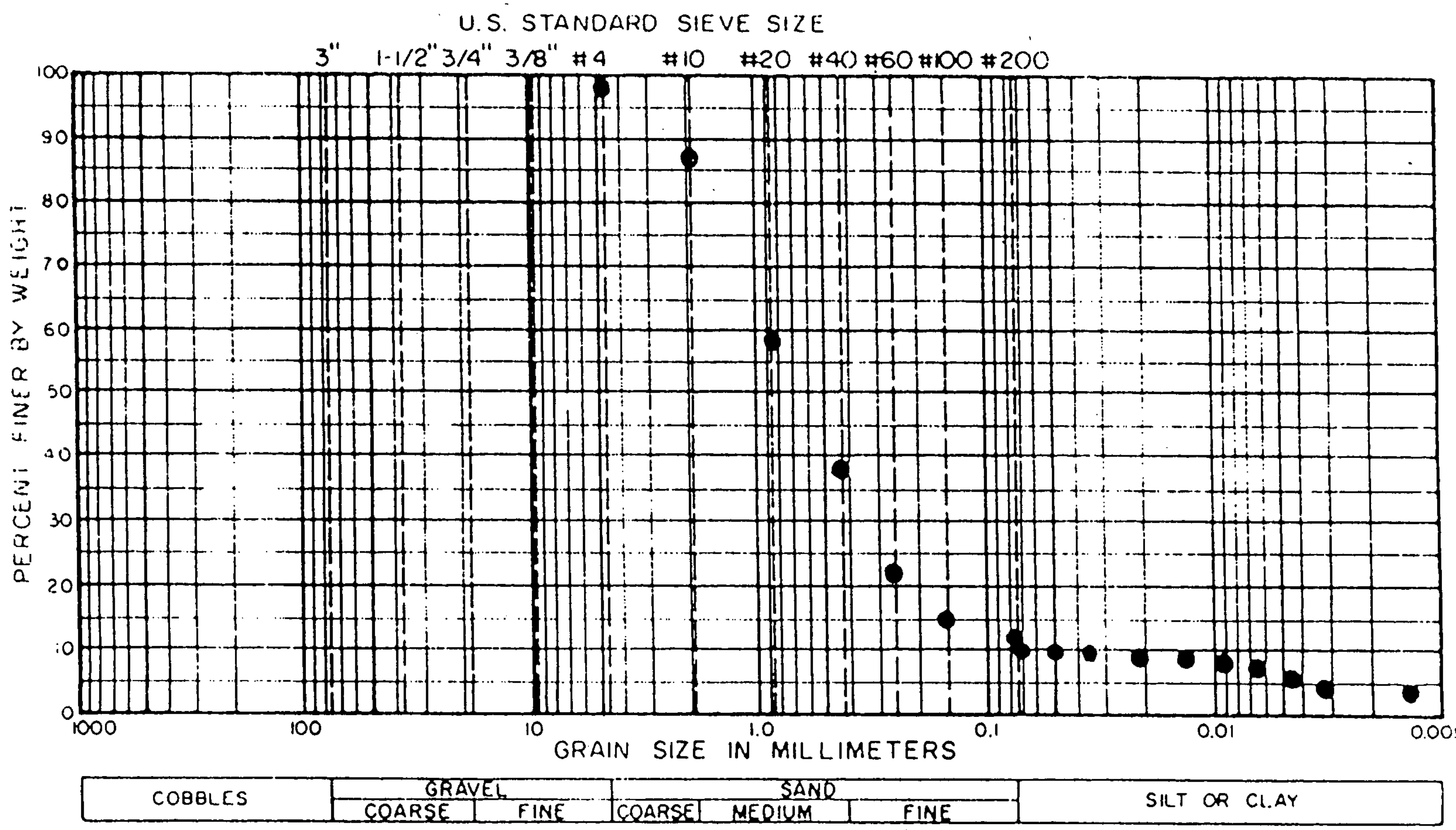

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Figure 4-22 Size Frequency Distribution of Arapahoe Conglomeratic Sandstones. Sample typical of key bed in the lower Arapahoe Formation is from Standley Lake (MV3-E, Station 256).

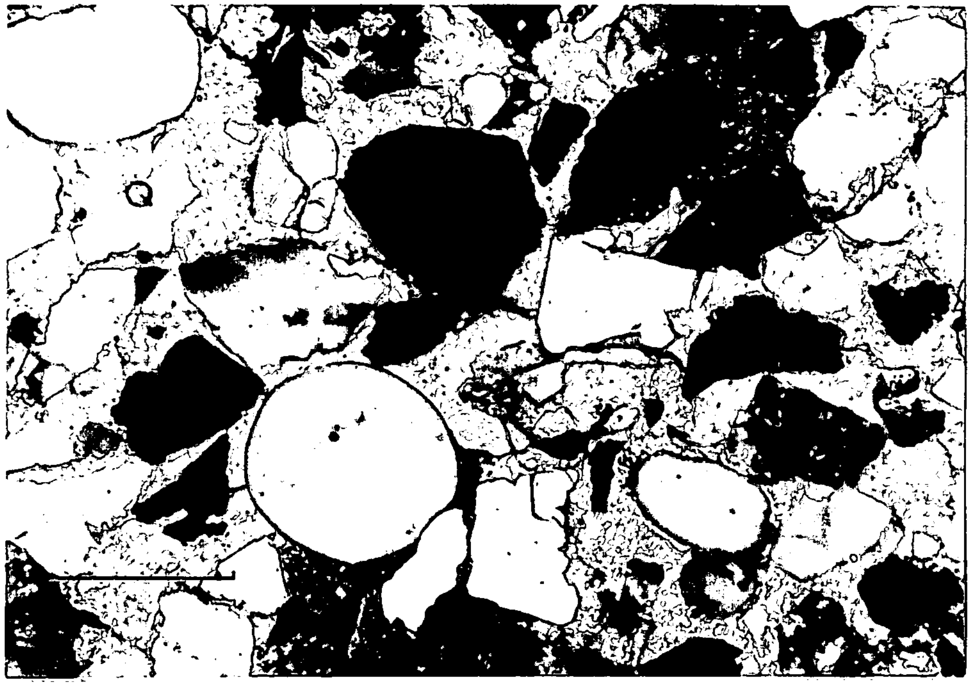

Figure 4-23(a). Photomicrograph Showing Calcareous Sandstone (MV65-N, Station 109). Calcite cement occurs as a large, single crystal holding detrital sand grains together. Note well-rounded quartz grains. Crossed Nicols. Magnification equals 50X. Scale bar is 400 micrometers.

Figure 4-23(b). Same as abov (MV65-N, Station 109). Plane polarized light. Magnification equals 50X. Scale bar is 400 micrometers.

nodules but tends to spread into the surrounding rock (Figure 4-24). Dendritic manganese oxide occurs along fractures in some quartz grains.

Interpretation

The coarse size of the sand grains and the presence of pebbles indicate that energy in the local depositional environment was high. The moderate to poor sorting also suggests somewhat rapid deposition in a high-energy environment. The presence of both subangular and well-rounded grains within the same size grade suggests that the grains were from multiple sources or that there were mixing of sediment from at least two different source environments. Frosting of quartz grains may result from chemical etching, incipient quartz overgrowths, or aeolian abrasion (Folk, 1974). The sudden influx of well-rounded, frosted grains suggests that the detrital material was from a previously untapped source (possibly the Lyons Formation). The subangular grains indicate that little rounding occurred in the most recent environment of deposition. Arapahoe sandstones range from immature to mature, indicating moderate to fairly rapid deposition in a high-energy environment.

Some Arapahoe sandstones have a clay matrix. Clay may be deposited mechanically, form by weathering of constituent grains, or occur as authigenic pore filling. Clay matrix is not as common in the Arapahoe Formation as it is in the Laramie Formation or Fox Hills Sandstone. The clay appears to have been deposited mechanically because it contains silt and does not have distinct boundaries, as would a weathered constituent grain. Some samples exhibit secondary fracture porosity and dissolution porosity around sand grains. Cementation by calcite, and to a lesser extent siderite, also accounts for some porosity reduction in the Arapahoe Formation.

4.2.4.2 Composition

Description

Arapahoe sandstones vary in composition from 55 to 98 percent quartz, 1 to 20 percent rock fragments, 0 to 18 percent ironstone fragments, 0 to 5 percent feldspar, 0 to 5 percent chert, 0 to 2 percent biotite and carbonaceous fragments, and a trace magnetite and muscovite. Conglomeratic sandstones typically have the highest percentages of rock fragments, ironstone fragments, feldspar, and chert. Medium-grained sandstones

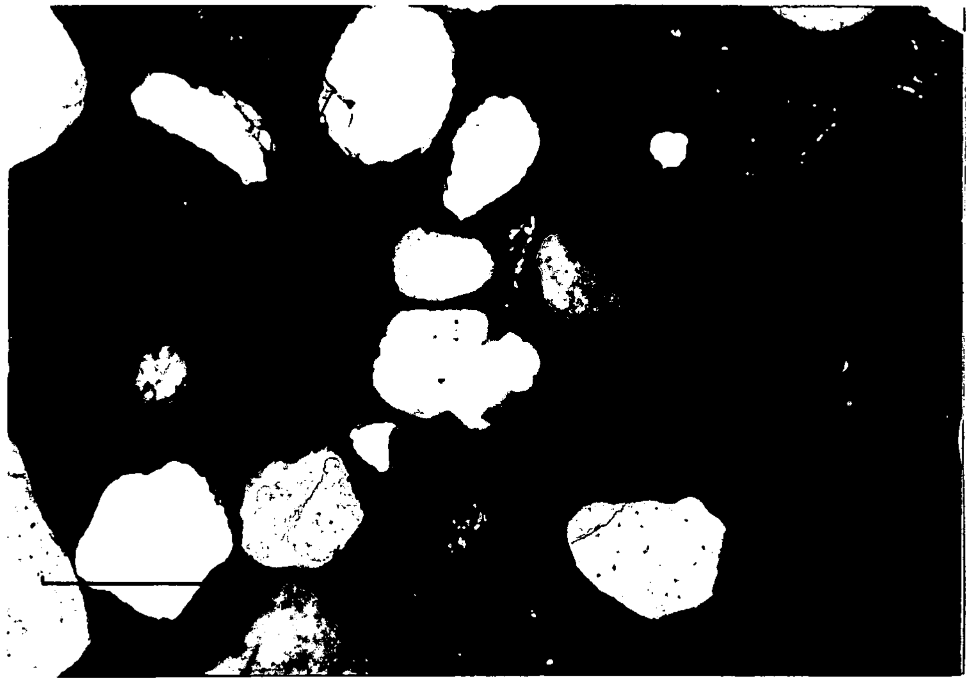

Figure 4-24(a). Photomicrograph Showing Siderite Cement (MV73-N, Station 280). Crossed Nicols. Magnification equals 50X. Scale bar is 400 micrometers.

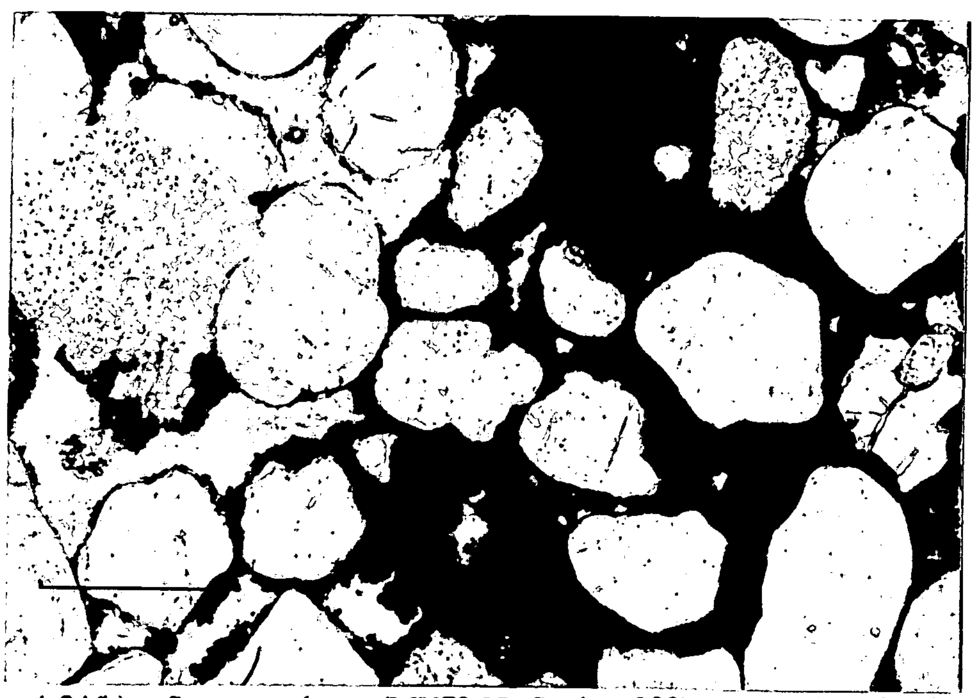

Figure 4-24(b). Same as above (MV73-N, Station 280). Note that siderite is red in plane light also. Plane polarized light. Magnification equals 50X. Scale bar is 400 micrometers.

are composed predominantly of quartz (Table 4-1). Most of the quartz grains are common plutonic quartz with subequant, xenomorphic grains that exhibit straight to slightly undulose extinction, some vacuoles, and a few microlites. A few grains are recrystallized metamorphic quartz with a mosaic of equant interlocking grains that exhibit straight to slightly undulose extinction and a few vacuoles.

Sedimentary and metamorphic rock fragments are most common and include siltstones, claystones, ironstones, and quartzites. Rounded siltstone and claystone fragments are completely cemented. Weathered volcanic rock fragments have been found only at Standley Lake. These rock fragments are large (fine pebble size), moderately dense, and intermediate in composition, with a large percentage of whole euhedral phenocrysts in a microlite-rich groundmass. Feldspar grains are rare. Reworked detrital chert is composed of microcrystalline quartz and is red, gray, or white in color. Accessory minerals, such as muscovite, biotite, and carbonaceous fragments, are rare. Magnetite and zircon are the only heavy minerals tentatively identified in the lower part of the Arapahoe Formation.

As determined on the basis of the average abundance of essential constituents, most of the medium-grained, frosted sandstones are quartzarenites and most of the conglomeratic sandstones are sublitharenites and litharenites (Folk, 1974). The average composition of medium-grained, frosted sandstones is 97 percent quartz, 2 percent rock fragments, and 1 percent feldspar. The average composition of conglomeratic sandstones is 80 percent quartz, 18 percent rock fragments, and 2 percent feldspar.

Interpretation

Provenance, or source-area lithology, controls the mineral composition of the Arapahoe sandstones (Folk, 1974). Although the quartzarenites are mature, they are subordinate to the immature litharenites and sublitharenites. A new sediment source (or sources) was probably tapped during deposition of the Arapahoe because it contains an influx of material (including rounded and frosted quartz sand grains, reworked ironstone, siltstone, and claystone pebbles, volcanic rock fragments, and chert) not found in the underlying Laramie Formation (Weimer,1976; and this study).

The rounded, frosted quartz sand may be derived from the Cretaceous Dakota Group sandstones, the Permian Lyons Sandstone, or possibly the Cambrian Sawatch

Sandstone, which crops out in south-central Colorado. Reworked ironstone, siltstone, and claystone pebbles may have been derived from the Cretaceous Laramie Formation, Fox Hills Sandstone, Pierre Shale, or Dakota Group sandstones. Volcanic rock fragments similar to those found at Standley Lake (Station 256) have been reported in the lower part of the Dawson Formation, which is stratigraphically equivalent to the Arapahoe Formation in the southern Denver Basin near Castle Rock and Colorado Springs. Morse (1979) suggested that the andesite fragments in the lower Dawson were derived from the Whitehorn Stock southwest of the Front Range near Salida, Colorado. Other similar-age volcanic centers closer to the map area, such as Central City and elsewhere in the Colorado Mineral Belt, may have been the source for igneous rock fragments in the Arapahoe Formation in the map area. Chert pebbles may have been derived from one of many chert pebble-bearing horizons, including the Cretaceous Dakota Group, Jurassic Morrison or Ralston Creek Formations, or the Permian-Triassic Lykins Formation.

4.3 VERTICAL SEQUENCE STRATIGRAPHY OF UPPER CRETACEOUS SEDIMENTARY ROCKS

Knowledge of the stratigraphic framework of bedrock is critical to development of a conceptual model for groundwater flow and estimation of flow direction, rate, and volume. The spatial distribution of rock types in the subsurface can be investigated through drill-core analysis and seismic methods and also through detailed description of correlative stratigraphic sections exposed in two and three dimensions at the surface. In addition, stratigraphic characteristics, such as the lateral extent and degree of interconnection of aquifer units, that directly affect the potential for groundwater contaminant transport can be more readily observed in surface exposures. The depositional environments of sedimentary rocks, which control the distribution of rock types, can also be interpreted from the vertical succession of sedimentary structures and lithologies and the lateral stratigraphic relationships exhibited in outcrop.

Measured stratigraphic sections of Upper Cretaceous sedimentary rocks in the map area (refer to Figure 1-2 for locations of measured sections) provide detailed lithologic and sedimentologic data from a vertical section of the bedrock. The vertical stratigraphic sequences observed in the measured sections of the three uppermost Cretaceous map units at RFP (Fox Hills Sandstone, Laramie Formation, and Arapahoe Formation) are described below.

4.3.1 Fox Hills Sandstone

Exposures of the Fox Hills Sandstone occur primarily in the northwestern portion of the map area. Sections of the Fox Hills Sandstone were measured near Marshall at Pine Ridge (Figure 4-25), along Eldorado Springs Drive (Figure 4-26), and at Eggleston Reservoir (Figure 4-27). An additional section of Fox Hills Sandstone was measured and described south of RFP along the D&RGW Railroad cut at Highway 93 (Figure 4-28).

The Fox Hills sandstones are typically massive, medium to thick bedded, and locally interbedded with single, thin claystone beds. At Pine Ridge, Eggleston Reservoir, and Eldorado Springs Drive, some thick sandstone beds exhibit large-scale (1 to 4 feet high), low-angle, planar cross-bedding. However, few other sedimentary structures are present within the Fox Hills Sandstone sections described.

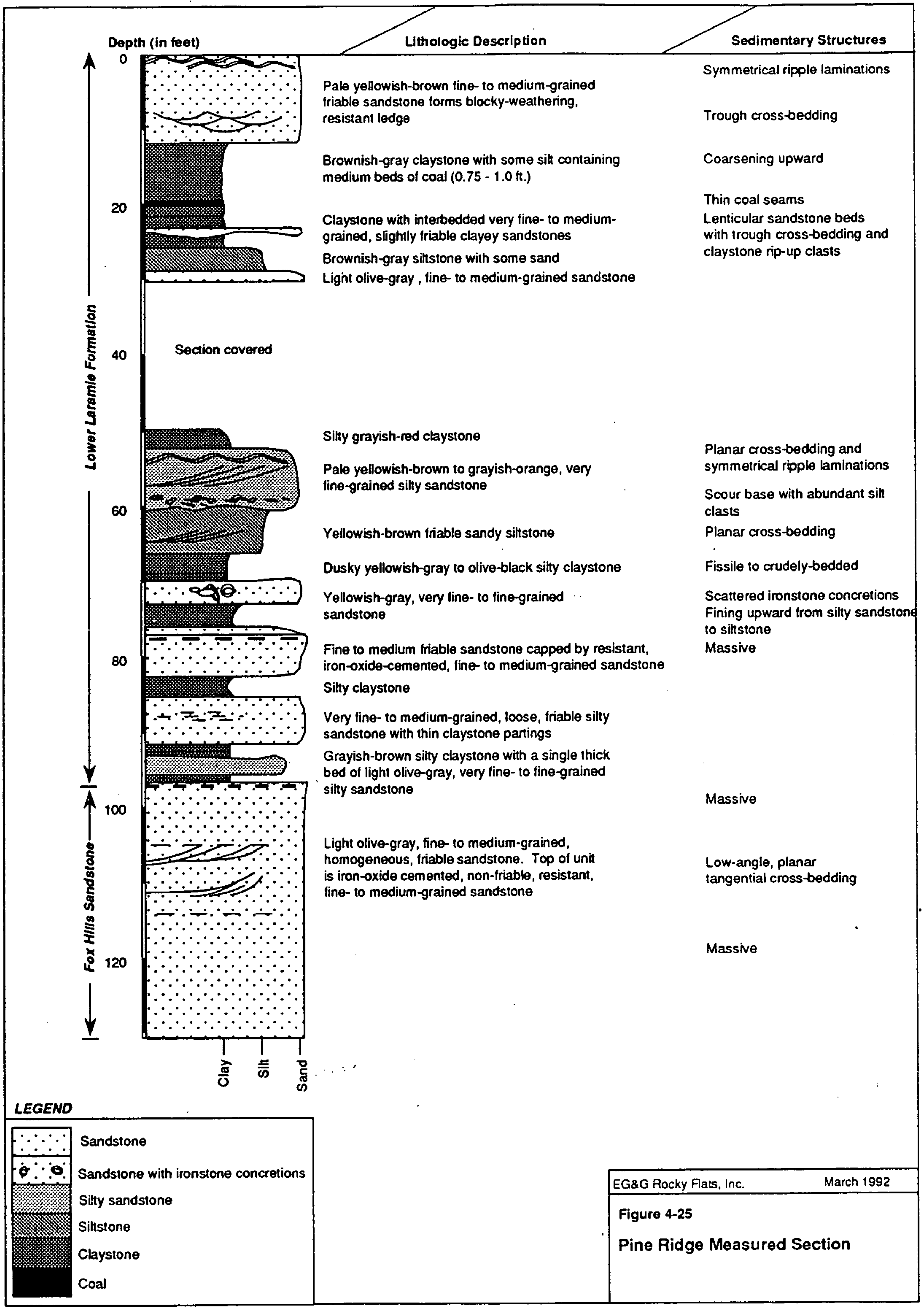

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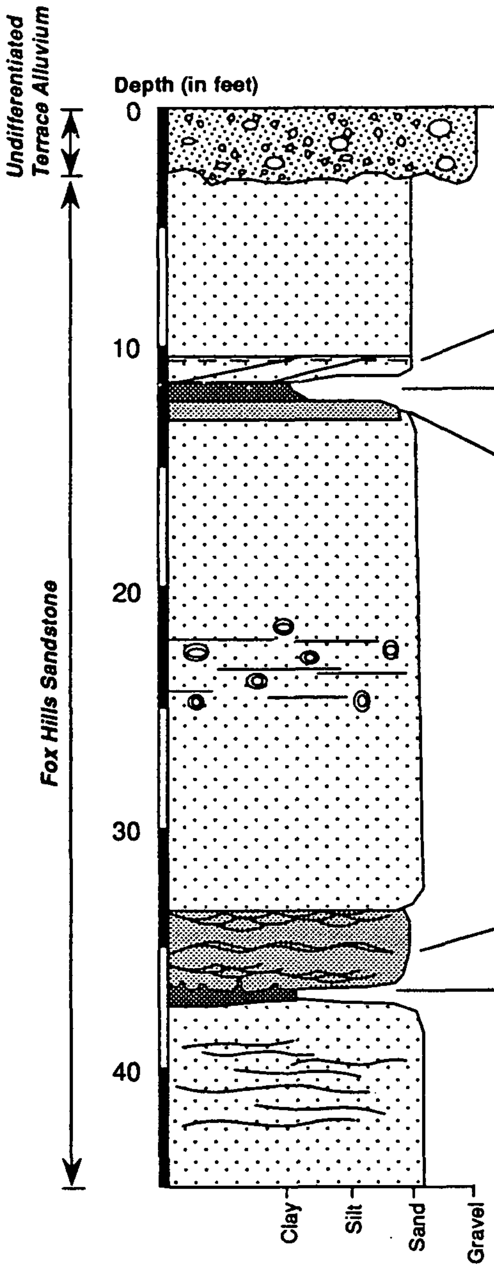
Figure 4-25

Pine Ridge Measured Section



Lithologic Description	Sedimentary Structures
Yellowish-gray, very fine- to fine-grained, friable sandstone	Massive
Yellowish-gray, very fine- to fine-grained, iron-oxide-cemented sandstone	Planar cross-bedding and subparallel laminated sands
Dark yellowish-brown organic-rich claystone with some silt	Blocky
Moderate-brown, fine- to medium-grained sandstone with some silt	Gradational upper contact
	Massive
Yellowish-gray, fine- to medium-grained friable homogeneous sandstone; few iron-stained laminae with coarse-sand-sized stone concretions	
Yellowish-gray, very fine- to fine-grained sandstone with some silt	Trough cross-bedding and lenticular bedding
Dusky-brown, fissile claystone interbedded with moderate-brown, clayey, fine- to medium-grained sandstone	Convoluted bedding, bed-load structures on top of bedding surface
Light olive to yellowish-gray, fine- to medium-grained friable sandstone	Massive with discontinuous silt partings

LEGEND

- Alluvial gravel
- Sandstone
- Sandstone with ironstone concretions
- Silty sandstone
- Claystone

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Figure 4-26

Eldorado Springs Drive Measured Section

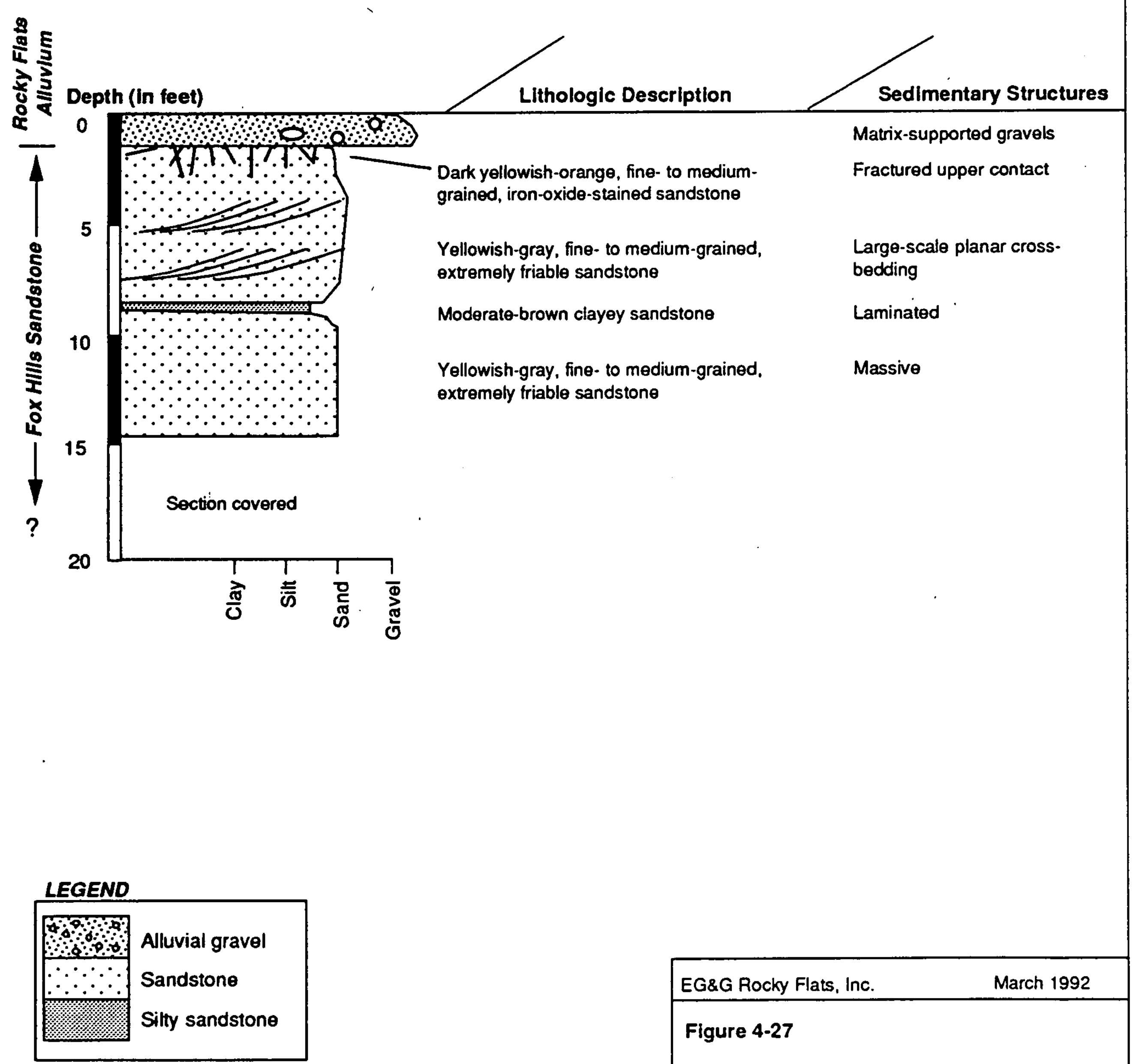

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Figure 4-27

Eggleston Reservoir Measured Section

At Pine Ridge (Figure 4-25), the Fox Hills Sandstone is composed of a fine- to medium-grained, friable sandstone. The top of the unit is completely cemented, heavily iron stained, resistant to weathering, and nonfriable. The unit is massive throughout the 35 feet exposed at Pine Ridge except for a band of low-angle, planar tangential cross-beds that occur from 10 to 20 feet below the top of the unit (Figure 4-25). These cross-beds are large-scale features (2 to 3 feet high) that are usually formed by the migration of megaripples in beach, shoals, and tidal channel environments (Reineck and Singh, 1980).

At Eldorado Springs Drive (Figure 4-26), the Fox Hills Sandstone is more lithologically diverse. More than 40 feet of Fox Hills Sandstone is exposed unconformably beneath a 3-foot section of Quaternary alluvial gravels. The section is predominantly composed of massive, fine- to medium-grained, friable sandstone as at Pine Ridge and Eggleston Reservoir. However, a thin bed of fissile claystone and a thin bed of organic-rich claystone are also present. Dusky brown, fissile claystone interbedded with moderate brown, clayey sandstone is present below a 2-foot-thick bed of fine- to medium-grained sandstone with some silt. The claystone exhibits convolute bedding at its upper contact surface with the overlying sandstone (Figure 4-29). Such structures may be produced by rapid deposition of sand over a hydroplastic mud layer. The overlying sandstone is cross-bedded, and the cross-sets fill gently sloping, trough-shaped depressions. The sandstone bed has a lenticular shape and is laterally discontinuous (extends 4 feet laterally). No trough cross-bedding is present in the overlying thick sandstone bed; however, a very thin (1-inch-thick), dark yellowish brown, organic-rich claystone with some silt is present at the top of a narrow fining-upward zone of fine- to medium-grained sandstone (Figure 4-26). The uppermost sandstone exposed is very fine to fine grained, and friable and has no bedding structures.

At Eggleston Reservoir (Figure 4-27), nearly 12 feet of Fox Hills Sandstone is exposed on the western shore of the reservoir (Figure 4-30). The sandstone is fine to medium grained and highly to moderately friable. Large-scale planar cross-beds occur in the upper 10 feet of the section, but the sandstone is predominantly massive with no bedding structures. Near the middle of the exposure, a thin bed of moderate brown, clayey sandstone is present. The clayey sandstone is highly to moderately friable and laminated but is not fissile or platy-breaking.

Figure 4-29. Shale Bed in the Fox Hills Sandstone (Station 10-1, Eldorado Springs Drive measured section). Load structures at the base of the sandstone overlie deformed shale.

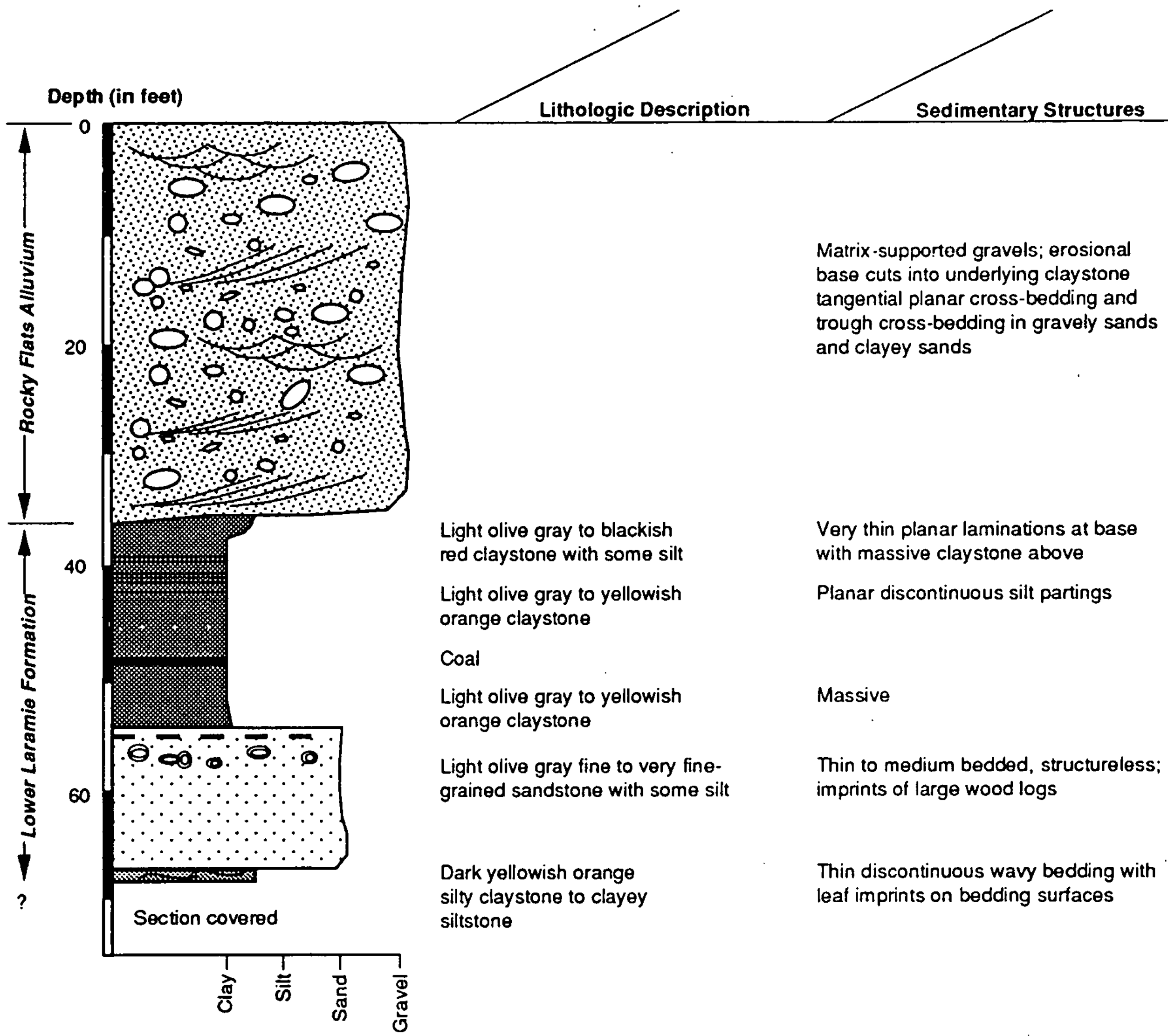
Figure 4-30. Massive Fox Hills Sandstone (Station 8-1, Eggleston Reservoir). Massive sandstone with weathered upper surface exposed at Eggleston Reservoir.

In the southern portion of the map area (Figure 1-2), a complete section of the Fox Hills Sandstone is exposed at the D&RGW Railroad cut (Figure 4-28). The base of the formation is transitional with the Pierre Shale but is defined here as the level at which sandstone beds dominate the section. At the railroad cut, the Fox Hills Sandstone is 90 feet thick and consists of (1) planar, interbedded sandstone and silty claystone and (2) thick, massive, very fine to fine-grained sandstone. The lowest 25 feet of the formation consist of very fine to fine-grained friable sandstone to silty sandstone. The sandstone gradually coarsens upward from the base of the formation, but some thin shale beds are present within the lower 15 feet. Bedding surfaces are planar except in the upper 10 feet of the formation. At the top of a massive, very thick bed of fine-grained sandstone (Figure 4-28), the sandstone exhibits small-scale (4 inches high) planar, tangential cross-bedding.

The dominance of massive sandstone beds within the upper portions of the Fox Hills Sandstone suggests either that sediments were deposited rapidly without formation of sedimentary structures or that sedimentary structures formed during deposition may have been eradicated by sediment liquefaction or extensive bioturbation. However, undisturbed, thin, silty claystone and sandy siltstone beds are present below and within the lower portions of massive sandstone. These fine-grained deposits may have resulted from variations in current intensities during rapid sediment deposition. Textural and compositional characteristics (Section 4.2.1) provide the best indicators of the depositional environment of the Fox Hills Sandstone because few sedimentary structures are present and vertical exposures are limited.

4.3.2 Lower Laramie Formation

The lower part of the Laramie Formation is the best exposed Upper Cretaceous map unit in the study area. Portions of the lower Laramie Formation are exposed along a north-northwest-trending hogback in the western portion of the map area. A continuous, 300-foot section of the Laramie Formation is exposed along the D&RGW Railroad cut southwest of RFP. Measured sections from Pine Ridge (Figure 4-25), the clay pits west of RFP (Figures 4-31 and 4-32), the D&RGW Railroad cut near Highway 93 (Figure 4-28), and Leyden Gulch (Figure 4-33) all describe portions of the lower Laramie Formation. These sections all lie approximately along the same hogback of steeply dipping strata west of RFP (locations shown in Figure 1-2);



LEGEND

Alluvial gravel	Siltstone
Sandstone	Claystone
Silty sandstone with ironstone concretions	Coal

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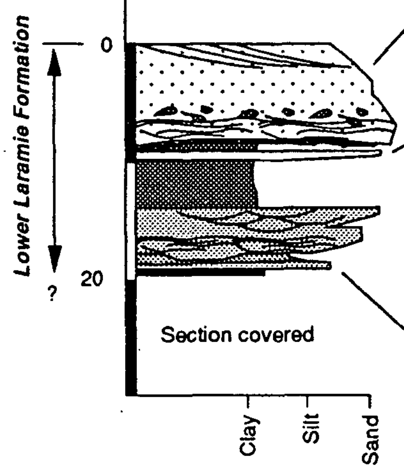
Figure 4-31

North Clay Pit I Measured Section

Depth (in feet)



Lithologic Description	Sedimentary Structures
Yellowish-gray silty very fine- to medium-grained sandstone	Medium- to thick-bedded; convoluted to wavy laminations at base; numerous claystone rip-up clasts; fines upwards into planar cross-bedded silty sandstone
Dark yellowish-orange to light olive-gray fine- to medium-grained sandstone	Lenticular bed of laminated siltstone grading upwards into sandstone
Yellowish-gray claystone	Massive thick bed
Yellowish-gray very fine- to medium-grained sandstone with some silt	Thin- to medium-bedded with wavy discontinuous laminations and small-scale trough cross bedding; sandstone thins laterally
Interlaminated yellowish-gray to grayish-orange very fine-grained sandstone, sandy siltstone, and sandy claystone	Uneven, planar parallel bedding, symmetrical ripple laminations at top of unit, trace fossils on claystone bedding surfaces; stem and wood imprints

LEGEND

- Sandstone
- Sandstone with claystone rip-up clasts
- Sandstone with ironstone concretions
- Silty Sandstone
- Claystone
- Ironstone

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Figure 4-32

North Clay Pit II Measured Section

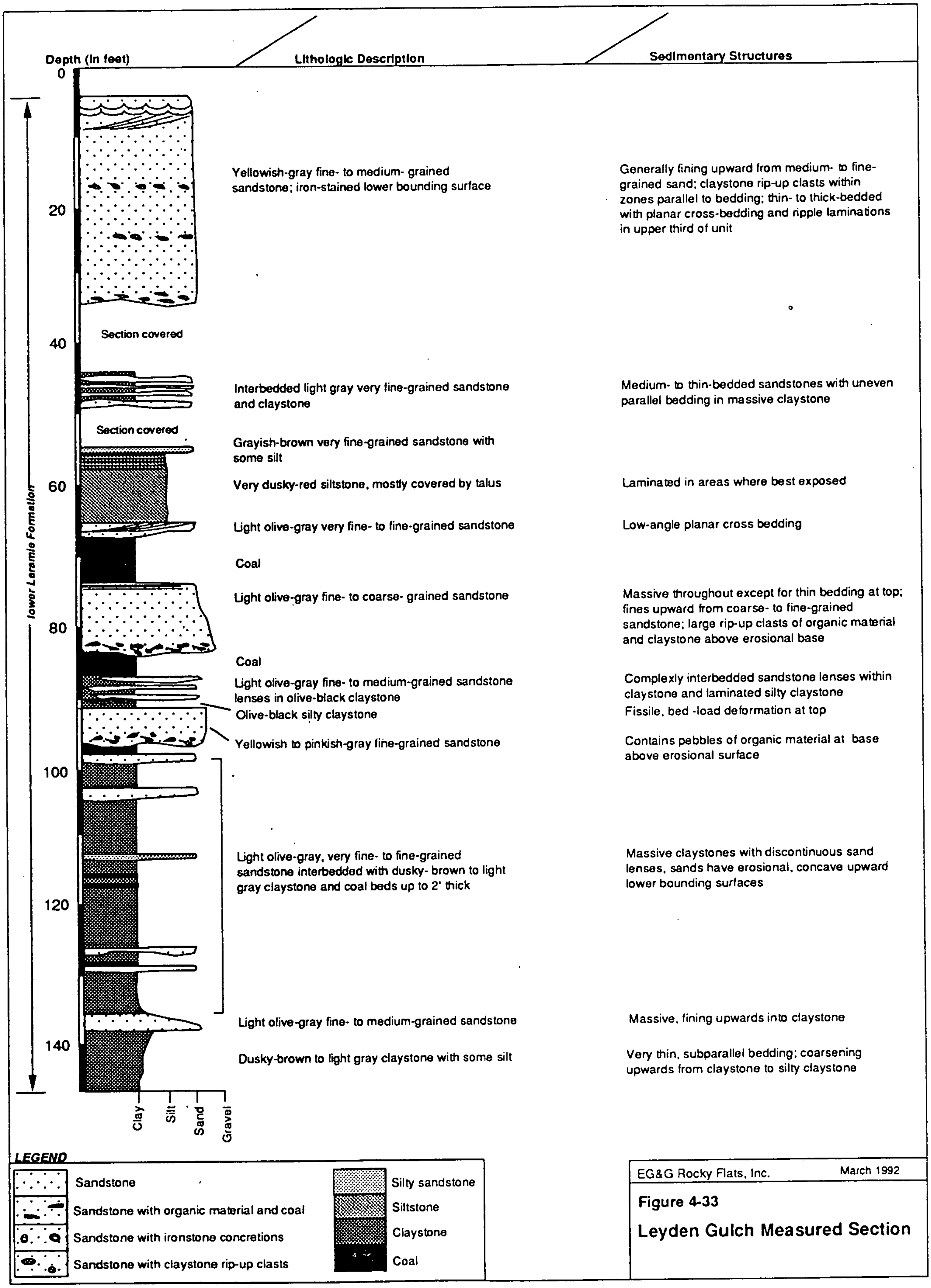

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Figure 4-33

Leyden Gulch Measured Section

thus, they provide a set of vertical profiles through the Laramie Formation along a laterally continuous line that extends 6 miles along strike. As discussed below, this group of vertical sections is highly variable along strike, but the same set of sedimentary sequences is repeated in each section.

A variety of lithologies are present within the lower Laramie Formation. The lower part of the formation typically consists of alternating sandstone, siltstone, and claystone beds with some discontinuous, thin coal beds. The assemblage of typical lithologies and vertical sequences is best seen at the D&RGW Railroad section near Highway 93 south of RFP (location shown in Figure 1-2). At this location, the lower Laramie Formation is more than 300 feet thick and is composed of alternating thick sandstone sections and thinner claystone, siltstone, and interbedded sandstone-claystone sections (Figure 4-28). Within this section, some of the lower Laramie claystones have been mined and the abandoned clay pits are now covered.

A number of lithologic sequences are repeated within the section at the D&RGW Railroad cut, and the same lithologic sequences are found in the other lower Laramie sections described across the field area. These lithologic sequences are:

1. Massive sandstone with a sharp, scour base overlain by organic-rich claystone or coal
2. Fining-upward sequence with thick, cross-bedded sandstone at the base that becomes ripple-laminated near the top and fines upward into interbedded siltstone and sandstone
3. Massive claystone with thin siltstone, silty claystone, and some discontinuous thin to thick sandstone beds
4. Coarsening-upward sequence of laminated claystone, siltstone, and sandstone

Massive sandstone beds range from 5 to 20 feet in thickness. These very thick sandstone beds commonly contain pebble- to cobble-size clasts of claystone or siltstone that are often deformed, stretched, or partially mixed into the supporting sandstone matrix (Figure 4-34). They also often contain lag deposits characterized by abundant plant imprints, including fossil logs, leaves, and twigs, and accumulations of pebble-size claystone and siltstone rip-up clasts (Figures 4-34 and 4-35). At the D&RGW Railroad cut, massive sandstone units between 130 and 150 feet, 180 and 208 feet, and

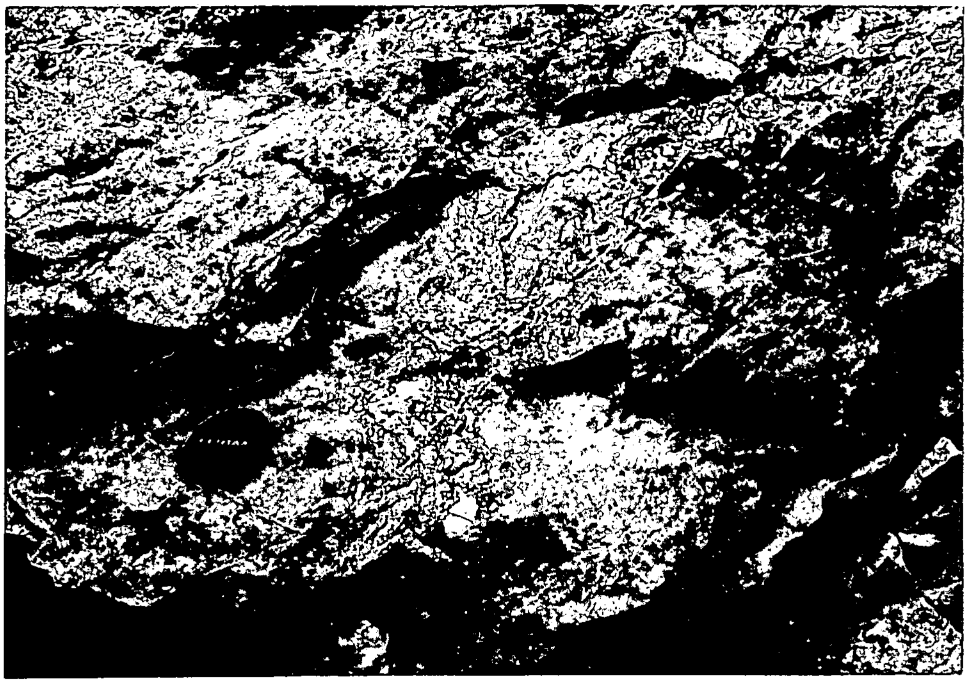


Figure 4-34. Massive Sandstone Bed Containing Pebble-Size Clasts of Siltstone (D&RGW Railroad measured section). Lag deposit in the lower Laramie, with a zone of concentrated white to yellow siltstone rip-up clasts within a massive sandstone.

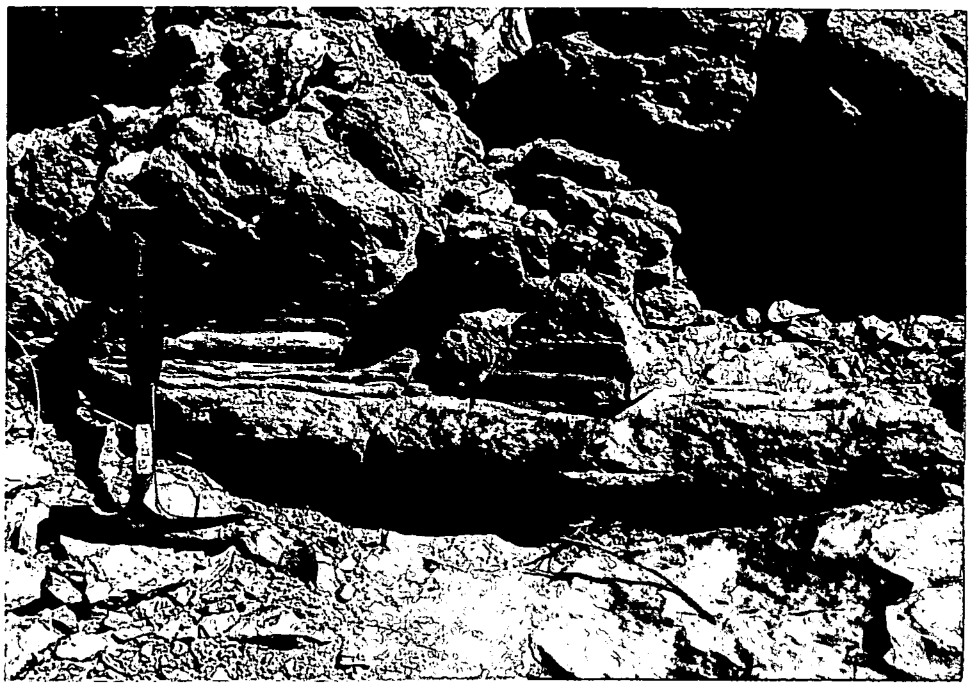


Figure 4-35. Fossil Log (Station 131, clay pit near RFP west gate). Lag deposit near the base of a channel sandstone in the lower Laramie contains large log imprints.

230 and 240 feet all have an irregular erosional base scoured into the finer grained sediments below. The lower surfaces of thick sandstone beds also often exhibit load structures preserved as molds, resulting in a hummocky or lumpy lower bounding surface. Thick, massive sandstone beds occur in measured sections at Pine Ridge (Figure 4-25, between 50 and 60 feet), the northernmost clay pit (Figure 4-32, between 0 and 8 feet), and at Leyden Gulch (Figure 4-33, between 5 and 35 feet and between 92 and 97 feet). In the clay pit immediately north of the RFP west gate (Station 18-1) a thick, apparently massive sandstone unit exhibits large-scale (greater than 8 feet high), low-angle, longitudinal cross-stratification. Longitudinal cross strata are formed by lateral accretion along tidal, delta, or river channels and not by current migration. As shown in Figure 4-36, small-scale ripple laminations at the top of a thick sandstone bed are symmetrical with straight crests and are approximately 0.5 inch high. They are overlain by wavy-laminated sandy siltstone and a thick sandstone bed exhibiting planar cross-sets within megaripples. Asymmetric ripples at the top of a different massive sandstone bed are shown in Figure 4-37. The ripples are less than 0.5 inch high and exhibit slightly undulose crests. In Figure 4-37 all of the cross-bedding and ripple lamination present in the sandstones appear to have been formed by current migration of ripple forms. Changes in the size and morphology of ripples may be indicative of variations in current intensities through time.

Repeated fining-upward sequences are composed of massive sandstone beds grading upward into ripple-laminated and planar-bedded, fine- to very fine grained sandstone and, less commonly, into siltstone. At the D&RGW Railroad cut, four consecutive fining-upward sequences occur at approximately 300 feet above the base of the Laramie Formation (Figure 4-28). Each sequence ends with fine-grained, ripple-laminated sandstone. At the top of each sequence, ripple laminations, convolute-bedding, and dewatering structures are truncated by overlying medium-grained, massive sandstone at the base of the successive sequence (Figure 4-38). Fining-upward sequences in lower portions of the Laramie Formation are also described at Pine Ridge (Figure 4-25, between 0 and 12 feet) and Leyden Gulch (Figure 4-33, between 75 and 83 feet). Repeated fining-upward sequences are commonly associated with channel point bars and flood-plain deposits.

Figure 4-36. Ripple Laminations and Tangential Cross-Bedding (Station 31-10). Thick sandstone unit from the lower Laramie Formation in the Marshall area.

Figure 4-37. Case-Hardened Ripple Laminations (Station 3-3, Marshall area). The tops of massive, thick sandstone beds frequently exhibit asymmetric ripple laminations.

Massive claystone sections often contain thin-bedded siltstone and silty claystone units or discontinuous thin to thick sandstone beds (Figure 4-39). These sequences also often contain thick- to thin-bedded (0.5 to 15 feet), discontinuous coal seams. Such vertical sequences occur at the D&RGW Railroad cut (Figure 4-39, between 80 and 107 feet), at the northernmost clay pit (Figure 4-32, between 9 and 19 feet, and Figure 4-40) and at Pine Ridge (Figure 4-25, between 22 and 30 feet). At Leyden Gulch, a massive 40-foot-thick claystone containing thick sandstone beds occurs at the base of the measured section.

Less common are coarsening-upward sequences of wavy-laminated claystone, siltstone, and lenticular, very fine grained sandstone. Figure 4-41 shows a fine-grained unit within the lower Laramie at Pine Ridge that generally coarsens upward. The proportion of sand-sized sediment increases upsection, and the unit is overlain by a thick sandstone bed (brown, overhanging ledge in Figure 4-41). The base of the overlying sandstone bed exhibits load casts, and the top of the lenticular-bedded, fine-grained sequence shows deformation due to sediment loading. Lenticular bedding is produced under conditions more favorable for the deposition and preservation of mud than for sand. The sand supply is meager, and only incomplete ripples are formed (Reineck and Singh, 1975). Lenticular bedding in fine-grained sediments has been described from marine deltas, subtidal zones, and intertidal zones. This sedimentary facies does not occur with the same frequency as fining-upward sequences or sequences with massive sandstones or claystones. However, wavy-laminated to lenticular-bedded sequences that show no upward coarsening are often present. Several coarsening-upward sequences composed predominantly of fine-grained sediments are present in the vertical sections of the lower Laramie Formation at Pine Ridge (Figure 4-41; and Figure 4-25, between 12 and 20 feet) and at the northernmost clay pit (Figure 4-31, between 36 and 40 feet).

Although all of the measured sections contain similar repeated lithologic sequences, the proportions and distributions of those sequences vary by location within the map area. For example, at Pine Ridge, the lower Laramie section is dominated by fine-grained rocks with some thin to thick beds of very fine to fine-grained sandstone. In contrast, sections described at Leyden Gulch, at the D&RGW Railroad cut, and at the North Clay Pit all contain a larger component of sandstone and, in particular, more numerous thick, massive sandstone beds. Within the clay pits on the west side of RFP, sandstones occur as lenticular-shaped beds within claystone or siltstone units or as

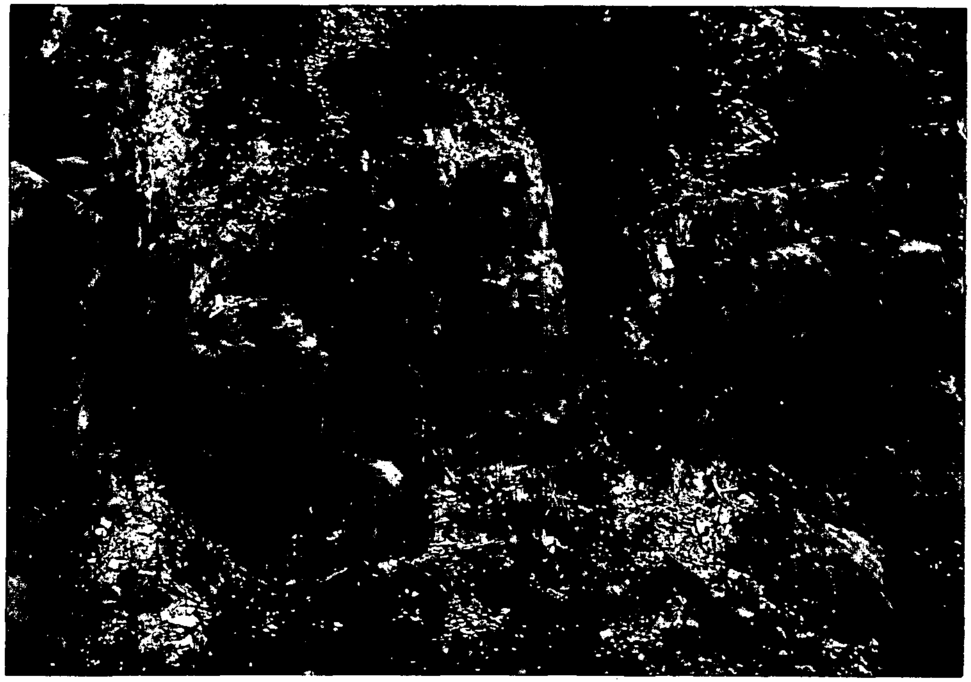


Figure 4-38. Three Fining-Upward Sequences (Station 158, D&RGW Railroad measured section). Fining-upward intervals are marked by orange flagging (strata are inclined approximately 90 degrees, left is top of strata). Base of each sequence is massive, medium-grained sandstone, with an erosional lower bounding surface.

Figure 4-39. Interbedded Claystone and Sandstone Beds (Station 158, D&RGW Railroad measured section). Claystones with thin, discontinuous siltstone and sandstone beds.

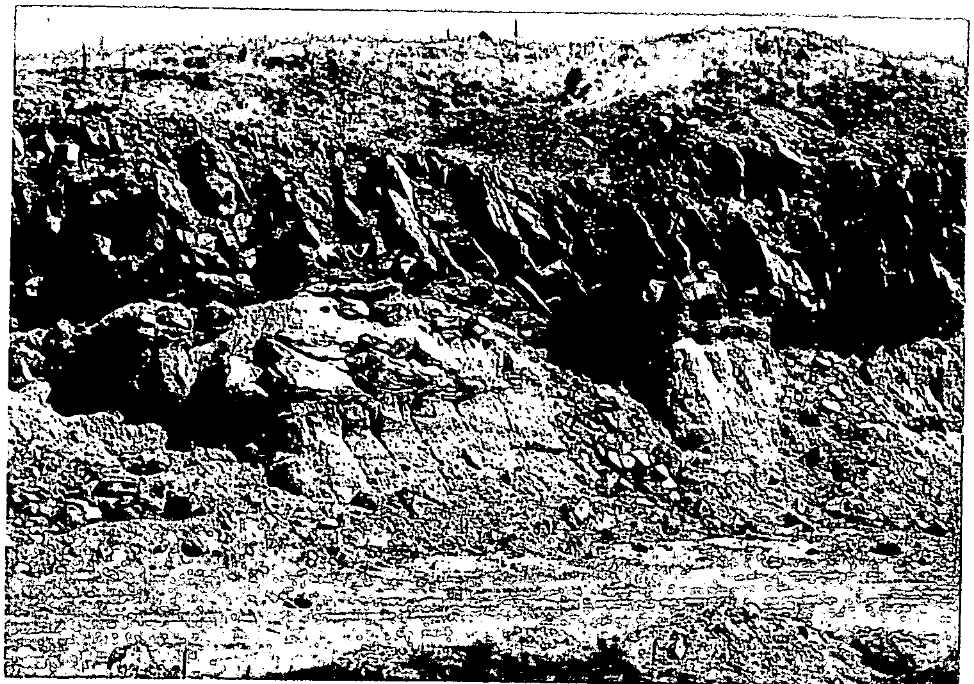


Figure 4-40. Lenticular Sandstone (Station 18-1, clay pit near RFP west gate). White sandstone lens, with sharp bounding surfaces in thick claystone sequence; overlain by thick, massive sandstone (brown).

Figure 4-41. Coarsening-Upward Sequence (Station 5-7, Pine Ridge). Fine-grained, ripple-laminated sandstones, siltstones, and claystones exhibit a general coarsening-upward.

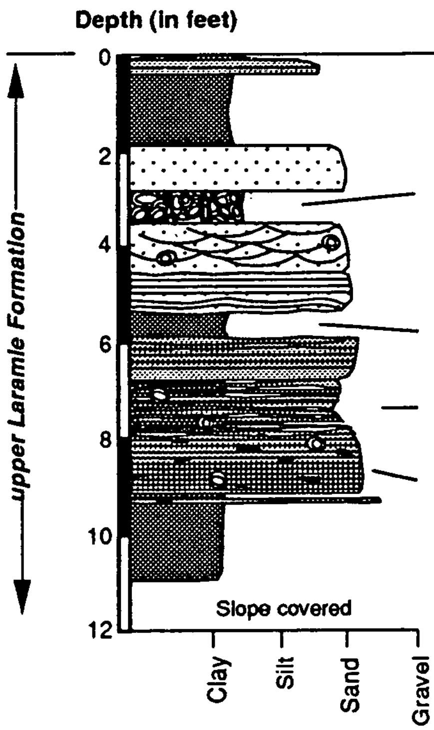
massive, more laterally continuous, thick sandstone units. One thick sandstone bed is present in each of the clay pit exposures and can be traced along strike for a total distance of more than 1 mile. Its thickness varies from 15 feet in the southern clay pit to 7.5 feet in the northernmost clay pit. Coal seams occur within the lower Laramie throughout the map area, from Leyden Gulch, where coal seams were measured up to 8 feet thick, to Pine Ridge in the Marshall area, where coal beds were measured at approximately 1 foot thick but range up to 10 feet thick in the subsurface (Spencer, 1961).

4.3.3 Upper Laramie Formation

Extremely limited exposure of the upper (top 300 to 500 feet) Laramie Formation within the map area restricts the number of locations suitable for measuring sections. Two sections from the upper 100 feet of the Laramie were measured along McCaslin Boulevard near the northeast boundary of RFP (Figures 4-42 and 4-43; location shown in Figure 1-2). In the field, the upper Laramie is distinguished from the lower Laramie by the predominance of fine-grained sediments. Upper Laramie vertical sequences also exhibit a much higher degree of cyclicity. In general, the upper Laramie is dominated by massive claystones interlayered with very fine to fine-grained, silty sandstones and siltstones. Sandstones in the upper Laramie Formation are concentrated within discontinuous, lenticular-shaped units that have sharp erosional lower bounding surfaces (Figure 4-44).

In the McCaslin Boulevard sections (Figures 4-42 and 4-43), the upper Laramie is composed of up to 50 percent sand-size sediment, found primarily within discrete lenticular units, and massive to laminated claystones. Sandstones fill lenticular channel forms with low-angle margins and limited lateral extent (50 to 100 feet). The sandstones exhibit a variety of sedimentary structures in a series of fining-upward sequences (Figure 4-45).

Figure 4-45 shows the outcrop appearance of the lower McCaslin Boulevard measured section (drawn in Figure 4-42). The photo shows a foreground sequence composed predominantly of very fine to fine-grained sandstone. These sediments lie within a channel form of limited lateral extent. The finer grained claystone section in the near background lies adjacent to the margin of that channel. The entire channel-fill sequence is less than 10 feet in thickness. Several small-scale fining-upward sequences



Lithologic Description	Sedimentary Structures
Light olive-gray, very fine-grained silty sandstone	Thin-bedded to laminated
Moderate to dark yellowish-brown claystone	Massive
Light olive-gray, very fine- to fine-grained, clean sandstone	Massive; extremely friable
Mrderate to grayish-brown ironstone	Concentric color banding
Light olive-gray, very fine- to fine-grained, calcite-cemented sandstone	Laminations and trough cross-bedding; platy breaking; contains scattered ironstone concretions
Light olive-gray, very fine- to fine-grained sandstone	Thin-bedded to laminated, with soft-sediment deformations, convoluted bedding, and load casts
Moderate yellowish-brown claystone	Sharp, wavy upper and lower bounding surfaces
Light olive-gray, very fine- to fine-grained sandstone	Planar bedding; slight upward coarsening, with thin, wavy clay laminae near top
Interbedded yellowish-gray, fine- to medium-grained sandstone and light olive-gray to moderate yellowish-brown claystone	Trough cross-bedding in thin, lenticular sands with scour bases; abundant organic material, ironstone concretions
Moderate to pale yellowish-brown, very fine-grained sandstone with some clay	Thin-bedded to laminated; irregular upper contact; abundant organic material, ironstone concretions
Olive-gray to moderate yellowish-brown claystone with yellowish-gray, medium-grained sandstone near top	Massive claystone; sand at top contains abundant pebble-sized fragments of organic material

LEGEND

- Sandstone
- Sandstone with organic material and coal
- Sandstone with ironstone concretions
- Silty sandstone
- Claystone
- Ironstone

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Figure 4-42

Lower McCaslin Boulevard Measured Section

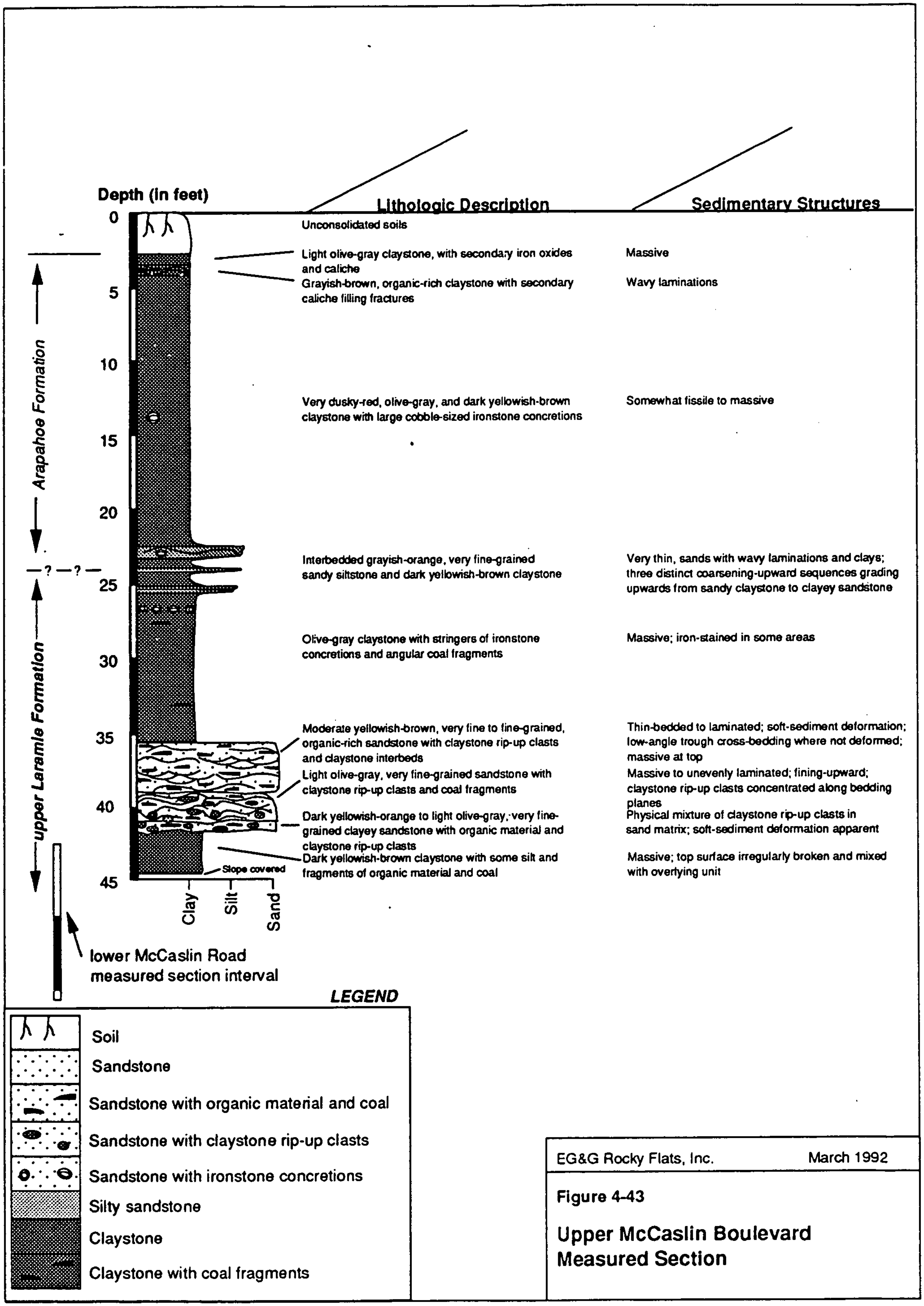

Figure 4-43

Upper McCaslin Boulevard Measured Section

Figure 4-44. Scoured Base (Upper McCaslin Boulevard measured section). Lens of trough cross-bedded sandstone at McCaslin Boulevard has downcut into underlying claystone. Erosional lower bounding surface is sharp.

Figure 4-45. Fining-Upward Sequences (Station 63, Lower McCaslin Boulevard measured section). Small-scale fining-upward sequences in upper Laramie Formation at lower McCaslin Road measured section location.

are present within the channel-fill sequence. Sandstones are coarsest at the base of the channel fill and contain abundant carbonaceous fragments (e.g., wood and leaves) and coarse sand to fine pebble size coal clasts. Coarse sandstone grades upward into thin-bedded to laminated, very fine grained sandstone. In a second fining-upward sequence (Figure 4-42, between 3.5 and 5.2 feet), thick planar-bedded sandstone grades upward into very thin to thin, trough cross-bedded, very fine to fine-grained sandstone. Original trough cross-bedding is deformed, but because bedding surfaces remain intact, the sandstone appears to have been deformed immediately after deposition but while the sediment was still soft. Thin-bedded sandstones in the upper Laramie Formation are often platy-breaking, calcite-cemented sandstones, as shown in Figure 4-46. At the lower McCaslin Boulevard section, the bottom bedding surface of a platy, planar-bedded sandstone shows elongate trace fossils. The presence of soft-sediment deformation in some sandstone beds and well-preserved trace fossils in others suggests that sand deposition was often rapid or episodic.

In the upper McCaslin Boulevard measured section, the base of a channel-fill sequence consists of a mixture of claystone rip-up clasts and organic fragments in a fine-grained clayey sandstone matrix (Figure 4-44). Fine organic material is concentrated along bedding surfaces within thin-bedded to laminated sandstones. Sandstones in this sequence are massive to unevenly laminated, commonly with deformed bedding surfaces or low-angle, channel-fill cross-bedding. Channel-fill cross-bedding can be locally common in fluvial sediments, especially in the areas of overbank flows and in levees of larger rivers (Reineck and Singh, 1975).

In both measured sections, coarse-grained sandstones occur only at the base of thicker fining-upward sequences. Finer grained sediments surround channel-fill deposits at both McCaslin Boulevard measured section locations. These sediments are predominantly composed of massive claystone, laminated silty and sandy claystones, and less common very fine to fine-grained sandstones with wavy laminations (Figure 4-43). Wavy-laminated sandstones are thin (less than 1 foot) and laterally discontinuous (extend less than 20 feet laterally). Dark gray, organic-rich claystones, generally less than 5 feet in thickness are also present in the upper Laramie Formation.

Near the top of the Laramie, deformation of bedding surfaces is common. Sediment deformation often occurs at the tops of wavy-laminated to trough cross-bedded clayey sandstone sequences. Oversteepened bedding, rotation of blocks along planar to concave-upward high-angle faults, and convolute-bedding structures (Figure 4-47) are

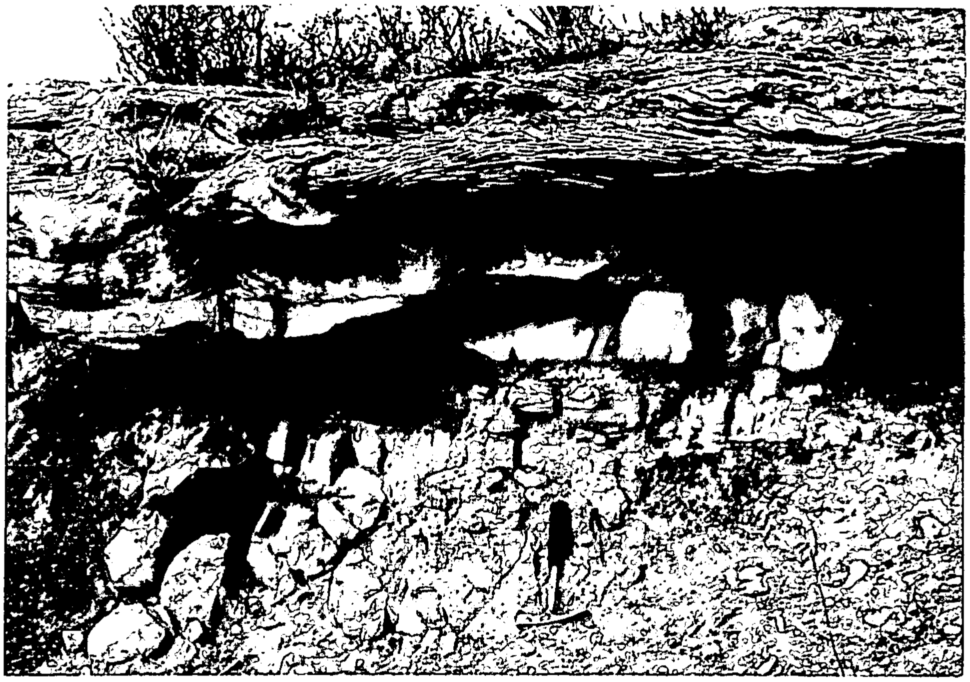

Figure 4-46. Planar Tangential Cross-Bedding (Station 222). Upper Laramie Formation fine-grained, calcium carbonate cemented sandstones.

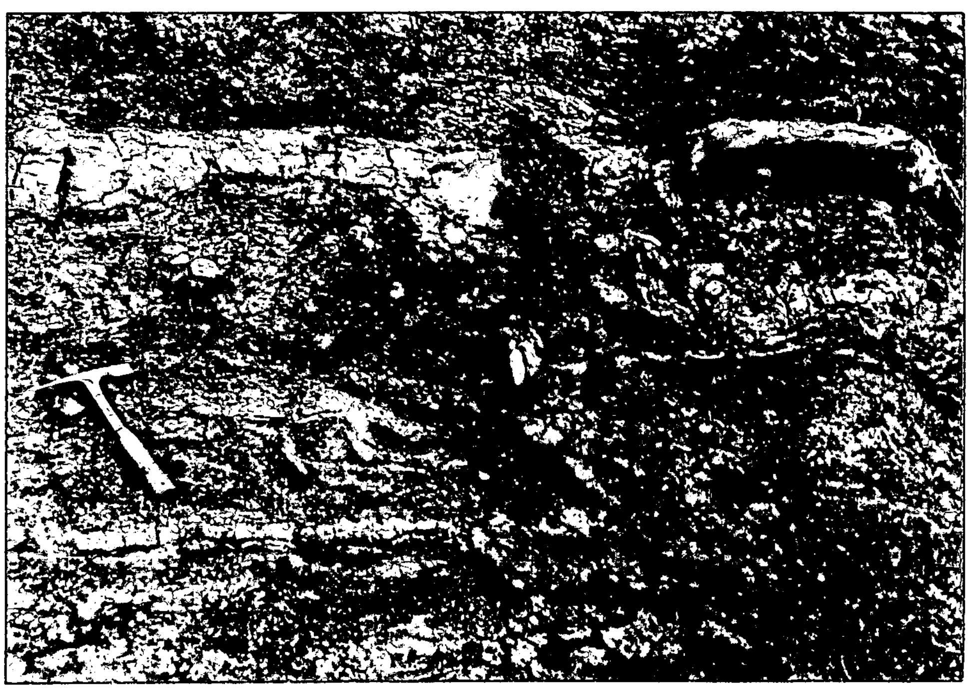

Figure 4-47. Convolute Bedding (Station 27-1). Highly deformed, convolute bedding within upper Laramie Formation fine-grained, silty sandstones and claystones.

present within sections of thin, interbedded claystones and sandy siltstones. Deformed or oversteepened bedding surfaces are truncated against overlying subhorizontal planar-bedded sandstones, resulting in angular unconformities along the base of planar-bedded sandstones (Figure 4-48). These sequences were observed at most locations where the upper Laramie was exposed beneath the Arapahoe Formation. Similar sequences are also present within the lower 50 feet of the Arapahoe along Community Ditch near Interlocken Business Park in Broomfield (Figure 4-49).

4.3.4 Arapahoe Formation

The best exposures of the Arapahoe Formation occur along the southern shore of Standley Lake, approximately 1.5 miles east of RFP (Station 33-1); along Indiana Street (Station 35-9) and Alkire Street (Station 32-9); and northeast of RFP along the north side of Highway 128 (Stations 28-3, 28-6, 28-9). These outcrops reveal medium- to coarse-grained sandstones interbedded with pebble conglomerates and conglomeratic sandstones (Figures 4-50 and 4-51). Lenticular bodies of medium-grained to conglomeratic sandstones lie within fine-grained silty claystones and claystones.

4.3.4.1 Description of Laramie-Arapahoe Contact

As discussed in Section 4.2.4, the Arapahoe Formation has been shown to consist of a diverse assemblage of conglomeratic sandstones, fine- to coarse-grained sandstones, and silty claystones and claystones. Conglomeratic sandstones and medium- to coarse-grained sandstones composed of well-rounded, frosted quartz grains have been shown to be compositionally and texturally distinct from upper Laramie Formation sandstones.

Several previous studies have identified conglomeratic sandstones at the base of the Arapahoe Formation and used these units to mark the formal stratigraphic boundary between the Laramie and Arapahoe Formations. Sandstone beds that are stratigraphically and lithologically equivalent to the conglomeratic sandstones described above (Section 4.2.4) mark the Laramie-Arapahoe contact in the Golden area (Van Horn, 1972; Weimer, 1976). Van Horn (1972) described the Arapahoe Formation within the Golden Quadrangle as composed of "light gray to brown quartzose sandstone and silty claystone; thick conglomerate locally at the base." Weimer (1976) provided a more detailed description of the Arapahoe Formation exposed in clay pits at CSM in Golden:

Figure 4-48. Syndepositional Deformation (Station 24-6, south of Leyden). Oversteepened bedding surfaces truncated by overlying subhorizontal sandstone bed; lens cap marks erosional base of sandstone bed.

Figure 4-49. Syndepositional Deformation in the Arapahoe Formation (Station 14-3, Community Ditch near Broomfield). Highly deformed, thin, interbedded siltstones and claystones underlying subhorizontal, platy sandstone within lower Arapahoe Formation.

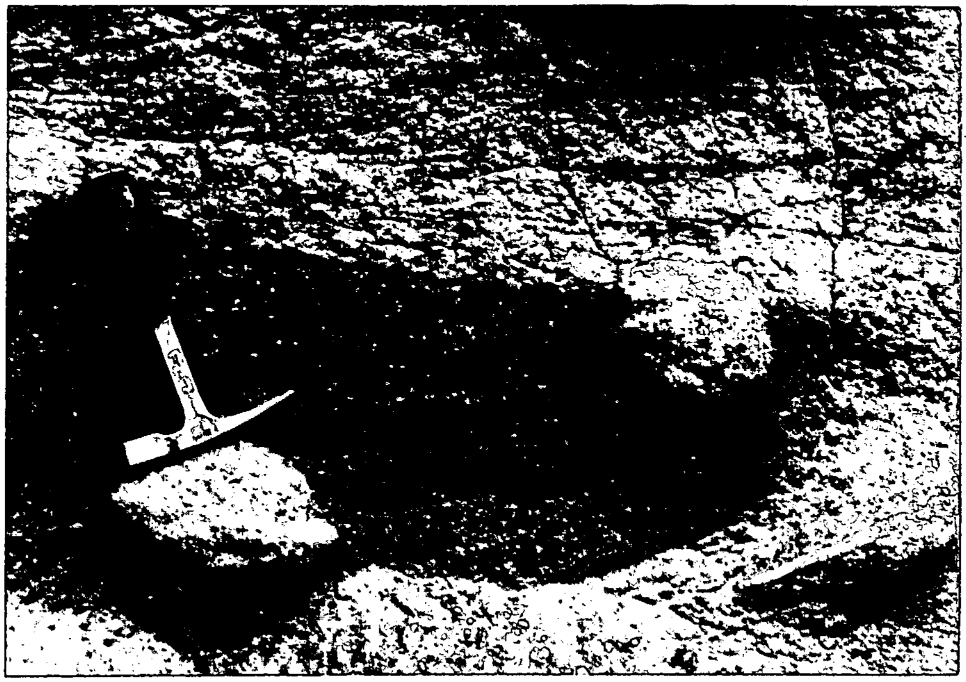

Figure 4-50. Cross-Bedded Conglomeratic Sandstone (Station 33-1, Standley Lake). Trough cross-bedded gravel at base of Arapahoe Formation well exposed at Standley Lake.

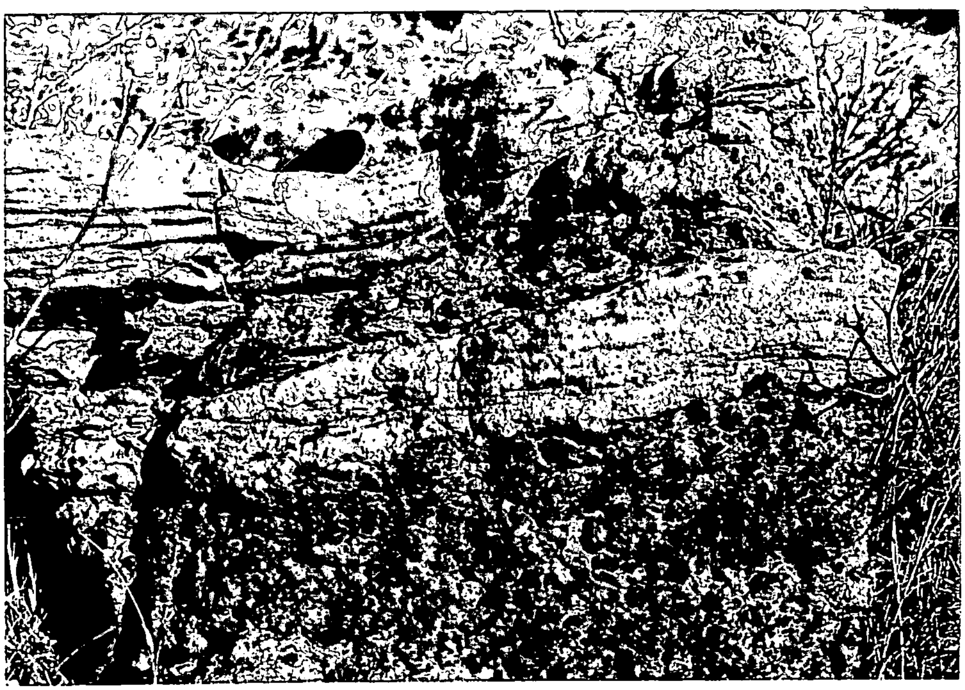

Figure 4-51. Arapahoe Formation Conglomeratic Sandstone and Medium- to Coarse-Grained Sandstone (Station 27-6). Alternating planar cross-bedded conglomerate and medium- to coarse-grained sandstone. Large pebbles in conglomerate are ironstone clasts in a sand matrix.

> The lower Arapahoe Formation is one of the most distinctive lithologic units in the area. Approximately 110 feet of the formation are exposed in the clay pits area. The lower 80 feet are composed dominantly of conglomerate and conglomeratic arkosic sandstone, with minor layers of gray claystone and siltstone....The conglomeratic sandstone rests on a sharp scour surface on the Laramie Formation.

Within the map area, including the RFP site, the base of the Arapahoe Formation is identifiable where the marker bed is exposed at the surface or is present in drill cores. Distinctive medium-grained to conglomeratic sandstones occurring at the base of the Arapahoe Formation have been used to demarcate the formal stratigraphic boundary between the Laramie and Arapahoe Formations. Discontinuous surface exposures of medium-grained to conglomeratic sandstones correlative to the Arapahoe marker bed were located at RFP (Stations 41-10, 42-3, 302, 316, 317, 318). Float occurrences of medium- to coarse-grained, frosted sandstone and conglomeratic sandstone occur in the RFP buffer zone in the southwestern portion of section 1, T2S, R70W (Stations 26-1, 26-3), section 2, T2S, R70W (Stations 37-3, 42-1, 42-3, 280), and section 14, T2S, R70W (Stations 41-4, 41-6, 41-10). Upon examination of cores from 63 boreholes and wells (see Appendix A), cores from 18 of the boreholes and wells were identified as containing the Arapahoe marker bed (medium- to coarse-grained frosted sandstones or conglomeratic sandstones; refer to Table 4-3 for compilation of cores). Lithologic criteria were used to correlate surface bedrock exposures to the subsurface stratigraphy and to mark the base of the Arapahoe Formation.

The Arapahoe Formation is stratigraphically and lithologically diverse on a regional scale, and the distribution of coarse sediments at the base of the Arapahoe Formation varies across the map area. For example, in the RFP vicinity, conglomeratic sandstones are sparse and occur only in thin beds within thicker sections of medium- to coarse-grained, frosted sandstone composed of well-rounded, frosted, quartz grains with chert, ironstone, and rock fragments (Figure 4-51). At locations within the map area where conglomeratic sandstones are not present, medium- to coarse-grained frosted sandstones commonly occur, and they mark the base of the Arapahoe Formation.

TABLE 4-3. Depth to the Base of the Arapahoe Formation at RFP

Borehole Number*	Depth to Base of Arapahoe	Elevation at Base of Arapahoe
0386	16'	5655'
6286	54'	5844'
BH0987	31.5'	5935'
1487BR	24'	5831'
2387BR	29'	5943'
2587BR	42'	5817'
3187BR	128'	5817'
3687BR	45'	5904'
P209189	26.3'	5954'
P209389	28.2'	5953'
P209489	35.6'	5945'
B315289	40'	5923'
P416289	38'	6001'
B217089	33'	5877'
B217289	23'	5655'
B217489	54'	5907'
B217689	45'	5916'

Outcrop Station Number	Elevation at Base of Arapahoe
35-9	5640'
41-10	5990'
42-3	5915'
44-1	5630'
280	5860' (float)
302	5920'
316	5810'
317	5810'
318	5800'

*Boreholes given as new number, see Appendix A-4 for old number

The Arapahoe marker bed can be laterally persistent. North of Highway 128, less than 1 mile northeast of RFP, medium- to coarse-grained, frosted sandstone can be traced (using discontinuous exposures and float on colluvial slopes) for more than 1 mile in the apparent dip direction (east) toward Community Ditch in Broomfield (Plate I). In other parts of the study area, the medium- to coarse-grained frosted sandstones and conglomerates are not as laterally extensive. In the northeast corner of the RFP buffer zone, medium- to coarse-grained, frosted quartzose sandstone outcrops and float can be traced on hillslopes north of Walnut Creek for approximately 0.5 mile from east to west (refer to Plate I for outcrop locations in the northeast quadrant of the RFP buffer zone). Further west however, along Rock Creek, exposures and float occurrences of Arapahoe marker sandstones are much less frequent, and drill cores (Nos. B203189, B203289, B203589, B203989) show that the marker bed is often absent from the vertical section. In areas of very poor bedrock exposure or limited lateral persistence of the distinctive marker bed, such as the south side of Rock Creek (Stations 17-6 and 37-3), the contact between the Laramie and Arapahoe Formations has been approximately located by projecting the contact surface from adjacent outcrops or from nearby drill cores.

The Arapahoe conglomeratic sandstones and medium- to coarse-grained, frosted sandstones described above generally occur within lenticular units (see Section 4.3.4.2 below for sequence descriptions) at the base of the formation. However, in some areas, multiple occurrences of the marker bed are present within a single vertical section. At Standley Lake (Station 33-1), conglomeratic sequences occur at two distinct elevations, but they are separated by less than 20 vertical feet. North of Highway 128, near Broomfield (Stations 28-3, 28-6, 28-9), conglomeratic sandstones are present at more than one elevation over a vertical distance of approximately 50 feet. However, there are no known locations west of Indiana Street where distinctive Arapahoe sandstone occurs at more than one stratigraphic level within a single vertical section, and none of the RFP cores contained multiple occurrences of distinctive medium-grained to conglomeratic, frosted sandstones.

The schematic diagram in Figure 4-52 shows the Laramie-Arapahoe contact and depicts how that contact surface is defined. The base of the Arapahoe Formation is defined as the lowest occurrence of lithologically distinct, medium- to coarse-grained, well-rounded, frosted sandstone or conglomeratic sandstone within a continuous vertical section. Where the marker bed is not present at any level within the vertical sequence, no lithologic break defines that contact and the contact surface, as shown on the

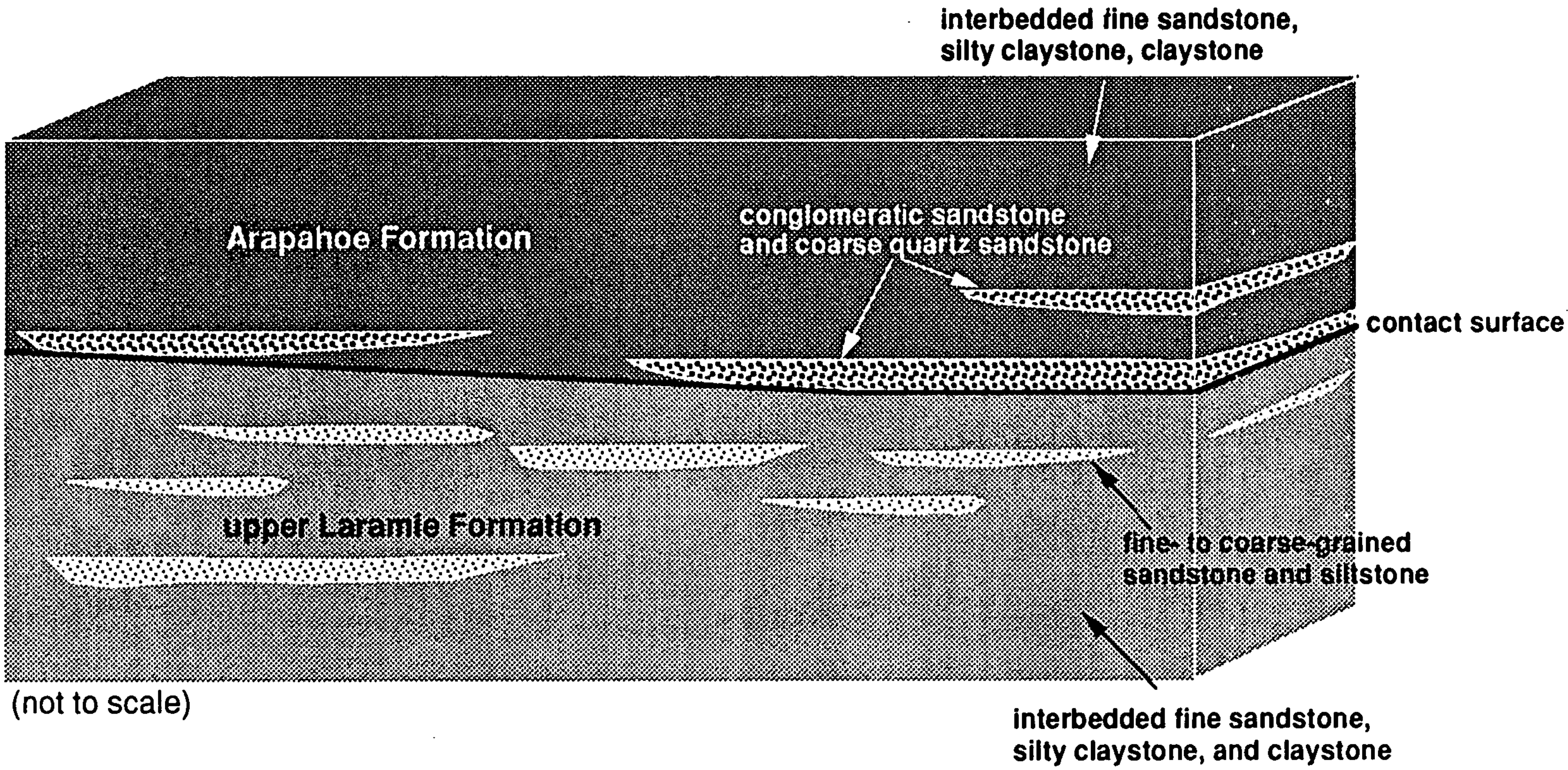

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Figure 4-52

Schematic Block Diagram Showing Laramie-Arapahoe Formation Contact Surface geologic map (Plate I), is projected from the nearest surface exposures of the Arapahoe marker bed.

As shown on Plate I, the areal extent of the Arapahoe Formation varies from south to north across the map area. In the southern portion of the map area, near Leyden Gulch (Station 36-5), the Arapahoe Formation is present immediately east of the prominant hogback formed by resistant sandstones in the lower Laramie Formation. In the northern portion of the map area, due west of RFP, the base of the Arapahoe Formation lies further east of the resistant lower Laramie hogbacks. The base of the Arapahoe Formation lies at a higher elevation to the north of RFP than to the south and as a result, erosion of the bedrock surface has removed a larger proportion of the bedrock section in the northern portion of the map area. The western extent of the Arapahoe Formation is controlled by relative depth of bedrock erosion. The western edge extends from the Leyden Gulch area (Station 36-5) northeast toward RFP, where the Laramie-Arapahoe contact lies immediately east of the West Spray Field (at 6001 feet in core P416289). The contact trace trends northeast toward Rock Creek (Station 37-3) and finally east to Broomfield (Stations 14-3, 29-2, 29-14). The northern extent of the Arapahoe Formation lies approximately 1/2 mile north of Highway 128, due north of RFP. This contact differs slightly from the contact surface shown by Hurr (1976). On that geologic map, the Laramie-Arapahoe contact trace trends north-south through the West Spray Field, and the contact surface occurs at a lower elevation.

Preliminary efforts at RFP to correlate onsite stratigraphy with stratigraphic sections located offsite relied primarily on geophysical logs from two offsite wells located 2 to 7 miles southeast of RFP, not on lithologic criteria. In the Geologic Characterization Report (EG&G, 1991d), the base of the Arapahoe Formation was defined on the basis of such correlations and five mappable sandstone intervals (Numbers 1, 2, 3, 4 and 5 sandstones) within the Arapahoe Formation were described. The sandstone intervals were defined on the basis of their depth within the stratigraphic sequence and correlated across plant site using drill cores and elevation criteria. The report states that coarse-grained and conglomeratic sandstones are present in cores from RFP. However, the core locations and depth intervals containing these types of deposits are not emphasized.

Stratigraphic and nomenclature discrepancies between the Geologic Characterization Report (EG&G, 1991d) and this report result from using distinctly different methods for correlation of the site stratigraphy to well-described offsite stratigraphic sequences.

Previous nomenclature (EG&G, 1991d) of sandstone intervals is based solely on the depth within the stratigraphic section at which the sandstones occur, whereas in this report, assignment of a formation name to sandstones is based on lithologic criteria. Figure 4-53 shows the most current conceptual model for the bedrock stratigraphy at RFP (from the Groundwater Monitoring and Protection Program Plan; EG&G, 1991e) compared with a stratigraphic section resulting from this study. The previous stratigraphic column shows the base of the Arapahoe Formation immediately underlying the Number 5 sandstone, at a depth of 150 feet below the central portion of the plant. During surface geologic mapping conducted for this investigation (Phase II Geologic Characterization Data Acquisition), the five sandstone intervals described previously were not correlated with surface exposures because of the very limited bedrock exposure in the plant area and immediate vicinity. However, using both available surface exposures and select drill cores to make lithologic correlations, the Arapahoe marker bed was mapped across RFP.

The contact surface shown on Plate I lies at the same elevation shown by Van Horn's (1972) geologic map of the Golden Quadrangle. However, that contact does not extend as far to the west and does not occur at the same elevation as the Laramie-Arapahoe contact described in the Geologic Characterization Report (EG&G, 1991d). In the western portion of the plant site, near the inner west gate, the Arapahoe marker bed lies at the same elevation as the Number 1 sandstone (6001 feet in core P416289) and is present below gravel deposits of the Rocky Flats Alluvium only as far as the east margin of the West Spray Field. In the central portion of RFP (Figure 4-53), the Arapahoe marker bed also lies at the same elevation as the Number 1 sandstone interval (at an elevation of 5935 to 5955 feet in cores BH0987, 1087BR, 2387BR, P209389, P209489, P210189) instead of the Number 5 sandstone (at an elevation of 5840 feet) as previously reported. In the eastern portion of the plant site, the base of the Arapahoe Formation lies at an elevation of 5820 feet in OU 2 near the inner east gate (cores 3187BR and 1487BR) and at 5655 feet near Indiana Street (cores 0386 and B217289). In these boreholes, the Arapahoe marker bed lies at the same elevation as the Number 3 sandstone interval.

4.3.4.2 Vertical Sequence of the Arapahoe Formation

Within the map area, the thickest sections of medium- to coarse-grained, frosted sandstones and conglomerates, defined as the Arapahoe marker bed, are generally confined to discontinuous, broad, lenticular units that cut into the underlying

Age	Formation	Thickness (feet)	Thickness (feet)	Formation	Summary Description
Quaternary	Rocky Flats Alluvium	0-100	10-20	Rocky Flats Alluvium	Clayey Sandy Gravels - reddish brown to yellowish brown matrix, grayish-orange to dark gray, poorly sorted, angular to subrounded, cobbles, coarse gravels, coarse sands and gravelly clays: varying amounts of caliche
Cretaceous	Arapahoe Formation	150	15-25	Arapahoe Fm.	Claystones, Silty Claystones, and Sandstone- light to medium olive-gray with some dark olive-black claystone and silty claystone weathers yellowish orange to yellowish brown; a mappable, light to olive gray, medium- to coarse-grained, frosted sandstone to conglomeratic sandstone occurs locally at the base (Arapahoe marker bed)
Cretaceous	Laramie Formation	800 upper interval: 500 lower interval: 300	600-800 upper interval: 300-500 lower interval: 300	Laramie Formation	Claystones, Silty Claystones, Clayey Sandstones, and Sandstones - kaolinitic, light to medium gray claystone and silty claystone and some dark gray to black carbonaceous claystone, thin (2') coal beds and thin discontinuous, very fine to medium-grained, moderatey sorted sandstone intervals Claystones, Sandstones, and Coals - light to medium gray, fine- to coarse-grained, poorly to moderately sorted, silty, immature quartzitic sandstone with numerous lenticular, sub-bituminous coal beds and seams that range from 2' to 8' thick
Cretaceous	Fox Hills Sandstone	75-125	90-140	Fox Hills Sandstone	Sandstones - grayish orange to light gray, calcareous, fine-grained, subrounded, glauconitic, friable sandstone
Cretaceous	Pierre Shale and older units			Pierre Shale and older units	

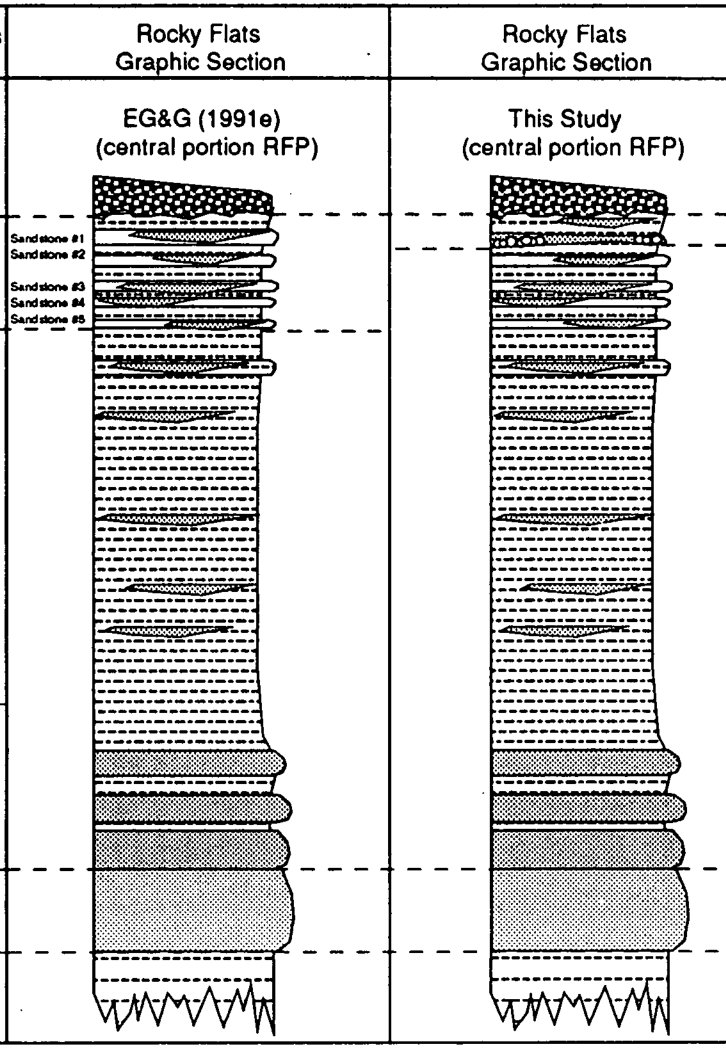

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Figure 4-53

Revised Stratigraphic Nomenclature for the Central Portion of Rocky Flats Plant: Laramie-Arapahoe Formation Contact interbedded silty sandstones and claystones of the upper Laramie Formation (Station 276, Indiana Street road cut; Station 256, Standley Lake). The remaining portion of the Arapahoe Formation is predominantly composed of fine-grained, silty sandstones interbedded with claystones and siltstones. Outcrops of the fine-grained, less-resistant component of the Arapahoe Formation occur less frequently than the coarse-grained sandstones and conglomeratic sandstones (Station 25-7, Highway 128; Stations 26-5, 26-8, Indiana Street).

Vertical exposures of the Arapahoe Formation at Standley Lake (greater than 40 feet of vertical exposure; Station 33-1), Indiana Street (11-foot vertical exposure, Station 276), and Alkire Street (15-foot vertical exposure; Station 32-9) all exhibit shallow channel forms containing conglomerates and medium- to coarse-grained sandstones. Vertical sequences within these channel-fill deposits are poorly developed, but the proportion of conglomeratic beds generally decreases upsection. Vertical sequences show no cyclicity and are characterized by numerous local, flat scour surfaces; discontinuous lag deposits; large entrained claystone blocks; and trough cross-bedded conglomerates and sandstones (Figures 4-3 and 4-53). Conglomeratic sandstone units range in thickness from 0.25 foot to more than 4 feet, and they are poorly sorted and composed of variably coarse beds of mixed coarse- to fine-grained pebbles, coarse- to medium-grained sand, and some fine-grained cobbles. No fining-upward or coarsening-upward grading is evident at this scale. Thin, impersistent claystone beds with deformed to convolute bedding surfaces are present within the conglomerates. The upper part of a conglomeratic sandstone unit is often scoured away, resulting in a lenticular shape. Within individual conglomeratic units, the sediments are trough cross bedded. Cross sets range from 0.25 foot to 2 feet in height. On a larger scale, conglomeratic sandstones and coarse sandstones fill channel forms in low-angle, planar cross sets that range up to 4 feet high. Coarse- to medium-grained sandstones showing either low-amplitude (less than 3 inches) undulatory or symmetric current ripples are also present at the top of complex conglomeratic sequences northeast of RFP (Station 14-3, Figure 4-54).

The coarse-grained sandstones and conglomerates described above fill channel forms that lie within thick, massive claystones containing thin, discontinuous silty sandstone lenses. Thick channel-fill sequences contain large entrained claystone blocks as much as 2.5 feet in diameter. Bedding surfaces beneath and adjacent to these claystone blocks are usually deformed or oversteepened where they wrap around the claystone blocks. These entrained blocks are derived from the claystones adjacent to the margins

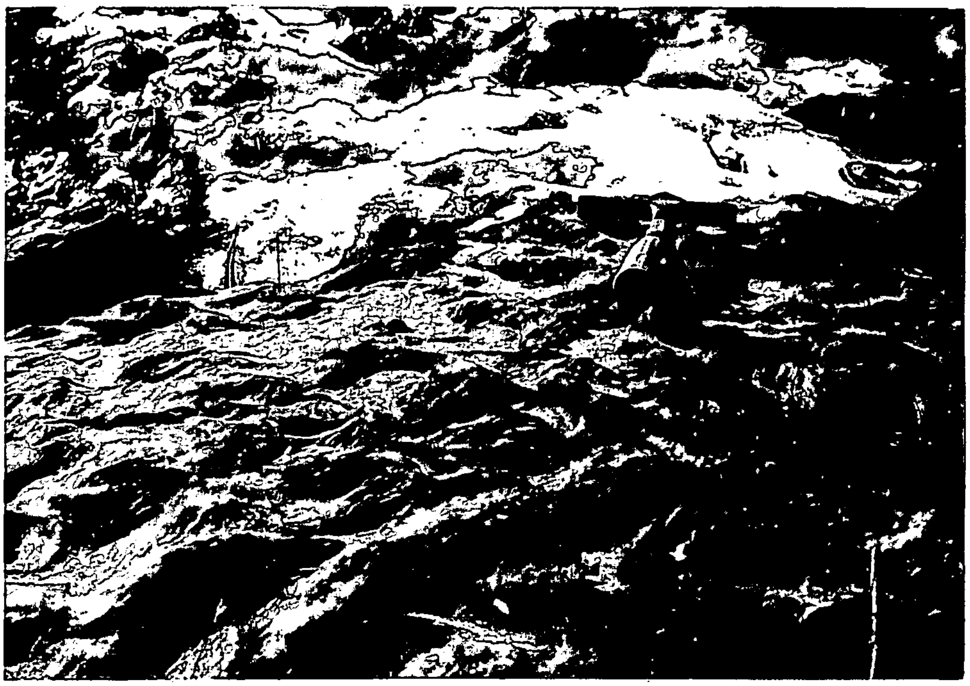


Figure 4-54. Multidirectional Ripples (Station 14-3, Community Ditch near Broomfield). Rippled top of medium- to coarse-grained sandstone bed within Arapahoe Formation at Community Ditch near Interlocken Business Park. Multidirectional ripples are 2 inches high.

of large-scale channel forms (such as those exposed at Standley Lake and Alkire Street), demonstrating that the coarsest components of the Arapahoe Formation lie on scour surfaces that erode the underlying upper Laramie sediments. The abundance of large, entrained claystone blocks, deformed bedding surfaces, and massive to cross-stratified conglomerates suggests that sediment was deposited rapidly and that flow velocities varied frequently.

The fine-grained components of the upper Laramie and Arapahoe Formations are indistinguishable in the field. Both are composed of massive to laminated claystones, silty claystones, and thin, fine-grained sandstones. Both are composed, in part, of shallow lens-shaped channel forms containing coarser sediments (as described for the upper Laramie Formation, Section 4.2.3). Conglomeratic lenses are more than 20 feet in thickness at Standley Lake, whereas pebble conglomerates in surface outcrops at RFP are not more than 3 feet in thickness. The thickest sections of coarse-grained sandstone are found in the southeastern portion of the map area. Coarse-grained sandstones and conglomerates north of RFP are at most 5 feet in thickness. Conglomerates at the base of the Arapahoe Formation become finer grained from south to north, suggesting that higher energy sedimentary environments were present in the southern portion of the map area than in the immediate RFP vicinity. Lewis et al. (1990) suggested that sinuous, anastomosing channel deposits are present in the Arapahoe Formation underlying RFP, whereas braided channel deposits mark the base of the Arapahoe Formation elsewhere.

5.0 STRUCTURAL GEOLOGY

The regional structural geologic setting was briefly summarized in Section 2.0. In this section, the findings of this study and several possible interpretations based on those findings are presented. These interpretations are compatible with the mapped surface geologic features and limited subsurface data in the context of the current regional structural model. Refinement of the structural geologic model for RFP will be possible after completion of the other elements of the Phase II Geologic Characterization Data Acquisition, particularly the deep and shallow seismic reflection studies and the borehole drilling program.

Exposures of the various structural features are limited within the map area. In some areas, the attitude of bedding was estimated using topographic control based on the location and elevation of marker beds. Some subsurface drill core and shallow seismic reflection data were used to supplement surface data. Collection of structural data was difficult near the town of Marshall because the ground surface has subsided over abandoned coal mines. Where mine subsidence had occurred, the orientation of bedding surfaces could not be measured because large blocks exposed at the surface had been rotated by mine collapse in the subsurface. In these areas, no bedding attitudes have been reported, and less information is available to describe nearby faults and folds.

Given the poor exposure of structures within the field area, vertical displacement related to faults was most often inferred from stratigraphic relationships. The following specific field criteria were established for designation of fault traces on the geologic map:

1. A fault contact between distinct rock units is observed.
2. Missing or repeated sections are observed in outcrop exposures.
3. An abrupt break in bedding attitude is present.
4. A lithologically distinct unit is vertically displaced relative to other units within the stratigraphic section.

These criteria are consistent with the identification of faults as outlined in Compton (1962, p. 67). Faults identified on the basis of any of the first three criteria are shown on the geologic map and cross-sections as solid or dashed lines, depending on the quality of exposure and control of location of the fault trace at the surface (Compton, 1962). Faults identified on the basis of the last criteria alone are described as "uncertain faults" (Wise et al., 1984) and are shown in Figures 5-17 and 5-18. The data obtained from surface mapping are not sufficient to confirm the presence of these fault structures.

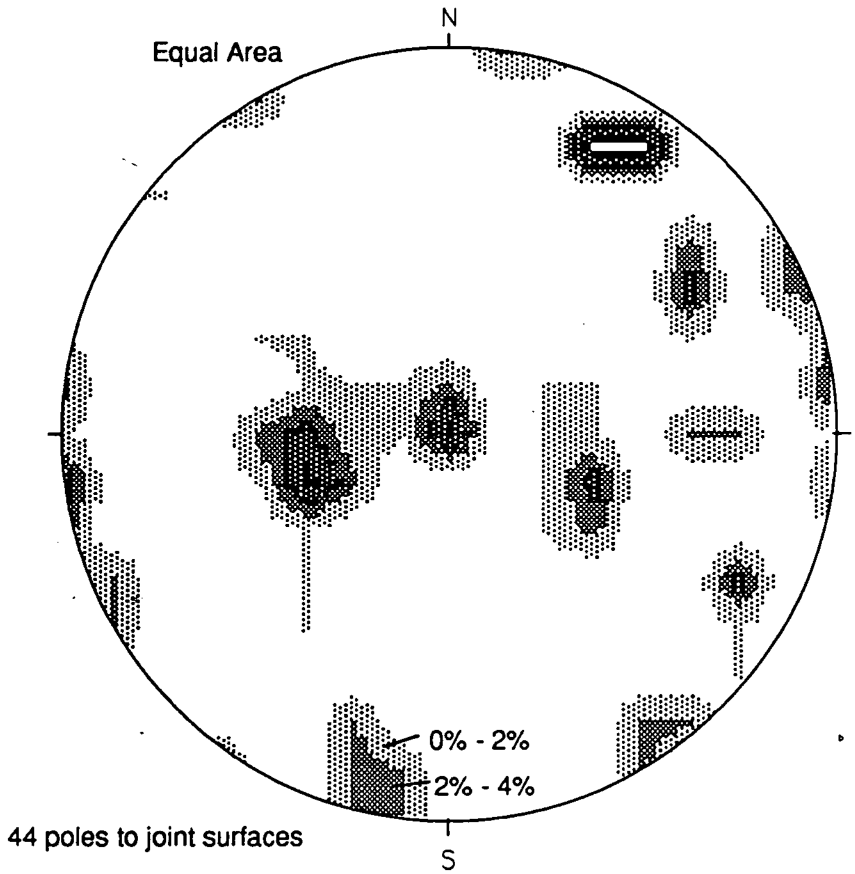
5.1 FOLDS

Steeply dipping Fox Hills and Laramie sandstones form a prominent hogback that strikes north-northwest across the map area from Leyden Gulch to Community Ditch near Marshall. Based on field data, it has been interpreted that upper Cretaceous strata on the west margin of the Denver Basin are folded into an asymmetrical, north-south-trending syncline with a steeply dipping to overturned western limb and a shallowly dipping eastern limb (Figure 5-1, Cross-section A-A'). The Geologic Characterization Report (EG&G, 1990b) and later shallow seismic reflection data (EG&G, 1991a, 1991b) support this subsurface configuration. However, the dip on the eastern limb, estimated with surface data, is 1 to 2 degrees east, whereas the apparent dip seen on seismic profiles is slightly higher at 2 to 3 degrees east. Deep seismic data may better constrain this feature.

Smaller scale folds are associated with some of the faults in the Marshall area (Figure 5-2, cross-section B-B'). Folded strata between steeply dipping faults appear to be genetically related to fault deformation. The western limb of a synclinal structure between the northern extensions of the Lake Mesa and South Gorham Faults steepens against the South Gorham Fault (Figure 5-2). Other steep fold limbs between the Pittsburg and South Gorham Faults and adjacent to the Peerless Fault also appear to be related to drag along adjacent fault surfaces. In general, however, folds in the area near Marshall are broad features with low-angle limbs.

5.2 JOINTS, FRACTURES, AND SLICKENSLIDES

Joints develop in rocks that have undergone dilation, distortion, or both (Davis, 1984). Bedrock exposures cut by planar joint sets are common in some parts of the map area. Figure 5-3 shows well-developed joint sets in the upper part of the Fox Hills Sandstone where Community Ditch crosses Highway 93 (Station 23). Orientations of systematic and nonsystematic joints were measured in an attempt to characterize the regional



Equal area plot of all poles to joint surface planes

Contours in 2% intervals of total data points
per 1% area of net

EG&G Rocky Flats, Inc. March 1992

Figure 5-4

Pole Density Diagram Showing the Orientations of Joints

tectonic stress field. Figure 5-4 is a pole density diagram showing the orientations of all joint measurements recorded in the map area. Orientations are diffuse, and no preferred joint-set orientation pattern was apparent. A comprehensive and systematic joint measurement and compilation program was not within the scope of this task.

In the buffer zone northeast of RFP and in the Protected Area, Arapahoe Formation sandstones are cut by fractures that exhibit cataclastic textures (Samples KT11-E to KT15-E; Stations 310, 316; and along the eastern boundary of the Protected Area). Small-scale bedding offset was also observed along these fractures. In addition, polished slickensides are present on fracture surfaces that cut through bedrock at a low angle to bedding (Station 317). Thin sections of the fractures revealed the presence of microbreccias (Figure 5-5) and rehealed cataclastic textures with 1- to 2-mm-thick fracture zones. Within the microbreccias, fractured quartz grains are often rotated or sheared. Similar cataclastic textures were observed in Arapahoe Formation sandstones along Rock Creek (Figure 5-6, Station 280) and in a road cut on Indiana Street (Figure 5-7, Station 276). Cataclasis was also observed in an area west of Highway 93 near Marshall (Station 86). Figures 5-8 and 5-9 show silicified fault breccia in a lower Laramie sandstone from this area. Fracturing is extensive, and the rock in the lower photograph exhibits a cataclastic texture within the fracture zone. Because cataclasites are associated with high rates of strain, this type of structural deformation is thought to be tectonic in origin (Higgins, 1971). In this area, fractured and silicified sandstones occur proximal to known faults such as the South Fox and High View Faults.

Sandstone beds of the lower Laramie Formation are fractured, silicified, and brecciated within fracture zones along a continuous north-south-trending hogback and are locally overturned near Leyden Gulch. Gude and McKeown (1952) showed a north-south-trending, high-angle (85 degree) reverse fault parallel to Leyden Ridge in the lower Laramie Formation. Silicification is present in sandstones along this hogback and may be a manifestation of quartz recrystallization or hydrothermal alteration related to faulting. It is possible fault structures along Leyden Ridge are splays of the Golden Fault.

Slickensides are common on the many fracture surfaces that cut through lower Laramie sandstones at Leyden Gulch, the D&RGW Railroad cut, and the clay pits west of RFP. Almost all slickensides trend parallel to the dip of the joint or fracture surface, which suggests that little strike-slip motion was associated with deformation. Slickenside

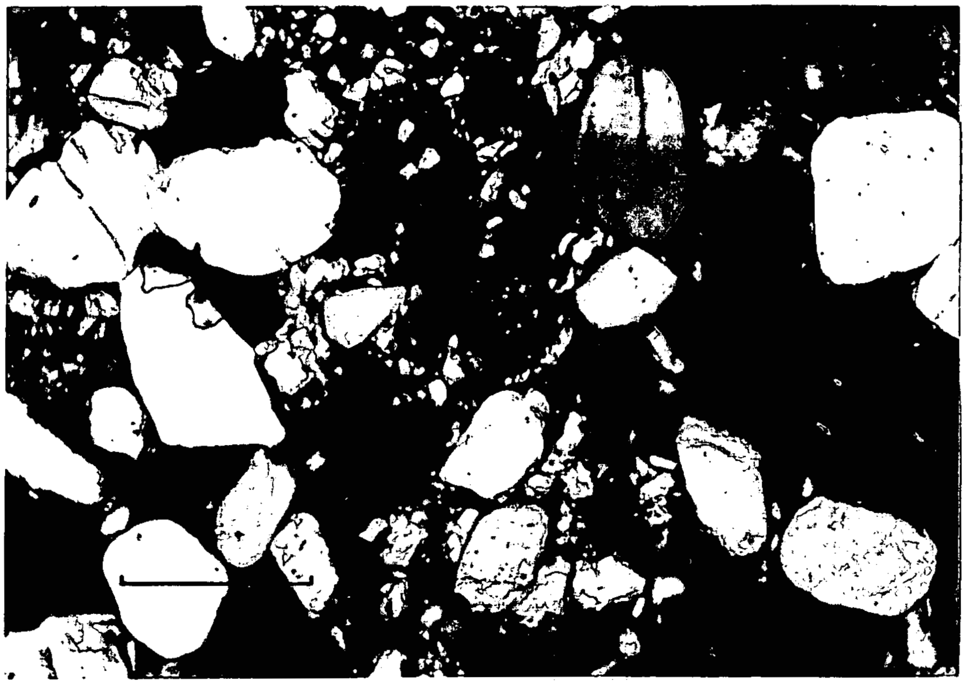


Figure 5-5(a). Photomicrograph Showing Cataclastic Texture in Arapahoe Sandstone (Station 316, Walnut Creek area). Tectonically shattered quartz grains are cemented with recrystallized silica within a microbrecciated zone between fracture surfaces. Crossed Nicols. Magnification equals 50X. Scale bar is 400 micrometers.

Figure 5-5(b). Same as above. Plane polarized light. Magnification equals 50X. Scale bar is 400 micrometers.

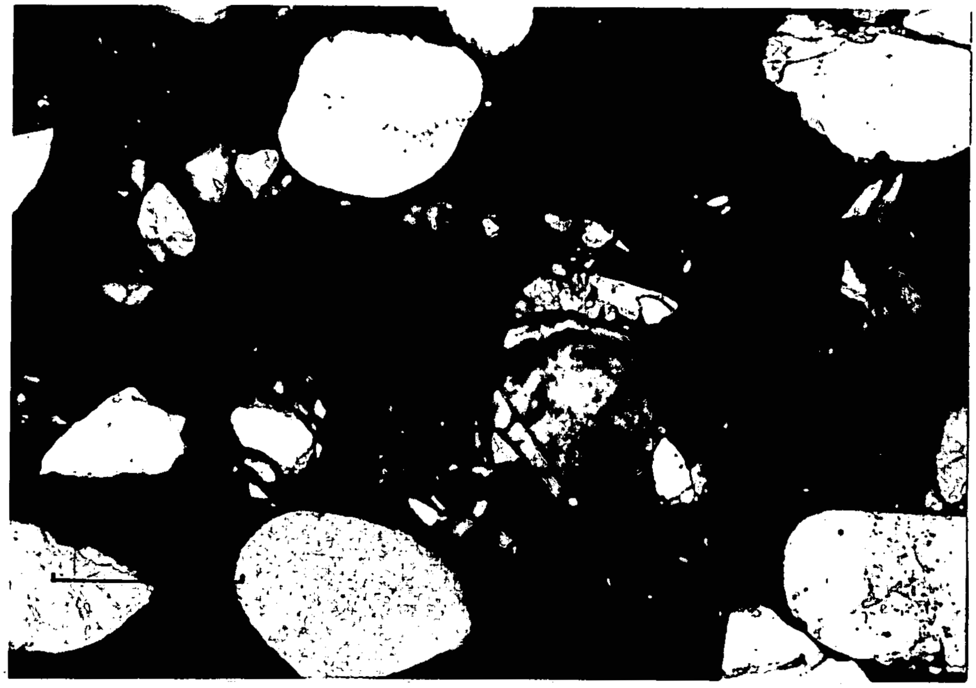


Figure 5-6(a). Photomicrograph Showing Fractured and Microbrecciated Sandstone (Station 280, Rock Creek in buffer zone). Sand grains within the basal Arapahoe are tectonically shattered. Note reddish brown siderite cement. Crossed Nicols. Magnification equals 50X. Scale bar is 400 micrometers.

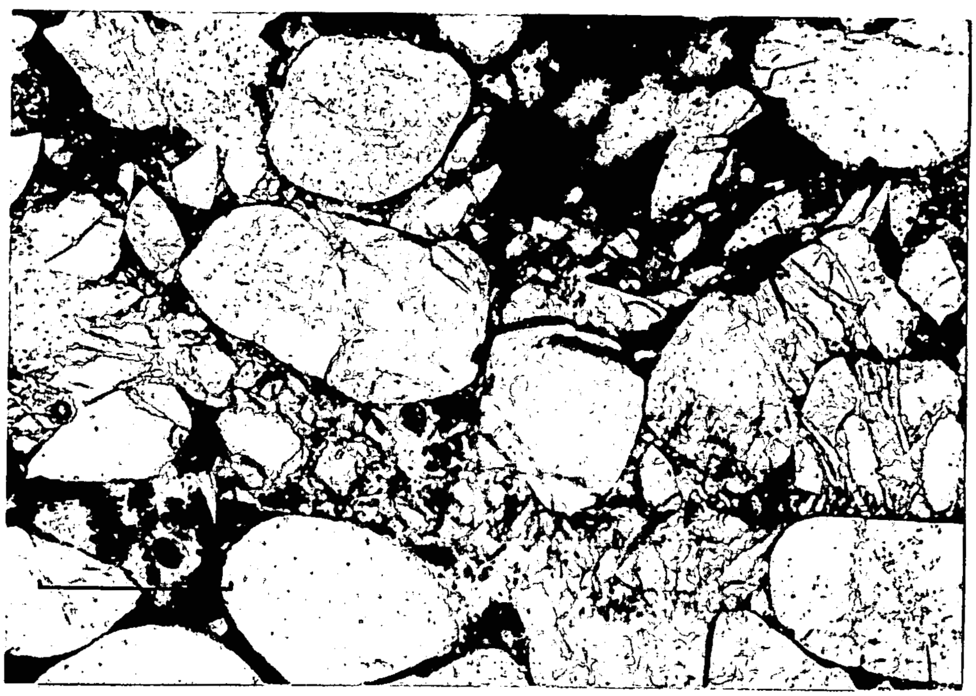


Figure 5-6(b). Same as above. Plane polarized light. Magnification equals 50X. Scale bar is 400 micrometers.

Figure 5-7(a). Photomicrograph Showing Shattered Quartz Grains (Station 276, Indiana Street road cut). Microbrecciated quartz sandstone from the basal Arapahoe Formation. Crossed Nicols. Magnification equals 50X. Scale bar is 400 micrometers.

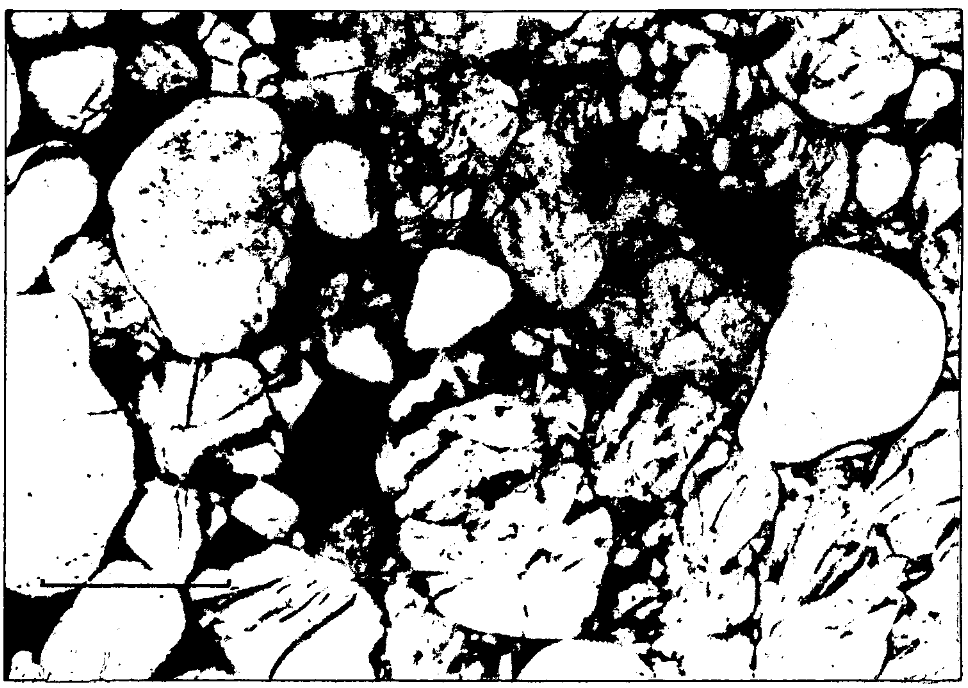


Figure 5-7(b). Same as above. Plane polarized light. Magnification equals 50X. Scale bar is 400 micrometers.

Figure 5-8. Silicified Fault Breccia in a Lower Laramie Sandstone (Station 86, Highway 93 south of Boulder). Sandstones near the South Fox Fault exhibit pervasive fracturing and silicification.

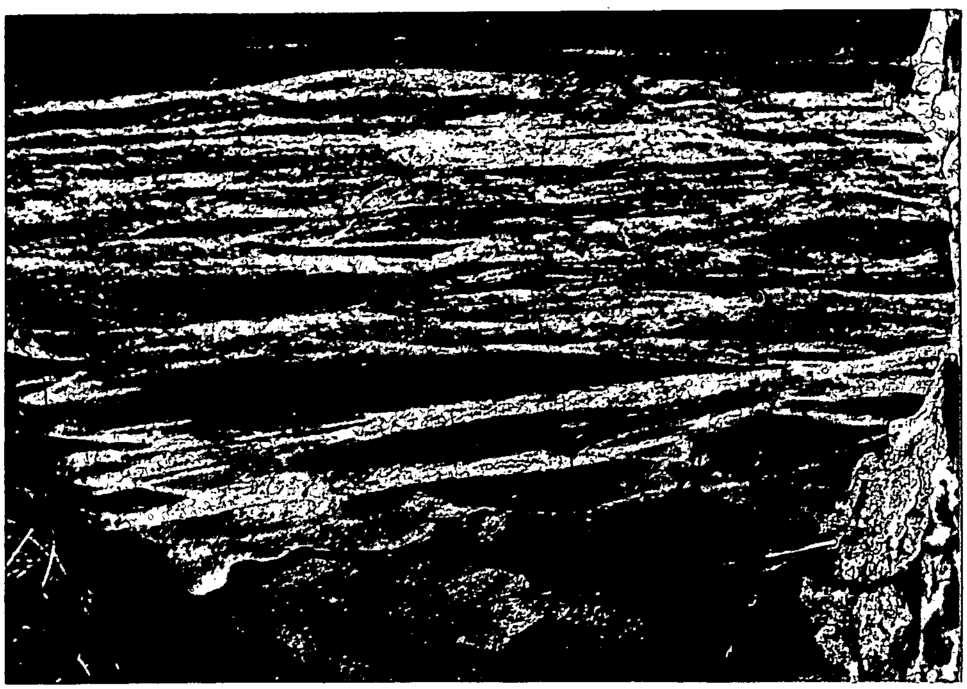


Figure 5-9. Cataclastic Texture (Station 86, Highway 93 south of Boulder). Extensive fracturing has resulted in a cataclastic texture in this lower Laramie sandstone.

orientations on fault surfaces were measured to determine fault motion. Figure 5-10 shows slickensides developed on a fracture surface in the Fox Hills Sandstone near the North Gorham Fault (Station 11). Figure 5-11 shows a joint surface in the lower Laramie Formation along the D&RGW Railroad cut (Station 158), with well-developed slickensides and readily apparent offset.

5.3 FAULTS

A major component of the surface geologic mapping program was to examine previously identified faults described in the literature and, from the field relationships, fully characterize them in terms of fault type and amount of displacement. Faults in and near the Precambrian basement along the Front Range are shown on the accompanying geologic map (Plate I); however, these faults were not examined in sufficient detail to allow for full characterization and are not discussed further. Some previously mapped faults, such as the East Matchless Fault near Superior (Spencer, 1961), were not included on the map because there was not sufficient evidence at the surface to indicate the presence of a fault. The North Lake Mesa Fault (Spencer, 1961) is not included on the map because subsurface data from the BFI-Marshall Landfill (Fox Consultants, 1983, 1984) suggested that the Fox Hills-Laramie contact along this inferred fault trace is depositional rather than structural. All other faults shown by Spencer (1961) within the map area were identified and described in the field. These faults and some additional structures are shown on the geologic map (Plate I) and are discussed below.

5.3.1 Characterization of Previously Identified Faults

The field evidence for faults is summarized in the following section. All of the fault traces shown on previous geologic maps were investigated in the field. Where evidence of movement along fault surfaces was present, the attitude of the fault plane was measured and the type of fault and sense of movement were determined. Fault planes were traced along strike to determine the areal extent of associated displacement.

Eggleston Fault

Spencer (1961) described the Eggleston Fault (Plate I) as a northwest-trending, west-dipping, high-angle reverse fault with a maximum of 300 feet of apparent separation.

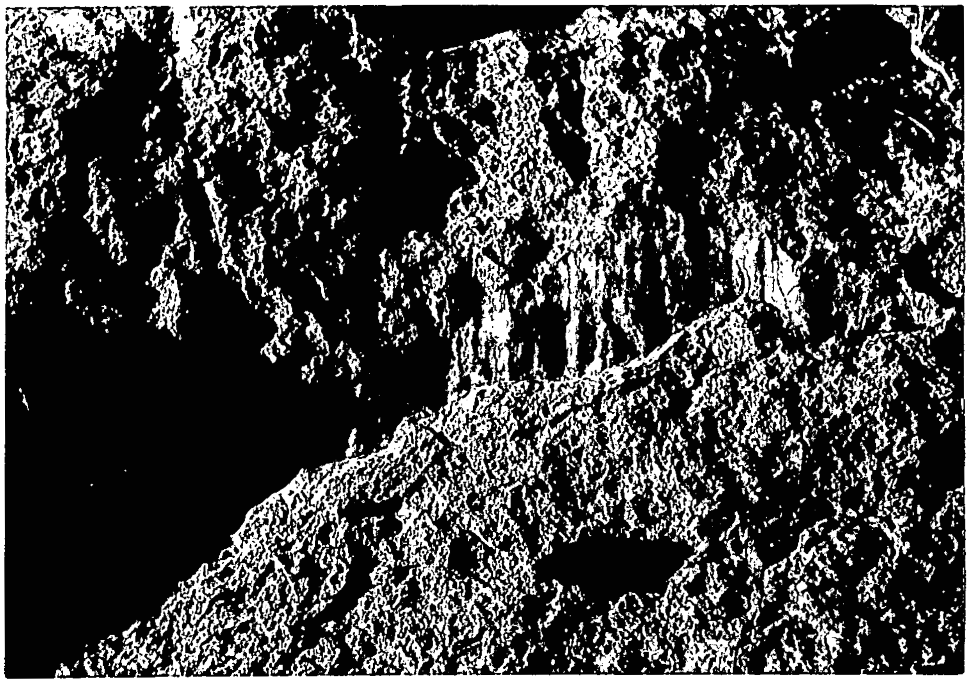


Figure 5-10. Slickensides in Fox Hills Sandstones (Station 11, near Marshall). Near-vertical fractures in Fox Hills sandstones exhibit slickensides oriented down the dip of the fracture, which suggests that movement was dip-slip.

Figure 5-11. Slickensides in Laramie Formation (Station 158, D&RGW Railroad cut). Apparent offset on this joint surface is more than above. Movement was probably dip-slip.

Hurr (1976) showed the fault with a slightly different orientation extending southeast into RFP, based on the alignment of several bedrock features possibly associated with faulting. Dames and Moore (1981) investigated three of these features to determine whether they were fault related, exhibited recent movement, and could be inferred to be a southward continuation of the Eggleston Fault. Dames and Moore (1981) also conducted a trenching program north of Eggleston Reservoir across the inferred fault trace in an attempt to verify the existence of the Eggleston Fault. They concluded that (1) the bedrock features south of the Eggleston Fault are syndepositional slumps and faults, (2) all bedrock units exposed near the reservoir are part of the Laramie Formation, and (3) the Eggleston Fault does not exist.

Field investigations for the present study demonstrated that bedrock exposed along the west side of the reservoir (Station 39B) is Fox Hills Sandstone based on textural and compositional characteristics outlined in Section 4.2.1, in agreement with Spencer (1961). To place the Fox Hills Sandstone at an elevation of 5850 feet along the west side of Eggleston Reservoir, vertical fault displacement is required. The fault trace was not observed in any surface outcrops; thus, its location on the map is approximate and its orientation is inferred. No better constraints on the geometry of the fault (dip angle, strike direction) are presently available.

High View Fault

The High View Fault (Spencer, 1961) trends approximately N80E and extends at least 1500 feet from the south-central portion of section 21, T1S, R70W west through Community Ditch and down the hillslope, where it dies out in the Pierre Shale (Plate I). The fault surface dips to the northwest at a high angle (70 to 90 degrees). The fault zone is exposed on the east bank of Community Ditch (Figure 5-12, Station 24) and in the road cut on the east side of Highway 93 (Station 93). A bedding attitude in the Laramie Formation was measured at N20E, 10SE in the road cut on the south side of the fault. Joint surfaces strike N50W and dip 45NE. Laramie sandstone beds exhibit drag on the north side of the fault. Offset of the Fox Hills Sandstone observed along the ditch indicates approximately 40 feet of apparent reverse displacement. Using drill-core data, Spencer (1961) estimated that a maximum of 50 feet of apparent displacement is present along the High View Fault. Laramie sandstone beds on the northwestern side of the fault dip approximately 10 to 20 degrees southeast and are only slightly disturbed. Sandstone beds on the southeast side of the fault are vertical or overturned adjacent to the fault but return to a dip of approximately 20SE within 20 to 25 feet.

West Fox Fault

The West Fox Fault (Spencer, 1961) is curvilinear (Plate I). It trends N10W for 1000 feet from its juncture with the Fox Fault along Davidson Ditch near the southwest corner of section 15, T1S, R70W (Station 20). From that point, the West Fox Fault trends approximately N60E for another 1000 feet. The fault surface dips southeast at approximately 20 to 30 degrees (Spencer, 1961). The West Fox Fault is not exposed at the surface and therefore could not be accurately characterized. Based on the elevation of coal beds on mine maps, apparent displacement is a maximum of 250 feet (Spencer, 1961). Sense of movement is reverse separation.

North and South Fox Faults

The South Fox Fault (Spencer, 1961) trends N45E and extends 3500 feet from the southwest corner of section 21, T1S, T70W, across Highway 93 where it joins the Pine Ridge Fault in the northeastern corner of section 21, T1S, R70W (Plate I). Farther north, the fault is exposed again and extends approximately 3000 feet to the middle of section 15, T1S, R70W (North Fox Fault). Spencer (1961) inferred that the South Fox Fault was continuous across section 21; however, because Laramie sandstone and claystone beds appear to be conformable in this area, the South Fox and North Fox faults are shown as separate faults in this study (Plate I).

The South Fox Fault is well exposed in a road cut at the top of the hill south of Boulder on Highway 93 (Figure 5-13, Stations 25, 38B). At this location, the fault surface dips 85SE. Estimated vertical displacement of strata is less than 60 feet. The North Fox Fault is exposed in two places along Davidson Ditch immediately east of Marshall (Figure 5-14, Stations 16, 20). Aerial photographs show a distinct lineament at this locality from Cherryvale Road up the hillslope to the northeast. Offset of the Fox Hills Sandstone along the ditch indicates that there is more than 100 feet of apparent vertical displacement. As portrayed on Cross-section B-B' (Figure 5-2), sense of movement is reverse separation.

Figure 5-12. High View Fault (Station 93, Highway 93 south of Boulder). Laramie Formation sandstones (white at right) are faulted against Laramie claystones (yellow at left) and exhibit drag along the fault.

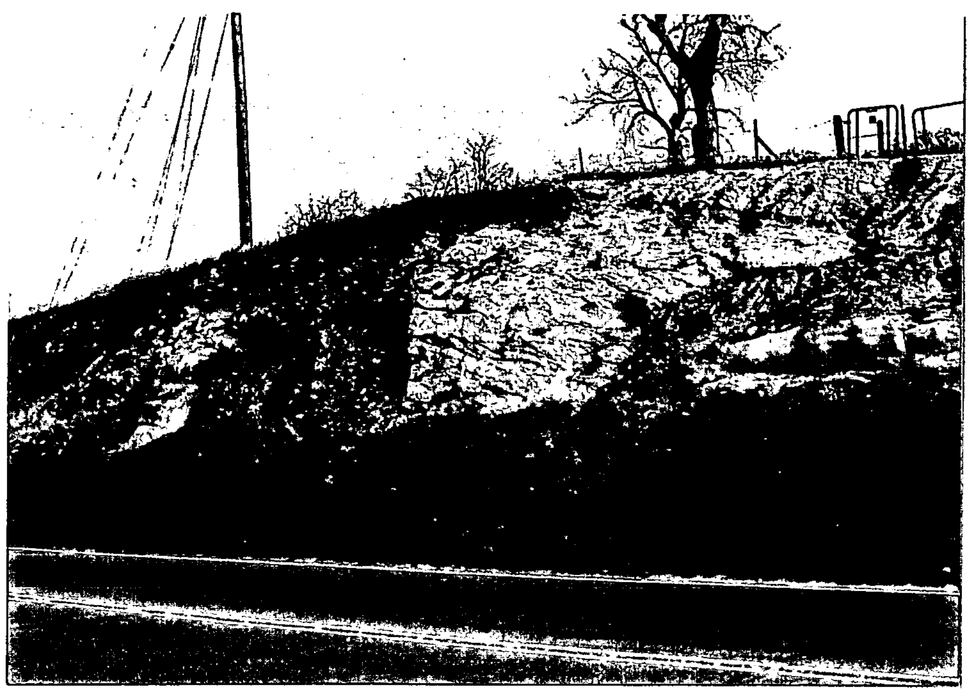


Figure 5-13. South Fox Fault (Station 38B, Highway 93 south of Boulder). Fox Hills Sandstone has been uplifted with respect to the lower Laramie (left). Fault zone contains some rotated blocks of sandstone.

A bedding attitude in the Laramie Formation near Highway 93 was measured at N45E, 10SE (Station 6-3). Conjugate joint sets in the Fox Hills Sandstone near Highway 93 (Station 23) strike N30W and N60W and dip 35NE and 75SW, respectively. Most joint surfaces are stained with iron oxide and are resistant to weathering. No striations or slickensides are evident on any of the joint surfaces.

Pine Ridge Fault

The Pine Ridge Fault (Spencer, 1961) trends approximately N50E and extends nearly 1 mile from the southwestern corner of section 21, T1S, R70W, around the base of Pine Ridge, to the northwestern corner of section 22, T1S, R70W (Plate I). The fault intersects the Pittsburgh Fault (Spencer, 1961) at its northeastern terminus (Station 36B). The fault surface appears to dip to the southeast at a high angle, but the Pine Ridge Fault is not exposed at the surface. Based on subsurface data, apparent displacement is a maximum of approximately 100 feet (Spencer, 1961) and decreases to the north. Separation is in a reverse sense.

Peerless and Peerless-Lewis Faults

The Peerless Fault (Spencer, 1961) trends N30E and extends at least 3000 feet from the top of the hill in the south-central portion of section 15, T1S, R70W to Marshall Road (Plate I). At Marshall Road, the fault trace curves westward and joins the Peerless-Lewis Fault. The Peerless Fault surface dips 88SE, and the fault trace follows a well-developed gully north of Marshall Road (Stations 18, 19). A ripple-laminated sandstone marker bed in the Laramie Formation on the west side of the fault strikes N50W and dips approximately 10SW. On the east side of the fault, the same ripple-laminated sandstone bed strikes approximately N80E and dips approximately 10NW but exhibits drag near the fault and is rotated toward the fault where the dip becomes more northwesterly. Spencer (1961) assumed that the Peerless was a high-angle normal fault with a maximum of 125 feet of apparent displacement. Based on the drag folds adjacent to the fault and the estimated offset of the ripple-laminated sandstone bed, it is more likely that the Peerless is a high-angle reverse fault with less than 100 feet of apparent displacement (Figure 5-2, Cross-section B-B').

The Peerless-Lewis Fault trends nearly east-west approximately 3000 feet from the Peerless Fault to its southern terminus at the Pine Ridge Fault. A sliver of Fox Hills

Sandstone, conformably overlain by the lowermost 20 or 30 feet of the Laramie Formation, crops out between the Peerless-Lewis Fault and the Pine Ridge Fault (Station 27). The outcrop exhibits polygonal fractures at a high angle to bedding surfaces (Figure 5-15). Conjugate joint sets strike N30E and N40W. Iron-oxide staining occurs on most joint surfaces. Vertical striations appear on a few joint surfaces. Because the Peerless-Lewis Fault is a continuation of the Peerless Fault, it is likely a high-angle reverse fault as well.

Pittsburgh Fault

The Pittsburgh Fault (Spencer, 1961) trends approximately N45E and extends almost 3000 feet from the southern portion of section 15, T1S, R70W to its terminus at the Pine Ridge Fault (Plate I). Laramie and Fox Hills sandstones form a small anticline between the Pittsburgh Fault and the Peerless Fault to the west (Stations 4, 5, 37A-40A, 73). Field relationships indicate that the fault surface dips to the northwest at a high angle. As shown on Cross-section B-B' (Figure 5-2), it is possible that the Pittsburgh Fault is a major thrust fault and a termination point for the Peerless, North Fox, and West Fox reverse faults. Apparent displacement on the Pittsburgh Fault is less than 100 feet. Spencer (1961) suggested that the Pittsburgh and Pine Ridge Faults were related and that they were both southeast-dipping, high-angle reverse faults. From the present study, it appears that the Pittsburgh Fault dips northwest and that the Pine Ridge Fault dips to the southeast. Apparent displacement decreases to the north along the Pittsburgh Fault.

Gorham Fault

The Gorham Fault (Spencer, 1961) trends N50E and extends more than 1 mile (Plate I) from the southwestern corner of section 21, T1S, R70W (South Gorham Fault) to the southwestern corner of section 15, T1S, R70W (North Gorham Fault). The fault surface dips northwest at a high angle (as shown in Figure 5-2). Apparent displacement on the fault is a maximum of 150 feet, based on subsurface mine data (Spencer, 1961). Sense of movement is normal. Slivers of Fox Hills Sandstone along the north branch of the fault exhibit low-angle conjugate fractures that strike N50W and N20E. Some of the fracture surfaces display slickensides and minor offsets parallel to slickenside trends (see Figure 5-10, Station 11). Lineations on these surfaces trend N30W and plunge 30SW. A splay of the South Gorham Fault is well exposed in a

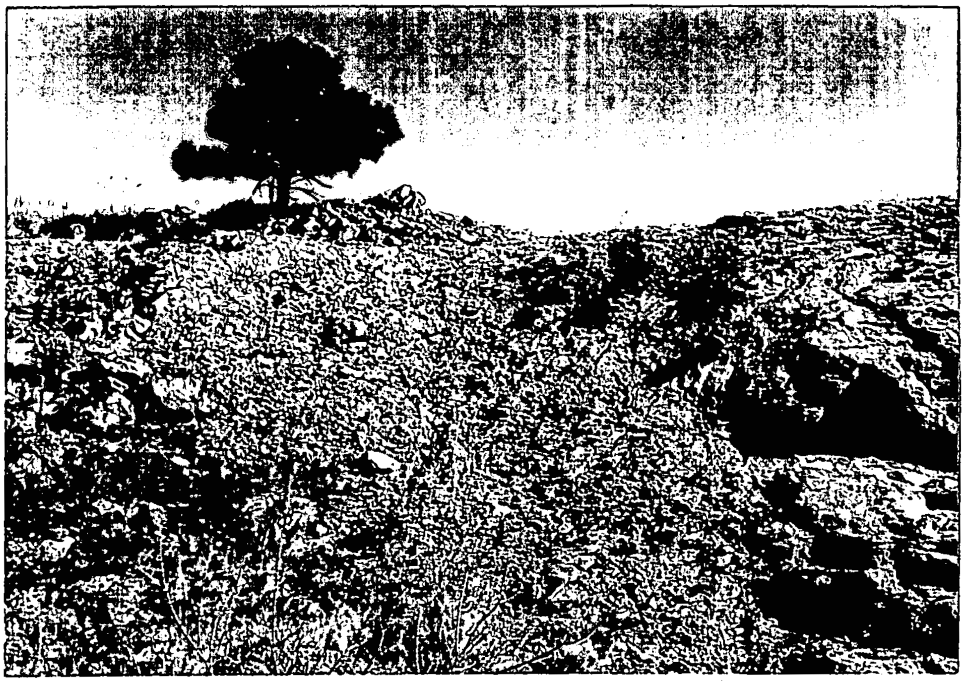


Figure 5-14. North Fox Fault (Station 20, near Cherryvale Road). Fox Hills Sandstone has been uplifted with respect to the lower Laramie (left). Vertical offset is approximately 100 feet.

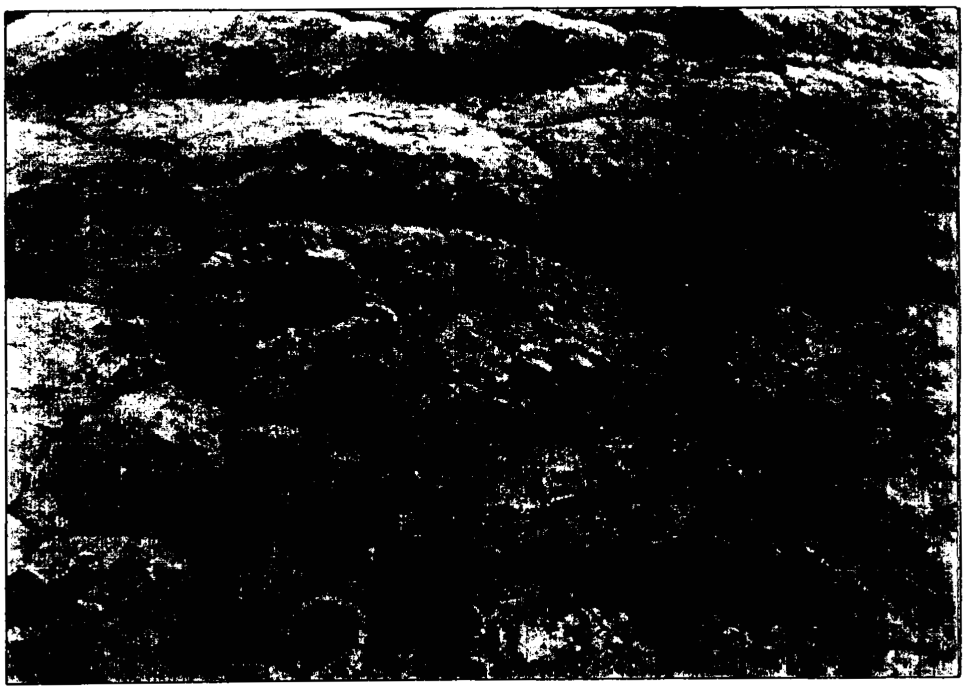


Figure 5-15. Polygonal Fractures (Station 27, north of Pine Ridge). Fox Hills Sandstone exhibits through-going vertical fractures in a polygonal pattern near the Peerless-Lewis Fault. Some fracture surfaces have slickensides.

road cut on a gravel driveway north of Marshall Road (Figure 5-16, Station 12B). The surface of this fault splay dips 50°SE. Sense of movement on this fault splay is normal.

Crown-Davidson Mesa Fault

The Crown-Davidson Mesa Fault extends at least 1 mile from the BFI-Marshall Landfill in the northwestern corner of section 23, T1S, R70W to State Highway 36 (Plate I). The trend of the fault is approximately N30E, and the fault surface dips to the west. Spencer (1961) inferred that the maximum amount of apparent displacement is 300 feet and extended the fault further southwest than is shown on this map. The fault plane is not exposed in the map area. Field evidence for the Crown-Davidson Mesa Fault can be found along South Boulder Road (Station 273) and on the western edge of Davidson Mesa in Louisville (Station 274).

Outcrops of Fox Hills Sandstone along South Boulder Road strike approximately N10E and dip 5NW (Station 273). Exposures of the Fox Hills Sandstone are vertically offset by the fault in the Paragon Estates subdivision in Louisville (Station 274). The Laramie Formation crops out in the Paragon Estates subdivision along Davidson Ditch but occurs at a lower elevation than the Fox Hills Sandstone (Station 274). A vertical component of displacement of at least 70 feet is required along the fault in this area. Subsurface data from the BFI-Marshall Landfill (Fox Consultants, 1983, 1984) indicated that apparent displacement at the southwestern end of the fault is probably less than 50 feet. Sandstone with shell fragments was described at a depth of 25 feet below ground surface (elevation approximately 5700 feet) in bedrock well BR-A, which was drilled along the gravel road east of the landfill near the southern boundary of section 23, T1S, R70W. This fossiliferous sandstone correlates with the shell bed in the Laramie Formation mapped along the southwestern shore of Marshall Lake, also at an elevation of approximately 5700 feet (Station 70).

Lake Mesa Fault

The Lake Mesa Fault (Spencer, 1961) trends N50E and extends from the corner of section 26, T1S, R70W to State Highway 36 and beyond, a distance of at least 2000 feet (Plate I). The fault surface dips to the northwest. Spencer (1961) suggested that the Lake Mesa Fault has a linear displacement of 500 feet, based on subsurface

Figure 5-16. South Gorham Fault (Station 2-3, driveway north of Marshall Road). Fault contact between Fox Hills and Laramie on a splay of the South Gorham Fault. Fault surface dips 50 degrees SE. Laramie is downthrown on the right.

information from nearby mines. Subsurface information from drill holes at the BFI-Marshall Landfill (Fox Consultants, 1983, 1984) suggested that the apparent displacement is less than 50 feet because no offset of sandstone beds within the Laramie Formation underlying the landfill was observed. The Lake Mesa Fault does not continue southwest into the landfill area.

Leader-Ajax Fault

The Leader-Ajax Fault (Spencer, 1961) trends N50E along Coal Creek from the northeastern corner of section 26, T1S, R70W to Superior (Plate I). Spencer's (1961) map shows the fault trending northeast from the southwest corner of section 24, T1S, R70W to Louisville in the southeastern corner of section 8, T1S, R69W. The dip angle of the fault surface is not known. Apparent displacement on the fault is a maximum of 450 feet (Spencer, 1961), based on the juxtaposition of gently southeast-dipping (7SE) Laramie Formation sandstone beds on the south side of the fault (Station 267) and northwest-dipping (18NW) Fox Hills Sandstone beds on the north side of the fault (Station 67). Field relationships in the map area indicated that the Laramie is down-dropped in a relative sense on the southeastern side of Coal Creek. The Laramie conformably overlies the Fox Hills Sandstone on the northwestern side of Coal Creek.

5.3.2 Characterization of Newly Identified Faults

One fault trace that appears on the geologic map, the Eldorado Fault (Plate I), does not appear on previously published geologic maps. Two other faults, one along Rock Creek and one north of Walnut Creek, have not been described in previous work. Those faults, identified solely on the basis of vertical displacement of lithologically distinct units relative to other units within the stratigraphic section, are described as "uncertain faults." Their apparent displacement may be due to stratigraphic discontinuities rather than to structural offset; additional information is required to confirm the presence of faults in these areas. Two reduced-area geologic maps show the locations of the inferred surface traces using the appropriate symbol (dashed lines with questions marks) to show that fault traces are only approximately located.

Eldorado Fault

The Eldorado Fault trends approximately N10E and extends approximately 1200 feet from Davidson Ditch (Station 82) northeast across Eldorado Springs Drive. The fault surface dips to the east, but the degree of dip is not known. Offset of the Fox Hills Sandstone indicates that there is at least 50 feet of apparent vertical displacement. Fox Hills Sandstone is uplifted on the east side of the fault, suggesting that the sense of movement is reverse separation.

Rock Creek

Infrared Landsat™ satellite images of the Front Range region show a strong regional northeast trend to drainage basins north of RFP. Rock Creek is coincident with the southernmost of three large-scale, northeast-trending linear features that extend from the Idaho Springs-Ralston Shear Zone.

An uncertain fault is shown parallel to Rock Creek in Figure 5-17, a geologic map of reduced area. Evidence for the presence of a fault structure in this area is primarily stratigraphic. Primary evidence supporting the presence of a fault in this area is found in Arapahoe Formation outcrops on the south side of Rock Creek near Highway 128 (Station 34-4). Flat-lying to slightly east-dipping sandstones at the base of the Arapahoe are present at an elevation of 5770 feet. The presence of the Laramie-Arapahoe contact at 5770 feet places the base of the Laramie (600 to 800 feet thick) at approximately 4970 to 5170 feet. However, at the Industrial Mine site in the southeastern portion of section 24, T1S, R70W, 2 miles north of Rock Creek, the base of the Laramie is estimated to occur at no less than 5400 feet, not at 4970 to 5170 feet as expected. The attitude of bedding surfaces between Rock Creek and the Industrial Mine appear consistently flat lying to southeast dipping. The difference between the predicted and the observed elevation of the Laramie Formation at the Industrial Mine (400 feet of vertical offset) strongly supports the presence of a fault along Rock Creek down-dropped in a relative sense on its south side.

An uncertain fault symbol is used to show this vertical offset in Figure 5-17 because its location is not well constrained by surface geologic data. More than one fault structure may be present between the south side of Rock Creek and the Industrial Mine south of Superior; however, the map interpretation of the surface data shows only one structure.

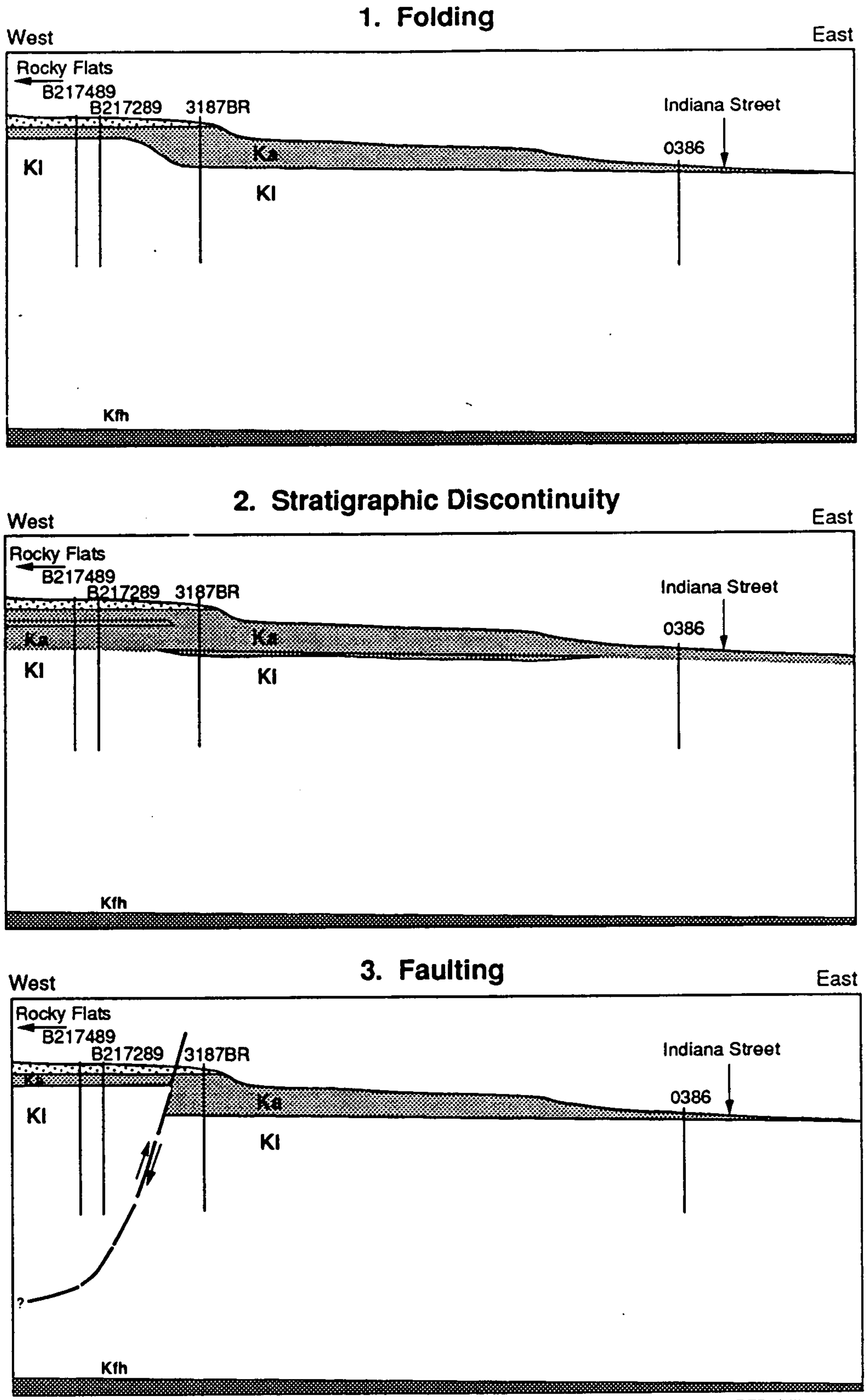
Without additional surface or subsurface data, the present interpretation may oversimplify the bedrock structure in the Rock Creek area.

Walnut Creek

An uncertain fault trace is shown trending northeast from Woman Creek and across Walnut Creek on the reduced area geologic map in Figure 5-18. A sharp vertical drop in the structural elevation of the marker bed (medium-grained to conglomeratic sandstones) at the base of the Arapahoe Formation is present immediately east of the RFP inner east gate. This offset was first suspected from observations made at surface outcrops of Arapahoe sandstones and was later confirmed with data from subsurface drill cores.

Outcrops at the base of the Arapahoe are present at 5900 feet along North Walnut Creek (Station 302). East of RFP, the Laramie-Arapahoe contact was located at 5600 feet, immediately above the south shore of Great Western Reservoir (Station 314) and north of Mower Reservoir (NENW section 18, T2S, R69W). The regional dip of Cretaceous strata underlying RFP as determined from outcrops is estimated at less than 1.5 degrees east-southeast. Given this low-angle regional dip, the base of the Arapahoe Formation at Great Western Reservoir is much lower than expected. Similarly, Arapahoe sandstones occur immediately below the Rocky Flats Alluvium in bedrock cores from wells B315289/5989BR and B217489/5689BR at the East Burial Trenches area (OU 2) of RFP. The elevation of Arapahoe sandstones is 5940 feet in these drill cores, which corresponds to the outcrop elevations at RFP. However, one core from the East Burial Trenches (3187BR, Arapahoe elevation = 5817 feet), one core from Woman Creek (1487BR, Arapahoe elevation = 5835 feet), and two cores from Indiana Street (0386BR and B217289, Arapahoe elevation = 5655 feet) contain Arapahoe sandstones at elevations consistent with the observed outcrop elevation of the Arapahoe sandstone at Great Western Reservoir (5600 feet). The combined surface and subsurface data suggest that the Laramie-Arapahoe contact drops more than 100 feet over a horizontal distance of less than 1000 feet. These relationships are clearly inconsistent with a simple 1.5-degree regional southeast dip.

Such an elevation change in the Laramie-Arapahoe Formation contact could occur in three possible ways (Figure 5-19): (1) the bedrock strata may be folded, (2) the Laramie-Arapahoe contact as delineated by the conglomeratic sandstone marker bed



Kfh: **Fox Hills Sandstone**
Kl: **Laramie Formation**
Ka: **Arapahoe Formation**

Numbers refer to RFP drill cores.

EG&G Rocky Flats, Inc. March 1992

Figure 5-19 Structure Interpretations for Walnut Creek

Three models to explain abrupt elevation changes observed in the Laramie-Arapahoe contact east of the Rocky Flats Plant.

may be discontinuous and occur at variable levels within the stratigraphic section, or (3) the bedrock may be faulted, with bedrock east of the fault down-dropped relative to bedrock west of the fault. These three possible explanations are presented below.

Folding of the strata could account for the 85 to 110 feet of apparent vertical displacement. However, this explanation is problematic in that seismic lines from OU 2 (EG&G, 1991a) show undeformed, gently southeast-dipping reflectors in the lower Laramie and Fox Hills sandstones. If a steep fold were to account for 85 to 110 feet of vertical offset, it is most likely that the fold would also deform beds in the Laramie and in the Fox Hills Sandstone, and the fold should be apparent in shallow seismic reflection data (Figure 5-19).

Stratigraphic discontinuities produced by vertical and lateral lithologic variability within the Arapahoe could also be responsible for the observed elevation change of the Laramie-Arapahoe contact (Figure 5-19). Coarse-grained channel material can occur at multiple levels within a sequence of deposits. However, none of the RFP drill cores reviewed for this study contained more than one interval composed of the medium-grained to conglomeratic sandstone marker bed. Further analysis of all of the existing drill cores would be necessary to confirm this observation.

Fault offset of the Laramie-Arapahoe contact is another explanation for the sudden eastward drop in elevation of the Arapahoe marker bed east of RFP. That fault structure, if present, must thicken the Laramie Formation to the west (Figure 5-19) because it does not appear to offset the Fox Hills Sandstone-Laramie Formation contact. The fault is probably a shallow structure floored within the Laramie Formation (Figure 5-19). Shallow seismic reflection and borehole data from OU 2 (EG&G, 1991a) indicate a thickening of the alluvium due to a step, downward to the east, in the top of the bedrock surface. Shallow seismic reflection data from Indiana Street and reprocessed CSM data indicate the presence of fault-type structures at RFP (EG&G, 1990b, 1991b). Preliminary interpretation of deep seismic data collected as part of the Phase II Geologic Characterization Data Acquisition indicates that numerous thrust faults, similar to the one previously identified in the Geologic Characterization Report (EG&G, 1990b, 1991b, 1991d), are present in the RFP area. The structure in the Indiana Street shallow seismic lines (EG&G, 1991b) may be related to the structural feature at Walnut Creek. The fault trace, as shown in Figure 5-18, crosses the area where a 30-foot drop in the depth to bedrock is known to occur (EG&G, 1991d). As in the Rock Creek area, the fault interpretation shown on Figure 5-18 was based on limited surface data and may greatly oversimplify the structural setting of this area. More than one fault structure or a series of smaller-scale structures could produce the observed offset if present in the Walnut Creek area.

In addition to large-scale field relationships, small-scale structures such as slickensides and fractures exhibiting cataclastic texture also support the presence of a fault in the area east of RFP. These structures, discussed in Section 5.2, are present in outcrops in the northeast buffer zone and in the Protected Area. Both areas are in what would be the hanging-wall block of a fault near Walnut Creek, as shown in Figures 5-18 and 5-19.

5.4 REGIONAL STRUCTURAL STYLE

Faults in the vicinity of RFP are generally northeast-trending, west- to northwest-dipping thrust or reverse faults with straight to curved geometries (Figures 5-1 and 5-2). Many of the faults intersect the surface at a high angle, indicating some component of vertical motion. However, it is likely that vertical motion at the surface is a reflection of horizontal compression at depth (Erslev et al., 1988). From RFP northward, Rock Creek, Coal Creek, and South Boulder Creek exhibit a northeast-southwest alignment that appears to be controlled by northeast-trending structures. The Upper Cretaceous stratigraphic section in this portion of the map area has little coherence. Repeated sections of Fox Hills sandstones and lower Laramie coals provide evidence for major emergent thrust faulting with a southeastward tectonic transport direction in the area of the Jefferson County Airport (Erslev et al., 1988; Kittleson, 1991). Some faults in the Marshall area (e.g., North Fox Fault, Peerless Fault) are northeast-trending, east- to southeast-dipping thrust or reverse faults with curved geometries. South of RFP, there is no readily apparent local or regional structural alignment of geomorphic features.

In the past, northeast-trending faults were mapped as either a series of horsts and grabens or as growth faults. Mine mapping data from the Boulder-Weld coalfield led to interpretations emphasizing the nearly vertical orientation of normal and reverse faults bounding the horsts and grabens (Spencer, 1961). Coal was interpreted to be absent in horst blocks, where uplift had exposed the Laramie Formation to erosion. Through detailed subsurface mapping, Kittleson (1991) showed that coal beds are displaced along decollement faults rather than eroded off horst blocks. Weimer (1973) proposed that the northeast-trending faults in the Boulder-Weld coalfield were growth faults that developed in response to oversteepening of sediments on a delta front. Thick deposits of coal were deposited on the downthrown side of these growth faults in subsiding marshes. Through detailed subsurface mapping of seven coal beds, Spencer (1986) showed that there is no appreciable difference in thickness of coal beds in horsts or grabens; therefore, it is unlikely that they are bounded by growth faults.

The northeast trend of most of the faults corresponds to the trend of some Precambrian basement structures, such as the Idaho Springs-Ralston Shear Zone, in the Front Range. Some of the northwest- and northeast-trending faults developed during the Precambrian were locally reactivated by Laramide or younger deformation (Boos and Boos, 1957). Uplift of the Front Range during the Laramide orogeny may have rejuvenated movement along pre-existing basement structures, such as the Idaho Springs-Ralston Shear Zone along Coal Creek.

6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 SUMMARY OF CONCLUSIONS

The following conclusions directly address the initial objectives of this study and provide a detailed description of the RFP geologic setting. A detailed (1:12,000 scale) geologic map of RFP and vicinity was produced using evidence from aerial photographs, surface outcrops, and subsurface geologic data. The Upper Cretaceous Fox Hills Sandstone, Laramie Formation, and Arapahoe Formation were described, and criteria were developed for their recognition in the surface and subsurface. Deformational structures that may affect the geometry of stratified bedrock beneath RFP were identified and characterized. Inconsistencies among previously published geologic maps of the Louisville and Golden Quadrangles have been resolved using stratigraphic correlations developed from bedrock outcrops and lithologic criteria developed through microscopic examination of outcrop samples and thin sections. However, a discrepancy remains between the base of the Arapahoe Formation as defined in this report and as previously described in the Geologic Characterization Report (EG&G, 1991d). Additional data gathered for various remedial investigations at RFP under the ER program may be useful in resolving this discrepancy.

6.1.1 Stratigraphy

The contact between the Laramie Formation and the Arapahoe Formation is identifiable where distinctive medium-grained to conglomeratic sandstones are exposed. These sandstones occur at the base of the Arapahoe Formation and can be readily and conclusively distinguished from Laramie Formation sandstones in outcrops and subsurface cores. These Arapahoe sandstones are medium- to coarse-grained and conglomeratic, with well-rounded, frosted quartz grains, ironstone pebbles, chert pebbles, and volcanic rock fragments.

This study determined that the Arapahoe Formation is present as a mappable unit within the field area. The presence of distinctive sandstones was used to mark the contact between the Laramie and Arapahoe Formations and to produce the geologic map. Previous workers (Van Horn, 1972; Weimer, 1976) used the same marker bed to demarcate the contact between the Laramie and Arapahoe Formations near Golden. With the recognition of the marker bed that defines the base of the Arapahoe Formation in the map area, the formal stratigraphic contact between the Laramie and Arapahoe Formations has now been mapped across RFP and vicinity. Onsite stratigraphic relationships are now directly tied to other geologic maps in the area and to the regional stratigraphy.

The base of the Arapahoe Formation varies in elevation from 5965 feet to 5920 feet in the central portion of RFP and from 5820 to 5665 feet on the eastern side of RFP. These elevations are consistent with some previous geologic maps of RFP and vicinity (Van Horn, 1972; Hurr, 1976). These elevations are not consistent with the depth to the base of the Arapahoe Formation as reported in the Geologic Characterization Report (EG&G, 1991d). In that report, the Laramie-Arapahoe contact is described as occurring at the base of the Number 5 sandstone interval, which varies in elevation from 5875 feet to 5600 feet from west to east across the plant site. Additional information gathered during ongoing ER program investigations may help to refine onsite stratigraphic relationships.

The lateral and vertical lithologic variations within the uppermost bedrock strata at RFP have been described. The upper Laramie Formation is composed predominantly of fine-grained sandstones, silty claystones, and claystones with less than 50 percent sand-sized material. The coarsest sandstone components of the upper Laramie sedimentary sequence lie within small (5 to 15 feet thick, 20 to 100 feet wide) channels that do not appear to be highly interconnected. The Arapahoe Formation has only limited exposure within the map area, but it appears to be composed predominantly of fine-grained rocks (fine-grained sandstones, siltstones, and claystones) except at the base of the formation where conglomeratic and medium- to coarse-grained sandstones are present. The coarse-grained components of the Arapahoe Formation are also confined to broad, shallow, and probably discontinuous lenses within finer grained claystones. These lenses do not appear to be highly interconnected.

6.1.2 Structures

On the western side of RFP, Upper Cretaceous strata dip steeply to the east along the western limb of an asymmetrical north-south-trending syncline (western edge of the Denver Basin). The strata are nearly flat lying to gently east dipping beneath RFP. East of RFP, Upper Cretaceous strata exhibit 1 to 2 degrees of east-directed dip.

Previously identified faults within the map area were examined and characterized wherever sufficient surficial expression of offset was available. Fault offset near Eggleston Reservoir, as described by Spencer (1961) and refuted by Dames and Moore (1981), was confirmed. The presence of a fault is required to explain the Fox Hills Sandstone outcrop at Eggleston Reservoir, but the fault trace was not recognizable in the field. The location, orientation, and character of the Eggleston Fault remains poorly constrained by available evidence gleaned from limited surface outcrops.

Faults in the Marshall area north of RFP are generally northeast-trending, west- to northwest-dipping normal or reverse faults with straight to curved geometries. The northeast trend of most of the faults corresponds to the trend of Precambrian basement structures such as the Idaho Springs-Ralston Shear Zone. Thus, pre-existing faults may have been reactivated during the Laramide orogeny or during subsequent deformation events.

Field relationships provide evidence for previously unrecognized structural deformation of Upper Cretaceous strata. Northeast-trending structures (shown as uncertain faults in Figures 5-17 and 5-18) are present in the Rock Creek and Walnut Creek drainages. The approximate locations and orientations of these structures are inferred, using all available surface and subsurface geologic data. Whereas offset of lithologically distinct beds is known to occur along these drainages, the structural geology of the Rock Creek and Walnut Creek areas may be more complex than that shown in Figures 5-17 and 5-18. Additional surface, subsurface, and geophysical data would be required to provide information regarding the location of inferred faults, the attitude of fault surfaces, the type of fault, and the sense of movement.

6.2 RECOMMENDATIONS

Although all of the objectives of the geologic mapping program were met, the following list of recommendations was compiled to guide future geologic characterization studies at RFP. Each recommendation is presented in three parts: a statement of the work or problem to be addressed, the intended purpose of work, and the recommended methods.

1. Shallow structures depicted as uncertain faults, shown on shallow seismic records (MPS13, MPS14, WIN2), and suspected in surface mapping (Rock Creek and Walnut Creek) should be characterized.

   These northeast-trending structures may extend beneath the plant, including 881 Hillside (OU 1) and 903 Pad (OU 2) areas, and could be pathways for or barriers to contaminant transport.

   Several methods could be used to characterize these structures. These include: (1) detailed geologic mapping of individual beds within the upper Laramie and lower Arapahoe Formations in the Walnut Creek and Woman Creek areas, (2) a shallow seismic line along the east entrance road that ties into WIN2 and into well 3187BR in the East Trenches area (OU 2), (3) a shallow seismic line perpendicular to the traces of the uncertain faults from Coal Creek to Woman Creek, and (4) borehole drilling to intersect the proposed Walnut Creek fault near RFP.

2. Shallow, high-resolution seismic reflection data should be reprocessed for identification of bedrock structures.

   Bedrock structures beneath RFP could provide pathways for or barriers to contaminant transport.

   The shallow, high-resolution seismic reflection data from OU 2 were collected and processed to emphasize flat-lying, shallow stratigraphic features. It is recommended that these data be reprocessed to emphasize steeper dipping, shallow structural features in that area.

3. A detailed stratigraphy of the upper Laramie and lower Arapahoe Formations should be developed and applied to subsurface stratigraphic correlation efforts at RFP.

   A detailed stratigraphy based on the Arapahoe marker bed described in this study would resolve discrepancies in nomenclature between the surface geologic map and existing subsurface stratigraphic correlations.

Geologic mapping of individual beds within the upper Laramie and lower Arapahoe Formations could be used in conjunction with description and correlation of marker beds in RFP drill core to develop a detailed stratigraphy.

4. The limits of the channels at the base of the Arapahoe Formation should be defined.

   Determination of the location and extent of channel deposits in the Arapahoe paleochannels would be useful in defining possible pathways for contaminant migration and in refining the hydrogeologic model.

   The location and extent of the conglomeratic channel deposits in the Arapahoe Formation could be determined by conducting a shallow seismic survey on the terrace north of Walnut Creek and by borehole drilling near surface outcrops.

5. Channel morphologies of sand channels in the lower Arapahoe Formation should be determined to refine the hydrogeologic model for RFP.

   The lateral extent of sandstone channels is controlled by the depositional environment and the resulting channel morphology. Channel morphologies directly influence groundwater movement and possible contaminant migration pathways.

   Channel sinuosity can be calculated using grain size and channel dimension parameters based on the methods of Brice (1964) and Schumm (1968).

6. Shallow seismic reflection lines should be shot across known shallow channels in both the Arapahoe and upper Laramie Formations to calibrate parameters and determine responses for past and future surveys.

   The measured parameters and responses from seismic reflection lines would allow for further discrimination between upper Laramie and Arapahoe sandstones at RFP sites prior to undertaking costly drilling campaigns and monitor-well installation.

Potential sites for these lines include the upper Laramie sandstone channels that crop out along McCaslin Boulevard and the Arapahoe sandstone channel exposed in a road cut on Indiana Street approximately 2 miles south of the east gate of RFP.

7. The paleoflow direction of coarse-grained deposits at the base of the Arapahoe Formation should be determined.

   Paleoflow directions would aid predictive modeling of stratigraphic variations in the Arapahoe Formation underlying RFP.

   Paleoflow directions could be determined by conducting a paleocurrent study of Arapahoe outcrops at Standley Lake and at other suitable locations throughout the study area.

8. The orientation, regional extent, and amount of displacement on the Eggleston Fault should be determined.

   Previous work (Hurr, 1976) has suggested that the Eggleston Fault extends beneath RFP and could be a potential contaminant migration pathway. Results from this study confirmed the presence of a fault but could not confirm the orientation or extent of that structure nor the amount of displacement on the fault.

   Because of the contrast in electrical properties of Fox Hills sandstones and Laramie claystones, resistivity or electromagnetic surveys could be used to delineate the boundary between these lithologies in a non-invasive study. This boundary should correspond to the location of the Eggleston Fault trace. A series of resistivity or electromagnetic surveys north and south of the reservoir could be used to determine the orientation and extent of the fault trace.

9. The geometry of northeast-trending faults near Marshall in the northern portion of the map area and their relationship, if any, to the Front Range Uplift should be further described.

Determining the relationships between faults near Marshall and the Front Range Uplift would help define regional structural style. Structural features near RFP could then be interpreted in terms of the regional conceptual model and evaluated for their hydrologic significance.

Several techniques may be useful in determining the geometry of faults and their relationship to the Front Range Uplift. These techniques include (1) detailed surface mapping along the Front Range, (2) subsurface mapping of beds within the Fox Hills Sandstone and Laramie Formation near Marshall, (3) measuring fault-plane orientations in three dimensions, (4) structural balancing of bed length and basement geometry in constructing true-scale cross-sections that are consistent with observed deformation based on the methods of Erslev (1986), (5) shooting a deep seismic line perpendicular to the northeast-trending faults, and possibly (6) remote sensing and/or thermal imaging.

10. The fine-grained beds (claystones) in the Laramie and Arapahoe Formations should be characterized.

    Determining the differences between claystones in the Laramie and Arapahoe Formations would allow them to be distinguished in cores and in outcrop and would be useful for stratigraphic correlation, especially in interchannel areas at the base of the Arapahoe Formation.

    Several methods could be used to characterize claystones in the Laramie and Arapahoe, including optical petrography, palynology, and x-ray diffraction studies of clay minerals.

11. The geologic map and report should be published.

    Publication would allow for professional review and critical comment of the map and report, and make a meaningful contribution to the scientific community.

    The map and report could be published as a USGS Open-File Report or in the Rocky Mountain Association of Geologists (RMAG) *Mountain Geologist*.

12. All surface and subsurface data should be compiled to produce an integrated geologic and geophysical report for RFP and vicinity.

Producing a comprehensive, integrated geologic and geophysical report would be useful in revising the conceptual model for the geologic setting of RFP.

After completion of all tasks under the Phase II Geologic Characterization Data Acquisition work order, data from the surface geologic map, shallow and deep seismic surveys, new boreholes and wells, and the comprehensive regional well-log compilation should be integrated to refine the conceptual model.

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8.0 GLOSSARY OF TERMS

Anastomosing - branching and recombining, as in a braided stream

Authigenic - formed or generated in place after deposition of the original sediment

Birefringence - the ability of crystals other than those of the isometric system to split a beam of ordinary light into two beams of unequal velocities; the difference between the greatest and least indices of refraction

Chalcedonic - composed of a cryptocrystalline variety of quartz (chalcedony)

Colloidal - any fine-grained material in suspension

Crossed Nicols - the two Nicol prisms in a polarizing microscope that are oriented such that the transmission planes of polarized light are at right angles; light that is transmitted from one will be intersected by the other

Denudation - the laying bare, uncovering, or exposure of bedrock or a designated rock formation through the removal of overlying material by erosion

Dissolution - solution; a process of chemical weathering by which mineral and rock material passes into solution

Embayed - penetration of microcrystalline groundmass material into phenocrysts (or cement into framework grains), making their normal euhedral boundaries incomplete

Equant - said of a sedimentary particle whose length is less than 1.5 times its width

Extinction - the more or less complete darkness obtained in a birefringent mineral at two positions during a complete rotation of a section between crossed Nicols

Friable - said of a rock or mineral that crumbles naturally or is easily broken, pulverized, or reduced to powder, such as a soft or poorly cemented sandstone

Frosting - a lusterless ground-glass or matte surface on rounded mineral grains, especially quartz, that results from chemical etching, formation of incipient quartz overgrowths, or innumerable grain impacts during wind action

Glauconite - a dull-green earthy or granular mineral of the mica group: $(K,Na)(Al, Fe^{+3}, Mg)_2(Al, Si)_4O_{10}(OH)_2$; commonly found in marine sedimentary rocks

Goethite - yellow, brown, or red mineral (FeO, OH); commonly occurs as a weathering product of iron-bearing minerals such as siderite, magnetite, pyrite

Healed - crustified; said of a vein in which the mineral filling is deposited in layers on the wall rock

Heavy mineral - a detrital mineral from a sedimentary rock, having a specific gravity greater than 2.85, and commonly forming as a minor constituent or accessory mineral of the rock

Indurated - said of a rock or soil hardened or consolidated by pressure, cementation, or heat

Intergranular porosity - the porosity between the grains or particles of a rock

Limonite - field term for a group of brown, amorphous, hydrous ferric oxides; a common secondary material, formed by weathering (oxidation) of iron-bearing metals

Litharenite - a general term used by Folk (1974) for a sandstone containing less than 75 percent quartz and metamorphic quartzite and more than 25 percent fine-grained volcanic, metamorphic, and sedimentary rock fragments, including chert; or whose content of such rock fragments is at least three times that of feldspar and plutonic rock fragments

Lithified - said of unconsolidated sediment that has been converted into a coherent, solid rock by the processes of cementation, compaction, desiccation, or crystallization

Matrix - the finer grained material enclosing, or filling the interstices between, the larger grains or particles of a sediment or sedimentary rock

Metamorphic quartz* - genetic quartz type derived from a metamorphic source; characterized by straight to slightly undulose extinction, some microlites and vacuoles, and interlocking grains that form a mosaic with grain borders that may be straight, smooth, crenulated, or granulated

Microlites - a microscopic crystal that polarizes light and has some determinable optical properties

Occludes - said of a cement that fills the pore spaces or interstices between grains in a sedimentary rock

Overgrowth - a secondary material deposited in optical and crystallographic continuity around a crystal grain of the same composition, as in the diagenetic process of enlargement

Palynology - the study of pollen and spores and their dispersal

Petrography - the description and systematic classification of rocks by means of microscopic examination of thin section; more restricted in scope than petrology

Plane-polarized - said of a moving wave of light that has been polarized so that it vibrates in a single plane

Plutonic quartz* - genetic quartz type derived from granite batholiths, granite-gneisses, or other plutonic sources; characterized by straight to slightly undulose extinction, some vacuoles, few microlites, and a subequant to xenomorphic shape

Provenance - the area from which the constituent materials of a sedimentary rock or facies is derived; also the rocks of which this area is composed

Pseudomatrix - a term introduced by Dickinson (1970) for a "discontinuous interstitial paste formed by the deformation of weak detrital grains" in litharenites and arkoses

Quartzarenite - orthoquartzite; a sandstone that is composed primarily of quartz; specifically, a sandstone containing more than 95 percent quartz framework grains, excluding detrital chert grains

Recrystallization - the formation, essentially in the solid state, of new crystalline mineral grains in a rock

Rip-up clast - a component of a sedimentary rock consisting of a fragment of weakly consolidated penecontemporaneous sediment that has been torn up or reworked and redeposited to form a new sediment

Siderite - a rhombohedral mineral of the calcite group: $FeCO_3$; often found in impure form in beds and nodules (of ironstone) in clays and shales, and as a directly precipitated deposit partially altered into iron oxides

Subequant - said of a sedimentary particle whose length is somewhat less than 1.5 times its width

Sublitharenite - a term used by Folk (1974) for a sandstone with 75 to 95 percent quartz and metamorphic quartzite and 5 to 25 percent fine-grained volcanic, metamorphic, and sedimentary rock fragments (including chert)

Terrane - a term applied to a rock or group of rocks and to the area in which they crop out

Terrigenous - sedimentary material derived from erosion of a land area outside the basin of deposition

Undulatory extinction - a type of extinction that occurs successively in adjacent areas as the mineral is rotated between crossed Nicols

Vacuoles - vesicle; a cavity of variable shape formed by the entrapment of a gas bubble during crystallization

Xenomorphic - said of the texture of a rock with anhedral crystals or grains

All definitions from Bates and Jackson (1980

* Term definitions from Folk (1974)

9.0 LIST OF CONTRIBUTORS

Marcella C. Broussard
EG&G Task Order Manager
EG&G Rocky Flats, Inc.
P.O. Box 464
Golden, CO 80402

Judith E. Flook, P.G.
Technical Advisor
Applied Environmental, Inc.
143 S. Willow Dr. - Suite 200
Englewood, CO 80111

Mark L. Griswold, P.G.
Work Order Manager
Ebasco Services Incorporated
143 Union Boulevard - Suite 1010
Lakewood, CO 80228

James W. Langman
EG&G Work Order Manager
EG&G Rocky Flats, Inc.
P.O. Box 464
Golden, CO 80402

Brent R. Lewis
Technical Advisor
Dept. of Energy-Rocky Flats Office
P.O. Box 928
Golden, CO 80402

Susan P. Serreze
Task Order Manager
The S.M. Stoller Corporation
5700 Flatiron Parkway
Boulder, CO 80301

Kathryn J. Tegtmeyer, Ph.D.
Geologist
The S.M. Stoller Corporation
5700 Flatiron Parkway
Boulder, CO 80301

Myra K. Vaag, P.G.
Geologist
Ebasco Services Incorporated
143 Union Boulevard - Suite 1010
Lakewood, CO 80228

NOTICE

This document (or documents) is oversized for 16mm microfilming, but is available in its entirety on the 35mm fiche card referenced below:

Document # 000307

Titled: Final Geologic Map of Rocky Flats and Vicinity Jefferson and Boulder Counties, Colorado

Fiche location: A-SW-M20

APPENDIX A

Sample Descriptions

Table A-1. List of Samples - Rocky Flats Geologic Mapping Project

Sample Number	Fm	Topographic Quadrangle	Location Township and Range	Rock Type	Use
KT1-N	Kl	Louisville	NWNE 22 T1S R70W	claystone	ms
KT2-N	Kl	Louisville	NWNE 22 T1S R70W	siltstone	ms
KT3-N	Kl	Louisville	SESE 15 T1S R70W	sandstone	ms
KT4a-N*	Kfh	Louisville	NESW 15 T1S R70W	sandstone	ms
KT4b-N	Kl	Louisville	SENW 22 T1S R70W	sandstone	ms
KT5-N	Kl	Louisville	SENE 21 T1S R70W	claystone	ms
KT6-N	Kfh	Louisville	SENE 21 T1S R70W	sandstone	ms,gs
KT7-N	Kfh	Louisville	SENE 21 T1S R70W	sandstone	ms,gs
KT8-N	Kl	Louisville	SENE 21 T1S R70W	sandstone	ms,gs
KT9-N	Kl	Louisville	SENE 21 T1S R70W	sandstone	ms,gs
KT10-N	Kl	Louisville	SENE 21 T1S R70W	sandstone	ms,gs
KT11-N	Kl	Louisville	SENE 21 T1S R70W	sandstone	ms,gs
KT12-N	Kl	Louisville	SENE 21 T1S R70W	sandstone	ms,gs
KT13-N	Kl	Louisville	SENE 21 T1S R70W	sandstone	ms,gs
KT14-N	Kl	Louisville	SESW 21 T1S R70W	sandstone	ms
KT15-N*	Kl	Louisville	SWSW 21 T1S R70W	sandstone	ms
KT16-N	Kl	Louisville	SWSW 21 T1S R70W	sandstone	ms
KT17-N	Kl	Louisville	SENE 27 T1S R70W	sandstone	ms
KT18-N*	Kfh	Louisville	SESW 33 T1S R70W	sandstone	ms
KT19-N	Kl	Louisville	SESW 33 T1S R70W	sandstone	ms
KT20-N	Kfh	Louisville	SENE 28 T1S R70W	sandstone	ms
KT21-N	Kfh	Louisville	SENE 28 T1S R70W	sandstone	ms
KT22-N*	Kfh	Louisville	SENW 21 T1S R70W	sandstone	ms
KT23-N*	Kfh	Louisville	SENW 21 T1S R70W	clayey ss	ms
KT24-N*	Kfh	Louisville	SENW 21 T1S R70W	sandstone	ms
KT25-N*	Kfh	Louisville	SENW 21 T1S R70W	sandstone	ms

* = sample description included; gs = grain size analysis; ms = microscopic examination; ts = thin section examination; cgl = conglomeratic; ss = sandstone

Table A-1. List of Samples - Rocky Flats Geologic Mapping Project (Cont.)

Sample Number	Fm	Topographic Quadrangle	Location Township and Range	Rock Type	Use
KT26-N*	Kfh	Louisville	SENW 21 T1S R70W	sandstone	ms
KT27-N	Kfh	Louisville	SENW 21 T1S R70W	claystone	ms
KT28-N*	Kfh	Louisville	SENW 21 T1S R70W	sandstone	ms
KT29-N*	Kfh	Louisville	SENW 21 T1S R70W	sandstone	ms
KT30-N	Kl	Louisville	NESE 35 T1S R70W	claystone	ms
KT31-N*	Kl	Louisville	NESW 31 T1S R69W	sandstone	ms
KT32-N*	Ka	Louisville	SWNW 33 T1S R69W	sandstone	ms
KT33-N*	Kl	Louisville	SWNE 29 T1S R69W	sandstone	ms,ts,gs
KT34-N*	Kl	Louisville	NENE 3 T2S R70W	sandstone	ms
KT35-N TO KT49-N		not collected			
KT50-N*	Ka	Louisville	SENW 1 T2S R70W	sandstone	ms
KT51-N*	Ka	Louisville	SENW 1 T2S R70W	sandstone	ms
KT52-N*	Ka	Louisville	NWSE 1 T2S R70W	conglomerate	ms
KT53-N*	Ka	Louisville	NWSE 1 T2S R70W	coarse ss	ms
KT54-N*	Ka	Louisville	SENW 1 T2S R70W	coarse ss	ms
KT55-N*	Ka	Louisville	NWNE 1 T2S R70W	coarse ss	ms
KT56-N*	Ka	Louisville	SWSW 32 T1S R69W	conglomerate	ms,ts
KT57-N*	Ka	Louisville	SWSW 32 T1S R69W	coarse ss	ms
KT58-N*	Kl	Louisville	SWNE 32 T1S R69W	sandstone	ms
KT59-N	Kd	Eldorado Springs	NWSW 31 T1S R70W	sandstone	ms
KT60-N*	Kl	Louisville	SWSW 31 T1S R69W	sandstone	ms,ts,gs
KT61-N*	Kl	Louisville	SWSW 31 T1S R69W	sandstone	ms,ts,gs

* = sample description included; gs = grain size analysis; ms = microscopic examination; ts = thin section examination; cgl = conglomeratic; ss = sandstone

Table A-1. List of Samples - Rocky Flats Geologic Mapping Project (Cont.)

Sample Number	Fm	Topographic Quadrangle	Location Township and Range	Rock Type	Use
KT1-S*	Ka	Golden	SESE 14 T2S R70W	sandstone	ms
KT2-S*	Ka	Golden	SWSW 14 T2S R70W	sandstone	ms,gs
KT3-S	not collected				
KT4-S	not collected				
KT5-S*	Ka	Golden	NWSW 22 T2S R70W	sandstone	ms
KT6-S*	Kl	Golden	SESE 22 T2S R70W	sandstone	ms
KT7-S	Kl	Golden	SESE 22 T2S R70W	sandstone	ms
KT8-S*	Kl	Louisville	NWSE 16 T2S R70W	sandstone	ms

* = sample description included; gs = grain size analysis; ms = microscopic examination; ts = thin section examination; cgl = conglomeratic; ss = sandstone

Table A-1. List of Samples - Rocky Flats Geologic Mapping Project (Cont.)

Sample Number	Fm	Topographic Quadrangle	Location Township and Range	Rock Type	Use
KT1-E*	Ka	Golden	NENE 29 T2S R69W	cgl ss	ms
KT2-E*	Ka	Golden	NENE 29 T2S R69W	cgl ss	ms
KT3-E to KT9-E not collected					
KT10-E*	Ka	Louisville	SWNE 11 T2S R70W	sandstone	ms,ts
KT11-E*	Ka	Louisville	SENW 1 T2S R70W	sandstone	ms,ts
KT12-E	Ka	Louisville	SENW 1 T2S R70W	ss w/slicks	ms
KT13-E*	Ka	Louisville	SWNE 11 T2S R70W	pyritic ss	ms,ts
KT14-E	Ka	Louisville	SWNE 11 T2S R70W	ss w/ joints	ms
KT15-E	Ka	Louisville	SWNE 11 T2S R70W	ss w/ joints	ms,gs

* = sample description included; gs = grain size analysis; ms = microscopic examination; ts = thin section examination; cgl = conglomeratic; ss = sandstone

Table A-1. List of Samples - Rocky Flats Geologic Mapping Project (Cont.)

Sample Number	Fm	Topographic Quadrangle	Location Township and Range	Rock Type	Use
KT1-W*	Kl	Louisville	SWSE 9 T2S R70W	sandstone	ms
KT2-W*	Kl	Louisville	NWSE 16 T2S R70W	sandstone	ms
KT3-W*	Kl	Louisville	NWSE 16 T2S R70W	sandstone	ms
KT4-W	Kl	Louisville	SWNE 16 T2S R70W	sandstone	ms
KT5-W	Kl	Louisville	NWSE 4 T2S R70W	claystone	ms
KT6-W*	Kl	Louisville	NWSE 4 T2S R70W	sandstone	ms
KT7-W	Kl	Louisville	NWSE 4 T2S R70W	claystone	ms
KT8-W	Kl	Louisville	NWSE 4 T2S R70W	claystone	ms
KT9-W	Kl	Louisville	NWSE 4 T2S R70W	claystone	ms
KT10-W*	Kl	Louisville	NESW 4 T2S R70W	sandstone	ms
KT11-W*	Kl	Louisville	NESW 4 T2S R70W	sandstone	ms
KT12-W*	Kl	Louisville	NESW 4 T2S R70W	sandstone	ms
KT13-W*	Kl	Louisville	NESW 4 T2S R70W	sandstone	ms,ts
KT14-W*	Kl	Golden	SESW 28 T2S R70W	sandstone	ms
KT15-W*	Kl	Golden	SESW 28 T2S R70W	sandstone	ms
KT16-W*	Kl	Golden	SESW 28 T2S R70W	sandstone	ms
KT17-W*	Kl	Golden	SESW 28 T2S R70W	sandstone	ms
KT18-W	not collected				
KT19-W	not collected				
KT20-W	Kfh	Golden	NESW 21 T2S R70W	sandstone	ms
KT21-W	Kfh	Golden	NESW 21 T2S R70W	sandstone	ms
KT22-W	Kfh	Golden	NESW 21 T2S R70W	sandstone	ms,gs
KT23-W	Kfh	Golden	NESW 21 T2S R70W	shale	ms
KT24-W	Kfh	Golden	NESW 21 T2S R70W	sandstone	ms,gs
KT25-W	Kfh	Golden	NESW 21 T2S R70W	sandstone	ms

* = sample description included; gs = grain size analysis; ms = microscopic examination; ts = thin section examination; cgl = conglomeratic; ss = sandstone

Table A-1. List of Samples - Rocky Flats Geologic Mapping Project (Cont.)

Sample Number	Fm	Topographic Quadrangle	Location Township and Range	Rock Type	Use
KT26-W	Kfh	Golden	NESW 21 T2S R70W	claystone	ms
KT27-W	Kfh	Golden	NESW 21 T2S R70W	sandstone	ms
KT28-W	Kl	Golden	NESW 21 T2S R70W	claystone	ms
KT29-W	Kl	Golden	NESW 21 T2S R70W	sandstone	ms
KT30-W	Kl	Golden	NESW 21 T2S R70W	sandstone	ms
KT31-W	Kl	Golden	NESW 21 T2S R70W	siltstone	ms
KT32-W	Kl	Golden	NESW 21 T2S R70W	sandstone	ms,gs
KT33-W	Kl	Golden	NESW 21 T2S R70W	sandstone	ms,gs
KT34-W	Kl	Golden	NESW 21 T2S R70W	sandstone	ms
KT35a-W	Kl	Golden	NESW 21 T2S R70W	sandstone	ms,gs
KT35b-W	Kl	Golden	NESW 21 T2S R70W	sandstone	ms,gs
KT36-W	Kl	Golden	NESW 21 T2S R70W	mudstone	ms
KT37-W	Kl	Golden	NESW 21 T2S R70W	sandstone	ms
KT38-W	Kl	Golden	NESW 21 T2S R70W	sandstone	ms
KT39-W	Kl	Golden	NESW 21 T2S R70W	sandstone	ms
KT40-W	Kl	Golden	NESW 21 T2S R70W	claystone	ms
KT41-W	Kl	Golden	NESW 21 T2S R70W	sandstone	ms
KT42-W	Kl	Golden	NESW 21 T2S R70W	sandstone	ms
KT43-W	Kl	Golden	NESW 21 T2S R70W	sandstone	ms
KT44-W	Kl	Golden	NESW 21 T2S R70W	sandstone	ms
KT45-W	Kl	Golden	NESW 21 T2S R70W	claystone	ms
KT46-W	Kl	Golden	NESW 21 T2S R70W	claystone	ms
KT47-W	Kl	Golden	NESW 21 T2S R70W	sandstone	ms
KT48-W	Kl	Golden	NESW 21 T2S R70W	sandstone	ms
KT49-W	Kl	Golden	NESW 21 T2S R70W	sandstone	ms
KT50-W	Kl	Golden	NESW 21 T2S R70W	sandstone	ms

• = sample description included; gs = grain size analysis; ms = microscopic examination; ts = thin section examination; cgl = conglomeratic; ss = sandstone

Table A-1. List of Samples - Rocky Flats Geologic Mapping Project (Cont.)

Sample Number	Fm	Topographic Quadrangle	Location Township and Range	Rock Type	Use
MV1-N	Kl	Louisville	NWNE 22 T1S R70W	coal	ms
MV2-N*	Kl	Louisville	SWSE 15 T1S R70W	sandstone	ms
MV3-N*	Kl	Louisville	SESE 15 T1S R70W	sandstone	ms
MV4-N*	Kfh	Louisville	SENE 21 T1S R70W	sandstone	ms,ts
MV5-N*	Kfh	Louisville	SENE 21 T1S R70W	sandstone	ms
MV6-N*	Kfh	Louisville	SENE 21 T1S R70W	sandstone	ms,ts
MV7-N	Kl	Louisville	SENE 21 T1S R70W	claystone	ms
MV8-N	Kl	Louisville	SENE 21 T1S R70W	sandstone	ms
MV9-N	Kl	Louisville	SENE 21 T1S R70W	claystone	ms
MV10-N	Kl	Louisville	SENE 21 T1S R70W	sandstone	ms
MV11-N	Kl	Louisville	SENE 21 T1S R70W	claystone	ms
MV12-N*	Kl	Louisville	SENE 21 T1S R70W	sandstone	ms
MV13-N	Kl	Louisville	SENE 21 T1S R70W	sandstone	ms
MV14-N	Kl	Louisville	SENE 21 T1S R70W	sandstone	ms
MV15-N	Kl	Louisville	SENE 21 T1S R70W	claystone	ms
MV16-N	Kl	Louisville	SENE 21 T1S R70W	sandstone	ms
MV17-N	Kl	Louisville	SENE 21 T1S R70W	claystone	ms
MV18-N	Kl	Louisville	SENE 21 T1S R70W	claystone	ms
MV19-N	Kl	Louisville	SENE 21 T1S R70W	siltstone	ms
MV20-N	Kl	Louisville	SENE 21 T1S R70W	sandstone	ms
MV21-N*	Kl	Louisville	SENE 21 T1S R70W	sandstone	ms
MV22-N	Kl	Louisville	SENE 21 T1S R70W	sandstone	ms
MV23-N	Kl	Louisville	SENE 21 T1S R70W	siltstone	ms
MV24-N	Kl	Louisville	SENE 21 T1S R70W	claystone	ms
MV25-N	Kl	Louisville	SENE 21 T1S R70W	sandstone	ms

* = sample description included; gs = grain size analysis; ms = microscopic examination; ts = thin section examination; cgl = conglomeratic; ss = sandstone

Table A-1. List of Samples - Rocky Flats Geologic Mapping Project (Cont.)

Sample Number	Fm	Topographic Quadrangle	Location Township and Range	Rock Type	Use
MV26-N	Kl	Louisville	SENE 21 T1S R70W	siltstone	ms
MV27-N	Kl	Louisville	SENE 21 T1S R70W	claystone	ms
MV28-N	Kl	Louisville	SENE 21 T1S R70W	coal	ms
MV29-N	Kl	Louisville	SENE 21 T1S R70W	coal	ms
MV30-N	Kl	Louisville	SENE 21 T1S R70W	claystone	ms
MV31-N	Kl	Louisville	SENE 21 T1S R70W	sandstone	ms
MV32-N	Kl	Louisville	NWSE 21 T1S R70W	sandstone	ms
MV33-N	Kl	Louisville	SENE 21 T1S R70W	sandstone	ms,gs
MV34-N	Kl	Louisville	SWNE 27 T1S R70W	claystone	ms
MV35-N	Kl	Louisville	NESW 33 T1S R70W	sandstone	ms
MV36-N	Kp	Louisville	SWSW 33 T1S R70W	shale	ms
MV37-N*	Kfh	Louisville	SENE 28 T1S R70W	sandstone	ms,gs
MV38-N*	Kfh	Louisville	SENE 28 T1S R70W	sandstone	ms,gs
MV39-N*	Kfh	Louisville	SENE 28 T1S R70W	sandstone	ms,gs
MV40-N	Kl	Louisville	NWNE 26 T1S R70W	sandstone	ms
MV41-N	Kl	Louisville	SESE 22 T1S R70W	shell ss	ms
MV42-N	Kl	Louisville	SESE 22 T1S R70W	shell ss	ms
MV43-N	Kfh	Louisville	NESW 21 T1S R70W	sandstone	ms
MV44-N	Kl	Louisville	NESW 21 T1S R70W	sandstone	ms
MV45-N	Kp	Louisville	NWSW 21 T1S R70W	shale	ms
MV46-N*	Kl	Louisville	SWSW 21 T1S R70W	sandstone	ms,ts
MV47-N	Kl	Louisville	SWSW 21 T1S R70W	sandstone	ms
MV48-N	Kl	Louisville	SWSW 21 T1S R70W	sandstone	ms
MV49-N	Kl	Louisville	SWSW 21 T1S R70W	sandstone	ms
MV50-N*	Kl	Louisville	NWNW 28 T1S R70W	sandstone	ms

* = sample description included; gs = grain size analysis; ms = microscopic examination; ts = thin section examination; cgl = conglomeratic; ss = sandstone

Table A-1. List of Samples - Rocky Flats Geologic Mapping Project (Cont.)

Sample Number	Fm	Topographic Quadrangle	Location Township and Range	Rock Type	Use
MV51-N	Kl	Louisville	NWNW 28 T1S R70W	sandstone	ms
MV52-N	Kfh	Louisville	SENE 21 T1S R70W	sandstone	ms
MV53-N	Kfh	Louisville	SENE 21 T1S R70W	sandstone	ms
MV54-N	Kl	Louisville	SENE 21 T1S R70W	siltstone	ms
MV55-N	Kl	Louisville	NWNW 22 T1S R70W	sandstone	gs,ms
MV56-N	Kl	Louisville	NWNW 22 T1S R70W	sandstone	gs,ms
MV57-N	Kl	Louisville	NESW 33 T1S R70W	sandstone	gs,ms
MV58-N	Kl	Louisville	NESW 33 T1S R70W	sandstone	gs,ms
MV59-N	Kl	Louisville	NESW 33 T1S R70W	sandstone	gs,ms
MV60-N	Kl	Louisville	NESW 33 T1S R70W	sandstone	gs,ms
MV61-N	Kl	Louisville	NESW 33 T1S R70W	sandstone	gs,ms
MV62-N	Kl	Louisville	SWSW 31 T1S R69W	sandstone	ms
MV63-N*	Ka	Lafayette	SWNW 33 T1S R69W	cgl ss	ms
MV64-N*	Ka	Lafayette	SWNW 33 T1S R69W	cgl ss	ms
MV65-N*	Ka	Lafayette	SESW 28 T1S R69W	cgl ss	ms,ts
MV66-N	Kl	Louisville	SWSW 21 T1S R70W	sandstone	ms
MV67-N*	Ka	Lafayette	SWSW 34 T1S R69W	sandstone	ms
MV68-N	Kp	Eldorado Springs	SWNE 5 T2S R70W	limestone	ms
MV69-N*	Ka	Louisville	NESW 1 T2S R70W	cgl ss	ms,gs
MV70-N*	Ka	Louisville	SESE 36 T1S R70W	cgl ss	ms
MV71a-N*	Ka	Louisville	SWSW 32 T1S R69W	coarse ss	ms
MV71b-N*	Ka	Louisville	SWSW 32 T1S R69W	conglomerate	ms
MV72-N	Kl	Louisville	NWNE 36 T1S R70W	sandstone	ms
MV73-N*	Ka	Louisville	NENW 2 T2S R70W	cgl ss	ms,ts
MV74-N*	Ka	Louisville	SESW 2 T2S R70W	cgl ss	ms,ts

* = sample description included; gs = grain size analysis; ms = microscopic examination; ts = thin section examination; cgl = conglomeratic; ss = sandstone

Table A-1. List of Samples - Rocky Flats Geologic Mapping Project (Cont.)

Sample Number	Fm	Topographic Quadrangle	Location Township and Range	Rock Type	Use
MV1-W*	Kl	Louisville	SWSE 9 T2S R70W	sandstone	ms
MV2-W*	Kl	Louisville	SWSE 9 T2S R70W	sandstone	ms
MV3-W*	Kl	Louisville	NESW 4 T2S R70W	sandstone	ms
MV4-W*	Kfh	Louisville	NESW 4 T2S R70W	sandstone	ms,gs
MV5-W*	Kl	Louisville	NWSE 16 T2S R70W	sandstone	ms,ts
MV6-W*	Kl	Louisville	NWSE 16 T2S R70W	sandstone	ms
MV7-W*	Kl	Louisville	NESW 16 T2S R70W	sandstone	ms
MV8-W*	Kfh	Louisville	SWSE 9 T2S R70W	sandstone	ms
MV9-W	Kl	Louisville	NWSE 16 T2S R70W	iron-rich ss	ms
MV10-W	Tki	Ralston Buttes	SENW 29 T2S R70W	igneous	ms,ts
MV11-W	Kl	Louisville	NWSE 16 T2S R70W	ironstone	ms
MV12-W	Kd	Eldorado Springs	NWNE 6 T2S R70W	conglomerate	ms
MV13-W	Kl	Golden	SESW 28 T2S R70W	coal	ms
MV14-W*	Kl	Golden	SESW 28 T2S R70W	sandstone	ms
MV15-W	Kl	Golden	SESW 8 T2S R70W	siltstone	ms
MV16-W*	Kl	Golden	SESW 28 T2S R70W	sandstone	ms
MV17-W*	Kl	Golden	SESW 28 T2S R70W	sandstone	ms
MV18-W*	Kl	Golden	SESW 28 T2S R70W	sandstone	ms
MV19-W	Kl	Golden	SESW 28 T2S R70W	clayey ss	ms
MV20-W	Kd	Eldorado Springs	NWSW 31 T1S R70W	shale	ms
MV21-W	Kd	Eldorado Springs	NWSW 31 T1S R70W	sandstone	ms

* = sample description included; gs = grain size analysis; ms = microscopic examination; ts = thin section examination; cgl = conglomeratic; ss = sandstone

Table A-1. List of Samples - Rocky Flats Geologic Mapping Project (Cont.)

Sample Number	Fm	Topographic Quadrangle	Location Township and Range	Rock Type	Use
MV1-E*	Ka	Louisville	SENE 1 T2S R70W	sandstone	ms
MV2-E*	Kl	Louisville	SWNE 7 T2S R69W	sandstone	ms
MV3-E*	Ka	Golden	NENE 29 T2S R69W	cgl ss	ms,ts,gs
MV4-E	Ka	Louisville	SWNE 11 T2S R70W	sandstone	ms
MV5-E	Ka	Louisville	NWNW 12 T2S R70W	clg ss	ms
MV6-E	Kl	Louisville	SWSW 31 T1S R69W	claystone	ms,gs
MV7-E	Kl	Louisville	SWSW 31 T1S R69W	sandstone	ms,gs
MV8-E	Kl	Louisville	SWSW 31 T1S R69W	sandstone	ms,gs
MV9-E	Kl	Louisville	SWSW 31 T1S R69W	claystone	ms,gs
MV10-E	Kl	Louisville	SWSW 31 T1S R69W	claystone	ms,gs
MV11-E	Kl	Louisville	SWSW 31 T1S R69W	sandstone	ms,gs
MV12-E	Kl	Louisville	SWSW 31 T1S R69W	claystone	ms,gs
MV13-E	Kl	Louisville	SWSW 31 T1S R69W	sandstone	ms,gs
MV14-E	Kl	Louisville	SWSW 31 T1S R69W	sandstone	ms,gs
MV15-E	Kl	Louisville	SWSW 31 T1S R69W	ironstone	ms,gs
MV16-E	Kl	Louisville	SWSW 31 T1S R69W	sandstone	ms,gs
MV17-E	Kl	Louisville	SWSW 31 T1S R69W	claystone	ms,gs
MV18-E	Kl	Louisville	SWSW 31 T1S R69W	sandstone	ms,gs
MV19-E	Kl	Louisville	SWSW 31 T1S R70W	claystone	ms,gs
MV20-E	Kl	Louisville	SWSW 31 T1S R70W	sandstone	ms,gs
MV21-E	Kl	Louisville	SWSW 31 T1S R70W	sandstone	ms,gs
MV22-E	Kl	Louisville	SWSW 31 T1S R70W	sandstone	ms,gs
MV23-E	Kl	Louisville	SWSW 31 T1S R70W	claystone	ms,gs
MV24-E	Kl	Louisville	SWSW 31 T1S R70W	claystone	ms,gs
MV25-E	Kl	Louisville	SWSW 31 T1S R70W	claystone	ms,gs

* = sample description included; gs = grain size analysis; ms = microscopic examination; ts = thin section examination; cgl = conglomeratic; ss = sandstone

Table A-1. List of Samples - Rocky Flats Geologic Mapping Project (Cont.)

Sample Number	Fm	Topographic Quadrangle	Location Township and Range	Rock Type	Use
MV26-E	Kl	Louisville	SWSW 31 T1S R70W	claystone	ms,gs
MV27-E	Ka	Louisville	SWSW 31 T1S R70W	claystone	ms,gs
MV28-E*	Ka	Golden	NWSW 19 T2S R69W	coarse ss	ms,ts,gs
MV29-E	Ka	Golden	SWNW 29 T2S R69W	cgl ss	ms

* = sample description included; gs = grain size analysis; ms = microscopic examination; ts = thin section examination; cgl = conglomeratic; ss = sandstone

Table A-1. List of Samples - Rocky Flats Geologic Mapping Project (Cont.)

Sample Number	Fm	Topographic Quadrangle	Location Township and Range	Rock Type	Use
MV1-S*	Kl	Golden	SESW 14 T2S R70W	sandstone	ms
MV2-S*	Ka	Golden	NENW 23 T2S R70W	sandstone	ms,gs
MV3-S*	Ka	Golden	NENE 22 T2S R70W	sandstone	ms,ts
MV4-S*	Kl	Golden	NWNW 23 T2S R70W	sandstone	ms
MV5-S*	Ka	Golden	NWNE 22 T2S R70W	sandstone	ms

* = sample description included; gs = grain size analysis; ms = microscopic examination; ts = thin section examination; cgl = conglomeratic; ss = sandstone

Table A-2. List of Thin Sections - Rocky Flats Geologic Mapping Project

Thin Section Number	Fm	Topographic Quadrangle	Location Township and Range	Rock Type
KT33-N	Kl	Louisville	SWNE 29 T1S R69W	sandstone
KT56-N	Ka	Louisville	SWSW 32 T1S R69W	conglomerate
KT60-N	Kl	Louisville	SWSW 31 T1S R69W	sandstone
KT61-N	Kl	Louisville	SWSW 31 T1S R69W	sandstone
KT10-E	Ka	Louisville	SWNE 11 T2S R70W	sandstone
KT11-E	Ka	Louisville	SENW 1 T2S R70W	sandstone
KT13-E	Ka	Louisville	SWNE 11 T2S R70W	pyritic ss
KT13-W	Kl	Louisville	NESW 4 T2S R70W	sandstone
MV4-N	Kfh	Louisville	SESE 21 T1S R70W	sandstone
MV6-N	Kfh	Louisville	SENE 21 T1S R70W	sandstone
MV46-N	Kl	Louisville	SWSW 21 T1S R70W	sandstone
MV65-N	Ka	Lafayette	SESW 28 T1S R69W	cgl ss
MV73-N	Ka	Louisville	NENW 2 T2S R70W	cgl ss
MV74-N	Ka	Louisville	SESW 2 T2S R70W	cgl ss
MV3-S	Ka	Golden	NENE 22 T2S R70W	sandstone
MV3-E	Ka	Golden	NENE 29 T2S R69W	cgl ss
MV28-E	Ka	Golden	NWSW 19 T2S R70W	coarse ss
MV5-W	Kl	Louisville	NWSE 16 T2S R70W	sandstone
MV10-W	Tki	Ralston Buttes	SENW 29 T2S R70W	igneous
0386BR (14.5ft)	Ka	Louisville	SENE 12 T2S R70W	sandstone
3286BR (95ft)	Kl	Louisville	SENW 11 T2S R70W	siltstone
6286 (55.3ft)	Ka	Louisville	SESW 11 T2S R70W	sandstone
0987BH (20.3ft)A	Ka	Louisville	NESW 11 T2S R70W	sandstone
0987BH (29.3ft)B	Ka	Louisville	NESW 11 T2S R70W	cgl ss

• = sample description included; gs = grain size analysis; ms = microscopic examination; ts = thin section examination; cgl = conglomeratic; ss = sandstone

Table A-2. List of Thin Sections - Rocky Flats Geologic Mapping Project (Cont.)

Sample Number	Fm	Topographic Quadrangle	Location Township and Range	Rock Type	Use
0987BH (30ft)	Ka	Louisville	NESW 11 T2S R70W	cgl ss	
0987BH (30.2ft)C	Ka	Louisville	NESW 11 T2S R70W	sandstone	
0987BH (31.0ft)D	Kl	Louisville	NESW 11 T2S R70W	claystone	
0987BH (33.0ft)E	Kl	Louisville	NESW 11 T2S R70W	sandstone	
1387BR (20.5ft)	Ka	Louisville	SWSE 11 T2S R70W	sandstone	
1487BR (10.5ft)	Ka	Louisville	SWSE 11 T2S R70W	sandstone	
1487BR (20ft)	Ka	Louisville	SWSE 11 T2S R70W	sandstone	
1687BR (137ft)	Kl	Louisville	NWSE 11 T2S R70W	sandstone	
1887BR (112ft)	Kl	Louisville	NWSE 11 T2S R70W	sandstone	
3187BR (128ft)	Ka	Louisville	NESE 11 T2S R70W	cgl ss	
3287BH (9.7ft)	Kl	Louisville	NESE 11 T2S R70W	sandstone	
3387BH (14.8ft)	Kl	Louisville	NESE 11 T2S R70W	sandstone	
3687BR (45ft)	Ka	Louisville	NWSE 11 T2S R70W	cgl ss	
4287BH (38.7ft)	Ka	Louisville	NWSE 11 T2S R70W	sandstone	
4287BH (55ft)	Kl	Louisville	NWSE 11 T2S R70W	sandstone	
4587 BH (23.8ft)	Kl	Louisville	SESW 11 T2S R70W	sandstone	
5289BR (33.5ft) (B217089)	Ka	Louisville	NWNE 11 T2S R70W	cgl ss	
5689BR (43ft) (B217489)	Ka	Louisville	NWSE 11 T2S R70W	sandstone	

* = sample description included; gs = grain size analysis; ms = microscopic examination; ts = thin section examination; cgl = conglomeratic; ss = sandstone
(B217089) = new well number

SURFACE SAMPLE DESCRIPTION

Sample Number KT4a-N

Thin Section ---

Location Collected Marshall NESW 15 T1S R70W (Station 3-5)

Formation Name Fox Hills

ROCK TYPE WITH MODIFIERS: Sandstone with some silt

COLOR (GSA Rock Color Chart): Light olive gray (5Y 6/1) weathers dark yellowish orange (10YR 6/6)

TEXTURE:

Grain Size: Range Very fine - medium sand Mode Fine

Sorting Moderate

Roundness Subangular to subrounded

Textural Maturity Submature

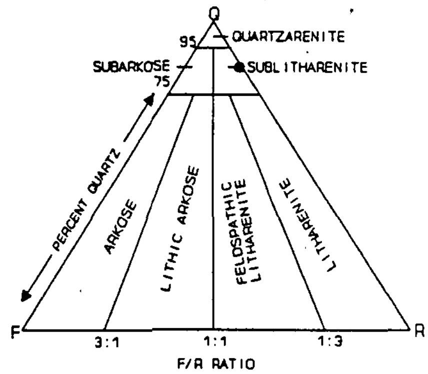
Porosity 20%

Cement/Matrix No cement/10% silt, 3% clay

Friability Slightly friable

COMPOSITION:

Mineral:	Percentage:
Quartz	85
Rock fragments	10
Chert	4
Biotite	1
Feldspar	Trace



CLASSIFICATION (Folk, 1974): Sublitharenite

MACROSCOPIC FIELD CHARACTERISTICS:

Weathering Characteristics Low-angle, non-resistant, forms slope

Bedding/Internal Structures Massive/structureless

Fractures/Slickensides None

FOSSILS: None

COMMENTS: Biotite varies from yellow to brown in color.

SURFACE SAMPLE DESCRIPTION

Sample Number: KT15-N
Thin Section: ---
Location Collected: Silicified knob near Eldorado Springs SWSW 21 T1S R70W
Formation Name: Laramie (Station 6-7)

ROCK TYPE WITH MODIFIERS: Sandstone with some silt and clay

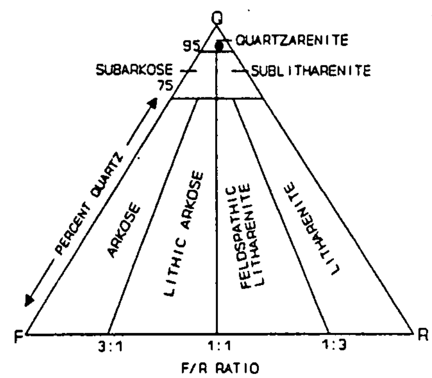
COLOR (GSA Rock Color Chart): Light olive gray (5Y 6/1) weathers yellowish gray (5Y 7/2)

TEXTURE:

Grain Size: Range Silt - very fine sand Mode Very fine
Sorting: Well
Roundness: Subangular
Textural Maturity: Immature
Porosity: 10%
Cement/Matrix: No cement/15% silt, 8% clay
Friability: Non friable

COMPOSITION:

Mineral:	Percentage:
Quartz	97
Rock fragments	2
Feldspar	1
Carbonaceous fragments	Trace
Muscovite	Trace



CLASSIFICATION (Folk, 1974): Quartzarenite

MACROSCOPIC FIELD CHARACTERISTICS:

Weathering Characteristics: Silicified, resistant ledge former, blocky weathering
Bedding/Internal Structures: Massive/structureless
Fractures/Slickensides: Silica-filled fractures

FOSSILS: None

COMMENTS: Clay obscures sand grains.

SURFACE SAMPLE DESCRIPTION

Sample Number	KT18-N
Thin Section	---
Location Collected	Coal Creek SESW 33 T1S R70W (Station 7-4)
Formation Name	Fox Hills

ROCK TYPE WITH MODIFIERS: Sandstone with some silt and clay

COLOR (GSA Rock Color Chart): Light olive gray (5Y 6/1) weathers moderate yellowish brown (10YR 5/4)

TEXTURE:

Grain Size: Range Very fine - medium sand Mode Fine

Sorting Moderate

Roundness Subangular to rounded

Textural Maturity Immature

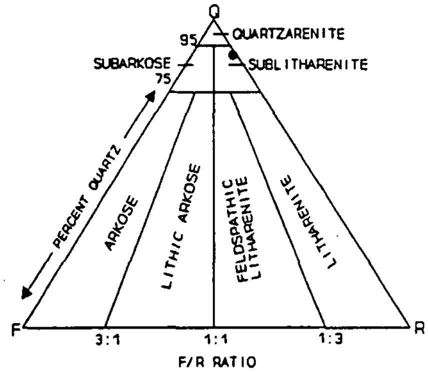
Porosity 15%

Cement/Matrix No cement/10% silt, 8% clay

Friability Moderately friable

COMPOSITION:

Mineral:	Percentage:
Quartz	90
Rock fragments	7
Chert	3
Feldspar, glauconite	Trace
Biotite, muscovite	Trace



CLASSIFICATION (Folk, 1974): Sublitharenite

MACROSCOPIC FIELD CHARACTERISTICS:

Weathering Characteristics: Forms rounded weathering ledge; more resistant at top

Bedding/Internal Structures: Massive

Fractures/Slickensides: Cut by planar joints

FOSSILS: None

COMMENTS: Biotite varies from yellow to brown in color; muscovite is clear; chert is black; rock fragments are yellow, light brown, or gray in color.

SURFACE SAMPLE DESCRIPTION

Sample Number: KT22-N
Thin Section: ---
Location Collected: Eldorado Springs SENW 21 T1S R70W (Station 10-1)
Formation Name: Fox Hills

ROCK TYPE WITH MODIFIERS: Sandstone with some silt

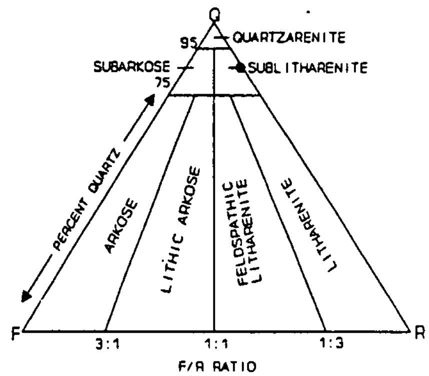
COLOR (GSA Rock Color Chart): Light olive gray (5Y 6/1) weathers dark yellowish orange (10YR 6/6)

TEXTURE:

Grain Size: Range Very fine - medium sand Mode Fine
Sorting: Moderate
Roundness: Subangular to rounded
Textural Maturity: Immature
Porosity: 20%
Cement/Matrix: No cement/8% silt, 5% clay
Friability: Highly friable

COMPOSITION:

Mineral:	Percentage:
Quartz	85
Rock fragments	10
Chert	5
Feldspar, glauconite	Trace
Biotite, zircon?	Trace



CLASSIFICATION (Folk, 1974): Sublitharenite

MACROSCOPIC FIELD CHARACTERISTICS:

Weathering Characteristics: Loose, non-resistant
Bedding/Internal Structures: Massive
Fractures/Slickensides: None

FOSSILS: None

COMMENTS: Clay is white, semi-irridescent, and tends to flocculate around sand grains.

SURFACE SAMPLE DESCRIPTION

Sample Number KT23-N

Thin Section ---

Location Collected Eldorado Springs SENW 21 T1S R70W (Station 10-1)

Formation Name Fox Hills

ROCK TYPE WITH MODIFIERS: Sandstone with some silt and clay

COLOR (GSA Rock Color Chart): Moderate brown (5YR 4/4 - 5YR 3/4)

TEXTURE:

Grain Size: Range Very fine - medium sand Mode Medium

Sorting Moderate

Roundness Angular to subrounded

Textural Maturity Immature

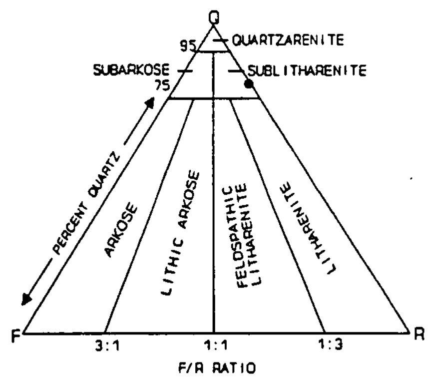
Porosity 5%

Cement/Matrix No cement/14% silt, 14% clay

Friability Moderately friable

COMPOSITION:

Mineral:	Percentage:
Quartz	80
Carbonaceous fragments	10
Chert	5
Rock fragments	5
Biotite	Trace



CLASSIFICATION (Folk, 1974): Sublitharenite

MACROSCOPIC FIELD CHARACTERISTICS:

Weathering Characteristics Rounded weathering, non-resistant ledge

Bedding/Internal Structures Massive - basal bedding surface shows bed load deformation structures

Fractures/Slickensides None

FOSSILS: None

COMMENTS: Iron-stained clay is abundant and obscures other constituents; carbonaceous fragments occur as medium-sized angular to subangular grains that break easily.

SURFACE SAMPLE DESCRIPTION

Sample Number	KT24-N
Thin Section	---
Location Collected	Eldorado Springs SENW 21 T1S R70W (Station 10-1)
Formation Name	Fox Hills

ROCK TYPE WITH MODIFIERS: Sandstone with some silt

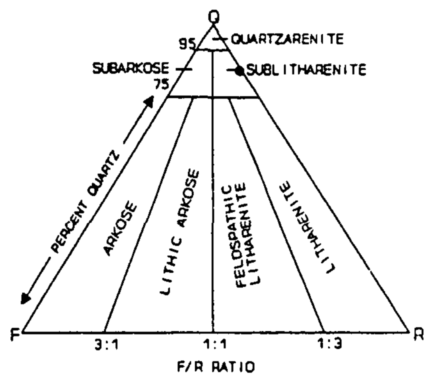
COLOR (GSA Rock Color Chart): Light olive gray (5Y 6/1) weathers moderate yellowish brown (10YR 5/4)

TEXTURE:

Grain Size: Range Very fine - medium sand Mode Fine
Sorting Moderate
Roundness Subangular to rounded
Textural Maturity Submature
Porosity 20%
Cement/Matrix No cement/10% silt, 3% clay
Friability Moderately friable

COMPOSITION:

Mineral:	Percentage:
Quartz	85
Rock fragments	5
Chert	10
Tourmaline?	Trace
Biotite, Muscovite	Trace



CLASSIFICATION (Folk, 1974): Sublitharenite

MACROSCOPIC FIELD CHARACTERISTICS:

Weathering Characteristics: Rounded weathering, non-resistant ledge

Bedding/Internal Structures: Low-angle planar cross bedding

Fractures/Slickensides: None

FOSSILS: None

COMMENTS: Tourmaline? occurs as a pinkish prismatic crystal; clay is iron stained and appears yellow in color.

SURFACE SAMPLE DESCRIPTION

Sample Number KT25-N
Thin Section ---
Location Collected Eldorado Springs SENW 21 T1S R70W (Station 10-1)
Formation Name Fox Hills

ROCK TYPE WITH MODIFIERS: Sandstone with some silt

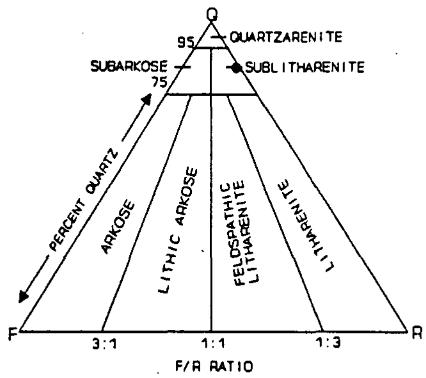
COLOR (GSA Rock Color Chart): Light olive gray (5Y 6/1) weathers grayish orange (10YR 7/4)

TEXTURE:

Grain Size: Range Very fine - medium sand Mode Fine
Sorting Moderate
Roundness Angular to subrounded
Textural Maturity Submature
Porosity 20%
Cement/Matrix No cement/10% silt, 3% clay
Friability Moderately friable

COMPOSITION:

Mineral:	Percentage:
Quartz	85
Rock fragments	10
Chert	3
Biotite, feldspar	1,1
Glauconite	Trace



CLASSIFICATION (Folk, 1974): Sublitharenite

MACROSCOPIC FIELD CHARACTERISTICS:

Weathering Characteristics Forms loose, rounded slope

Bedding/Internal Structures Massive

Fractures/Slickensides None

FOSSILS: None

COMMENTS: Clay is white, opaque, semi-iridescent; biotite varies from yellow to brown in color and is sometimes altered.

SURFACE SAMPLE DESCRIPTION

Sample Number KT26-N

Thin Section ---

Location Collected Eldorado Springs SENW 21 T1S R70W (Station 10-1)

Formation Name Fox Hills

ROCK TYPE WITH MODIFIERS: Sandstone with some silt and clay

COLOR (GSA Rock Color Chart): Moderate brown (5YR 3/4)

TEXTURE:

Grain Size: Range Very fine - medium sand Mode Fine

Sorting Moderate

Roundness Subangular to rounded

Textural Maturity Immature

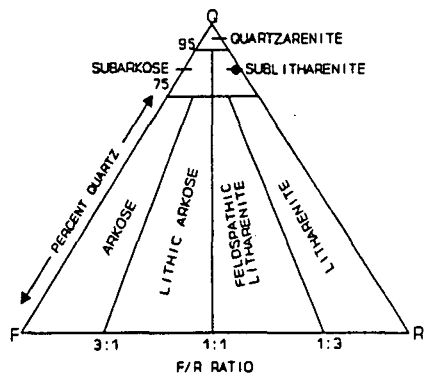
Porosity 20%

Cement/Matrix No cement/7% silt, 6% clay

Friability Moderately friable

COMPOSITION:

Mineral:	Percentage:
Quartz	85
Rock fragments	4
Chert	10
Feldspar	1
Biotite	Trace



CLASSIFICATION (Folk, 1974): Sublitharenite

MACROSCOPIC FIELD CHARACTERISTICS:

Weathering Characteristics Forms loose, rounded ledge and shallow slope

Bedding/Internal Structures Massive with planar lower bounding surface

Fractures/Slickensides None

FOSSILS: None

COMMENTS: Clay is iron stained and appears orange to reddish-brown in color.

SURFACE SAMPLE DESCRIPTION

Sample Number	KT28-N
Thin Section	---
Location Collected	Eldorado Springs SENW 21 T1S R70W (Station 10-1)
Formation Name	Fox Hills

ROCK TYPE WITH MODIFIERS: Sandstone with some silt

COLOR (GSA Rock Color Chart): Light olive gray (5Y 6/1) weathers dark yellowish orange (10YR 6/6) to moderate brown (5YR 3/4)

TEXTURE:

Grain Size: Range Very fine - fine sand Mode Fine

Sorting Moderate

Roundness Subangular to subrounded

Textural Maturity Submature

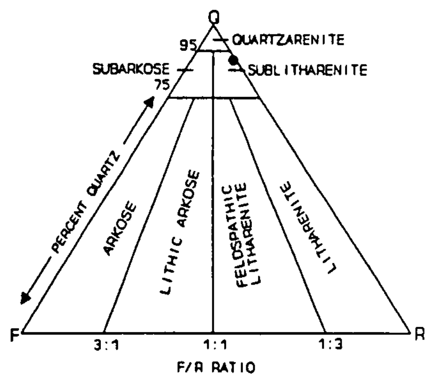
Porosity 20%

Cement/Matrix No cement/10% silt, 3% clay

Friability Slightly friable

COMPOSITION:

Mineral:	Percentage:
Quartz	90
Rock fragments	6
Chert	4
Feldspar	Trace
Muscovite, Coal?	Trace



CLASSIFICATION (Folk, 1974): Sublitharenite

MACROSCOPIC FIELD CHARACTERISTICS:

Weathering Characteristics Forms non-resistant slope; top 2 inches is iron-stained and is resistant to weathering

Bedding/Internal Structures Massive

Fractures/Slickensides None

FOSSILS: None

COMMENTS: Rock fragments vary from light brown to black in color.

SURFACE SAMPLE DESCRIPTION

Sample Number KT29-N

Thin Section ---

Location Collected Eldorado Springs SENW 21 T1S R70W (Station 10-1)

Formation Name Fox Hills

ROCK TYPE WITH MODIFIERS: Sandstone with some silt

COLOR (GSA Rock Color Chart): Light olive gray (5Y 6/1) weathers dark yellowish orange (10YR 6/6)

TEXTURE:

Grain Size: Range Very fine - medium sand Mode Fine

Sorting Moderate

Roundness Subangular to rounded

Textural Maturity Submature

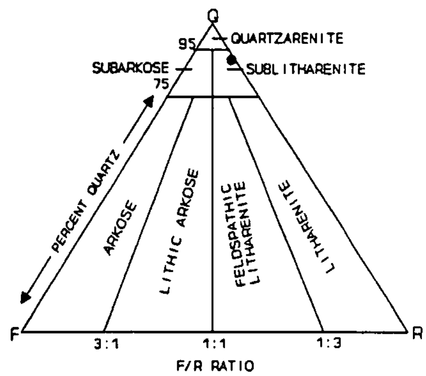
Porosity 25%

Cement/Matrix No cement/6% silt, 2% clay

Friability Highly friable

COMPOSITION:

Mineral:	Percentage:
Quartz	90
Rock fragments	7
Chert	3
Biotite, Muscovite, Glaconite	Trace
Feldspar, Zircon?	Trace



CLASSIFICATION (Folk, 1974): Sublitharenite

MACROSCOPIC FIELD CHARACTERISTICS:

Weathering Characteristics Forms steep loose slope; top 1 foot fractured by roots; iron-oxide stained

Bedding/Internal Structures Massive

Fractures/Slickensides None

FOSSILS: None

COMMENTS: Some sand grains have quartz overgrowths.

SURFACE SAMPLE DESCRIPTION

Sample Number	KT31-N
Thin Section	---
Location Collected	Drainage north of Highway 128 NESW 31 T1S R69W
Formation Name	Laramie (Station 11-5)

ROCK TYPE WITH MODIFIERS: Calcareous sandstone

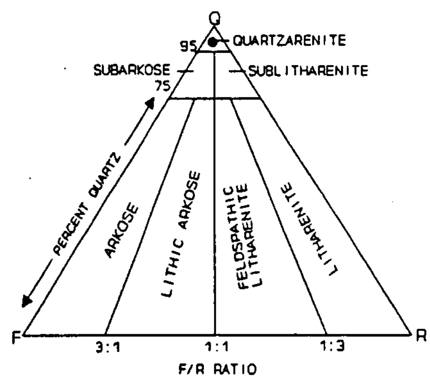
COLOR (GSA Rock Color Chart): Light olive gray (5Y 6/1) weathers dark yellowish orange (10YR 6/6)

TEXTURE:

- Grain Size: Range Very fine - medium sand Mode Medium
- Sorting Moderate
- Roundness Subangular to well rounded
- Textural Maturity Submature
- Porosity 10%
- Cement/Matrix 15% calcite cement, 5% silt, 3% clay
- Friability Non-friable

COMPOSITION:

Mineral:	Percentage:
Quartz	98
Feldspar	1
Rock fragments	1
Magnetite	Trace



CLASSIFICATION (Folk, 1974): Quartzarenite

MACROSCOPIC FIELD CHARACTERISTICS:

Weathering Characteristics	Resistant ledge forming
Bedding/Internal Structures	Laminated, cross-bedded, irregular thickness to beds
Fractures/Slickensides	None

FOSSILS: None

COMMENTS: Rounded quartz grains are frosted, subangular quartz grains are not frosted; trace olive green clay.

SURFACE SAMPLE DESCRIPTION

Sample Number: KT32-N
Thin Section: ---
Location Collected: Community Ditch near Interlocken SWNW 33 T1S R69W
Formation Name: Arapahoe (Station 14-1)

ROCK TYPE WITH MODIFIERS: Carbonaceous sandstone with some silt and clay

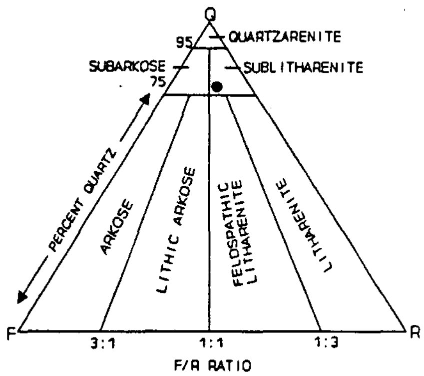
COLOR (GSA Rock Color Chart): Yellowish gray (5Y 7/2) weathers dark yellowish orange (10YR 6/6)

TEXTURE:

Grain Size: Range Very fine - fine sand Mode Very fine
Sorting: Moderate
Roundness: Subangular
Textural Maturity: Immature
Porosity: 15%
Cement/Matrix: No cement/10% silt, 8% clay
Friability: Slightly friable

COMPOSITION:

Mineral:	Percentage:
Quartz	78
Carbonaceous fragments	20
Rock fragments	2
Feldspar	Trace
Muscovite	Trace



CLASSIFICATION (Folk, 1974): Sublitharenite

MACROSCOPIC FIELD CHARACTERISTICS:

Weathering Characteristics: Resistant

Bedding/Internal Structures: Medium bedded/planar tangential cross-laminations

Fractures/Slickensides:

FOSSILS: None

COMMENTS: Carbonaceous fragments are concentrated along laminae as "lag" deposits; trace olive green clay.

SURFACE SAMPLE DESCRIPTION

Sample Number KT33-N
Thin Section KT33-N
Location Collected Highway 36 roadcut SWNE 29 T1S R69W (Station 14-5)
Formation Name Laramie

ROCK TYPE WITH MODIFIERS: Sandstone with some silt and clay

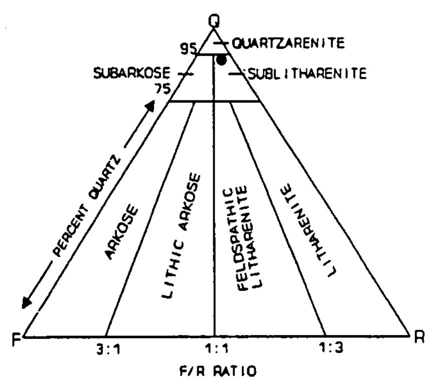
COLOR (GSA Rock Color Chart): Light olive gray (5Y 5/2) weathers light olive brown (5Y 5/6)

TEXTURE:

Grain Size: Range Very fine - fine sand Mode Fine
Sorting Well
Roundness Subangular
Textural Maturity Immature
Porosity 15%
Cement/Matrix No cement/12% silt, 6% clay
Friability Moderately friable

COMPOSITION:

Mineral:	Percentage:
Quartz	94
Rock fragments	3
Carbonaceous fragments	2
Feldspar	1
Muscovite	Trace



CLASSIFICATION (Folk, 1974): Quartzarenite

MACROSCOPIC FIELD CHARACTERISTICS:

Weathering Characteristics: Friable, loose, occurs on steep bank of road cut
Bedding/Internal Structures: Planar laminated sandstone interbedded with laminated silty claystone
Fractures/Slickensides:

FOSSILS: None

COMMENTS: Clay is white, semi-irridescent; clay occurs along laminae and fills some intergranular porosity; stringers of organic material.

SURFACE SAMPLE DESCRIPTION

Sample Number	KT34-N
Thin Section	---
Location Collected	Highway 128 near Rock Creek NENE 3 T2S R70W
Formation Name	Laramie (Station 17-5)

ROCK TYPE WITH MODIFIERS: Calcareous sandstone

COLOR (GSA Rock Color Chart): Olive gray (5Y 4/1) weathers same

TEXTURE:

Grain Size: Range Very fine - medium sand Mode Fine

Sorting Moderate

Roundness Subangular to subrounded

Textural Maturity Submature

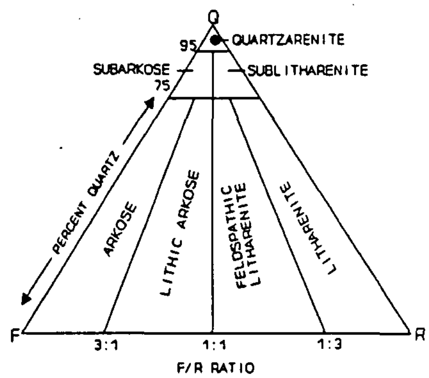
Porosity 10%

Cement/Matrix 15% calcite cement/5% silt, 3% clay

Friability Moderately friable

COMPOSITION:

Mineral:	Percentage:
Quartz	98
Rock fragments	1
Carbonaceous fragments	1
Muscovite	Trace



CLASSIFICATION (Folk, 1974): Quartzarenite

MACROSCOPIC FIELD CHARACTERISTICS:

Weathering Characteristics Friable, loose weathering

Bedding/Internal Structures

Fractures/Slickensides Fractures filled with caliche

FOSSILS: None

COMMENTS: Quartz grains are not frosted.

SURFACE SAMPLE DESCRIPTION

Sample Number	KT50-N
Thin Section	---
Location Collected	Northeast Buffer Zone SENW 1 T2S R70W (Station 25-7)
Formation Name	Arapahoe

ROCK TYPE WITH MODIFIERS: Sandstone with some silt

COLOR (GSA Rock Color Chart): Light olive gray (5Y 6/1) weathers dark yellowish orange (10YR 6/6)

TEXTURE:

Grain Size: Range Fine - medium sand Mode Medium

Sorting Moderate to well

Roundness Subangular to well rounded

Textural Maturity Mature

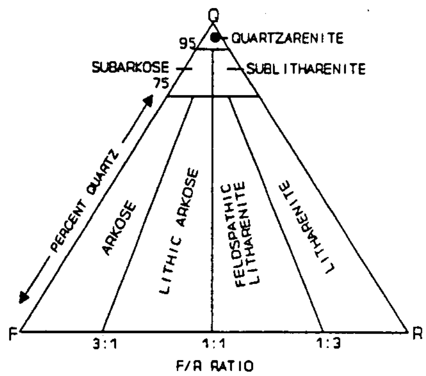
Porosity 25%

Cement/Matrix No cement/8% silt, no clay

Friability Moderately friable

COMPOSITION:

Mineral:	Percentage:
Quartz	98
Rock fragments	1
Chert	1
Feldspar	Trace
Magnetite	Trace



CLASSIFICATION (Folk, 1974): Quartzarenite

MACROSCOPIC FIELD CHARACTERISTICS:

Weathering Characteristics Forms rounded ledge

Bedding/Internal Structures Massive

Fractures/Slickensides None

FOSSILS: None

COMMENTS: Some quartz grains are frosted.

SURFACE SAMPLE DESCRIPTION

Sample Number: KT51-N

Thin Section: ---

Location Collected: Northeast Buffer Zone SENW 1 T2S R70W (Station 25-7)

Formation Name: Arapahoe

ROCK TYPE WITH MODIFIERS: Calcareous sandstone with some silt

COLOR (GSA Rock Color Chart): Light olive gray (5Y 5/2) weathers light olive brown (5Y 5/6)

TEXTURE:

Grain Size: Range Very fine - medium sand Mode Fine

Sorting: Moderate

Roundness: Subangular to rounded

Textural Maturity: Submature

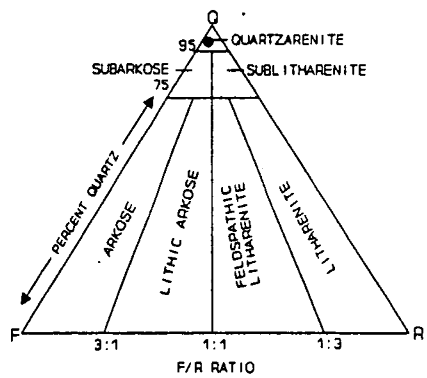
Porosity: None

Cement/Matrix: 18% calcite cement/10% silt, 5% clay

Friability: Non-friable

COMPOSITION:

Mineral:	Percentage:
Quartz	97
Feldspar	2
Rock fragments	1
Muscovite	Trace
Magnetite	Trace



CLASSIFICATION (Folk, 1974): Quartzarenite

MACROSCOPIC FIELD CHARACTERISTICS:

Weathering Characteristics: Forms resistant platy ledge

Bedding/Internal Structures: Thickly laminated with subparallel planar bedding surfaces

Fractures/Slickensides: None

FOSSILS: None

COMMENTS: Some quartz grains are frosted; platy laminated sandstone.

SURFACE SAMPLE DESCRIPTION

Sample Number KT52-N

Thin Section ---

Location Collected Northeast Buffer Zone NWSE 1 T2S R70W (Station 26-1)

Formation Name Arapahoe

ROCK TYPE WITH MODIFIERS: Calcareous pebbly sandstone with some silt/clay

COLOR (GSA Rock Color Chart): Yellowish gray (5Y 7/2) weathers dark yellowish orange to dark yellowish brown (10YR 6/6-4/2)

TEXTURE:

Grain Size: Range Fine sand - fine pebble Mode Coarse sand

Sorting Poor

Roundness Subangular to well rounded

Textural Maturity Immature

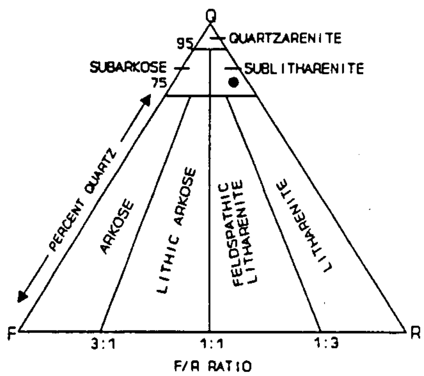
Porosity 10%

Cement/Matrix 15% calcite cement/3% silt, 5% clay

Friability Highly friable

COMPOSITION:

Mineral:	Percentage:
Quartz	80
Rock fragments	15
Feldspar	4
Chert	1
Magnetite	Trace



CLASSIFICATION (Folk, 1974): Sublitharenite

MACROSCOPIC FIELD CHARACTERISTICS:

Weathering Characteristics Forms slope

Bedding/Internal Structures Thin bedded to laminated with planar cross-bedding

Fractures/Slickensides None

FOSSILS: None

COMMENTS: Most quartz grains are well rounded and frosted.

SURFACE SAMPLE DESCRIPTION

Sample Number KT53-N
Thin Section ---
Location Collected Northeast Buffer Zone NWSE 1 T2S R70W (Station 26-1)
Formation Name Arapahoe

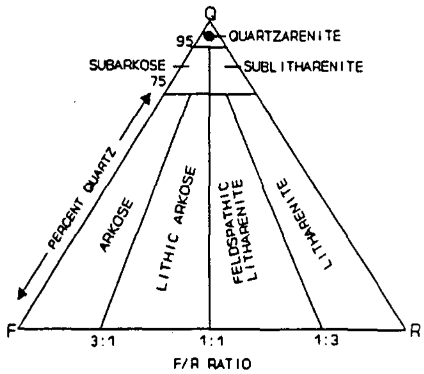
ROCK TYPE WITH MODIFIERS: Calcareous sandstone

COLOR (GSA Rock Color Chart): Light olive gray (5Y 5/2) weathers dark yellowish brown (10YR 4/2)

TEXTURE:
Grain Size: Range Fine to coarse sand Mode Medium
Sorting Moderate
Roundness Subangular to well rounded
Textural Maturity Submature
Porosity 10%
Cement/Matrix 20% calcite cement/2% silt, 1% clay
Friability Non-friable

COMPOSITION:

Mineral:	Percentage:
Quartz	98
Feldspar	1
Rock fragments	1



CLASSIFICATION (Folk, 1974): Quartzarenite

MACROSCOPIC FIELD CHARACTERISTICS:

Weathering Characteristics Large slab on hillslope

Bedding/Internal Structures Thickly laminated to thin bedded

Fractures/Slickensides None

FOSSILS: None

COMMENTS: Some quartz grains are rounded and frosted, other quartz grains are subangular and clear; bimodal grain size distribution.

SURFACE SAMPLE DESCRIPTION

Sample Number: KT54-N
Thin Section: ---
Location Collected: Northeast Buffer Zone SENW 1 T2S R70W (Station 26-3)
Formation Name: Arapahoe

ROCK TYPE WITH MODIFIERS: Calcareous sandstone

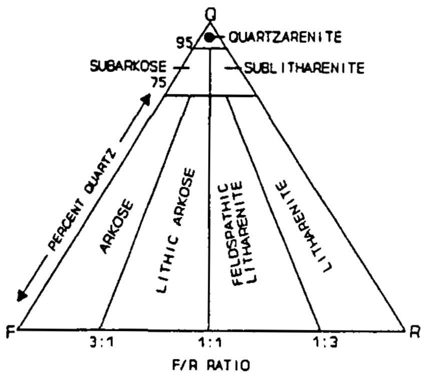
COLOR (GSA Rock Color Chart): Yellowish gray (5Y 5/2) weathers dark yellowish brown (10YR 4/2)

TEXTURE:

Grain Size: Range Fine to medium sand Mode Medium
Sorting: Well
Roundness: Subangular to well rounded
Textural Maturity: Mature
Porosity: 15%
Cement/Matrix: 15% calcite cement/3% silt, no clay
Friability: Non-friable

COMPOSITION:

Mineral:	Percentage:
Quartz	98
Feldspar	1
Rock fragments	1



CLASSIFICATION (Folk, 1974): Quartzarenite

MACROSCOPIC FIELD CHARACTERISTICS:

Weathering Characteristics: Friable slabs on hillslope
Bedding/Internal Structures: Not apparent
Fractures/Slickensides: None

FOSSILS: None

COMMENTS: Some quartz grains are frosted.

SURFACE SAMPLE DESCRIPTION

Sample Number: KT55-N
Thin Section: ---
Location Collected: North of Highway 128 NWNE 1 T2S R70W (Station 27-2)
Formation Name: Arapahoe

ROCK TYPE WITH MODIFIERS: Calcareous sandstone with some silt

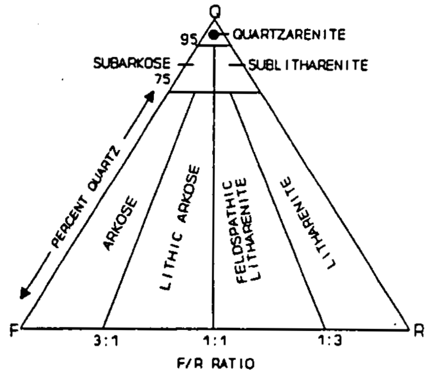
COLOR (GSA Rock Color Chart): Light olive gray (5Y 5/2) weathers dark yellowish brown (10YR 4/2)

TEXTURE:

Grain Size: Range Very fine - medium sand Mode Medium
Sorting: Moderate
Roundness: Subrounded to well rounded
Textural Maturity: Submature to mature
Porosity: None
Cement/Matrix: 25% calcite cement/5% silt, 3% clay
Friability: Non-friable

COMPOSITION:

Mineral:	Percentage:
Quartz	98
Feldspar	1
Rock fragments	1
Magnetite	Trace



CLASSIFICATION (Folk, 1974): Quartzarenite

MACROSCOPIC FIELD CHARACTERISTICS:

Weathering Characteristics: Slabs on hillslope

Bedding/Internal Structures: Not apparent

Fractures/Slickensides: None

FOSSILS: None

COMMENTS: Bimodal grain size distribution; medium sized, well rounded quartz grains are frosted; fine sized, subangular quartz grains are not frosted.

SURFACE SAMPLE DESCRIPTION

Sample Number KT56-N
Thin Section KT56-N
Location Collected North of Highway 128 SWSW 32 T1S R69W (Station 29-3)
Formation Name Arapahoe

ROCK TYPE WITH MODIFIERS: Calcareous pebbly sandstone

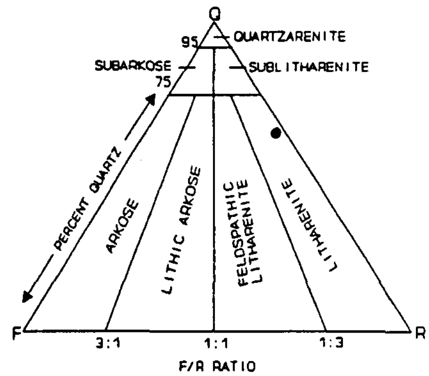
COLOR (GSA Rock Color Chart): Pale yellowish brown (10YR 6/2) weathers moderate to dark yellowish brown (5YR 3/4-10YR 4/2)

TEXTURE:

Grain Size: Range Fine sand - coarse pebble Mode Coarse sand
Sorting Poor
Roundness Subangular to well rounded
Textural Maturity Immature
Porosity None
Cement/Matrix 25% calcite cement/5% silt, 3% clay
Friability Non-friable

COMPOSITION:

Mineral:	Percentage:
Quartz	55
Rock fragments	20
Ironstone fragments	18
Chert	5
Feldspar	2



CLASSIFICATION (Folk, 1974): Litharenite

MACROSCOPIC FIELD CHARACTERISTICS:

Weathering Characteristics Sample taken from blocky cobbles of float

Bedding/Internal Structures Not apparent

Fractures/Slickensides Quartz grains are tectonically shattered

FOSSILS: None

COMMENTS: Coarse pebbles are all ironstone fragments; siderite rhombs selectively replace calcite near ironstone fragments; calcite cement selectively replaces grains resulting in embayments; well rounded quartz grains are frosted; some quartz grains are tectonically shattered - clay infills fractures; trace apatite microlites in quartz grains.

SURFACE SAMPLE DESCRIPTION

Sample Number	KT57-N
Thin Section	---
Location Collected	North of Highway 128 SWSW 32 T1S R69W (Station 29-3)
Formation Name	Arapahoe

ROCK TYPE WITH MODIFIERS: Calcareous sandstone with some silt

COLOR (GSA Rock Color Chart): Yellowish gray (5Y 7/2) weathers dark yellowish brown (10YR 4/2)

TEXTURE:

Grain Size: Range Very fine - medium sand Mode Medium

Sorting Moderate to well

Roundness Subangular to well rounded

Textural Maturity Mature

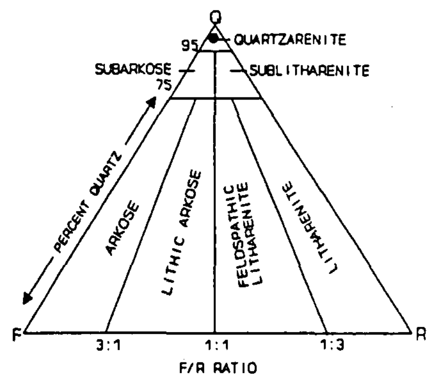
Porosity 10%

Cement/Matrix 20% calcite cement/3% silt, no clay

Friability Non-friable

COMPOSITION:

Mineral:	Percentage:
Quartz	98
Feldspar	1
Rock fragments	1
Magnetite	Trace



CLASSIFICATION (Folk, 1974): Quartzarenite

MACROSCOPIC FIELD CHARACTERISTICS:

Weathering Characteristics: Large blocky slabs on hillslopes - float

Bedding/Internal Structures: Not apparent

Fractures/Slickensides: None

FOSSILS: None

COMMENTS: Large irregular vug filled with uncemented sand; well rounded quartz sand grains are frosted.

SURFACE SAMPLE DESCRIPTION

Sample Number: KT58-N

Thin Section: ---

Location Collected: Drainage north of Highway 128 SWNE 32 T1S R69W

Formation Name: Laramie (Station 29-8)

ROCK TYPE WITH MODIFIERS: Calcareous sandstone with some silt

COLOR (GSA Rock Color Chart): Light olive gray (5Y 5/2) weathers moderate yellowish brown (10YR 5/4)

TEXTURE:

Grain Size: Range Very fine - medium sand Mode Medium

Sorting Moderate

Roundness Subangular to subrounded

Textural Maturity Submature

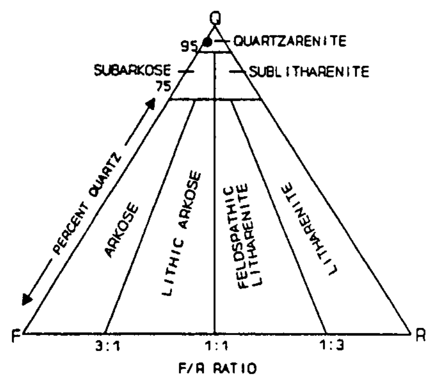
Porosity 5%

Cement/Matrix 15% calcite cement/8% silt, 5% clay

Friability Non-friable

COMPOSITION:

Mineral:	Percentage:
Quartz	97
Feldspar	2
Rock fragments	1
Biotile	Trace
Magnetite	Trace



CLASSIFICATION (Folk, 1974): Quartzarenite

MACROSCOPIC FIELD CHARACTERISTICS:

Weathering Characteristics: Highly resistant - ledge forming

Bedding/Internal Structures: Laminated

Fractures/Slickensides: None

FOSSILS: None

COMMENTS: Quartz grains are not frosted; laminations are highlighted by iron stain.

SURFACE SAMPLE DESCRIPTION

Sample Number: KT60-N
Thin Section: KT60-N
Location Collected: McCaslin Boulevard roadcut SWSW 31 T1S R69W
Formation Name: Laramie (Station 28-7)

ROCK TYPE WITH MODIFIERS: Pebbly sandstone

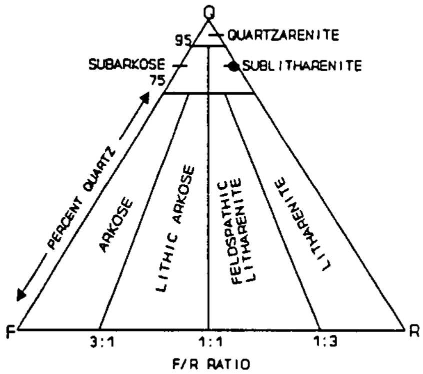
COLOR (GSA Rock Color Chart): Light olive gray (5Y 6/1) weathers moderate yellowish brown (10YR 5/4)

TEXTURE:

Grain Size: Range Fine sand - medium pebble Mode Medium sand
Sorting: Poor
Roundness: Subangular to rounded
Textural Maturity: Submature
Porosity: 25%
Cement/Matrix: No cement/5% silt, 3% clay
Friability: Moderately friable

COMPOSITION:

Mineral:	Percentage:
Quartz	85
Chert	6
Rock fragments	5
Carbonaceous fragments	3
Feldspar	1
Magnetite	Trace



CLASSIFICATION (Folk, 1974): Sublitharenite

MACROSCOPIC FIELD CHARACTERISTICS:

Weathering Characteristics: Friable, loose weathering

Bedding/Internal Structures: Wavy bedded

Fractures/Slickensides: Fractures with cataclastic texture

FOSSILS: None

COMMENTS: Rounded quartz grains are frosted; subangular quartz grains are clear; carbonaceous fragments are large (up to 0.7 inches in length); in places where carbonaceous fragments have weathered out, the cavity is iron stained; grains are tectonically shattered; some cataclastic texture.

SURFACE SAMPLE DESCRIPTION

Sample Number KT61-N

Thin Section KT61-N

Location Collected McCaslin Boulevard roadcut SWSW 31 T1S R69W

Formation Name Laramie (Station 28-7)

ROCK TYPE WITH MODIFIERS: Calcareous sandstone with some silt

COLOR (GSA Rock Color Chart): Light olive gray (5Y 5/2) weathers moderate yellowish brown (10YR 5/4)

TEXTURE:

Grain Size: Range Very fine - medium sand Mode Medium

Sorting Moderate

Roundness Subangular to rounded

Textural Maturity Submature

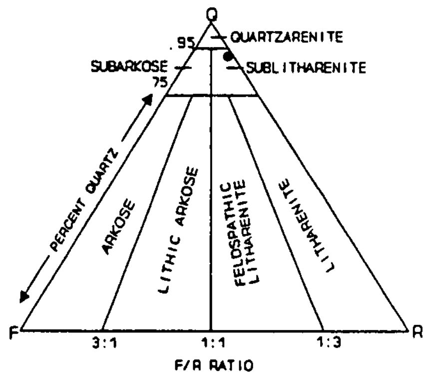
Porosity 5%

Cement/Matrix 20% calcite cement/10% silt, 3% clay

Friability Non-friable

COMPOSITION:

Mineral:	Percentage:
Quartz	92
Chert	5
Rock fragments	2
Feldspar	1
Muscovite	Trace
Carbonaceous fragments	Trace



CLASSIFICATION (Folk, 1974): Sublitharenite

MACROSCOPIC FIELD CHARACTERISTICS:

Weathering Characteristics Platy breaking, resistant ledge forming

Bedding/Internal Structures Laminated to thin bedded

Fractures/Slickensides

FOSSILS: Trace fossils on base of bedding planes

COMMENTS: Platy laminated sandstone; trace small olive green clay clasts; fracture or solution porosity along laminae; in thin section laminae appear to be due to density of grains and amount of cement; some slight grain size variation in laminae.

SURFACE SAMPLE DESCRIPTION

Sample Number: KT1-S
Thin Section: ---
Location Collected: Drainage north of Barbara Gulch SESE 14 T2S R70W
Formation Name: Arapahoe (Station 19-7)

ROCK TYPE WITH MODIFIERS: Calcareous sandstone with some silt

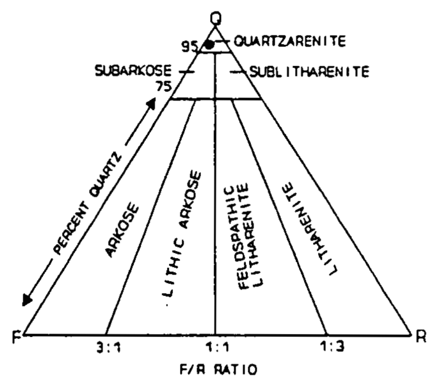
COLOR (GSA Rock Color Chart): Light olive gray (5Y 5/2) weathers light olive brown (5Y 5/6)

TEXTURE:

Grain Size: Range Very fine - fine sand Mode Fine
Sorting: Moderate
Roundness: Subangular to subrounded
Textural Maturity: Submature
Porosity: None
Cement/Matrix: 20% calcite cement/8% silt, 5% clay
Friability: Non-friable

COMPOSITION:

Mineral:	Percentage:
Quartz	97
Feldspar	2
Rock fragments	1
Chert, Magnetite	Trace
Muscovite	Trace



CLASSIFICATION (Folk, 1974): Quartzarenite

MACROSCOPIC FIELD CHARACTERISTICS:

Weathering Characteristics: Resistant, platy breaking ledge

Bedding/Internal Structures: Massive to thinly planar bedded and subparallel lenticular bedded

Fractures/Slickensides: None

FOSSILS: None

COMMENTS: Platy laminated sandstone.

SURFACE SAMPLE DESCRIPTION

Sample Number	KT2-S
Thin Section	---
Location Collected	Drainage north of Barbara Gulch SWSW 14 T2S R70W
Formation Name	Arapahoe (Station 19-10)

ROCK TYPE WITH MODIFIERS: Sandstone

COLOR (GSA Rock Color Chart): Yellowish gray (5Y 7/2) weathers dark yellowish orange (10YR 6/6)

TEXTURE:

Grain Size: Range Fine - medium sand Mode Medium

Sorting Well

Roundness Subangular to well rounded

Textural Maturity Mature

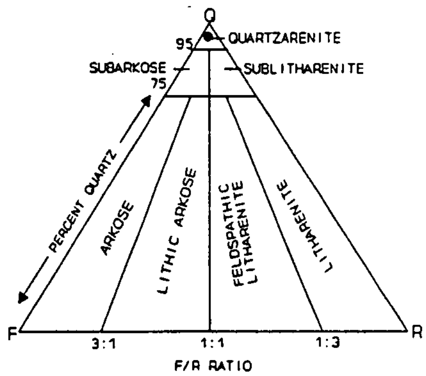
Porosity 25%

Cement/Matrix No cement/5% silt, 3% clay

Friability Highly friable

COMPOSITION:

Mineral:	Percentage:
Quartz	98
Rock fragments	2
Feldspar	Trace



CLASSIFICATION (Folk, 1974): Quartzarenite

MACROSCOPIC FIELD CHARACTERISTICS:

Weathering Characteristics: Extremely friable loose sand on hillslope near animal burrow

Bedding/Internal Structures: None

Fractures/Slickensides: Cataclastic texture along fractures

FOSSILS: None

COMMENTS: Quartz grains are frosted; clay is yellow in color and occurs at point contacts between quartz grains.

SURFACE SAMPLE DESCRIPTION

Sample Number: KT5-S
Thin Section: ---
Location Collected: Barbara Gulch NWSW 22 T2S R70W (Station 21-7)
Formation Name: Arapahoe

ROCK TYPE WITH MODIFIERS: Sandstone with some silt

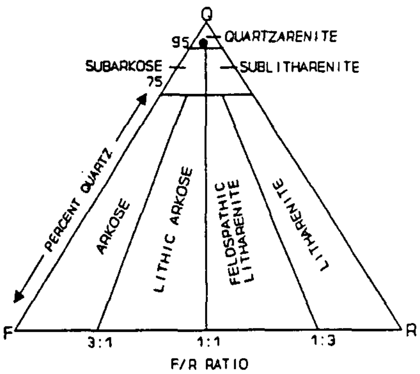
COLOR (GSA Rock Color Chart): Light olive gray (5Y 6/1) weathers dark yellowish orange (10YR 6/6)

TEXTURE:

Grain Size: Range Very fine - medium sand Mode Fine
Sorting: Moderate
Roundness: Subangular to rounded
Textural Maturity: Immature
Porosity: 15%
Cement/Matrix: 3% calcite cement/10% silt, 5% clay
Friability: Slightly friable

COMPOSITION:

Mineral:	Percentage:
Quartz	96
Rock fragments	2
Feldspar	2
Muscovite	Trace



CLASSIFICATION (Folk, 1974): Quartzarenite

MACROSCOPIC FIELD CHARACTERISTICS:

Weathering Characteristics: Friable, loose slope-former
Bedding/Internal Structures: Interbedded with thin claystones and siltstones
Fractures/Slickensides: None

FOSSILS: Abundant small (<1 inch) scattered wood impressions

COMMENTS: Medium-sized quartz grains are frosted; very fine - fine-sized quartz grains are not frosted; clay is white, semi-irridescent, and tends to flocculate around sand grains.

SURFACE SAMPLE DESCRIPTION

Sample Number KT6-S
Thin Section ---
Location Collected Barbara Gulch SESE 22 T2S R70W (Station 21-8)
Formation Name Laramie

ROCK TYPE WITH MODIFIERS: Calcareous sandstone

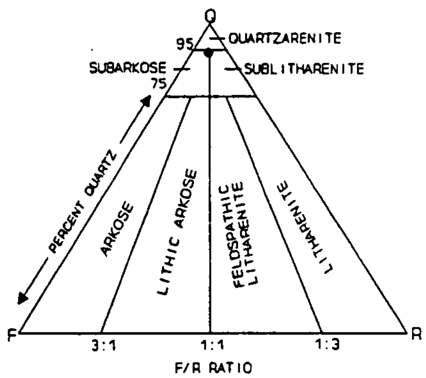
COLOR (GSA Rock Color Chart): Pale to dark yellowish brown (10YR 6/2 - 10YR 4/2)

TEXTURE:

Grain Size: Range Very fine - medium sand Mode Medium
Sorting Moderate
Roundness Subangular to rounded
Textural Maturity Submature
Porosity 15%
Cement/Matrix 10% calcite cement/5% silt, 3% clay
Friability Slightly friable

COMPOSITION:

Mineral:	Percentage:
Quartz	95
Rock fragments	2
Feldspar	2
Chert	1
Magnetite	Trace



CLASSIFICATION (Folk, 1974): Quartzarenite

MACROSCOPIC FIELD CHARACTERISTICS:

Weathering Characteristics Blocky within large slump deposit

Bedding/Internal Structures Thin bedded/wavy to platy laminations

Fractures/Slickensides None

FOSSILS: None

COMMENTS: Medium-sized, rounded quartz grains are frosted; very-fine to fine-sized subangular quartz grains are not frosted.

SURFACE SAMPLE DESCRIPTION

Sample Number: KT8-S
Thin Section: ---
Location Collected: South Claypit NWSE 16 T2S R70W (Station 18-4)
Formation Name: Laramie

ROCK TYPE WITH MODIFIERS: Sandstone

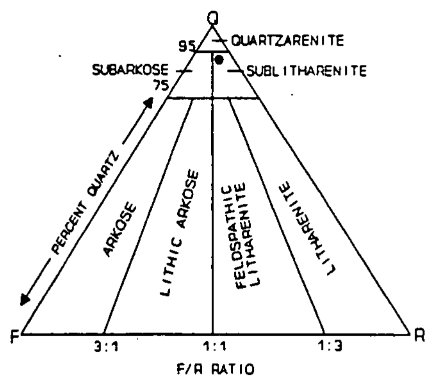
COLOR (GSA Rock Color Chart): Light olive gray (5Y 6/1) weathers dark yellowish orange (10YR 6/6)

TEXTURE:

Grain Size: Range Fine - medium sand Mode Medium
Sorting: Moderate
Roundness: Subangular to rounded
Textural Maturity: Submature
Porosity: 20%
Cement/Matrix: 5% silica cement/5% silt, 3% clay
Friability: Non-friable

COMPOSITION:

Mineral:	Percentage:
Quartz	92
Rock fragments	5
Feldspar	3



CLASSIFICATION (Folk, 1974): Sublitharenite

MACROSCOPIC FIELD CHARACTERISTICS:

Weathering Characteristics: Resistant - ledge forming
Bedding/Internal Structures: Planar very thin to thin beds with some planar cross-bedding
Fractures/Slickensides: None

FOSSILS: Large (1-2 inch) wood impressions

COMMENTS: Silica cement occurs as microcrystalline quartz.

SURFACE SAMPLE DESCRIPTION

Sample Number	KT1-E
Thin Section	---
Location Collected	Standley Lake NENE 29 T2S R69W (Station 33-1)
Formation Name	Arapahoe

ROCK TYPE WITH MODIFIERS: Calcareous pebbly sandstone with some silt/clay

COLOR (GSA Rock Color Chart): Dark yellowish orange (10YR 6/6) to moderate yellowish brown (10YR 5/4)

TEXTURE:

Grain Size: Range Medium sand - m pebble Mode Coarse sand

Sorting Poor

Roundness Subangular to well rounded

Textural Maturity Immature

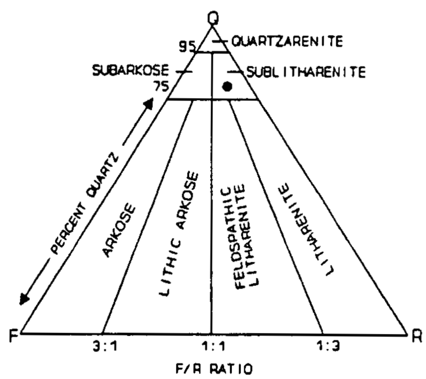
Porosity 10%

Cement/Matrix 15% calcite cement/3% silt, 5% clay

Friability Highly friable

COMPOSITION:

Mineral:	Percentage:
Quartz	80
Rock fragments	15
Feldspar	5
Muscovite, Biotite	Trace
Magnetite	Trace



CLASSIFICATION (Folk, 1974): Sublitharenite

MACROSCOPIC FIELD CHARACTERISTICS:

Weathering Characteristics	Forms loose weathering cut bank of steep drainage
Bedding/Internal Structures	Thick bedded/low angle planar tangential cross bedding
Fractures/Slickensides	None

FOSSILS: None

COMMENTS: Fining upward and coarsening upward sequences; usually extremely friable but locally cemented into more resistant nodules (4 to 8 inches in diameter); well rounded quartz grains are frosted, subangular quartz grains are not frosted.

SURFACE SAMPLE DESCRIPTION

Sample Number KT2-E
Thin Section ---
Location Collected Standley Lake NENE 29 T2S R69W (Station 33-1)
Formation Name Arapahoe

ROCK TYPE WITH MODIFIERS: Pebbly sandstone with some silt and clay

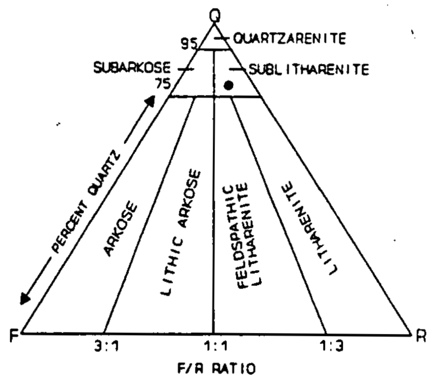
COLOR (GSA Rock Color Chart): Dark yellowish orange (10YR 6/6) to moderate yellowish brown (10YR 5/4)

TEXTURE:

Grain Size: Range Medium sand - f pebble Mode Coarse sand
Sorting Poor
Roundness Subangular to well rounded
Textural Maturity Immature
Porosity 10%
Cement/Matrix 15% calcite cement/3% silt, 5% clay
Friability Highly friable

COMPOSITION:

Mineral:	Percentage:
Quartz	78
Rock fragments	15
Feldspar	5
Biotite	2
Magnetite	Trace



CLASSIFICATION (Folk, 1974): Sublitharenite

MACROSCOPIC FIELD CHARACTERISTICS:

Weathering Characteristics: Forms loose weathering cut bank of steep drainage; usually extremely friable but locally cemented into more resistant nodules (4" - 8" diameter)

Bedding/Internal Structures: Low-angle planar tangential cross bedding, both fining and coarsening upward sequences within thick beds

Fractures/Slickensides: None

FOSSILS: None

COMMENTS: Calcite cement concentrated in discrete nodules; some well rounded quartz grains are frosted, others are not frosted.

SURFACE SAMPLE PETROGRAPHIC DESCRIPTION

Sample Number KT10-E
Thin Section KT10-E
Location Collected Walnut Creek in Buffer Zone SWNE 11 T2S R70W
Formation Name Arapahoe

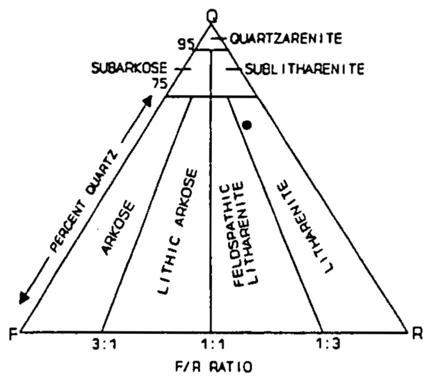
ROCK TYPE WITH MODIFIERS: Sandstone

COLOR (GSA Rock Color Chart): Light to moderate brown (5YR 5/6-5YR 3/4)

TEXTURE:
- Grain Size: Range Very fine to fine Mode Fine
- Sorting Moderate
- Roundness Subangular to subrounded
- Textural Maturity Submature
- Porosity 15%
- Cement/Matrix 18% siderite or iron-oxides/no silt or clay
- Friability Highly to moderately friable

COMPOSITION:

Mineral:	Percentage:
Quartz	62
Chert	25
Other rock fragments	<5
Feldspar	8
Biotite (and other mafics)	Trace



CLASSIFICATION (Folk, 1974): Litharenite

MACROSCOPIC FIELD CHARACTERISTICS:

Weathering Characteristics

Bedding/Internal Structures

Fractures/Slickensides

FOSSILS:

COMMENTS: Quartz grains are subangular to subrounded; equant/subspherical in shape; chert grains more irregularly shaped.

SURFACE SAMPLE PETROGRAPHIC DESCRIPTION

Sample Number: KT11-E

Thin Section: KT11-E

Location Collected: Walnut Creek in Buffer Zone SENW 1 T2S R70W

Formation Name: Arapahoe

ROCK TYPE WITH MODIFIERS: Sandstone

COLOR (GSA Rock Color Chart):

TEXTURE:

Grain Size: Range Very fine-medium Mode Fine

Sorting: Moderate

Roundness: Subangular to well rounded

Textural Maturity: Submature

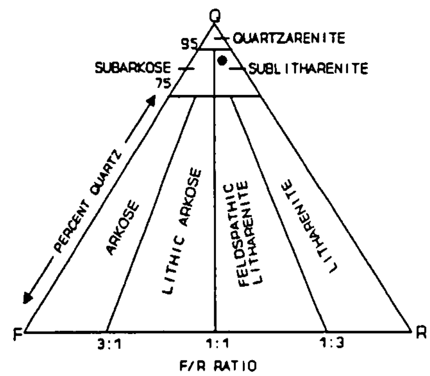
Porosity: Variable <1% in fracture, mostly 20%

Cement/Matrix: 5% calcite cement/5% silt, 3% clay

Friability: Highly friable

COMPOSITION:

Mineral:	Percentage:
Quartz	92
Chert	4
Rock fragments	1
Feldspar	2



CLASSIFICATION (Folk, 1974): Sublitharenite

MACROSCOPIC FIELD CHARACTERISTICS:

Weathering Characteristics:

Bedding/Internal Structures:

Fractures/Slickensides: Low-angle conjugate joint sets with cataclastic texture

FOSSILS:

COMMENTS: Cataclastic textures within fractures; fractured sand grains, some sheared within fracture zone; "milled" quartz grains fill fracture zone, porosity drastically reduced within fracture; very thin clay coatings on some rounded quartz grains; most quartz grains are subrounded to well rounded and frosted.

SURFACE SAMPLE PETROGRAPHIC DESCRIPTION

Sample Number KT13-E
Thin Section KT13-E (Polished Section)
Location Collected Northeast Buffer Zone SWNE 11 T2S R70W
Formation Name Arapahoe

ROCK TYPE WITH MODIFIERS: Pyritic sandstone

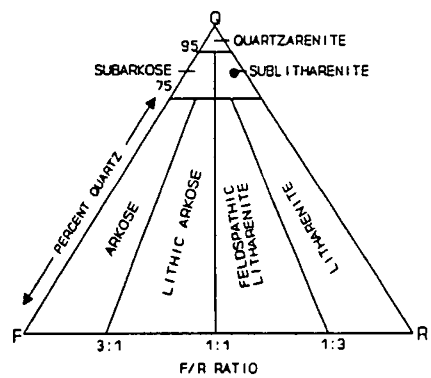
COLOR (GSA Rock Color Chart): Light to moderate brown (5 YR 5/6 - 5 YR 3/4)

TEXTURE:

Grain Size: Range Very fine-fine Mode Fine
Sorting Well
Roundness Subangular
Textural Maturity Submature
Porosity <2%
Cement/Matrix 30% Pyrite (FeS_2) and Fe-oxide
Friability Moderately to non-friable

COMPOSITION:

Mineral: Sand grains only	Percentage:
Quartz	85
Chert	12
Feldspar	3
Mafics/oxides	Trace



CLASSIFICATION (Folk, 1974): Quartzarenite

MACROSCOPIC FIELD CHARACTERISTICS:

Weathering Characteristics --

Bedding/Internal Structures --

Fractures/Slickensides --

FOSSILS: None

COMMENTS: Quartz grains have ragged edges -- etched by hydrothermal diagenetic fluids that deposited/precipitated Fe-sulfides. No clay present. Pyrite fills pre-existing void spaces in more than 70% of rock section.

SURFACE SAMPLE DESCRIPTION

Sample Number: KT1-W
Thin Section: ---
Location Collected: West Gate Claypit SWSE 9 T2S R70W (Station 18-1)
Formation Name: Laramie

ROCK TYPE WITH MODIFIERS: Sandstone with some silt and clay

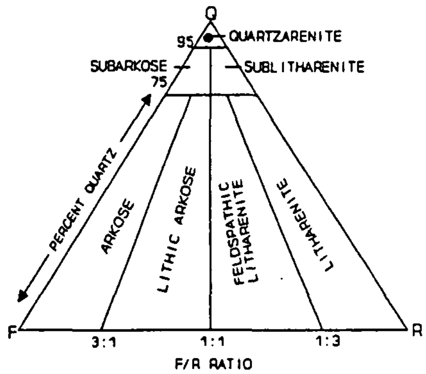
COLOR (GSA Rock Color Chart): Olive gray (5Y 4/1) weathers dusky yellow (5Y 6/4)

TEXTURE:

Grain Size: Range Very fine - fine sand Mode Very fine
Sorting: Moderate to well
Roundness: Subangular
Textural Maturity: Immature
Porosity: None
Cement/Matrix: 5% silica cement/15% silt, 13% clay
Friability: Non-friable

COMPOSITION:

Mineral:	Percentage:
Quartz	97
Carbonaceous fragments	2
Feldspar	1
Muscovite	Trace



CLASSIFICATION (Folk, 1974): Quartzarenite

MACROSCOPIC FIELD CHARACTERISTICS:

Weathering Characteristics: Forms resistant ledge

Bedding/Internal Structures: Thin to thick bedded/planar cross bedding

Fractures/Slickensides: None

FOSSILS: Wood twigs (circular cross-section, fairly straight segments)

COMMENTS: Minor black, dendritic manganese oxide stain; wood fragments are oxidized.

SURFACE SAMPLE DESCRIPTION

Sample Number KT2-W
Thin Section ---
Location Collected South Claypit NWSE 16 T2S R70W (Station 18-4)
Formation Name Laramie

ROCK TYPE WITH MODIFIERS: Siliceous sandstone

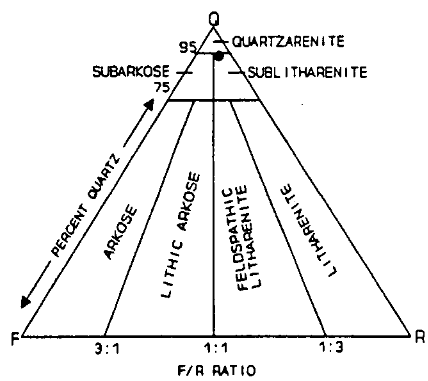
COLOR (GSA Rock Color Chart): Light olive gray (5Y 6/1) weathers grayish orange (10YR 7/4)

TEXTURE:

Grain Size: Range Very fine - coarse sand Mode Medium
Sorting Poor
Roundness Subangular to rounded
Textural Maturity Submature
Porosity 5%
Cement/Matrix 20% silica cement/5% silt, 3% clay
Friability Non-friable

COMPOSITION:

Mineral:	Percentage:
Quartz	95
Rock fragments	3
Feldspar	2
Magnetite	Trace



CLASSIFICATION (Folk, 1974): Quartzarenite

MACROSCOPIC FIELD CHARACTERISTICS:

Weathering Characteristics Blocky weathering, ledge former

Bedding/Internal Structures Thinly interbedded with claystone

Fractures/Slickensides Slickenslides on clay-lined joint surface

FOSSILS: None

COMMENTS: Few quartz grains are rounded and frosted, most are subangular and clear; clay is white, semi-irridescent; silica cement occurs as microcrystalline quartz; some iron-oxide staining on weathered surface; feldspar is kaolinized.

SURFACE SAMPLE DESCRIPTION

Sample Number	KT3-W
Thin Section	---
Location Collected	South Claypit NWSE 16 T2S R70W (Station 18-4)
Formation Name	Laramie

ROCK TYPE WITH MODIFIERS: Siliceous sandstone

COLOR (GSA Rock Color Chart): Light olive gray (5Y 6/1) weathers grayish orange (10YR 7/4)

TEXTURE:

Grain Size: Range Very fine - medium sand Mode Medium

Sorting Moderate

Roundness Subangular to subrounded

Textural Maturity Submature

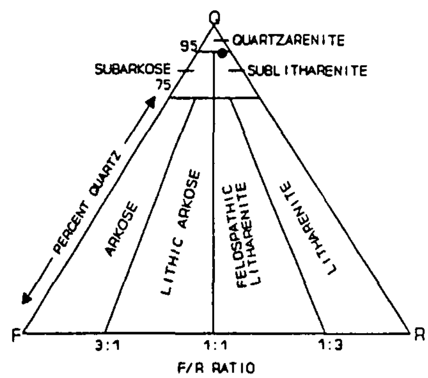
Porosity 10%

Cement/Matrix 15% silica cement/5% silt, 3% clay

Friability Non-friable

COMPOSITION:

Mineral:	Percentage:
Quartz	95
Rock fragments	3
Chert	1
Feldspar	1
Muscovite	Trace



CLASSIFICATION (Folk, 1974): Quartzarenite

MACROSCOPIC FIELD CHARACTERISTICS:

Weathering Characteristics Blocky weathering, resistant ledge former

Bedding/Internal Structures

Fractures/Slickensides None

FOSSILS: None

COMMENTS: Silica cement occurs as microcrystalline quartz; feldspar grains are kaolinized; clay is white, semi-irridescent.

SURFACE SAMPLE DESCRIPTION

Sample Number KT6-W
Thin Section ---
Location Collected North Claypit NWSE 4 T2S R70W (Station 20-1)
Formation Name Laramie

ROCK TYPE WITH MODIFIERS: Siliceous sandstone

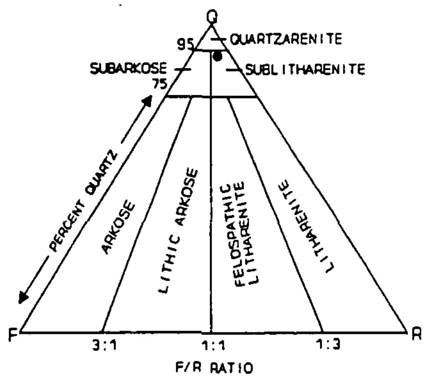
COLOR (GSA Rock Color Chart): Light olive gray (5Y 6/1) weathers pale yellowish orange (10YR 8/6)

TEXTURE:

Grain Size: Range Very fine - fine sand Mode Fine
Sorting Moderate
Roundness Subangular to subrounded
Textural Maturity Submature
Porosity 5%
Cement/Matrix 20% silica cement/5% silt, 3% clay
Friability Non-friable

COMPOSITION:

Mineral:	Percentage:
Quartz	93
Rock fragments	5
Feldspar	2
Carbonaceous fragments	Trace
Magnetite	Trace



CLASSIFICATION (Folk, 1974): Sublitharenite

MACROSCOPIC FIELD CHARACTERISTICS:

Weathering Characteristics Forms ledge

Bedding/Internal Structures Thin to medium bedded/structureless

Fractures/Slickensides None

FOSSILS: None

COMMENTS: Silica cement occurs as microcrystalline quartz grains; clay is white, semi-irridescent.

SURFACE SAMPLE DESCRIPTION

Sample Number: KT10-W
Thin Section: ---
Location Collected: North Claypit NESW 4 T2S R70W (Station 20-1)
Formation Name: Laramie

ROCK TYPE WITH MODIFIERS: Siliceous sandstone

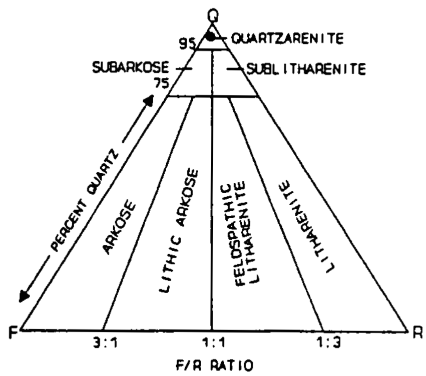
COLOR (GSA Rock Color Chart): Dark yellowish orange (10YR 6/6) weathers same

TEXTURE:

Grain Size: Range Very fine - fine sand Mode Fine
Sorting: Moderate to well
Roundness: Subangular
Textural Maturity: Mature
Porosity: 5%
Cement/Matrix: 20% silica cement/5% silt, 3% clay
Friability: Slightly friable

COMPOSITION:

Mineral:	Percentage:
Quartz	98
Rock fragments	1
Feldspar	1
Muscovite	Trace
Magnetite	Trace



CLASSIFICATION (Folk, 1974): Quartzarenite

MACROSCOPIC FIELD CHARACTERISTICS:

Weathering Characteristics: Slightly friable

Bedding/Internal Structures: Thin bedded/ripple laminated at top of unit

Fractures/Slickensides: None

FOSSILS: None

COMMENTS: Heavily iron-stained silty claystone band (¼ inch thick) at top of unit; silica cement occurs as microcrystalline quartz; clay is iron-stained and is yellow in color.

SURFACE SAMPLE DESCRIPTION

Sample Number: KT11-W
Thin Section: ---
Location Collected: North Claypit NESW 4 T2S R70W (Station 20-1)
Formation Name: Laramie

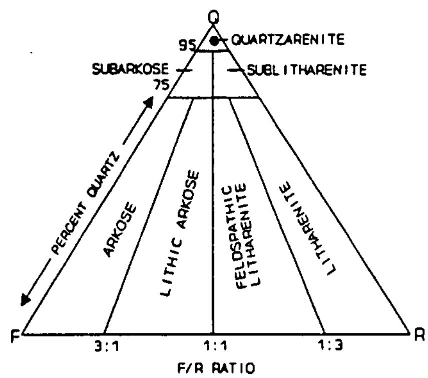
ROCK TYPE WITH MODIFIERS: Siliceous sandstone

COLOR (GSA Rock Color Chart): Light olive gray (5Y 6/1) weathers yellowish gray (5Y 7/2)

TEXTURE:
Grain Size: Range Very fine - fine sand Mode Very fine
Sorting: Moderate to well
Roundness: Subangular
Textural Maturity: Mature
Porosity: 5%
Cement/Matrix: 20% silica cement/5% silt, 3% clay
Friability: Non-friable

COMPOSITION:

Mineral:	Percentage:
Quartz	97
Rock fragments	2
Feldspar	1
Muscovite	Trace



CLASSIFICATION (Folk, 1974): Quartzarenite

MACROSCOPIC FIELD CHARACTERISTICS:

Weathering Characteristics: Resistant, forms ledge; unit is lenticular, irregular thickness
Bedding/Internal Structures: Thin to medium bedded/wavy discontinuous laminations, small trough cross laminae
Fractures/Slickensides: None

FOSSILS: None

COMMENTS: Minor black dendritic manganese oxide stain; silica cement occurs as microcrystalline quartz; feldspar grains are kaolinized.

SURFACE SAMPLE DESCRIPTION

Sample Number: KT12-W
Thin Section: ---
Location Collected: North Claypit NESW 4 T2S R70W (Station 20-1)
Formation Name: Laramie

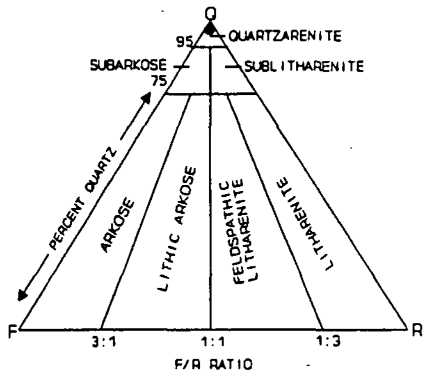
ROCK TYPE WITH MODIFIERS: Siliceous sandstone with some silt and clay

COLOR (GSA Rock Color Chart): Dark yellowish orange (10YR 6/6) weathers same

TEXTURE:
Grain Size: Range Silt - very fine sand Mode Very fine sand
Sorting: Well
Roundness: Subangular
Textural Maturity: Immature
Porosity: None
Cement/Matrix: 10% silica cement/15% silt, 8% clay
Friability: Non-friable

COMPOSITION:

Mineral:	Percentage:
Quartz	99
Rock fragments	1
Feldspar	Trace



CLASSIFICATION (Folk, 1974): Quartzarenite

MACROSCOPIC FIELD CHARACTERISTICS:

Weathering Characteristics: Forms ledge
Bedding/Internal Structures: Thin laminated silt grading into massive sand
Fractures/Slickensides: None

FOSSILS: Plant fragments occur along parting planes.

COMMENTS: Silica cement occurs as microcrystalline quartz; clay is iron-stained and is brown to yellow in color; iron-oxide staining occurs along laminae.

SURFACE SAMPLE DESCRIPTION

Sample Number: KT13-W
Thin Section: KT13-W
Location Collected: North Claypit NESW 4 T2S R70W (Station 20-1)
Formation Name: Laramie

ROCK TYPE WITH MODIFIERS: Sandstone with claystone rip-up charts

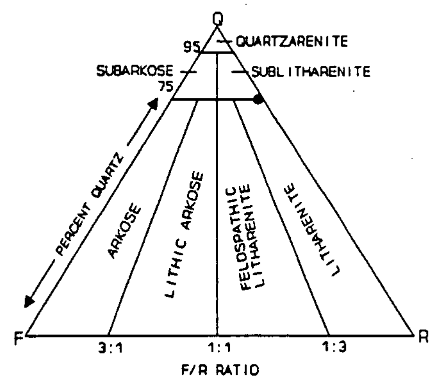
COLOR (GSA Rock Color Chart): Pale yellowish brown (10YR 6/2) weathers light brown (5YR 5/6)

TEXTURE:

Grain Size: Range Very fine - medium   Mode Medium
Sorting: Moderate
Roundness: Subangular - subrounded
Textural Maturity: Immature
Porosity: 20%
Cement/Matrix: No cement/8% silt, 5% clay
Friability: Moderately friable

COMPOSITION:

Mineral:	Percentage:
Quartz	75
Rock fragments	22
Chert	2
Feldspar	1
Muscovite, zircon	Trace



CLASSIFICATION (Folk, 1974): Sublitharenite

MACROSCOPIC FIELD CHARACTERISTICS:

Weathering Characteristics: Resistant, ledge forming, non-friable

Bedding/Internal Structures: Fining upwards from medium sandstone to silty sandstone; contains rip-up clasts of silty sandstone

Fractures/Slickensides:

FOSSILS: None

COMMENTS: Rock fragments are claystone rip-up clasts; rip-up clasts are smeared out along terminations suggesting that they were not completely lithified when deposited; quartz grains are coated with clay -- may be authigenic.

SURFACE SAMPLE DESCRIPTION

Sample Number KT14-W

Thin Section ---

Location Collected Leyden Gulch SESW 28 T2S R70W (Station 21-1)

Formation Name Laramie

ROCK TYPE WITH MODIFIERS: Siliceous sandstone with some silt

COLOR (GSA Rock Color Chart): Light olive gray (5Y 6/1) weathers grayish orange (10YR 7/4)

TEXTURE:

Grain Size: Range Very fine - medium sand Mode Medium

Sorting Moderate

Roundness Subangular to rounded

Textural Maturity Submature

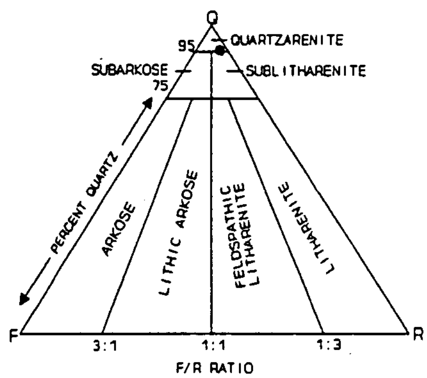
Porosity 10%

Cement/Matrix 10% silica cement/10% silt, 3% clay

Friability Non-friable

COMPOSITION:

Mineral:	Percentage:
Quartz	95
Rock fragments	3
Chert	1
Feldspar	1
Muscovite	Trace



CLASSIFICATION (Folk, 1974): Quartzarenite

MACROSCOPIC FIELD CHARACTERISTICS:

Weathering Characteristics: Forms thick, blocky resistant hogback along Leyden Ridge with

Bedding/Internal Structures: Massive claystone with rip-up clasts

Fractures/Slickensides: Silicified, pervasively fractured; fractures filled with silica cement

FOSSILS: None

COMMENTS: Silica cement occurs as microcrystalline quartz; rounded quartz grains are frosted, subangular quartz grains are not frosted and are clear; feldspar grains are kaolinized.

SURFACE SAMPLE DESCRIPTION

Sample Number	KT15-W
Thin Section	---
Location Collected	Leyden Gulch SESW 28 T2S R70W (Station 21-1)
Formation Name	Laramie

ROCK TYPE WITH MODIFIERS: Siliceous sandstone

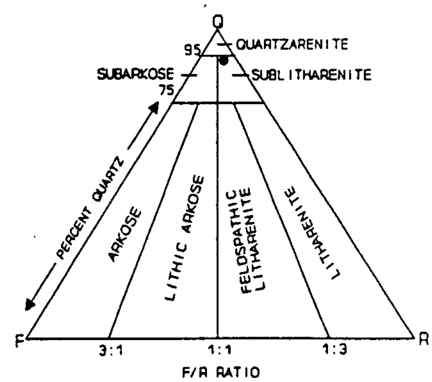
COLOR (GSA Rock Color Chart): Light olive gray (5Y 6/1) weathers dark yellowish orange (10YR 6/6)

TEXTURE:

- Grain Size: Range Very fine - medium sand Mode Medium
- Sorting Moderate
- Roundness Subangular to subrounded
- Textural Maturity Submature
- Porosity 15%
- Cement/Matrix 10% silica cement/5% silt, 3% clay
- Friability Slightly friable

COMPOSITION:

Mineral:	Percentage:
Quartz	94
Rock fragments	4
Feldspar	2
Muscovite	Trace
Carbonaceous fragments	Trace



CLASSIFICATION (Folk, 1974): Sublitharenite

MACROSCOPIC FIELD CHARACTERISTICS:

Weathering Characteristics	Resistant ledge former
Bedding/Internal Structures	Rip-up clasts of siltstone at base of massive bed
Fractures/Slickensides	Numerous fractures oriented perpendicular to bedding

FOSSILS: None

COMMENTS: Silica cement occurs as microcrystalline quartz; feldspar grains are kaolinized; clay is iron-oxide stained and is yellow in color.

SURFACE SAMPLE DESCRIPTION

Sample Number KT16-W
Thin Section ---
Location Collected Leyden Gulch SESW 28 T2S R70W (Station 21-1)
Formation Name Laramie

ROCK TYPE WITH MODIFIERS: Siliceous sandstone with some silt

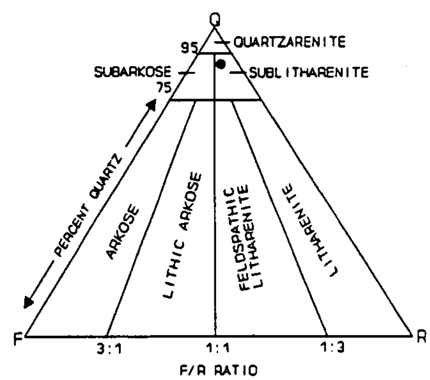
COLOR (GSA Rock Color Chart): Light olive gray (5Y 6/1) weathers grayish orange (10YR 7/4)

TEXTURE:

Grain Size: Range Very fine - medium sand Mode Fine
Sorting Moderate
Roundness Subangular to subrounded
Textural Maturity Submature
Porosity 10%
Cement/Matrix 10% silica cement/10% silt, 3% clay
Friability Slightly friable

COMPOSITION:

Mineral:	Percentage:
Quartz	92
Rock fragments	5
Feldspar	3
Magnetite, Zircon?	Trace
Carbonaceous fragments	Trace



CLASSIFICATION (Folk, 1974): Sublitharenite

MACROSCOPIC FIELD CHARACTERISTICS:

Weathering Characteristics: Ledge forming sandstones - resistant to weathering
Bedding/Internal Structures: Complexly interbedded lenticular sandstones in claystone
Fractures/Slickensides: Cut by fractures at high angle to bedding up to 5" down-dip displacement

FOSSILS: None

COMMENTS: Silica cement occurs as microcrystalline quartz; feldspar grains are kaolinized; clay is white, semi-irridescent.

SURFACE SAMPLE DESCRIPTION

Sample Number KT17-W
Thin Section ---
Location Collected Leyden Gulch SESW 28 T2S R70W (Station 21-1)
Formation Name Laramie

ROCK TYPE WITH MODIFIERS: Siliceous sandstone with some silt

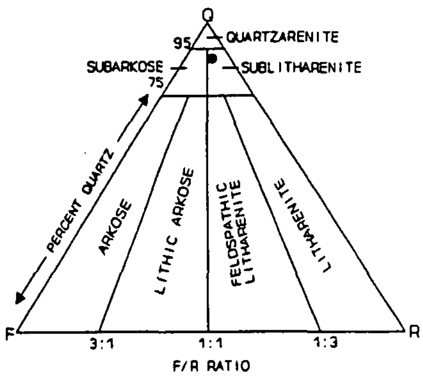
COLOR (GSA Rock Color Chart): Light olive gray (5Y 6/1) weathers grayish orange (10YR 7/4)

TEXTURE:

Grain Size: Range Very fine - fine sand Mode Fine
Sorting Moderate
Roundness Subangular to rounded
Textural Maturity Submature
Porosity 10%
Cement/Matrix 10% silica cement/10% silt, 3% clay
Friability Silghtly friable

COMPOSITION:

Mineral:	Percentage:
Quartz	92
Rock fragments	3
Carbonaceous fragments	3
Feldspar	2
Magnetite	Trace



CLASSIFICATION (Folk, 1974): Sublitharenite

MACROSCOPIC FIELD CHARACTERISTICS:

Weathering Characteristics

Bedding/Internal Structures Rip-up clasts of coal at base; very thin wavy laminae

Fractures/Slickensides Fractures cut perpendicular to bedding; fe-oxide stain on fracture surfaces

FOSSILS: None

COMMENTS: Carbonaceous fragments occur along laminae; silica cement occurs as microcrystalline quartz.

SURFACE SAMPLE DESCRIPTION

Sample Number MV2-N
Thin Section ---
Location Collected Marshall Road area SWSE 15 T1S R70W (Station 9)
Formation Name Laramie

ROCK TYPE WITH MODIFIERS: Sandstone with some silt

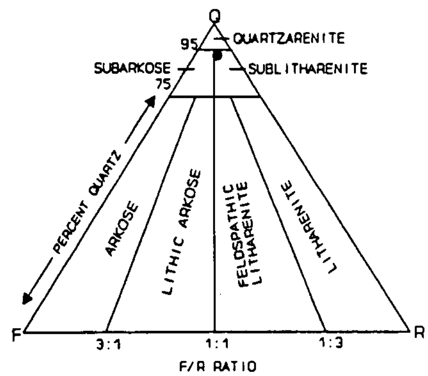
COLOR (GSA Rock Color Chart): Light olive gray (5Y 6/1) weathers moderate brown (5YR 3/4)

TEXTURE:

Grain Size: Range Very fine - medium sand Mode Fine
Sorting Moderate
Roundness Subangular to subrounded
Textural Maturity Submature
Porosity 15%
Cement/Matrix 5% silica cement/10% silt, 3% clay
Friability Slightly friable

COMPOSITION:

Mineral:	Percentage:
Quartz	94
Rock fragments	3
Feldspar	2
Carbonaceous fragments	1
Muscovite	Trace



CLASSIFICATION (Folk, 1974): Sublitharenite

MACROSCOPIC FIELD CHARACTERISTICS:

Weathering Characteristics Forms resistant ledge

Bedding/Internal Structures Thin to thick bedded/structureless

Fractures/Slickensides None

FOSSILS: Small plant impressions

COMMENTS: Large carbonaceous fragments scattered throughout; silica cement occurs as microcrystalline quartz.

SURFACE SAMPLE DESCRIPTION

Sample Number	MV3-N
Thin Section	---
Location Collected	Marshall Road area SESE 15 T1S R70W (Station 10)
Formation Name	Laramie

ROCK TYPE WITH MODIFIERS: Siliceous sandstone

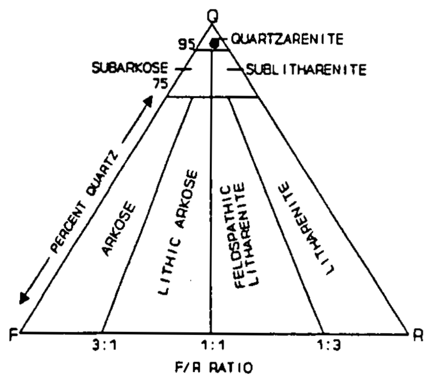
COLOR (GSA Rock Color Chart): Light gray (N7) weathers pale yellowish brown (10YR 6/2)

TEXTURE:

Grain Size: Range Very fine - medium sand Mode Fine
Sorting Moderate
Roundness Subangular to subrounded
Textural Maturity Submature
Porosity 20%
Cement/Matrix 10% silica cement/3% silt, no clay
Friability Moderately friable

COMPOSITION:

Mineral:	Percentage:
Quartz	97
Rock fragments	2
Feldspar	1
Muscovite	Trace



CLASSIFICATION (Folk, 1974): Quartzarenite

MACROSCOPIC FIELD CHARACTERISTICS:

Weathering Characteristics: Forms resistant ledge

Bedding/Internal Structures: Thin to thick bedded/structureless

Fractures/Slickensides: None

FOSSILS:

COMMENTS: Silica cement occurs as microcrystalline quartz; underlain by reddish brown claystone; salt and pepper sandstone.

SURFACE SAMPLE DESCRIPTION

Sample Number: MV4-N
Thin Section: MV4-N
Location Collected: Pine Ridge SENE 21 T1S R70W (Station 15)
Formation Name: Fox Hills

ROCK TYPE WITH MODIFIERS: Sandstone with some silt

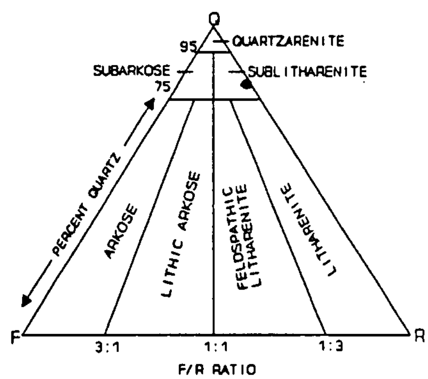
COLOR (GSA Rock Color Chart): Light olive gray (5Y 5/2) weathers same

TEXTURE:

Grain Size: Range Very fine - medium sand Mode Fine
Sorting: Moderate
Roundness: Angular to subrounded
Textural Maturity: Submature
Porosity: 20%
Cement/Matrix: No cement/10% silt, 3% clay
Friability: Slightly friable

COMPOSITION:

Mineral:	Percentage:
Quartz	80
Rock fragments	10
Chert	5
Biotite	3
Feldspar	1
Glauconite	1



CLASSIFICATION (Folk, 1974): Sublitharenite

MACROSCOPIC FIELD CHARACTERISTICS:

Weathering Characteristics: Forms smooth recessed cliff

Bedding/Internal Structures: Massive, few clay partings, giant iron concretions

Fractures/Slickensides: Vertical joints, polygonal fracture pattern

FOSSILS: None

COMMENTS: Biotite is altered to limonite; clay is iron-stained; sample collected near base of measured section; clay occurs in intergranular pores and pore throats; trace zircon and tourmaline?

SURFACE SAMPLE DESCRIPTION

Sample Number: MV5-N (=KT6-N)

Thin Section: ---

Location Collected: Pine Ridge SENE 21 T1S R70W (Station 15)

Formation Name: Fox Hills

ROCK TYPE WITH MODIFIERS: Sandstone with some silt and clay

COLOR (GSA Rock Color Chart): Light olive gray (5Y 6/1) weathers moderate yellowish brown (10YR 5/4)

TEXTURE:

Grain Size: Range Very fine - medium sand Mode Fine

Sorting: Moderate

Roundness: Subangular to rounded

Textural Maturity: Immature

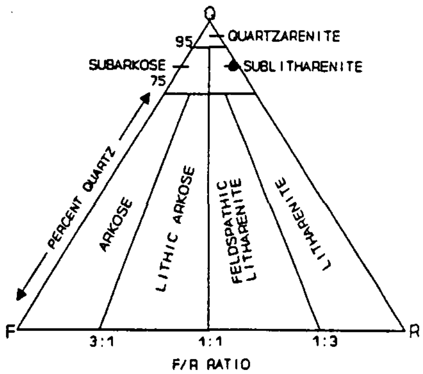
Porosity: 15%

Cement/Matrix: No cement/10% silt, 8% clay

Friability: Moderately friable

COMPOSITION:

Mineral:	Percentage:
Quartz	85
Rock fragments	10
Chert	3
Feldspar	2
Biotite, Zircon, Glauconite	Trace



CLASSIFICATION (Folk, 1974): Sublitharenite

MACROSCOPIC FIELD CHARACTERISTICS:

Weathering Characteristics: Forms smooth recessed cliff

Bedding/Internal Structures: Planar laminations; large-scale (1-1½ ft.) planar cross-bedding

Fractures/Slickensides: None

FOSSILS: None

COMMENTS: Clay is iron-stained; biotite(?) is yellow to brown in color; sample collected 20 feet above base of measured section.

SURFACE SAMPLE DESCRIPTION

Sample Number: MV6-N (=KT7-N)
Thin Section: MV6-N
Location Collected: Pine Ridge SENE 21 T1S R70W (Station 15)
Formation Name: Fox Hills

ROCK TYPE WITH MODIFIERS: Sandstone with some silt

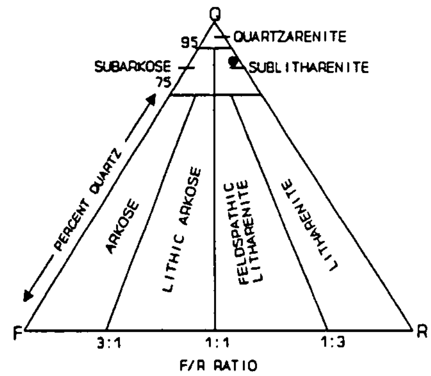
COLOR (GSA Rock Color Chart): Moderate yellowish brown (10YR 5/4) weathers dark yellowish brown (10YR 4/2)

TEXTURE:

Grain Size: Range Very fine - medium sand Mode Fine
Sorting: Moderate
Roundness: Angular to subrounded
Textural Maturity: Submature
Porosity: 10%
Cement/Matrix: 3% silica cement/15% silt, 5% clay
Friability: Moderately friable

COMPOSITION:

Mineral:	Percentage:
Quartz	88
Rock fragments	6
Chert	4
Feldspar	2
Biotite, Glauconite	Trace



CLASSIFICATION (Folk, 1974): Sublitharenite

MACROSCOPIC FIELD CHARACTERISTICS:

Weathering Characteristics: Resistant iron-stained ledge at top of cliff

Bedding/Internal Structures: Massive/structureless

Fractures/Slickensides: None

FOSSILS: Iron-stained root traces

COMMENTS: Clay is iron-stained; glauconite may have been oxidized; biotite is yellow in color; sample collected from ledge at top of cliff; trace iron oxide (goethite or hematite); few shattered or fractured quartz grains.

SURFACE SAMPLE DESCRIPTION

Sample Number MV12-N

Thin Section ---

Location Collected Pine Ridge SENE 21 T1S R70W (Station 15)

Formation Name Laramie

ROCK TYPE WITH MODIFIERS: Sandstone

COLOR (GSA Rock Color Chart): Light olive gray (5Y 5/2) weathers grayish orange (10YR 7/4)

TEXTURE:

Grain Size: Range Very fine - fine sand Mode Fine

Sorting Moderate to well

Roundness Subangular to rounded

Textural Maturity Submature

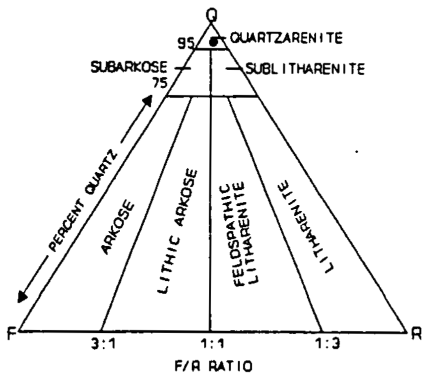
Porosity 20%

Cement/Matrix 5% silica cement/5% silt, 3% clay

Friability Moderately friable

COMPOSITION:

Mineral:	Percentage:
Quartz	97
Rock fragments	2
Feldspar	1
Biotite, Tourmaline?	Trace
Carbonaceous fragments	Trace



CLASSIFICATION (Folk, 1974): Quartzarenite

MACROSCOPIC FIELD CHARACTERISTICS:

Weathering Characteristics Forms rounded blocks on slope

Bedding/Internal Structures Thin to thick bedded/structureless

Fractures/Slickensides Vegetation growth along joint surfaces

FOSSILS: None

COMMENTS: Silica cement occurs as microcrystalline quartz; clay is iron-oxide stained; unit is capped by a very resistant iron-stained sandstone.

SURFACE SAMPLE DESCRIPTION

Sample Number: MV21-N
Thin Section: ---
Location Collected: Pine Ridge SENE 21 T1S R70W (Station 15)
Formation Name: Laramie

ROCK TYPE WITH MODIFIERS: Sandstone with some silt

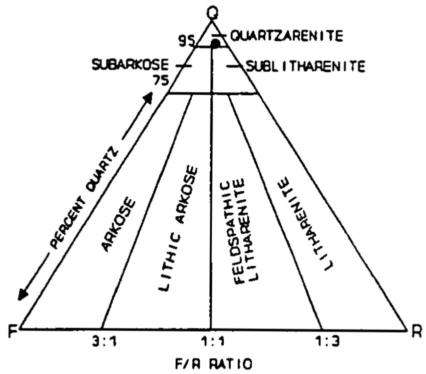
COLOR (GSA Rock Color Chart): Light olive gray (5Y 6/1) weathers very pale orange (10YR 8/2)

TEXTURE:

Grain Size: Range Silt - fine sand Mode Very fine sand
Sorting: Moderate
Roundness: Subangular
Textural Maturity: Submature
Porosity: 20%
Cement/Matrix: No cement/10% silt, 3% clay
Friability: Moderately friable

COMPOSITION:

Mineral:	Percentage:
Quartz	96
Carbonaceous fragments	2
Rock fragments	1
Feldspar	1
Muscovite	Trace



CLASSIFICATION (Folk, 1974): Quartzarenite

MACROSCOPIC FIELD CHARACTERISTICS:

Weathering Characteristics: Forms weak cliff
Bedding/Internal Structures: Thin bedded/ripple laminations, trough cross bedding
Fractures/Slickensides: None

FOSSILS: None

COMMENTS: Carbonaceous fragments scattered throughout; generally fine-sized grains.

SURFACE SAMPLE DESCRIPTION

Sample Number	MV37-N
Thin Section	---
Location Collected	Eggleston Reservoir SENE 28 T1S R70W (Station 39B)
Formation Name	Fox Hills

ROCK TYPE WITH MODIFIERS: Sandstone with some silt

COLOR (GSA Rock Color Chart): Light olive gray (5Y 6/1) weathers light olive brown (5Y 5/6)

TEXTURE:

Grain Size: Range Very fine - fine sand Mode Fine

Sorting Moderate

Roundness Subangular to subrounded

Textural Maturity Submature

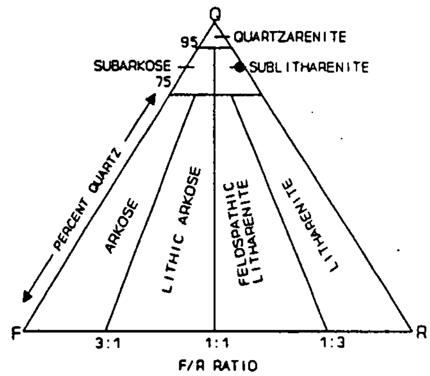
Porosity 25%

Cement/Matrix No cement/6% silt, 2% clay

Friability Highly friable

COMPOSITION:

Mineral:	Percentage:
Quartz	85
Rock fragments	10
Chert	2
Biotite, Muscovite	1,1
Feldspar	1
Zircon(?), Glauconite	Trace



CLASSIFICATION (Folk, 1974): Sublitharenite

MACROSCOPIC FIELD CHARACTERISTICS:

Weathering Characteristics Forms smooth recessed cliff

Bedding/Internal Structures Massive with thin claystone laminae

Fractures/Slickensides None

FOSSILS: None

COMMENTS: Rock fragments are light brown to black, subangular grains; sample collected 14 feet above base of measured section.

SURFACE SAMPLE DESCRIPTION

Sample Number: MV38-N

Thin Section: ---

Location Collected: Eggleston Reservoir SENE 28 T1S R70W (Station 39B)

Formation Name: Fox Hills

ROCK TYPE WITH MODIFIERS: Sandstone with some silt

COLOR (GSA Rock Color Chart): Light olive gray (5Y 6/1) weathers moderate yellowish brown (10YR 5/4)

TEXTURE:

Grain Size: Range Very fine - fine sand Mode Fine

Sorting: Moderate

Roundness: Subangular to subrounded

Textural Maturity: Submature

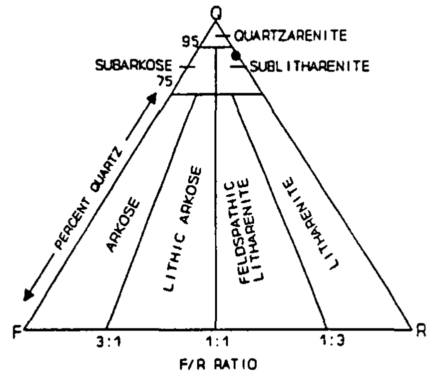
Porosity: 25%

Cement/Matrix: No cement/6% silt, 2% clay

Friability: Highly friable

COMPOSITION:

Mineral:	Percentage:
Quartz	90
Rock fragments	6
Chert	4
Biotite, Muscovite	Trace
Feldspar	Trace



CLASSIFICATION (Folk, 1974): Sublitharenite

MACROSCOPIC FIELD CHARACTERISTICS:

Weathering Characteristics: Forms smooth cliff

Bedding/Internal Structures: Large scale planar cross-bedding

Fractures/Slickensides: None

FOSSILS: None

COMMENTS: Biotite is yellow to brown in color; rock fragments vary from light brown to greenish brown to gray in color; some biotite is altered to limonite; sample collected 19 feet above base of measured section.

SURFACE SAMPLE DESCRIPTION

Sample Number: MV39-N

Thin Section: ---

Location Collected: Eggleston Reservoir SENE 28 T1S R70W (Station 39B)

Formation Name: Fox Hills

ROCK TYPE WITH MODIFIERS: Sandstone with some silt

COLOR (GSA Rock Color Chart): Light olive gray (5Y 6/1) weathers grayish orange (10YR 7/4)

TEXTURE:

Grain Size: Range: Very fine - medium sand   Mode: Fine

Sorting: Moderate

Roundness: Subangular to rounded

Textural Maturity: Submature

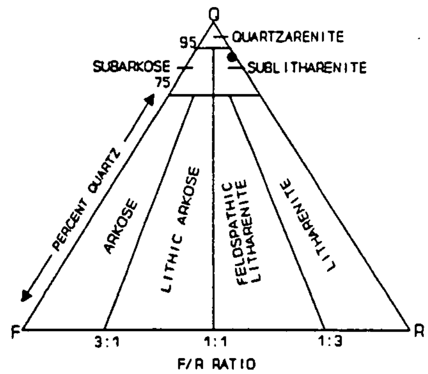
Porosity: 25%

Cement/Matrix: No cement/6% silt, 2% clay

Friability: Highly friable

COMPOSITION:

Mineral:	Percentage:
Quartz	90
Rock fragments	5
Chert	3
Biotite, Feldspar	1,1
Glauconite, Coal(?)	Trace



CLASSIFICATION (Folk, 1974): Sublitharenite

MACROSCOPIC FIELD CHARACTERISTICS:

Weathering Characteristics: Forms smooth cliff

Bedding/Internal Structures: Large scale planar cross-bedding

Fractures/Slickensides: None

FOSSILS: None

COMMENTS: Rock fragments vary from yellow to black in color and are subangular; biotite is yellow to brown; sample collected 23 feet above base of measured section.

SURFACE SAMPLE DESCRIPTION

Sample Number: MV46-N
Thin Section: MV46-N
Location Collected: Silicified knob near Eldorado Springs SWSW 21 T1S R70W
Formation Name: Laramie (Station 86)

ROCK TYPE WITH MODIFIERS: Siliceous sandstone with some silt

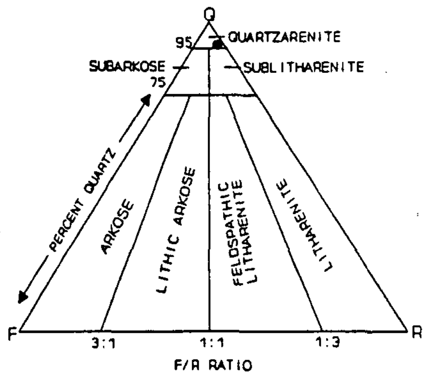
COLOR (GSA Rock Color Chart): Light olive gray (5Y 6/1) weathers moderate brown (5 YR 3/4)

TEXTURE:

Grain Size: Range Very fine - medium Mode Medium
Sorting: Moderate
Roundness: Subangular - subrounded
Textural Maturity: Submature
Porosity: None
Cement/Matrix: 20% silica cement/10% silt, 3% clay
Friability: Non-friable

COMPOSITION:

Mineral:	Percentage:
Quartz	96
Chert	2
Rock fragments	2
Feldspar	Trace
Carbonaceous fragments	Trace



CLASSIFICATION (Folk, 1974): Quartzarenite

MACROSCOPIC FIELD CHARACTERISTICS:

Weathering Characteristics: Forms large resistant blocks on hillside
Bedding/Internal Structures: Thick bedded/structureless
Fractures/Slickensides: Fractures exhibit cataclastic texture

FOSSILS: None

COMMENTS: Silica cement is due to cataclasis and occurs as microcrystalline quartz; cement is not pervasive -- it occurs in 0.1 - 0.5 inch fractures as "stockwork" and "boxwork" veins; in thin section, some quartz grains are tectonically shattered.

SURFACE SAMPLE DESCRIPTION

Sample Number: MV50-N
Thin Section: ---
Location Collected: Community Ditch near Eldorado Springs NWNW 28 T1S R70W
Formation Name: Laramie (Station 90)

ROCK TYPE WITH MODIFIERS: Sandstone with some silt and clay

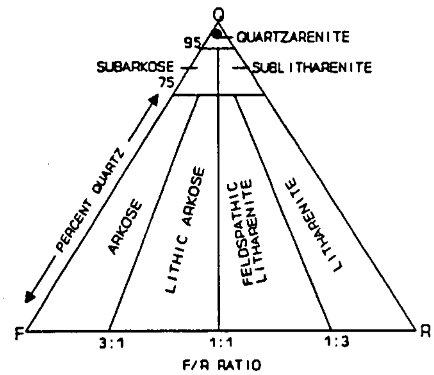
COLOR (GSA Rock Color Chart): Light olive gray (5Y 6/1) weathers moderate yellowish brown (10YR 5/4)

TEXTURE:

Grain Size: Range Very fine - fine sand Mode Very fine
Sorting: Well
Roundness: Subangular to subrounded
Textural Maturity: Immature
Porosity: 15%
Cement/Matrix: No cement/10% silt, 8% clay
Friability: Slightly friable

COMPOSITION:

Mineral:	Percentage:
Quartz	98
Chert	1
Rock fragments	1
Biotite	Trace



CLASSIFICATION (Folk, 1974): Quartzarenite

MACROSCOPIC FIELD CHARACTERISTICS:

Weathering Characteristics: Sandstone exposed above ditch; weathers into rounded blocks
Bedding/Internal Structures: Massive
Fractures/Slickensides: Highly fractured; vertical joint surfaces trend NS

FOSSILS: None

COMMENTS:

SURFACE SAMPLE DESCRIPTION

Sample Number: MV63-N

Thin Section: ---

Location Collected: Community Ditch near Interlocken SWNW 33 T1S R69W

Formation Name: Arapahoe (Station 107)

ROCK TYPE WITH MODIFIERS: Calcareous pebbly sandstone with some silt/clay

COLOR (GSA Rock Color Chart): Dark yellowish brown (10YR 4/2)

TEXTURE:

Grain Size: Range Fine sand - c pebble Mode Coarse sand

Sorting: Poor

Roundness: Subrounded to well rounded

Textural Maturity: Immature

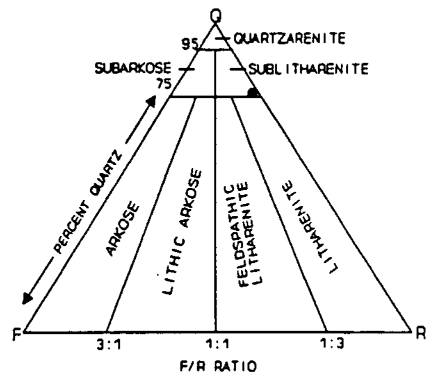
Porosity: None

Cement/Matrix: 20% calcite cement/6% silt, 7% clay

Friability: Non-friable

COMPOSITION:

Mineral:	Percentage:
Quartz	75
Rock fragments	15
Ironstone	10
Carbonaceous fragments	Trace
Feldspar, Chert	Trace



CLASSIFICATION (Folk, 1974): Sublitharenite

MACROSCOPIC FIELD CHARACTERISTICS:

Weathering Characteristics: Forms resistant ledge along ditch; blocky weathering

Bedding/Internal Structures: Thick bedded

Fractures/Slickensides: None

FOSSILS: Wood impressions

COMMENTS: Large rock fragments are sandstone and ironstone; small rock fragments are quartzite; quartz grains are frosted; must have been exposed for a long time to become so well cemented.

SURFACE SAMPLE DESCRIPTION

Sample Number: MV64-N
Thin Section: ---
Location Collected: Community Ditch near Interlocken SWNW 33 T1S R69W
Formation Name: Arapahoe (Station 107)

ROCK TYPE WITH MODIFIERS: Calcareous pebbly sandstone with silica cement

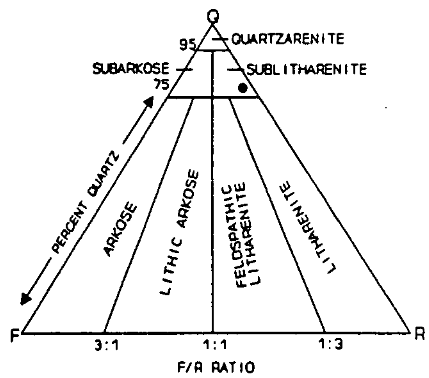
COLOR (GSA Rock Color Chart): Yellowish gray (5Y 7/2) to lt olive gray (5Y 5/2) weathers dark yellowish brown (10YR 4/2)

TEXTURE:

Grain Size: Range Fine sand - c pebble Mode Coarse sand
Sorting: Poor
Roundness: Subangular to well rounded
Textural Maturity: Immature
Porosity: None
Cement/Matrix: 25% calcite cement/3% silt, 5% clay
Friability: Non-friable

COMPOSITION:

Mineral:	Percentage:
Quartz	78
Rock fragments	10
Ironstone	10
Carbonaceous fragments	2
Feldspar	Trace



CLASSIFICATION (Folk, 1974): Sublitharentie

MACROSCOPIC FIELD CHARACTERISTICS:

Weathering Characteristics: Forms resistant ledge along ditch; blocky weathering
Bedding/Internal Structures: Thick bedded
Fractures/Slickensides: None

FOSSILS: Wood impressions

COMMENTS: Large rock fragments are sandstone, claystone, and ironstone; small rock fragments are ironstone; quartz grains are well rounded and frosted; must have been exposed for a long time to become so well cemented.

SURFACE SAMPLE DESCRIPTION

Sample Number	MV65-N
Thin Section	MV65-N
Location Collected	Horse pasture northwest of Interlocken SESW 28 T1S R69W
Formation Name	Arapahoe (Station 109)

ROCK TYPE WITH MODIFIERS: Calcareous pebbly sandstone

COLOR (GSA Rock Color Chart): Light olive gray (5Y 6/1) weathers olive gray (5Y 4/1)

TEXTURE:

Grain Size: Range Very fine sand - fine pebble Mode Medium sand

Sorting Poor

Roundness Subangular - well rounded

Textural Maturity Submature

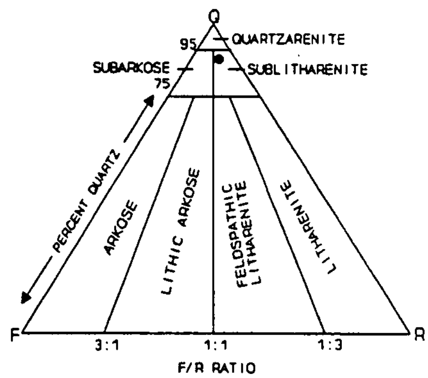
Porosity 5%

Cement/Matrix 23% calcite cement/5% silt, no clay

Friability Non-friable

COMPOSITION:

Mineral:	Percentage:
Quartz	93
Chert	4
Feldspar	2
Rock fragments	1



CLASSIFICATION (Folk, 1974): Sublitharenite

MACROSCOPIC FIELD CHARACTERISTICS:

Weathering Characteristics: Loose slabs on slope

Bedding/Internal Structures: Thin bedded/planar laminated

Fractures/Slickensides: Quartz grains are tectonically shattered

FOSSILS: None

COMMENTS: Feldspar includes plagioclase and microcline; in thin section grains appear to be floating in cement; quartz grains are tectonically shattered and fractures are filled with calcite cement; calcite has selectively replaced edges of quartz grains resulting in embayments; some quartz grains are frosted; other quartz grains have quartz overgrowths.

SURFACE SAMPLE DESCRIPTION

Sample Number MV67-N
Thin Section ---
Location Collected Jefferson County Airport SWSW 34 T1S R69W (Station 111)
Formation Name Arapahoe

ROCK TYPE WITH MODIFIERS: Sandstone with some silt

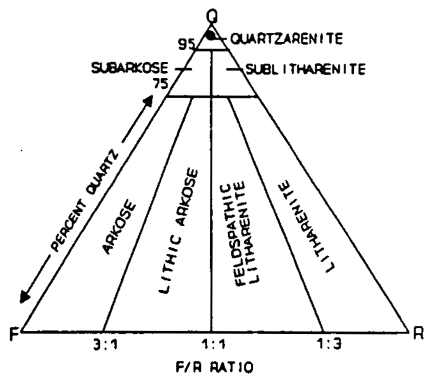
COLOR (GSA Rock Color Chart): Light olive gray (5Y 6/1) weathers light olive brown (5Y 5/6)

TEXTURE:

Grain Size: Range Fine - medium sand Mode Medium
Sorting Moderate
Roundness Subangular to subrounded
Textural Maturity Submature
Porosity 20%
Cement/Matrix No cement/10% silt, 3% clay
Friability Slightly friable

COMPOSITION:

Mineral:	Percentage:
Quartz	98
Rock fragments	1
Feldspar	1
Chert	trace



CLASSIFICATION (Folk, 1974): Quartzarenite

MACROSCOPIC FIELD CHARACTERISTICS:

Weathering Characteristics Blocky weathering; friable ledge former
Bedding/Internal Structures Massive sand bed has lenticular shape
Fractures/Slickensides None

FOSSILS: None

COMMENTS: Most quartz grains are not frosted.

SURFACE SAMPLE DESCRIPTION

Sample Number MV69-N

Thin Section ---

Location Collected Northeast Buffer Zone NESW 1 T2S R70W (Station 198)

Formation Name Arapahoe

ROCK TYPE WITH MODIFIERS: Calcareous sandstone

COLOR (GSA Rock Color Chart): Yellowish gray (5Y 7/2) weathers light olive brown (5Y 5/6)

TEXTURE:

Grain Size: Range Fine - coarse sand Mode Medium

Sorting Moderate

Roundness Subangular to well rounded

Textural Maturity Submature to mature

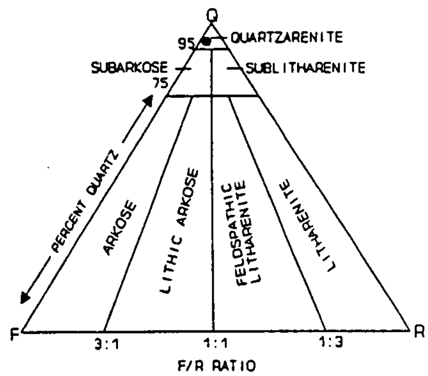
Porosity 20%

Cement/Matrix 10% calcite cement/3% silt, no clay

Friability Slightly friable

COMPOSITION:

Mineral:	Percentage:
Quartz	97
Feldspar	2
Rock fragments	1



CLASSIFICATION (Folk, 1974): Quartzarenite

MACROSCOPIC FIELD CHARACTERISTICS:

Weathering Characteristics Forms thin resistant ledge

Bedding/Internal Structures Thin bedded; slabby/planar crossbedding

Fractures/Slickensides None

FOSSILS: None

COMMENTS: Quartz grains are well rounded and frosted; rock fragments occur along laminae.

SURFACE SAMPLE DESCRIPTION

Sample Number MV70-N
Thin Section ---
Location Collected North of Highway 128 SESE 36 T1S R70W (Station 209)
Formation Name Arapahoe

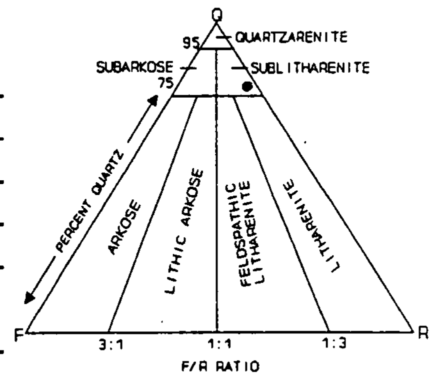
ROCK TYPE WITH MODIFIERS: Calcareous pebbly sandstone with some silt/clay

COLOR (GSA Rock Color Chart): Yellowish gray (5Y 7/2) weathers moderate yellowish brown (10YR 5/4)

TEXTURE:
Grain Size: Range Fine sand - m pebbles Mode Coarse sand
Sorting Poor
Roundness Subrounded to well rounded
Textural Maturity Immature
Porosity None
Cement/Matrix 20% calcite cement/6% silt, 7% clay
Friability Non-friable

COMPOSITION:

Mineral:	Percentage:
Quartz	78
Ironstone	15
Rock fragments	5
Carbonaceous fragments	1
Feldspar	1



CLASSIFICATION (Folk, 1974): Sublitharenite

MACROSCOPIC FIELD CHARACTERISTICS:

Weathering Characteristics Forms resistant ledge

Bedding/Internal Structures Thin bedded/planar crossbedding

Fractures/Slickensides None

FOSSILS: None

COMMENTS: Quartz grains are well rounded and frosted; thin bedded ironstone pebble sandstones and conglomerates occur within a sequence of platy laminated calcareous sandstones.

SURFACE SAMPLE DESCRIPTION

Sample Number MV71a-N
Thin Section ---
Location Collected North of Highway 128 SWSW 32 T1S R69W (Station 230)
Formation Name Arapahoe

ROCK TYPE WITH MODIFIERS: Calcareous sandstone

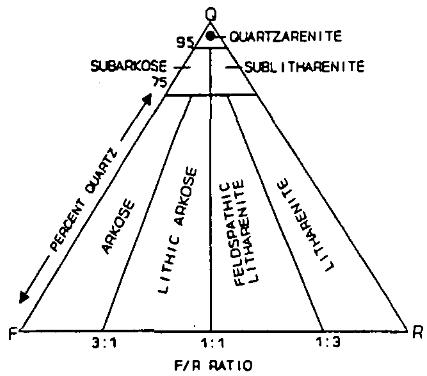
COLOR (GSA Rock Color Chart): Light olive gray (5Y 5/2) weathers dark yellowish brown (10YR 4/2)

TEXTURE:

Grain Size: Range Fine - medium sand Mode Medium
Sorting Moderate
Roundness Subangular to well rounded
Textural Maturity Submature to mature
Porosity No porosity
Cement/Matrix 25% calcite cement/5% silt, 3% clay
Friability Non-friable

COMPOSITION:

Mineral:	Percentage:
Quartz	97
Chert	3
Feldspar	Trace
Rock fragments	Trace
Magnetite	Trace



CLASSIFICATION (Folk, 1974): Quartzarenite

MACROSCOPIC FIELD CHARACTERISTICS:

Weathering Characteristics Forms resistant ledge in drainage

Bedding/Internal Structures Thin bedded/planar cross bedding

Fractures/Slickensides None

FOSSILS: None

COMMENTS: Fine-sized grains are subangular, medium-sized grains are well rounded; some grains are frosted and some are not frosted; chert is white in color; bimodal sand; clay is iron stained and is yellow in color.

SURFACE SAMPLE DESCRIPTION

Sample Number: MV71b-N
Thin Section: ---
Location Collected: Highway 128 SWSW 32 T1S R69W (Station 230)
Formation Name: Arapahoe

ROCK TYPE WITH MODIFIERS: Calcareous pebbly sandstone with some silt/clay

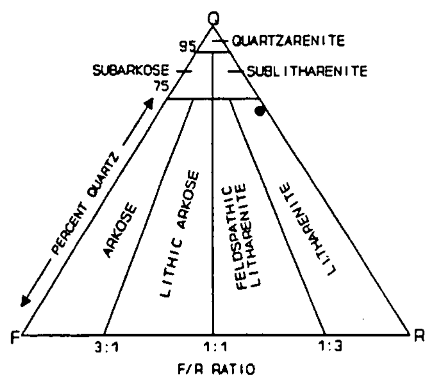
COLOR (GSA Rock Color Chart): Grayish brown (5YR 3/2)

TEXTURE:

Grain Size: Range Fine sand - m pebble Mode Coarse sand
Sorting: Poor
Roundness: Subangular to rounded
Textural Maturity: Immature
Porosity: None
Cement/Matrix: 20% calcite cement/6% silt, 7% clay
Friability: Non-friable

COMPOSITION:

Mineral:	Percentage:
Quartz	70
Rock fragments	15
Ironstone	10
Chert	5



CLASSIFICATION (Folk, 1974): Litharenite

MACROSCOPIC FIELD CHARACTERISTICS:

Weathering Characteristics: Forms resistant ledge in drainage
Bedding/Internal Structures: Thin bedded/planar cross bedding
Fractures/Slickensides: None

FOSSILS: None

COMMENTS: Some quartz grains are frosted, others are not frosted.

SURFACE SAMPLE DESCRIPTION

Sample Number: MV73-N
Thin Section: MV73-N
Location Collected: Rock Creek in Buffer Zone NENW 2 T2S R70W (float)
Formation Name: Arapahoe (Station 280)

ROCK TYPE WITH MODIFIERS: Pebbly sandstone with some silt and clay

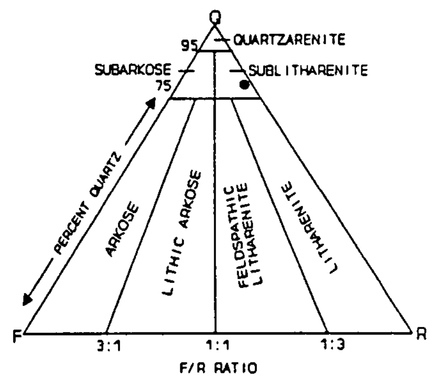
COLOR (GSA Rock Color Chart): Moderate brown (5YR 4/4 - 5YR 3/4)

TEXTURE:

Grain Size: Range Fine sand - fine pebbles Mode Coarse sand
Sorting: Poor
Roundness: Subangular to well rounded
Textural Maturity: Submature
Porosity: 5%
Cement/Matrix: 23% siderite (goethite?) cement/3% silt, 2% clay
Friability: Non-friable

COMPOSITION:

Mineral:	Percentage:
Quartz	80
Chert	10
Rock fragments	5
Ironstone	4
Feldspar	1



CLASSIFICATION (Folk, 1974): Sublitharenite

MACROSCOPIC FIELD CHARACTERISTICS:

Weathering Characteristics: Forms resistant ledge near small drainage

Bedding/Internal Structures: Thin bedded

Fractures/Slickensides: Fractures with cataclastic texture

FOSSILS: None

COMMENTS: Heavily iron stained; iron cement is siderite (?) or goethite (?) and occurs as meniscus and in places intergranular cement; some grains exhibit tectonic shattering; thin cataclastic zone in thin section; iron oxide occurs near cataclastic zone; some quartz grains are well-rounded and frosted.

SURFACE SAMPLE DESCRIPTION

Sample Number	MV74-N
Thin Section	MV74-N
Location Collected	Landfill in Buffer Zone SESW 2 T2S R70W (Station 302)
Formation Name	Arapahoe

ROCK TYPE WITH MODIFIERS: Pebbly sandstone

COLOR (GSA Rock Color Chart): Moderate to dark yellowish brown (10YR5/4-4/2)

TEXTURE:

Grain Size: Range Med sand - med pebble Mode Coarse sand

Sorting Poor

Roundness Subangular to well rounded

Textural Maturity Immature

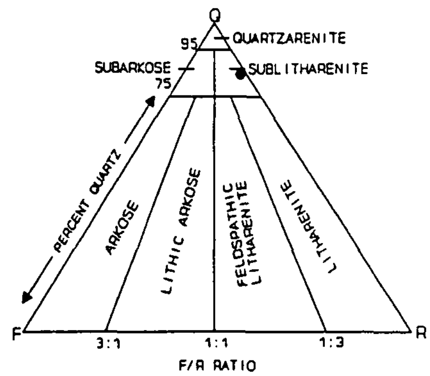
Porosity 5%

Cement/Matrix 15% calcite cement/3% silt, 8% clay

Friability Moderately friable

COMPOSITION:

Mineral:	Percentage:
Quartz	84
Chert	10
Rock Fragments	6
Feldspar	Trace



CLASSIFICATION (Folk, 1974): Sublitharenite

MACROSCOPIC FIELD CHARACTERISTICS:

Weathering Characteristics: Forms poorly exposed, rounded outcrop on slope

Bedding/Internal Structures: Faint cross-bedding

Fractures/Slickensides: Calcite-filled fractures

FOSSILS: None

COMMENTS: Porosity is intergranular and vuggy; some grains have clay coats; in places quartz grains are floating in cement; tectonically shattered grains -- fractures cemented with calcite; embayed grains show quartz being replaced by calcite; dissolution has occurred around some grains; some quartz grains are well-rounded and frosted.

SURFACE SAMPLE DESCRIPTION

Sample Number	MV1-S
Thin Section	—
Location Collected	Drainage north of Barbara Gulch SESW 14 T2S R70W
Formation Name	Laramie (Station 145)

ROCK TYPE WITH MODIFIERS: Sandstone

COLOR (GSA Rock Color Chart): Light olive gray (5Y 5/2) weathers same

TEXTURE:

Grain Size: Range Very fine - fine sand Mode Very fine

Sorting Well

Roundness Subangular

Textural Maturity Submature

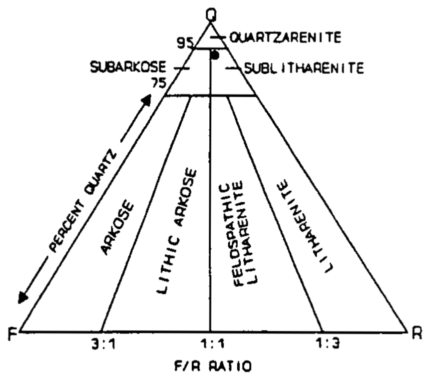
Porosity 20%

Cement/Matrix 5% calcite cement/5% silt, 3% clay

Friability Moderately friable

COMPOSITION:

Mineral:	Percentage:
Quartz	94
Carbonaceous fragments	3
Feldspar	2
Biotite	1



CLASSIFICATION (Folk, 1974): Sublitharenite

MACROSCOPIC FIELD CHARACTERISTICS:

Weathering Characteristics Outcrop is in steep cut bank

Bedding/Internal Structures Laminated to very thin bedded/small scale planar and tangential cross bedding

Fractures/Slickensides None

FOSSILS: Pale brown root casts

COMMENTS: Glauconite is bluish-green to green, soft; sandstone is interbedded or interlaminated with blocky, olive gray to yellowish orange claystone.

SURFACE SAMPLE DESCRIPTION

Sample Number	MV2-S
Thin Section	---
Location Collected	Drainage north of Barbara Gulch NENW 23 T2S R70W
Formation Name	Arapahoe (Station 146)

ROCK TYPE WITH MODIFIERS: Sandstone

COLOR (GSA Rock Color Chart): Yellowish gray (5Y 8/1) weathers dark yellowish orange (10YR 6/6) to moderate brown (5YR4/4)

TEXTURE:

Grain Size: Range Fine - coarse sand Mode Medium

Sorting Moderate

Roundness Subangular to subrounded

Textural Maturity Submature

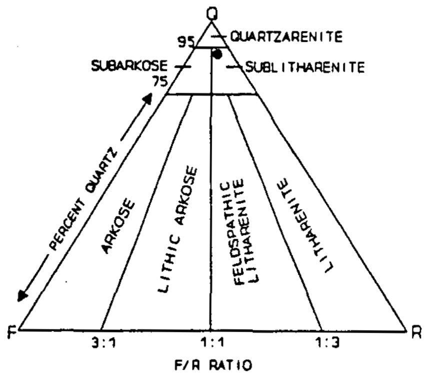
Porosity 20%

Cement/Matrix 10% siderite cement/3% silt, no clay

Friability Slightly friable

COMPOSITION:

Mineral:	Percentage:
Quartz	94
Feldspar	2
Chert	2
Rock fragments	2
Magnetite	Trace



CLASSIFICATION (Folk, 1974): Quartzarenite

MACROSCOPIC FIELD CHARACTERISTICS:

Weathering Characteristics Forms slope

Bedding/Internal Structures Massive

Fractures/Slickensides None

FOSSILS: None

COMMENTS: Sandstone is completely oxidized and weathered except circular patches that may be burrows; most quartz grains are not frosted.

SURFACE SAMPLE DESCRIPTION

Sample Number: MV3-S
Thin Section: MV3-S
Location Collected: Drainage north of Barbara Gulch NENE 22 T2S R70W (float)
Formation Name: Arapahoe (Station 149)

ROCK TYPE WITH MODIFIERS: Calcareous sandstone with some silt and clay

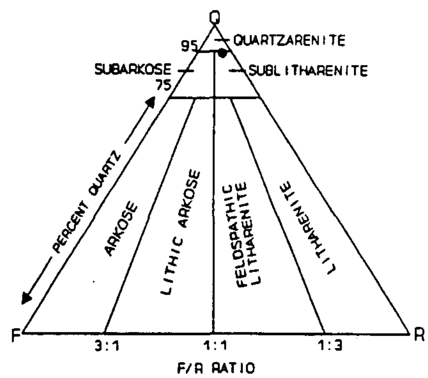
COLOR (GSA Rock Color Chart): Moderate yellowish brown (10YR 5/4)

TEXTURE:

Grain Size: Range Fine - medium sand Mode Medium
Sorting: Moderate
Roundness: Subangular to rounded
Textural Maturity: Immature
Porosity: 5%
Cement/Matrix: 15% calcite cement/6% silt, 7% clay
Friability: Non-friable

COMPOSITION:

Mineral:	Percentage:
Quartz	95
Chert	3
Feldspar	1
Rock fragments	1
Muscovite	Trace



CLASSIFICATION (Folk, 1974): Quartzarenite

MACROSCOPIC FIELD CHARACTERISTICS:

Weathering Characteristics: Forms slabs on slope
Bedding/Internal Structures: Thin bedded/planar laminations
Fractures/Slickensides: Open fractures

FOSSILS: None

COMMENTS: Clay is heavily iron stained; some quartz grains are frosted; fracture porosity; calcite cement has "eaten away" at quartz grains causing embayments.

SURFACE SAMPLE DESCRIPTION

Sample Number MV4-S
Thin Section ---
Location Collected Drainage north of Barbara Gulch NWNW 23 T2S R70W
Formation Name Laramie (Station 151)

ROCK TYPE WITH MODIFIERS: Calcareous sandstone

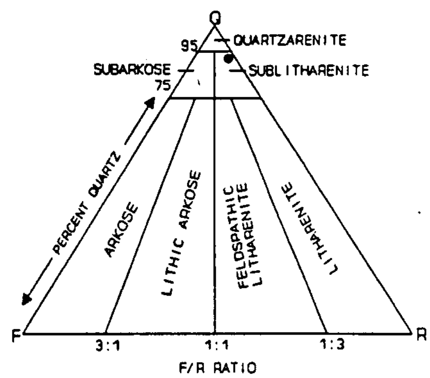
COLOR (GSA Rock Color Chart): Olive gray (5Y 4/1) weathers moderate olive brown (5Y 4/4)

TEXTURE:

Grain Size: Range Very fine - fine sand Mode Very fine
Sorting Well
Roundness Subangular to subrounded
Textural Maturity Submature
Porosity 10%
Cement/Matrix 15% calcite cement/5% silt, 3% clay
Friability Non-friable

COMPOSITION:

Mineral:	Percentage:
Quartz	93
Rock fragments	2
Carbonaceous fragments	2
Biotite	2
Feldspar	1



CLASSIFICATION (Folk, 1974): Sublitharenite

MACROSCOPIC FIELD CHARACTERISTICS:

Weathering Characteristics Forms thin lense in cut bank claystones

Bedding/Internal Structures Laminated to very thin bedded

Fractures/Slickensides None

FOSSILS: None

COMMENTS: Platy laminated sandstone; quartz grains are not frosted.

SURFACE SAMPLE DESCRIPTION

Sample Number MV5-S
Thin Section ---
Location Collected Drainage north of Barbara Gulch NWNE 22 T2S R70W
Formation Name Arapahoe (Station 154)

ROCK TYPE WITH MODIFIERS: Siliceous sandstone

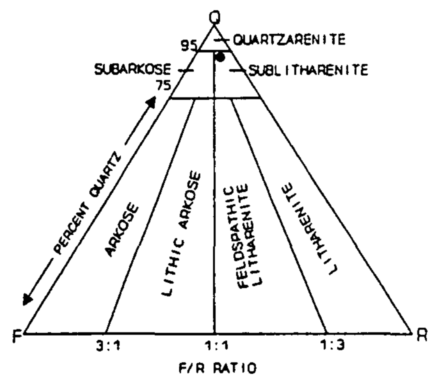
COLOR (GSA Rock Color Chart): Yellowish gray (5Y 8/1) weathers dk yellowish orange to mod yellowish brown (10YR 6/6-5/4)

TEXTURE:

Grain Size: Range Fine - coarse sand Mode Medium
Sorting Moderate
Roundness Subangular to subrounded
Textural Maturity Submature
Porosity 20%
Cement/Matrix 10% siderite cement/3% silt, no clay
Friability Slightly friable

COMPOSITION:

Mineral:	Percentage:
Quartz	94
Chert	2
Rock fragments	2
Feldspar	2



CLASSIFICATION (Folk, 1974): Sublitharenite

MACROSCOPIC FIELD CHARACTERISTICS:

Weathering Characteristics Forms rounded blocks on slope
Bedding/Internal Structures Massive
Fractures/Slickensides None

FOSSILS: None

COMMENTS: Most quartz grains are not frosted; sample is heavily iron stained.

SURFACE SAMPLE DESCRIPTION

Sample Number	MV1-W
Thin Section	---
Location Collected	West Gate Claypit SWSE 9 T2S R70W (Station 131)
Formation Name	Laramie

ROCK TYPE WITH MODIFIERS: Siliceous sandstone

COLOR (GSA Rock Color Chart): Light gray (N7) weathers yellowish gray (5Y 7/2)

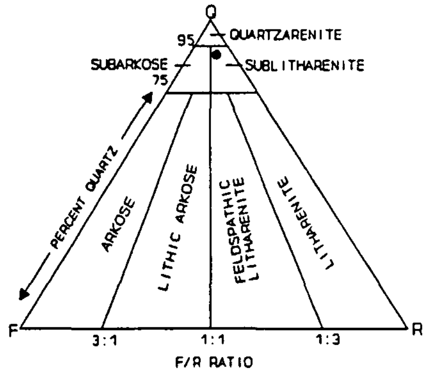
TEXTURE:

Grain Size: Range Very fine - medium sand Mode Medium

Sorting	Moderate
Roundness	Subangular to subrounded
Textural Maturity	Submature
Porosity	5%
Cement/Matrix	20% silica cement/5% silt, 3% clay
Friability	Non-friable

COMPOSITION:

Mineral:	Percentage:
Quartz	92
Rock fragments	5
Feldspar	3
Muscovite	Trace
Chert	Trace



CLASSIFICATION (Folk, 1974): Sublitharenite

MACROSCOPIC FIELD CHARACTERISTICS:

Weathering Characteristics	Forms resistant ledge
Bedding/Internal Structures	Thin to thick bedded/structureless
Fractures/Slickensides	Silica cemented fractures (cataclasis?)

FOSSILS: Large leaf impressions in outcrop

COMMENTS: Silica cement occurs as microcrystalline quartz; some feldspar grains are kaolinized.

SURFACE SAMPLE DESCRIPTION

Sample Number MV2-W
Thin Section ---
Location Collected West Gate Claypit SWSE 9 T2S R70W (Station 131)
Formation Name Laramie

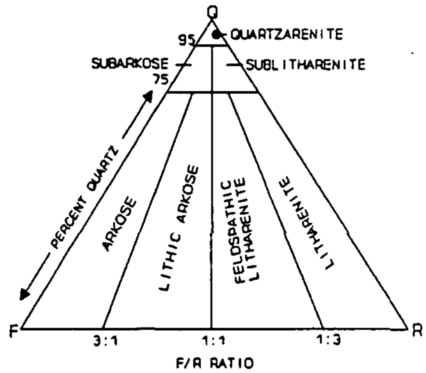
ROCK TYPE WITH MODIFIERS: Siliceous sandstone

COLOR (GSA Rock Color Chart): Light olive gray (5Y 6/1) weathers moderate brown (5YR 4/4 - 5YR 3/4)

TEXTURE:
Grain Size: Range Very fine - medium sand Mode Medium
Sorting Moderate
Roundness Subangular to rounded
Textural Maturity Submature
Porosity 5%
Cement/Matrix 20% silica cement/5% silt, 3% clay
Friability Non-friable

COMPOSITION:

Mineral:	Percentage:
Quartz	97
Chert	2
Rock fragments	1
Muscovite	Trace
Magnetite	Trace



CLASSIFICATION (Folk, 1974): Quartzarenite

MACROSCOPIC FIELD CHARACTERISTICS:

Weathering Characteristics Forms resistant ledge

Bedding/Internal Structures Thin to thick bedded/structureless

Fractures/Slickensides None

FOSSILS: None

COMMENTS: Silica cement occurs as microcrystalline quartz; chert is brown to gray in color.

SURFACE SAMPLE DESCRIPTION

Sample Number: MV3-W

Thin Section: ---

Location Collected: North Claypit NESW 4 T2S R70W (Station 132)

Formation Name: Laramie

ROCK TYPE WITH MODIFIERS: Siliceous sandstone with some silt

COLOR (GSA Rock Color Chart): Light olive gray (5Y 6/1) weathers moderate yellowish brown (10YR 5/4)

TEXTURE:

Grain Size: Range Very fine - fine sand Mode Very fine

Sorting: Moderate

Roundness: Subangular to subrounded

Textural Maturity: Submature

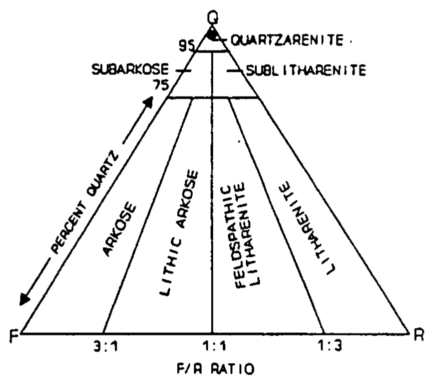
Porosity: None

Cement/Matrix: 20% silica cement/10% silt, 3% clay

Friability: Non-friable

COMPOSITION:

Mineral:	Percentage:
Quartz	98
Rock fragments	1
Feldspar	1
Carbonaceous fragments	Trace



CLASSIFICATION (Folk, 1974): Quartzarenite

MACROSCOPIC FIELD CHARACTERISTICS:

Weathering Characteristics: Forms low resistant ledge

Bedding/Internal Structures: Thick bedded/massive

Fractures/Slickensides: None

FOSSILS: None

COMMENTS: Black dendritic manganese-oxide staining; massive ironstone on upper bounding surface; iron-oxide staining occurs along laminae.

SURFACE SAMPLE DESCRIPTION

Sample Number	MV4-W
Thin Section	---
Location Collected	North Claypit NESW 4 T2S R70W (Station 132)
Formation Name	Fox Hills

ROCK TYPE WITH MODIFIERS: Sandstone with some silt, clay, and glauconite

COLOR (GSA Rock Color Chart): Light olive gray (5Y 6/1) weathers yellowish gray (5Y 7/2)

TEXTURE:

Grain Size: Range Very fine - fine sand Mode Fine

Sorting Well

Roundness Subangular to subrounded

Textural Maturity Immature

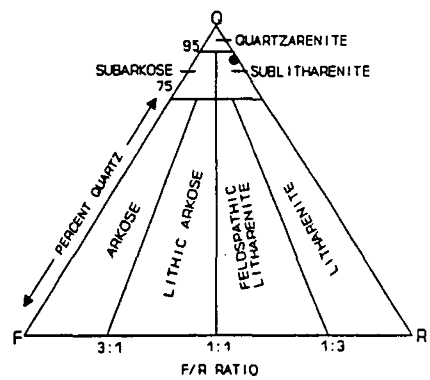
Porosity None

Cement/Matrix 5% silica cement/20% silt, 8% clay

Friability Non-friable

COMPOSITION:

Mineral:	Percentage:
Quartz	90
Rock fragments	7
Glauconite	2
Chert	1
Tourmaline, Garnet	Trace



CLASSIFICATION (Folk, 1974): Sublitharenite

MACROSCOPIC FIELD CHARACTERISTICS:

Weathering Characteristics Forms small hogback with resistant iron-stained ledge at top

Bedding/Internal Structures Massive/structureless

Fractures/Slickensides None

FOSSILS: None

COMMENTS: Silica cement occurs as microcrystalline quartz.

SURFACE SAMPLE DESCRIPTION

Sample Number	MV5-W
Thin Section	MV5-W
Location Collected	South Claypit NWSE 16 T2S R70W (Station 134)
Formation Name	Laramie

ROCK TYPE WITH MODIFIERS: Sandstone with some silt and clay

COLOR (GSA Rock Color Chart): Light olive gray (5Y 6/1) weathers moderate yellowish brown (10YR 5/4)

TEXTURE:

Grain Size: Range Very fine - fine Mode Very fine

Sorting Moderate to well

Roundness Subangular

Textural Maturity Immature

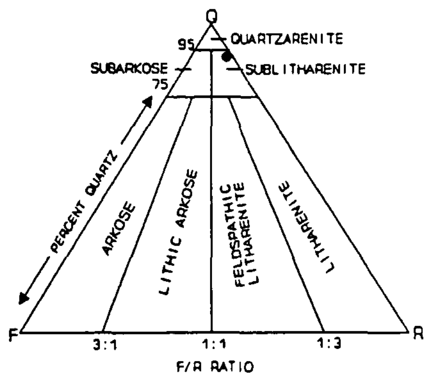
Porosity None

Cement/Matrix 10% silica cement/15% silt, 8% clay

Friability Non-friable

COMPOSITION:

Mineral:	Percentage:
Quartz	94
Chert	3
Rock fragments	3
Muscovite	Trace



CLASSIFICATION (Folk, 1974): Quartzarenite

MACROSCOPIC FIELD CHARACTERISTICS:

Weathering Characteristics: Forms resistant ledge on west edge of claypit

Bedding/Internal Structures: Thick bedded/structureless

Fractures/Slickensides: None

FOSSILS: Abundant oxidized plant remains; plant impressions

COMMENTS: Silica cement occurs as microcrystalline quartz; iron oxide (limonite or goethite) lines root molds.

SURFACE SAMPLE DESCRIPTION

Sample Number	MV6-W
Thin Section	---
Location Collected	South Claypit NWSE 16 T2S R70W (Station 134)
Formation Name	Laramie

ROCK TYPE WITH MODIFIERS: Siliceous sandstone

COLOR (GSA Rock Color Chart): Light gray (N7) weathers moderate yellowish brown (10YR 5/4)

TEXTURE:

Grain Size: Range Very fine - medium sand Mode Fine

Sorting Moderate

Roundness Subangular to subrounded

Textural Maturity Submature

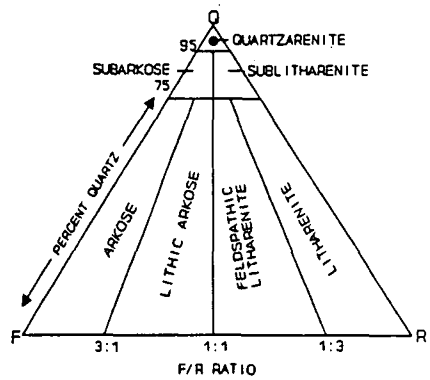
Porosity 5%

Cement/Matrix 20% silica cement/5% silt, 3% clay

Friability Non-friable

COMPOSITION:

Mineral:	Percentage:
Quartz	97
Rock fragments	2
Feldspar	1
Muscovite	Trace
Chert	Trace



CLASSIFICATION (Folk, 1974): Quartzarenite

MACROSCOPIC FIELD CHARACTERISTICS:

Weathering Characteristics: Forms resistant lenticular-shaped ledge

Bedding/Internal Structures: Thin to thick bedded/planar laminations

Fractures/Slickensides: Open fractures/striations in claystones on bedding planes

FOSSILS: Abundant wood impressions on bedding planes

COMMENTS: Silica cement occurs as microcrystalline quartz.

SURFACE SAMPLE DESCRIPTION

Sample Number: MV7-W
Thin Section: ---
Location Collected: South Claypit NWSE 16 T2S R70W (Station 138a)
Formation Name: Laramie

ROCK TYPE WITH MODIFIERS: Siliceous sandstone with claystone rip-up clasts

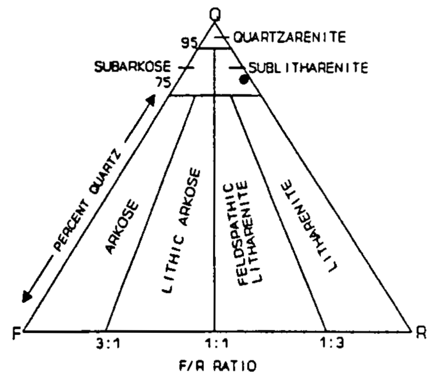
COLOR (GSA Rock Color Chart): Dark yellowish brown sand (10YR 6/6) with light olive gray (5Y 6/1) rip-up clasts

TEXTURE:

Grain Size: Range Very fine sand - c pebbles Mode Fine sand
Sorting: Moderate to poor
Roundness: Subangular to subrounded
Textural Maturity: Immature
Porosity: None
Cement/Matrix: 20% silica cement/7% silt, 6% clay
Friability: Non-friable

COMPOSITION:

Mineral:	Percentage:
Quartz	80
Rock fragments	19
Feldspar	1
Muscovite	Trace



CLASSIFICATION (Folk, 1974): Sublitharenite

MACROSCOPIC FIELD CHARACTERISTICS:

Weathering Characteristics: Forms resistant ledge

Bedding/Internal Structures: Thin to thick bedded/claystone rip-up clasts

Fractures/Slickensides: None

FOSSILS: None

COMMENTS: Iron-stained sandstone with large (1-2 inch) gray silty claystone rip-up clasts; clay in matrix is iron-stained; rip-up clasts appear distorted along terminations indicating that they were not entirely lithified.

SURFACE SAMPLE DESCRIPTION

Sample Number MV8-W

Thin Section ---

Location Collected West Gate Claypit SWSE 9 T2S R70W (Station 135b)

Formation Name Fox Hills

ROCK TYPE WITH MODIFIERS: Sandstone with some silt and clay

COLOR (GSA Rock Color Chart): Light olive gray (5Y 6/1) weathers grayish yellow (5Y 8/4)

TEXTURE:

Grain Size: Range Very fine - medium sand Mode Fine

Sorting Moderate

Roundness Subangular to rounded

Textural Maturity Immature

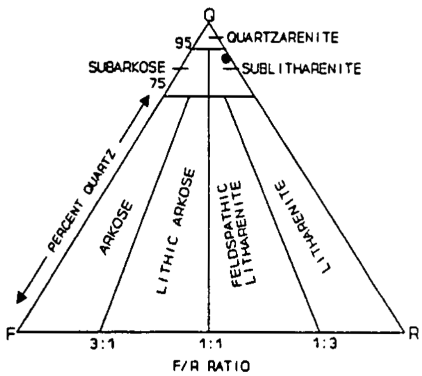
Porosity 15%

Cement/Matrix No cement/10% silt, 8% clay

Friability Moderately friable

COMPOSITION:

Mineral:	Percentage:
Quartz	90
Rock fragments	7
Chert	3
Feldspar, Mica	Trace
Glauconite	Trace



CLASSIFICATION (Folk, 1974): Sublitharenite

MACROSCOPIC FIELD CHARACTERISTICS:

Weathering Characteristics Dip slope of friable sandstone on edge of claypit

Bedding/Internal Structures Massive/structureless

Fractures/Slickensides None

FOSSILS: None

COMMENTS: Few quartz grains have quartz overgrowths; small flakes of irridescent white clay occur in clumps in pores and pore throats.

SURFACE SAMPLE DESCRIPTION

Sample Number: MV14-W
Thin Section: ---
Location Collected: Leyden Gulch SESW 28 T2S R70W (Station 156)
Formation Name: Laramie

ROCK TYPE WITH MODIFIERS: Sandstone

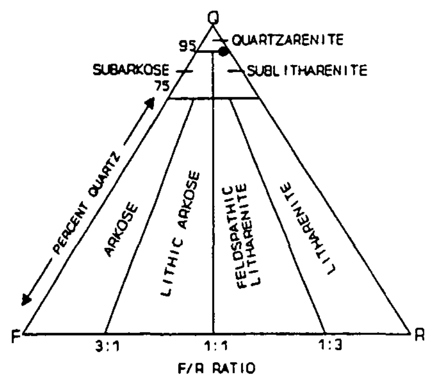
COLOR (GSA Rock Color Chart): Light gray (N7) weathers light brown (5YR 5/6)

TEXTURE:

Grain Size: Range Fine - coarse sand Mode Medium
Sorting: Moderate
Roundness: Subangular to rounded
Textural Maturity: Submature
Porosity: 20%
Cement/Matrix: 5% silica cement/5% silt, 3% clay
Friability: Slightly friable

COMPOSITION:

Mineral:	Percentage:
Quartz	95
Rock fragments	2
Carbonaceous fragments	2
Feldspar	1



CLASSIFICATION (Folk, 1974): Quartzarenite

MACROSCOPIC FIELD CHARACTERISTICS:

Weathering Characteristics: Forms lenticular-shaped resistant ledge
Bedding/Internal Structures: Thin to thick bedded/low angle planar cross bedding
Fractures/Slickensides: None

FOSSILS: None

COMMENTS: Silica cement occurs as microcrystalline quartz; clay is heavily iron stained; few sand grains are well rounded and frosted.

SURFACE SAMPLE DESCRIPTION

Sample Number	MV16-W
Thin Section	---
Location Collected	Leyden Gulch SESW 28 T2S R70W (Station 156)
Formation Name	Laramie

ROCK TYPE WITH MODIFIERS: Siliceous sandstone with some silt and clay

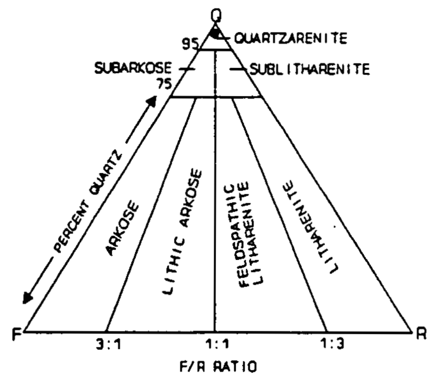
COLOR (GSA Rock Color Chart): Medium light gray (N6) weathers moderate brown (5YR 3/4)

TEXTURE:

- Grain Size: Range Very fine - medium sand Mode Very fine
- Sorting Moderate
- Roundness Subangular
- Textural Maturity Immature
- Porosity None
- Cement/Matrix 20% silica cement/7% silt, 6% clay
- Friability Non-friable

COMPOSITION:

Mineral:	Percentage:
Quartz	98
Carbonaceous fragments	2
Muscovite	Trace
Feldspar	Trace



CLASSIFICATION (Folk, 1974): Quartzarenite

MACROSCOPIC FIELD CHARACTERISTICS:

Weathering Characteristics	Forms low resistant ledge
Bedding/Internal Structures	Thin to thick bedded/parallel bedding surfaces
Fractures/Slickensides	None

FOSSILS: None

COMMENTS: Heavily iron stained; iron-oxide occurs in bands; minor black dendritic manganese-oxide staining.

SURFACE SAMPLE DESCRIPTION

Sample Number	MV17-W
Thin Section	---
Location Collected	Leyden Gulch SESW 28 T2S R70W (Station 156)
Formation Name	Laramie

ROCK TYPE WITH MODIFIERS: Siliceous sandstone with some silt and clay

COLOR (GSA Rock Color Chart): Light olive gray (5Y 6/1) weathers yellowish gray (5Y 8/1)

TEXTURE:

Grain Size: Range Very fine - fine sand Mode Very fine

Sorting Moderate to well

Roundness Subangular

Textural Maturity Immature

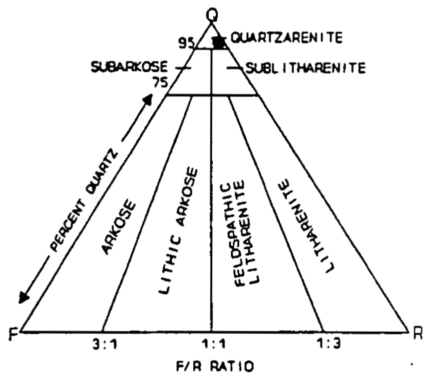
Porosity 5%

Cement/Matrix 15% silica cement/7% silt, 6% clay

Friability Non-friable

COMPOSITION:

Mineral:	Percentage:
Quartz	96
Carbonaceous fragments	2
Rock fragments	1
Biotite	1
Muscovite	Trace



CLASSIFICATION (Folk, 1974): Quartzarenite

MACROSCOPIC FIELD CHARACTERISTICS:

Weathering Characteristics: Partly covered; forms slope

Bedding/Internal Structures: Laminated to thin bedded/planar cross bedding

Fractures/Slickensides: None

FOSSILS: Pale brown root casts; abundant trace fossils on bedding planes

COMMENTS: Silica cement occurs as microcrystalline quartz.

SURFACE SAMPLE DESCRIPTION

Sample Number: MV18-W
Thin Section: ---
Location Collected: Leyden Gulch SESW 28 T2S R70W (Station 156)
Formation Name: Laramie

ROCK TYPE WITH MODIFIERS: Siliceous sandstone with some silt and clay

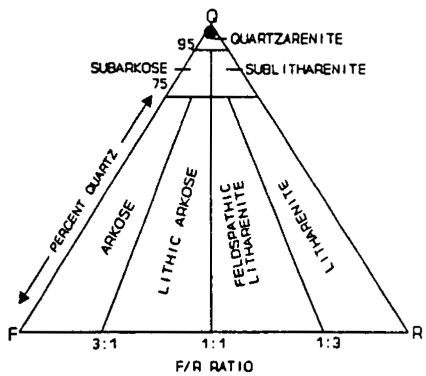
COLOR (GSA Rock Color Chart): Very dusky red purple (5RP 2/2) weathers grayish red (5R 4/2)

TEXTURE:

Grain Size: Range Very fine - medium sand Mode Fine
Sorting: Moderate
Roundness: Subangular
Textural Maturity: Immature
Porosity: None
Cement/Matrix: 10% silica cement/10% silt, 13% clay
Friability: Non-friable

COMPOSITION:

Mineral:	Percentage:
Quartz	98
Feldspar	1
Muscovite	1



CLASSIFICATION (Folk, 1974): Quartzarenite

MACROSCOPIC FIELD CHARACTERISTICS:

Weathering Characteristics: Forms resistant ledge
Bedding/Internal Structures: Thin bedded/structureless
Fractures/Slickensides: None

FOSSILS: None

COMMENTS: Heavily iron stained; silica cement occurs as microcrystalline quartz; matrix is so abundant that quartz grains appear to be floating in it.

SURFACE SAMPLE DESCRIPTION

Sample Number: MV1-E
Thin Section: ---
Location Collected: Indiana Street roadcut SENE 1 T2S R70W (Station 200)
Formation Name: Arapahoe

ROCK TYPE WITH MODIFIERS: Sandstone with some silt

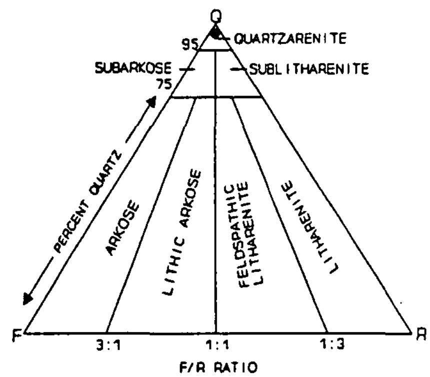
COLOR (GSA Rock Color Chart): Light olive gray (5Y 6/1) weathers dark yellowish orange (10YR 6/6)

TEXTURE:

Grain Size: Range Very fine - medium sand Mode Medium
Sorting: Moderate
Roundness: Subangular to rounded
Textural Maturity: Submature
Porosity: 20%
Cement/Matrix: 5% calcite cement/8% silt, no clay
Friability: Moderately friable (highly friable in outcrop)

COMPOSITION:

Mineral:	Percentage:
Quartz	98
Chert	1
Rock fragments	1
Feldspar	Trace



CLASSIFICATION (Folk, 1974): Quartzarenite

MACROSCOPIC FIELD CHARACTERISTICS:

Weathering Characteristics: Forms ledge under tree in roadcut; generally forms slope
Bedding/Internal Structures: Laminated
Fractures/Slickensides: None

FOSSILS: None

COMMENTS: Heavily iron stained - most of rock sample is dark yellowish orange.

SURFACE SAMPLE DESCRIPTION

Sample Number: MV2-E
Thin Section: ---
Location Collected: Great Western Reservoir SWNE 7 T2S R69W
Formation Name: Laramie (Station 251)

ROCK TYPE WITH MODIFIERS: Sandstone with some silt

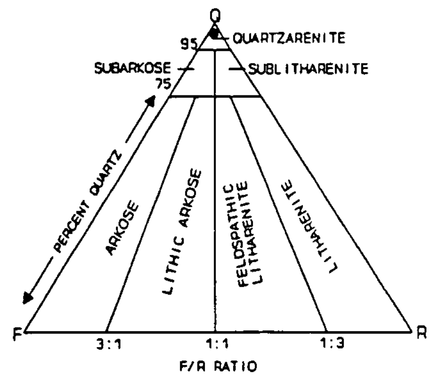
COLOR (GSA Rock Color Chart): Light olive gray (5Y 5/2) weathers moderate to dark yellowish brown (10YR 5/4-10YR 4/2)

TEXTURE:

- Grain Size: Range: Fine - medium sand Mode: Medium
- Sorting: Moderate to well
- Roundness: Subangular to rounded
- Textural Maturity: Mature
- Porosity: 25%
- Cement/Matrix: No cement/8% silt, no clay
- Friability: Slightly friable

COMPOSITION:

Mineral:	Percentage:
Quartz	98
Rock fragments	2
Chert	Trace
Magnetite	Trace



CLASSIFICATION (Folk, 1974): Quartzarenite

MACROSCOPIC FIELD CHARACTERISTICS:

- Weathering Characteristics: Forms slope above ditch
- Bedding/Internal Structures: Massive/interbedded with gray & orange mottled claystones
- Fractures/Slickensides: Calcite-filled fractures (Caliche?)

FOSSILS: None

COMMENTS: Some quartz grains are frosted.

SURFACE SAMPLE DESCRIPTION

Sample Number	MV3-E
Thin Section	MV3-E
Location Collected	Standley Lake NENE 29 T2S R69W (Station 256)
Formation Name	Arapahoe

ROCK TYPE WITH MODIFIERS: Calcarous pebbly sandstone with some clay

COLOR (GSA Rock Color Chart): Moderate yellowish brown (10YR 5/4)

TEXTURE:

Grain Size: Range Medium sand - vf pebble Mode Coarse sand

Sorting Poor

Roundness Subangular to well rounded

Textural Maturity Immature

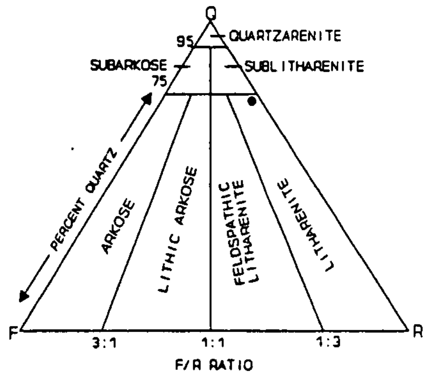
Porosity 15%

Cement/Matrix 10% calcite cement/1% silt, 7% clay

Friability Highly friable

COMPOSITION:

Mineral:	Percentage:
Quartz	73
Rock fragments	20
Feldspar	5
Chert	2
Biotite	Trace
Magnetite	Trace



CLASSIFICATION (Folk, 1974): Litharenite

MACROSCOPIC FIELD CHARACTERISTICS:

Weathering Characteristics	Forms steep slope in drainage above lake
Bedding/Internal Structures	Thin to thick bedded/planar tangential and trough crossbedding
Fractures/Slickensides	None

FOSSILS: None

COMMENTS: Coarse sand-sized quartz grains are well rounded; pebbles are composed of rock fragments (mostly weathered volcanic fragments with a few siltstones); all grains have clay coats; porosity occurs as intergranular and shrinkage porosity around grains; some quartz grains are well-rounded and frosted.

SURFACE SAMPLE DESCRIPTION

Sample Number	MV28-E
Thin Section	MV28-E
Location Collected	Indiana Street roadcut NWSW 19 T2S R69W (Station 276)
Formation Name	Arapahoe

ROCK TYPE WITH MODIFIERS: Sandstone

COLOR (GSA Rock Color Chart): Grayish orange (10YR 7/4)

TEXTURE:

Grain Size: Range Fine - medium sand Mode Medium

Sorting Moderate

Roundness Subrounded to well rounded

Textural Maturity Mature

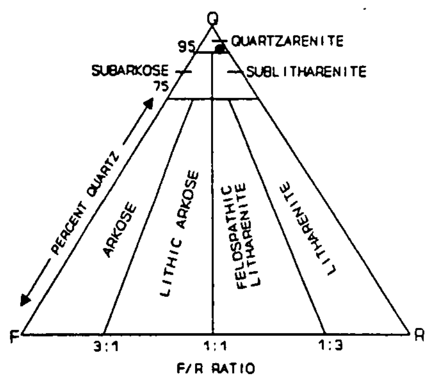
Porosity 30%

Cement/Matrix No cement/no silt, 3% clay

Friability Highly friable

COMPOSITION:

Mineral:	Percentage:
Quartz	96
Chert	4
Feldspar	Trace
Rock fragments	Trace



CLASSIFICATION (Folk, 1974): Quartzarenite

MACROSCOPIC FIELD CHARACTERISTICS:

Weathering Characteristics	Forms slope
Bedding/Internal Structures	Thin bedded/low angle cross-bedding
Fractures/Slickensides	Low angle, SE-dipping joints with cataclastic texture

FOSSILS:

COMMENTS: Quartz grains have very thin clay coats; cataclastic zone with fractured and rotated grains; secondary silica "cement" due to cataclasis; rounded quartz grains are frosted

CORE SAMPLE DESCRIPTION

Sample Number	0386BR (14.5ft)
Thin Section	0386BR (14.5ft)
Location Collected	Buffer zone near Indiana Street - Rocky Flats Plant
	SENE 12 T2S R70W
Formation Name	Arapahoe

ROCK TYPE WITH MODIFIERS: Sandstone

COLOR (GSA Rock Color Chart): Yellowish gray (5YR 7/2) weathers grayish orange (10YR 7/4)

TEXTURE:

Grain Size: Range Very fine - medium sand Mode Medium

Sorting Moderate

Roundness Subrounded to well rounded

Textural Maturity Submature

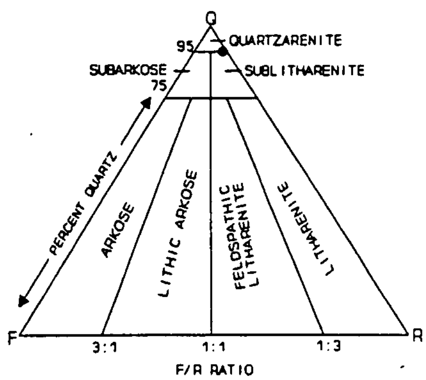
Porosity 25%

Cement/Matrix No cement/5% silt, 3% clay

Friability Highly friable

COMPOSITION:

Mineral:	Percentage:
Quartz	95
Rock fragments	4
Chert	1
Feldspar	Trace



CLASSIFICATION (Folk, 1974): Quartzarenite

MACROSCOPIC FIELD CHARACTERISTICS:

Weathering Characteristics

Bedding/Internal Structures

Fractures/Slickensides

FOSSILS:

COMMENTS: Friability of sample has caused thin section to appear as if rock is not grain supported - grains are floating in blue epoxy in pores; some rock fragments are quartzite; few quartz grains are tectonically shattered; medium-sized grains are rounded and frosted.

CORE SAMPLE DESCRIPTION

Sample Number 3286BR (95ft)
Thin Section 3286BR (95ft)
Location Collected Protected Area - Rocky Flats Plant SENW 11 T2S R70W
Formation Name Laramie

ROCK TYPE WITH MODIFIERS: Siltstone with claystone laminae

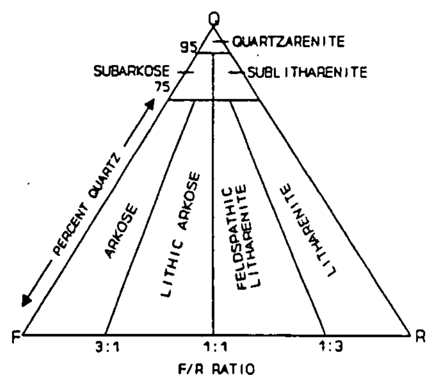
COLOR (GSA Rock Color Chart): Light to medium olive gray (5Y 6/1 - 4/1)

TEXTURE:

Grain Size: Range Very fine sand - clay Mode Silt
Sorting
Roundness
Textural Maturity Immature
Porosity 5%
Cement/Matrix No cement/clay matrix
Friability Non-friable

COMPOSITION:

Mineral: Percentage:
Too fine grained to determine



CLASSIFICATION (Folk, 1974): N/A

MACROSCOPIC FIELD CHARACTERISTICS:

Weathering Characteristics
Bedding/Internal Structures Laminated/contorted laminae
Fractures/Slickensides

FOSSILS:

COMMENTS: Iron-stained laminae; porosity occurs along laminae and may be due to dissolution; organic matter has been oxidized

CORE SAMPLE DESCRIPTION

Sample Number 6286 (55.3ft)
Thin Section 6286 (55.3 ft)
Location Collected 881 Hillside - Rocky Flats Plant SESW 11 T2S R70W
Formation Name Arapahoe

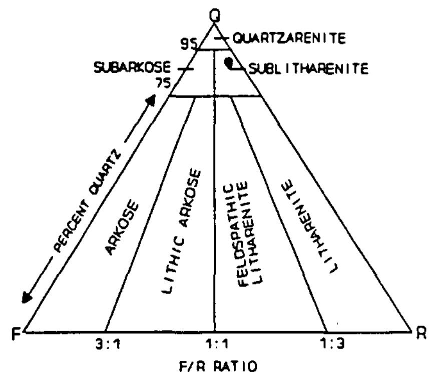
ROCK TYPE WITH MODIFIERS: Clayey sandstone

COLOR (GSA Rock Color Chart): --

TEXTURE:
Grain Size: Range Very fine - medium Mode Fine
Sorting Moderate
Roundness Subangular to rounded
Textural Maturity Immature
Porosity 10%
Cement/Matrix No cement/10% silt, 13% clay
Friability --

COMPOSITION:

Mineral:	Percentage:
Quartz	88
Rock fragments	8
Feldspar	3
Biotite	1



CLASSIFICATION (Folk, 1974): Sublitharenite

MACROSCOPIC FIELD CHARACTERISTICS:

Weathering Characteristics --

Bedding/Internal Structures --

Fractures/Slickensides --

FOSSILS: None

COMMENTS: Biotite is strongly weathered; some quartz grains are rounded to well rounded and frosted; other quartz grains have ragged edges

CORE SAMPLE DESCRIPTION

Sample Number 0987BH (20.3ft) A
Thin Section 0987BH (20.3ft) A
Location Collected 881 Hillside - Rocky Flats Plant NESW 11 T2S R70W
Formation Name Arapahoe

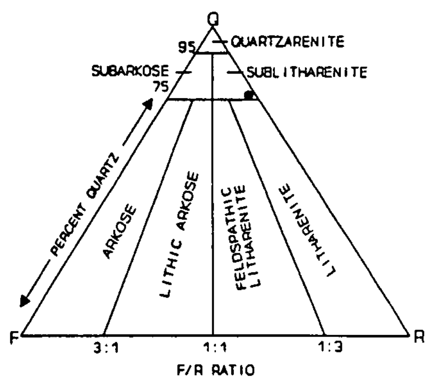
ROCK TYPE WITH MODIFIERS: Sandstone

COLOR (GSA Rock Color Chart): --

TEXTURE:
Grain Size: Range Very fine - fine Mode Fine
Sorting Well
Roundness Subangular to rounded
Textural Maturity Submature
Porosity 30%
Cement/Matrix No cement/3% silt, no clay
Friability --

COMPOSITION:

Mineral:	Percentage:
Quartz	77
Chert	15
Rock fragments	5
Feldspar	3
Zircon	Trace



CLASSIFICATION (Folk, 1974): Sublitharenite

MACROSCOPIC FIELD CHARACTERISTICS:

Weathering Characteristics --

Bedding/Internal Structures --

Fractures/Slickensides --

FOSSILS: None

COMMENTS: Trace iron oxide fragments

CORE SAMPLE DESCRIPTION

Sample Number: 0987BH (29.3ft) B
Thin Section: 0987BH (29.3ft) B
Location Collected: 881 Hillside - Rocky Flats Plant NESW 11 T2S R70W
Formation Name: Arapahoe

ROCK TYPE WITH MODIFIERS: Pebbly sandstone

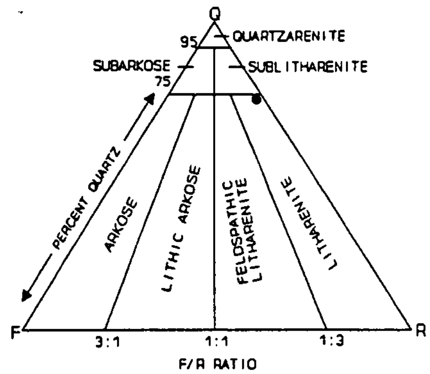
COLOR (GSA Rock Color Chart): --

TEXTURE:

Grain Size: Range Fine sand - pebble Mode Medium sand
Sorting: Poor
Roundness: Subrounded to well rounded
Textural Maturity: Submature
Porosity: 30%
Cement/Matrix: No cement/2% silt, 1% clay
Friability: --

COMPOSITION:

Mineral:	Percentage:
Quartz	74
Rock fragments	20
Chert	5
Feldspar	1
Zircon	Trace



CLASSIFICATION (Folk, 1974): Litharenite

MACROSCOPIC FIELD CHARACTERISTICS:

Weathering Characteristics: --

Bedding/Internal Structures: --

Fractures/Slickensides: --

FOSSILS: None

COMMENTS: Single large (fine pebble sized) clast of silty sandstone makes up twenty percent of thin section; pebble is surrounded by cleaner, more porous sandstone; clast may be diagenetic rather than detrital -- an area of reduced porosity; well-rounded quartz grains are frosted.

CORE SAMPLE DESCRIPTION

Sample Number	0987BH (30ft)
Thin Section	0987BH (30ft)
Location Collected	881 Hillside - Rocky Flats Plant NESW 11 T2S R70W
Formation Name	Arapahoe

ROCK TYPE WITH MODIFIERS: Pebbly sandstone

COLOR (GSA Rock Color Chart): Dark yellowish orange (10YR 6/6)

TEXTURE:

Grain Size: Range Fine sand - coarse pebble Mode Medium sand

Sorting Poor

Roundness Subrounded to well rounded

Textural Maturity Submature

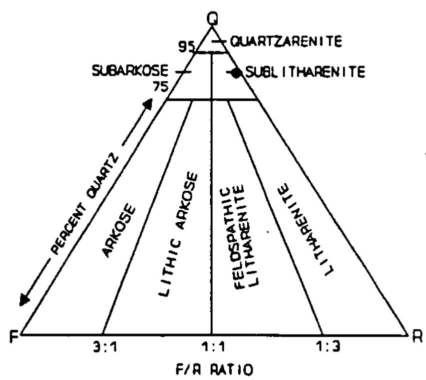
Porosity 30%

Cement/Matrix No cement/1% silt, 2% clay

Friability Highly friable

COMPOSITION:

Mineral:	Percentage:
Quartz	85
Chert	10
Rock fragments	5
Feldspar	Trace



CLASSIFICATION (Folk, 1974): Quartzarenite

MACROSCOPIC FIELD CHARACTERISTICS:

Weathering Characteristics

Bedding/Internal Structures

Fractures/Slickensides

FOSSILS:

COMMENTS: Friability of sample has caused thin section to appear as if rock is not grain supported - grains are loating in pores; clay occurs as clay coats and meniscus cement; large rock fragments are sandy siltstone or claystone from the Laramie Formation; well-rounded quartz grains are frosted.

CORE SAMPLE DESCRIPTION

Sample Number: 0987BH (30.2ft) C
Thin Section: 0987BH (30.2ft) C
Location Collected: 881 Hillside - Rocky Flats Plant NESW 11 T2S R70W
Formation Name: Arapahoe

ROCK TYPE WITH MODIFIERS: Sandstone

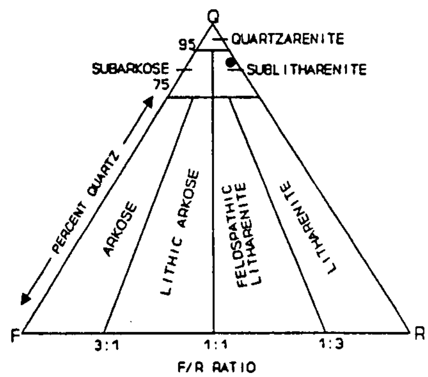
COLOR (GSA Rock Color Chart): --

TEXTURE:

Grain Size: Range Fine - coarse sand Mode Medium
Sorting: Moderate
Roundness: Subrounded to well rounded
Textural Maturity: Submature
Porosity: 22%
Cement/Matrix: 5% siderite or iron-oxide cement/3% silt, 3% clay
Friability: --

COMPOSITION:

Mineral:	Percentage:
Quartz	88
Chert	10
Feldspar	2
Zircon	Trace



CLASSIFICATION (Folk, 1974): Sublitharenite

MACROSCOPIC FIELD CHARACTERISTICS:

Weathering Characteristics: --

Bedding/Internal Structures: --

Fractures/Slickensides: --

FOSSILS: None

COMMENTS: Some quartz grains have ragged edges and appear to be etched; well-rounded quartz grains are frosted.

CORE SAMPLE DESCRIPTION

Sample Number 0987BH (31.0ft) D
Thin Section 0987BH (31.0ft) D
Location Collected 881 Hillside - Rocky Flats Plant NESW 11 T2S R70W
Formation Name Laramie

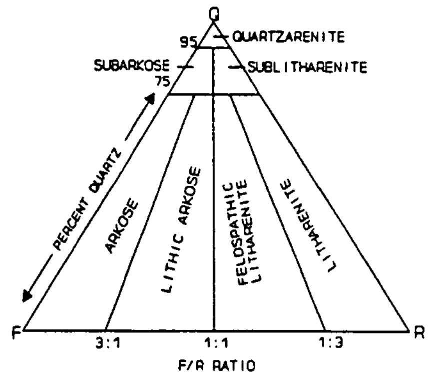
ROCK TYPE WITH MODIFIERS: Sandy claystone

COLOR (GSA Rock Color Chart): --

TEXTURE:
Grain Size: Range Clay - fine pebble Mode Clay
Sorting Poor
Roundness --
Textural Maturity --
Porosity --
Cement/Matrix Patches of iron oxide cement
Friability --

COMPOSITION:

Mineral:	Percentage:
Clay	50
Quartz	30
Rock fragments	17
Mica	3



CLASSIFICATION (Folk, 1974): --

MACROSCOPIC FIELD CHARACTERISTICS:

Weathering Characteristics --

Bedding/Internal Structures Crude planar laminations

Fractures/Slickensides --

FOSSILS: None

COMMENTS: Rock fragments in a sandy claystone matrix include fine pebble sized Precambrian granite and coarse sand sized, iron oxide cemented, sandstone that resembles the Arapahoe Formation; sandstone grains are well rounded; sandstones are possibly breccia fragments in a claystone, and may be fault related.

CORE SAMPLE DESCRIPTION

Sample Number 0987BH (33.0ft) E
Thin Section 0987BH (33.0ft) E
Location Collected 881 Hillside - Rocky Flats Plant NESW 11 T2S R70W
Formation Name Laramie

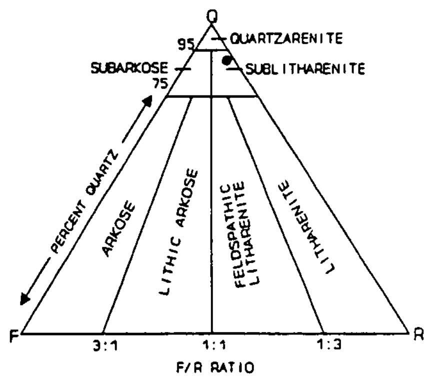
ROCK TYPE WITH MODIFIERS: Clayey sandstone

COLOR (GSA Rock Color Chart): --

TEXTURE:
Grain Size: Range Very fine - fine sand Mode Fine
Sorting Well
Roundness Subangular
Textural Maturity Immature
Porosity 10%
Cement/Matrix No cement/8% silt, 15% clay
Friability --

COMPOSITION:

Mineral:	Percentage:
Quartz	90
Rock fragments	5
Muscovite	4
Feldspar	1
Zircon	Trace



CLASSIFICATION (Folk, 1974): Sublitharenite

MACROSCOPIC FIELD CHARACTERISTICS:

Weathering Characteristics --

Bedding/Internal Structures Crudely laminated

Fractures/Slickensides --

FOSSILS: None

COMMENTS: Porosity is intergranular and fracture (or root mold) porosity; abundance of clay imparts a crude character to the sandstone; trace iron oxide and carbonaceous material

CORE SAMPLE DESCRIPTION

Sample Number	1387BR (20.5ft)
Thin Section	1387BR (20.5ft)
Location Collected	Woman Creek - Rocky Flats Plant SWSE 11 T2S R70W
Formation Name	Arapahoe

ROCK TYPE WITH MODIFIERS: Silty sandstone

COLOR (GSA Rock Color Chart): --

TEXTURE:

Grain Size: Range Silt - medium sand Mode Very fine sand

Sorting Poor

Roundness Subangular to rounded

Textural Maturity Immature

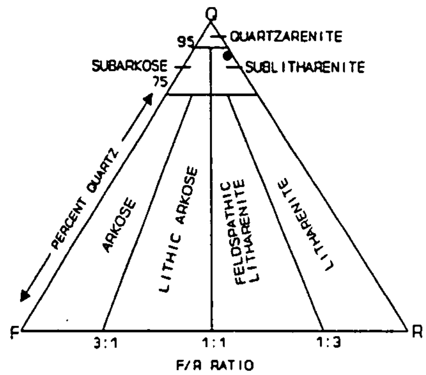
Porosity 5%

Cement/Matrix 3% siderite or iron oxide cement/15% silt, 10% clay

Friability --

COMPOSITION:

Mineral:	Percentage:
Quartz	91
Chert	6
Biotite	3



CLASSIFICATION (Folk, 1974): Sublitharenite

MACROSCOPIC FIELD CHARACTERISTICS:

Weathering Characteristics --

Bedding/Internal Structures --

Fractures/Slickensides --

FOSSILS: None

COMMENTS: Extreme bimodal grain size distribution; rounded, medium-grained quartz sand within very fine grained sand and silt matrix

CORE SAMPLE DESCRIPTION

Sample Number 1487BR (10.5ft)
Thin Section 1487BR (10.5ft)
Location Collected Woman Creek - Rocky Flats Plant SWSE 11 T2S R70W
Formation Name Arapahoe

ROCK TYPE WITH MODIFIERS: Sandstone

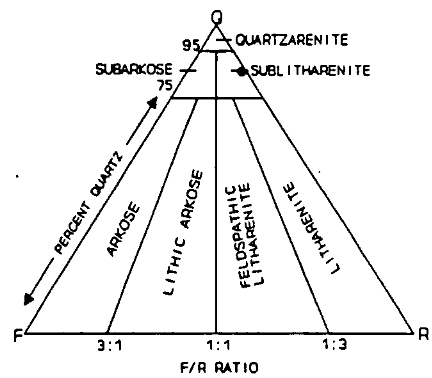
COLOR (GSA Rock Color Chart): --

TEXTURE:

Grain Size: Range Very fine - fine Mode Fine
Sorting Moderate
Roundness Subangular to subrounded
Textural Maturity Submature to immature
Porosity 18%
Cement/Matrix No cement/8% silt, 7% clay
Friability --

COMPOSITION:

Mineral:	Percentage:
Quartz	85
Chert	10
Biotite	5
Feldspar	Trace



CLASSIFICATION (Folk, 1974): Sublitharenite

MACROSCOPIC FIELD CHARACTERISTICS:

Weathering Characteristics --

Bedding/Internal Structures Very fine cross-laminations

Fractures/Slickensides --

FOSSILS: None

COMMENTS: Chert grains common

CORE SAMPLE DESCRIPTION

Sample Number 1487BR (20ft)
Thin Section 1487BR (20ft)
Location Collected Woman Creek - Rocky Flats Plant SWSE 11 T2S R70W
Formation Name Arapahoe

ROCK TYPE WITH MODIFIERS: Sandstone with some silt

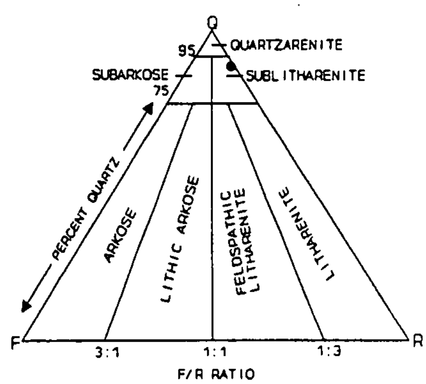
COLOR (GSA Rock Color Chart): --

TEXTURE:

Grain Size: Range Very fine - medium Mode Medium
Sorting Moderate
Roundness Subangular to well rounded
Textural Maturity Submature to immature
Porosity 20%
Cement/Matrix No cement/6% silt, 7% clay
Friability --

COMPOSITION:

Mineral:	Percentage:
Quartz	90
Rock fragments	8
Biotite	2



CLASSIFICATION (Folk, 1974): Sublitharenite

MACROSCOPIC FIELD CHARACTERISTICS:

Weathering Characteristics --

Bedding/Internal Structures --

Fractures/Slickensides Fractured quartz grains

FOSSILS: None

COMMENTS: Some medium-sized quartz grains are fractured and broken

CORE SAMPLE DESCRIPTION

Sample Number: 1687BR (137ft)
Thin Section: 1687BR (137ft)
Location Collected: 903 Pad - Rocky Flats Plant NWSE 11 T2S R70W
Formation Name: Laramie

ROCK TYPE WITH MODIFIERS: Sandstone with some silt and clay

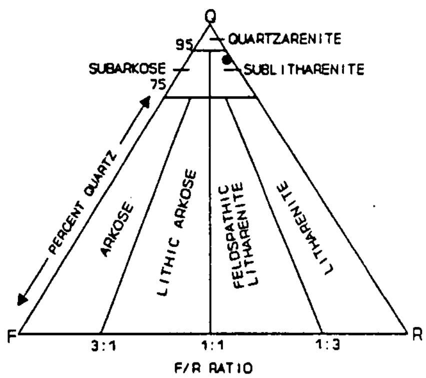
COLOR (GSA Rock Color Chart): Light olive gray (5Y 6/1)

TEXTURE:

Grain Size: Range Very fine - fine sand Mode Fine
Sorting: Well
Roundness: Angular to subangular
Textural Maturity: Immature
Porosity: 20%
Cement/Matrix: No cement/8% silt, 5% clay
Friability: Slightly friable

COMPOSITION:

Mineral:	Percentage:
Quartz	90
Chert	5
Rock fragments	3
Biotite	2
Feldspar	Trace



CLASSIFICATION (Folk, 1974): Sublitharenite

MACROSCOPIC FIELD CHARACTERISTICS:

Weathering Characteristics:
Bedding/Internal Structures: Laminated to very thin bedded
Fractures/Slickensides:

FOSSILS:

COMMENTS: Some laminae are contorted.

CORE SAMPLE DESCRIPTION

Sample Number 1887BR (112ft)
Thin Section 1887BR (112ft)
Location Collected East Inner Gate - Rocky Flats Plant NWSE 11 T2S R70W
Formation Name Laramie

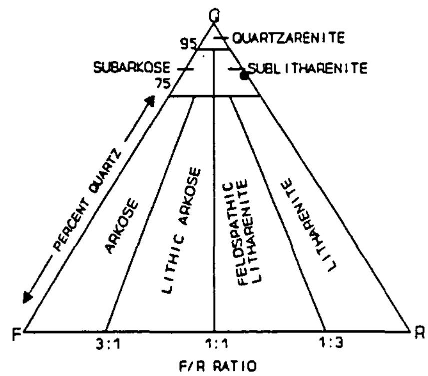
ROCK TYPE WITH MODIFIERS: Calcareous sandstone

COLOR (GSA Rock Color Chart): Light olive gray (5Y 6/1)

TEXTURE:
Grain Size: Range Very fine - fine sand Mode Fine sand
Sorting Well
Roundness Angular to subangular
Textural Maturity Immature
Porosity 12%
Cement/Matrix 13% calcite cement/3% silt, 5% clay
Friability Slightly friable

COMPOSITION:

Mineral:	Percentage:
Quartz	83
Chert	7
Carbonaceous fragments	5
Rock fragments	3
Biotite, Feldspar	1, 1



CLASSIFICATION (Folk, 1974): Sublitharenite

MACROSCOPIC FIELD CHARACTERISTICS:

Weathering Characteristics

Bedding/Internal Structures Very thin bedded/planar tangential cross bedding

Fractures/Slickensides

FOSSILS:

COMMENTS: Porosity occurs along uncemented laminae; stringers of organic material along laminae.

CORE SAMPLE DESCRIPTION

Sample Number	3187BR (128ft)
Thin Section	3187BR (128ft)
Location Collected	East Trenches - Rocky Flats Plant NESE 11 T2S R70W
Formation Name	Arapahoe

ROCK TYPE WITH MODIFIERS: Pebbly sandstone

COLOR (GSA Rock Color Chart): Light olive gray (5Y 6/1)

TEXTURE:

Grain Size: Range Fine sand - fine pebble Mode Medium sand

Sorting Poor

Roundness Subangular to well rounded

Textural Maturity Immature

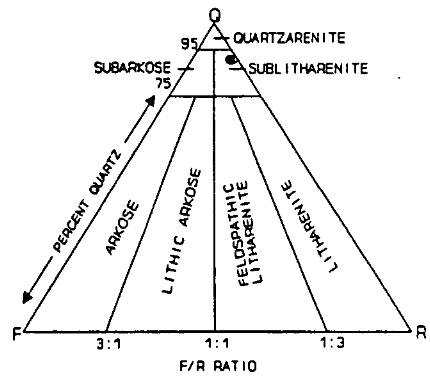
Porosity 15%

Cement/Matrix No cement/8% silt, 10% clay

Friability Highly friable

COMPOSITION:

Mineral:	Percentage:
Quartz	90
Chert	3
Rock fragments	3
Carbonaceous fragments	3
Feldspar	1



CLASSIFICATION (Folk, 1974): Quartzarenite

MACROSCOPIC FIELD CHARACTERISTICS:

Weathering Characteristics

Bedding/Internal Structures Laminated

Fractures/Slickensides

FOSSILS:

COMMENTS: Bimodal grain size distribution in some laminae; larger grains are well rounded and frosted, smaller grains are angular; other laminae are very fine sand; thin stringers of organic material.

CORE SAMPLE DESCRIPTION

Sample Number 3287BH (9.7ft)
Thin Section 3287BH (9.7ft)
Location Collected East Trenches - Rocky Flats Plant NESE 11 T2S R70W
Formation Name Laramie

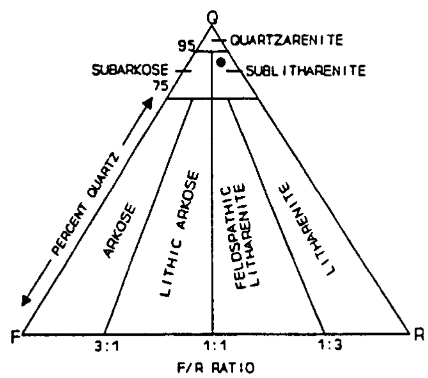
ROCK TYPE WITH MODIFIERS: Sandstone with some silt and clay

COLOR (GSA Rock Color Chart): --

TEXTURE:
Grain Size: Range Very fine - medium Mode Fine
Sorting Moderate to poor
Roundness Subangular to subrounded
Textural Maturity Immature
Porosity 5%
Cement/Matrix No cement/10% silt, 18% clay
Friability --

COMPOSITION:

Mineral:	Percentage:
Quartz	90
Rock fragments	6
Feldspar	2
Mica	2



CLASSIFICATION (Folk, 1974): Sublitharenite

MACROSCOPIC FIELD CHARACTERISTICS:

Weathering Characteristics --

Bedding/Internal Structures Crudely laminated

Fractures/Slickensides --

FOSSILS: None

COMMENTS: Two-thirds of slide is composed of Laramie Formation sandstone; one third of slide is composed of Arapahoe Formation sandstone with medium grained, well rounded quartz sand; core sample may have been collected near the depositional contact between the Laramie and Arapahoe, or it may have been collected near a fault contact

CORE SAMPLE DESCRIPTION

Sample Number 3287BH (9.7ft)
Thin Section 3287BH (9.7ft)
Location Collected East Trenches - Rocky Flats Plant NESE 11 T2S R70W
Formation Name Laramie

ROCK TYPE WITH MODIFIERS: Sandstone with some silt and clay

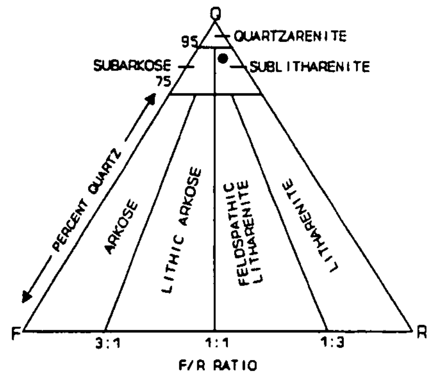
COLOR (GSA Rock Color Chart): --

TEXTURE:

Grain Size: Range Very fine - medium Mode Fine
Sorting Moderate to poor
Roundness Subangular to subrounded
Textural Maturity Immature
Porosity 5%
Cement/Matrix No cement/10% silt, 18% clay
Friability --

COMPOSITION:

Mineral:	Percentage:
Quartz	90
Rock fragments	6
Feldspar	2
Mica	2



CLASSIFICATION (Folk, 1974): Sublitharenite

MACROSCOPIC FIELD CHARACTERISTICS:

Weathering Characteristics --

Bedding/Internal Structures Crudely laminated

Fractures/Slickensides --

FOSSILS: None

COMMENTS: Two-thirds of slide is composed of Laramie Formation sandstone; one third of slide is composed of Arapahoe Formation sandstone with medium grained, well rounded quartz sand; core sample may have been collected near the depositional contact between the Laramie and Arapahoe, or it may have been collected near a fault contact

CORE SAMPLE DESCRIPTION

Sample Number: 3387BH (14.8ft)
Thin Section: 3387BH (14.8ft)
Location Collected: East Trenches - Rocky Flats Plant NESE 11 T2S R70W
Formation Name: Laramie

ROCK TYPE WITH MODIFIERS: Clayey sandstone

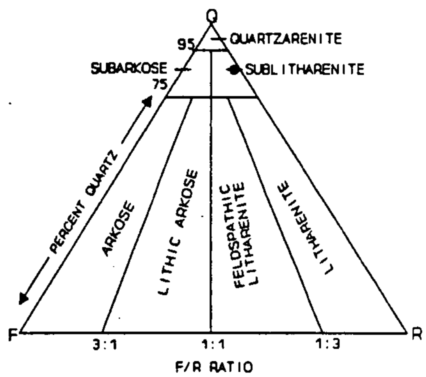
COLOR (GSA Rock Color Chart): --

TEXTURE:

Grain Size: Range Very fine - medium Mode Very fine
Sorting: Moderate
Roundness: Subangular to subrounded
Textural Maturity: Immature
Porosity: 15%
Cement/Matrix: 3% iron oxide cement/no silt, 15% clay
Friability: --

COMPOSITION:

Mineral:	Percentage:
Quartz	85
Biotite	7
Rock fragments	5
Chert	3



CLASSIFICATION (Folk, 1974): Sublitharenite

MACROSCOPIC FIELD CHARACTERISTICS:

Weathering Characteristics: --

Bedding/Internal Structures: Wavy laminations

Fractures/Slickensides: --

FOSSILS: None

COMMENTS: Porosity is intergranular; biotite appears to be strongly weathered; feldspar has weathered to clay; sandstone is very dirty; patchy iron oxide cement

CORE SAMPLE DESCRIPTION

Sample Number 3687BR (45ft)
Thin Section 3687BR (45ft)
Location Collected East Trenches - Rocky Flats Plant NWSE 11 T2S R70W
Formation Name Arapahoe

ROCK TYPE WITH MODIFIERS: Pebbly sandstone with some silt and clay

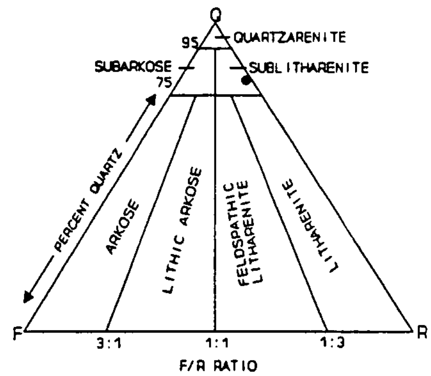
COLOR (GSA Rock Color Chart): Dark yellowish orange (10YR 6/6)

TEXTURE:

Grain Size: Range Fine sand - medium pebble Mode Medium sand
Sorting Poor
Roundness Subangular to well rounded
Textural Maturity Immature
Porosity 5%
Cement/Matrix No cement/8% silt, 20% clay
Friability Highly friable

COMPOSITION:

Mineral:	Percentage:
Quartz	80
Chert	15
Rock fragments	5
Feldspar	Trace



CLASSIFICATION (Folk, 1974): Quarzarenite

MACROSCOPIC FIELD CHARACTERISTICS:

Weathering Characteristics

Bedding/Internal Structures

Fractures/Slickensides

FOSSILS:

COMMENTS: Porosity occurs around grains as dissolution porosity; quartz grains floating in clay matrix; microcline grains are frosted; semi-bimodal grain size distribution with larger rounded grains and smaller angular grains; porosity reduced by iron oxide coatings on sand grains; rock fragments are claystone rip-up clasts.

CORE SAMPLE DESCRIPTION

Sample Number 4287BH (38.7ft)
Thin Section 4287BH (38.7ft)
Location Collected East Trenches - Rocky Flats Plant NWSE 11 T2S R70W
Formation Name Arapahoe

ROCK TYPE WITH MODIFIERS: Sandstone

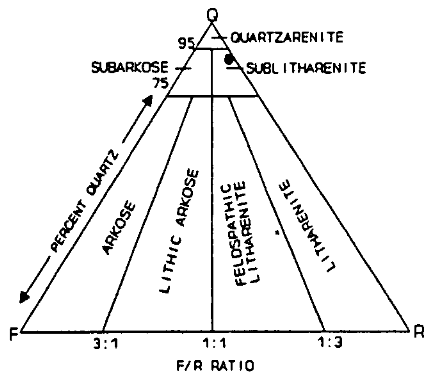
COLOR (GSA Rock Color Chart): --

TEXTURE:

Grain Size: Range Fine - coarse sand Mode Medium
Sorting Moderate to poor
Roundness Subrounded to well rounded
Textural Maturity Mature
Porosity 30%
Cement/Matrix No cement/3% silt, trace clay
Friability Highly friable

COMPOSITION:

Mineral:	Percentage:
Quartz	90
Chert	8
Rock fragments	2



CLASSIFICATION (Folk, 1974): Sublitharenite

MACROSCOPIC FIELD CHARACTERISTICS:

Weathering Characteristics --

Bedding/Internal Structures --

Fractures/Slickensides --

FOSSILS: None

COMMENTS: Clay adheres to sand grains -- clay coats; some lithic rock fragments are altered to clay; few siltstone rock fragments; several varieties of metamorphic quartz grains; well-rounded quartz grains are frosted.

CORE SAMPLE DESCRIPTION

Sample Number 4287BH (55ft)
Thin Section 4287BH (55ft)
Location Collected East Trenches - Rocky Flats Plant NWSE 11 T2S R70W
Formation Name Laramie

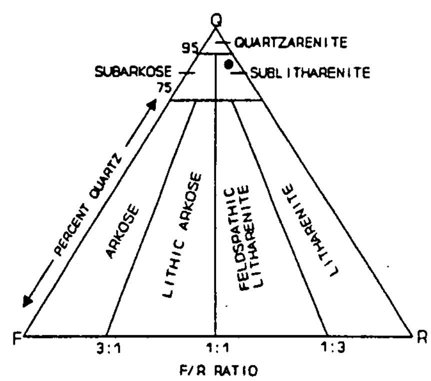
ROCK TYPE WITH MODIFIERS: Clayey sandstone

COLOR (GSA Rock Color Chart): --

TEXTURE:
Grain Size: Range Very fine - medium Mode Fine
Sorting Moderate
Roundness Subangular to well rounded
Textural Maturity Immature
Porosity 15%
Cement/Matrix No cement/5% silt, 13% clay
Friability --

COMPOSITION:

Mineral:	Percentage:
Quartz	90
Rock fragments	5
Chert	3
Feldspar	2
Mica	Trace



CLASSIFICATION (Folk, 1974): Sublitharenite

MACROSCOPIC FIELD CHARACTERISTICS:

Weathering Characteristics --

Bedding/Internal Structures Laminated

Fractures/Slickensides --

FOSSILS: None

COMMENTS: Clay occurs as coats on sand grains and as matrix; patchy iron oxide cement; some laminae are more clay rich and others are more porous; intergranular and fracture porosity; few well rounded quartz grains

CORE SAMPLE DESCRIPTION

Sample Number	4587BH (23.8ft)
Thin Section	4587BH (23.8ft)
Location Collected	881 Hillside - Rocky Flats Plant SESW 11 T2S R70W
Formation Name	Laramie

ROCK TYPE WITH MODIFIERS: Clayey sandstone

COLOR (GSA Rock Color Chart): --

TEXTURE:

Grain Size: Range Very fine - fine sand Mode Fine

Sorting Well

Roundness Subangular

Textural Maturity Immature

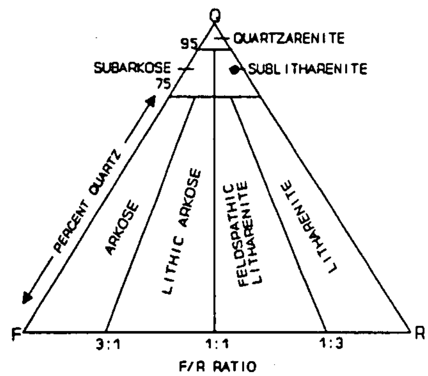
Porosity 20%

Cement/Matrix No cement/Trace silt, 13% clay

Friability --

COMPOSITION:

Mineral:	Percentage:
Quartz	85
Chert	8
Biotite	3
Rock fragments	2
Feldspar	2



CLASSIFICATION (Folk, 1974): Sublitharenite

MACROSCOPIC FIELD CHARACTERISTICS:

Weathering Characteristics --

Bedding/Internal Structures Massive

Fractures/Slickensides --

FOSSILS: None

COMMENTS: Most of biotite is highly weathered and altered to chlorite; sandstone is very dirty; porosity distribution is variable due to the occurrance of clay; some lithic fragments are replaced by clay; some quartz sand grains have clay coats

CORE SAMPLE DESCRIPTION

Sample Number 5289BR (33.5ft) (B217089)
Thin Section 5289BR (33.5ft)
Location Collected South Walnut Creek - Rocky Flats Plant NWNE 11 T2S R70W
Formation Name Arapahoe

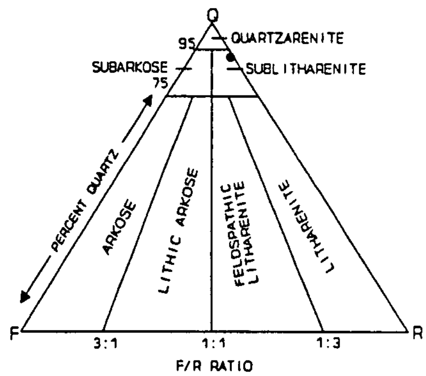
ROCK TYPE WITH MODIFIERS: Pebbly sandstone

COLOR (GSA Rock Color Chart): Yellowish gray (5Y 7/2) weathers dark yellowish orange (10YR 6/6)

TEXTURE:
Grain Size: Range Fine sand - med. pebble Mode Medium sand
Sorting Poor
Roundness Subangular to well rounded
Textural Maturity Submature
Porosity 25%
Cement/Matrix No cement/5% silt, 3% clay
Friability Moderately friable

COMPOSITION:

Mineral:	Percentage:
Quartz	92
Rock fragments	8



CLASSIFICATION (Folk, 1974): Sublitharenite

MACROSCOPIC FIELD CHARACTERISTICS:

Weathering Characteristics

Bedding/Internal Structures

Fractures/Slickensides

FOSSILS:

COMMENTS: Claystone rip-up clasts; well rounded quartz grains are frosted; some grains in thin section have been plucked.

CORE SAMPLE DESCRIPTION

Sample Number 5689BR (43ft) (B217489)
Thin Section 5689BR (43ft)
Location Collected East Inner Gate - Rocky Flats Plant NWSE 11 T2S R70W
Formation Name Arapahoe

ROCK TYPE WITH MODIFIERS: Sandstone

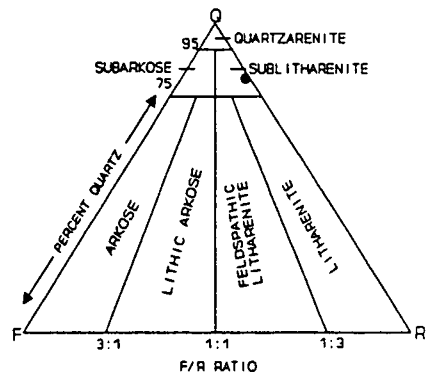
COLOR (GSA Rock Color Chart): Grayish orange (10YR 7/4)

TEXTURE:

Grain Size: Range Fine sand - fine pebble Mode Medium sand
Sorting Moderate to poor
Roundness Subangular to well rounded
Textural Maturity Submature
Porosity 30%
Cement/Matrix No cement/2% silt, 1% clay
Friability Highly friable

COMPOSITION:

Mineral:	Percentage:
Quartz	82
Chert	10
Rock fragments	7
Feldspar	1



CLASSIFICATION (Folk, 1974): Sublitharenite

MACROSCOPIC FIELD CHARACTERISTICS:

Weathering Characteristics

Bedding/Internal Structures

Fractures/Slickensides

FOSSILS:

COMMENTS: Well rounded quartz grains are frosted; claystone rip-up clasts; friability of sample has caused thin section to appear as if rock is not grain supported - grains are floating in blue epoxy in pore spaces.

TABLE A-5. Drill Cores Examined for Rocky Flats Geologic Mapping Project

Old Number	New Number	Surface Elevation	Interval Examined	RFP Sandstone # (EG&G, 1991d)	Base of Arapahoe Depth	Base of Arapahoe Elevation
0386	0386	5670.8	0'-28'	3	16'	5955'
0986	0986	5996.4	0'-30'			
2186	2186	5991.1	0'-30'			
2386	2386	5964.2	0'-22'			
3286	3286	5964.5	0'-13', 90'-100'	3		
3486	3486	5910.4	0'-40'			
5286	5286	6142.2	78'-136'	3		
6286	6286	5897.5	0'-59.3'	3	54'	5844'
BH0987	BH0987	5966.0	0'-37.5'	1	31.5'	5935'
1087BR	1087BR	5982.0	0'-53'	1	25'	5957'
1287BR	1287BR	5934.7	0'-16'			
1487BR	1487BR	5855	8'-25.5'	3	24'	5831'
1687BR	1687BR	5969.2	0'-40', 130'-140'	3		
1887BR	1887BR	5967.4	100'-128'	3		
2387BR	2387BR	5972.3	0'-40'	1	29'	5943'
2587BR	2587BR	5858.9	0'-47'	1	42'	5817'
2887BR	2887BR	5947.2	0'-68'			
3187BR	3187BR	5945.0	0'-142'	3	128'	5817'
3687BR	3687BR	5949.0	18'-58'	1	45'	5904'
4187BR	4187BR	5882.8	82'-89'	3		
BH4587	4587BH	5952.7	0'-25'	1		
2789BR	B203189	5986	0'-32'			
2889BR	B203289	5956.7	0'-40'			
3089BR	B203589	5935.2	0'-32'			
3489BR	B203989	5921	0'-45'			
3689BR	B204189	5826.9	0'-60'			
3789BR	B304289	5901.4	0'-45.5'			
3889BR	B204689	5901.4	0'-10'			
3989BR	B304789	5867.5	0'-30.4'			
4089BR	B304889	5730.6	0'-29'			
4389BR	B405289	5965.7	0'-33'			
4489BR	B305389	5831.9	0'-28.7'			
LF0289BR	B206189	5984.5	0'-35'			
LF0389BR	B206289	5977.6	38'-48'			
LF0689BR	B206589	5967.8	10'-35'			
LF0989BR	B206789	5927.9	0'-20'			
LF1189BR	B206989	5882.4	0'-20'			
LF1289BR	B207089	5883.1	0'-40'			
LF1389BR	B207189	5884.8	0'-30',91'-105.5'	3		

Table A-5. Drill Cores Examined (Cont.)

Old Number	New Number	Surface Elevation	Interval Examined	RFP Sandstone # (EG&G, 1991d)	Base of Arapahoe Depth	Base of Arapahoe Elevation
LF1489BR	B207289	5948.3	0'-25'			
SEP0789BR	B207989	5963.1	0'-26.2'			
SEP0889	B208089	5935.4	0'-22'			
SEP1089BR	B208289	5850.7	0'-20'			
SEP1289BR	B208489	5876.3	0'-30'			
SEP1689BR	P208889	5947.3	10'-30'			
SEP1789BR	P208989	5962.5	0'-23'			
SEP1889BR	P209089	5972.2	0'-22'			
SEP1989BR	P209189	5980.7	0'-36'	1	26.3'	5954'
SEP2189	P209389	5981.5	0'-35'	1	28.2'	5953'
SEP2289	P209489	5978.0	0'-41'	1	40.5'	5937'
SEP2689BR	P209889	5940.3	0'-24'			
SEP3089BR	P210189	5980.8	0'-38.6'	1	35.6'	5945'
SEP3289BR	B210389	5873.2	0'-19'			
PZ1489	P213889	5954.1	0'-31'			
PZ1489A	P213989	5954.3	0'-10'			
PZ3789	P114589	5832.2?	0'-41.5'			
5989BR	B315289	5963.2	0'-54'	1	40'	5923'
PZ5789	P416289	6038.6	0'-40'	1	38'	6001'
5289BR	B217089	5910	0'-40'		33'	5877'
5389BR	B317189	5730	60'-74', 200'-216'			
5489BR	B217289	5678	0'-27'	1	23'	5655'
5689BR	B217489	5961	0'-60'		54'	5907'
5889BR	B217689	5961	20'-55'		45'	5916'

NOTICE

This document (or documents) is oversized for 16mm microfilming, but is available in its entirety on the 35mm fiche card referenced below:

Document # 000307

Titled: Sample Location Map Plate A1

Fiche location: A-SW-M21

APPENDIX B

Station Locations

NOTICE

This document (or documents) is oversized for 16mm microfilming, but is available in its entirety on the 35mm fiche card referenced below:

Document # 000307

Titled: Station Location Map Plate B1

Fiche location: A-SW-M21

NOTICE

This document (or documents) is oversized for 16mm microfilming, but is available in its entirety on the 35mm fiche card referenced below:

Document # 000307

Titled: STATION Location Map Plate BII

Fiche location: A-SW-M21

APPENDIX C

Grain Size Analyses

Table C-1. List of Grain Size Samples by Formation

Sample Number	Formation	Topographic Quadrangle	Location Township and Range	General Location
KT6-N	Fox Hills	Louisville	SENE 21 T1S R70W	Pine Ridge
KT22-W	Fox Hills	Golden	NESW 21 T2S R70W	D&RGW RR
KT24-W	Fox Hills	Golden	NESW 21 T2S R70W	D&RGW RR
MV4-W	Fox Hills	Louisville	NESW 4 T2S R70W	RFP Claypit
MV38-N	Fox Hills	Louisville	SENE 28 T1S R70W	Eggleston Reservoir
KT32-W	lower Laramie	Golden	NESW 21 T2S R70W	D&RGW RR
KT33-W	lower Laramie	Golden	NESW 21 T2S R70W	D&RGW RR
KT35a-W	lower Laramie	Golden	NESW 21 T2S R70W	D&RGW RR
KT35b-W	lower Laramie	Golden	NESW 21 T2S R70W	D&RGW RR
KT33-N	upper Laramie	Louisville	SWNE 29 T1S R69W	Superior/Broomfield
KT60-N	upper Laramie	Louisville	SWSW 31 T1S R69W	McCaslin Boulevard
KT61-N	upper Laramie	Louisville	SWSW 31 T1S R69W	McCaslin Boulevard
MV9-E	upper Laramie	Louisville	SWSW 31 T1S R69W	McCaslin Boulevard
MV10-E	upper Laramie	Louisville	SWSW 31 T1S R69W	McCaslin Boulevard
MV11-E	upper Laramie	Louisville	SWSW 31 T1S R69W	McCaslin Boulevard
KT2-S	Arapahoe	Golden	SWSW 14 T2S R70W	Barbara Gulch
KT15-E	Arapahoe	Louisville	SWNE 11 T2S R70W	RFP-PA
MV69-N	Arapahoe	Louisville	NESW 1 T2S R70W	RFP-Buffer
MV3-E	Arapahoe	Golden	NENE 29 T2S R69W	Standley Lake
MV28-E	Arapahoe	Golden	NWSW 19 T2S R69W	Indiana Street

MECHANICAL ANALYSIS - SIEVE TEST DATA

CLIENT ASI

JOB NO. 2081-03

BORING NO.	KT6-N	SAMPLED	--
DEPTH	--	DATE TESTED	10-28-91 TNU
SAMPLE NO.	Fox Hills	WASH SIEVE	Yes
SOIL DESCR.	Pine Ridge Marshall	DRY SIEVE	No

MOISTURE DATA

HYGROSCOPIC	Yes
NATURAL	No
Wt. Wet Soil & Pan (g)	65.25
Wt. Dry Soil & Pan (g)	65.07
Wt. Lost Moisture (g)	0.18
Wt. of Pan Only (g)	3.67
Wt. of Dry Soil (g)	61.40
Moisture Content %	0.3
Wt. Hydrom. Sample Wet (g)	80.02
Wt. Hydrom. Sample Dry (g)	79.79

WASH SIEVE ANALYSIS

Wt. Total Sample Wet (g)	80.02
Weight of + #10 Before Washing (g)	0.00
Weight of + #10 After Washing (g)	0.00
Weight of - #10 Wet (g)	80.02
Weight of - #10 Dry (g)	79.79
Wt. Total Sample Dry (g)	79.79
Calc. Wt. "W" (g)	79.79
Calc. Mass + #10	0.00

Sieve Number (Size)	Pan Weight (g)	Indiv. Wt. + Pan (g)	Indiv. Wt. Retain.	Cum. Wt. Retain.	Cum. % Retain.	% Finer By Wt.
1 1/2"	0.00	0.00	0.00	0.00	0.0	100.0
3/4"	0.00	0.00	0.00	0.00	0.0	100.0
3/8"	0.00	0.00	0.00	0.00	0.0	100.0
#4	0.00	0.00	0.00	0.00	0.0	100.0
#10	0.00	0.00	0.00	0.00	0.0	100.0
#20	1.31	1.35	0.04	0.04	0.1	99.9
#40	1.33	1.40	0.07	0.11	0.1	99.9
#60	1.31	12.89	11.58	11.69	14.7	85.3
#100	1.32	38.77	37.45	49.14	61.6	38.4
#200	1.32	15.72	14.40	63.54	79.6	20.4

ADVANCED TERRA TESTING, INC.

MECHANICAL ANALYSIS - SIEVE TEST DATA

CLIENT	ASI	JOB NO.	2081-03
BORING NO.	KT22-W	SAMPLED	--
DEPTH	--	DATE TESTED	10-29-91 SR
SAMPLE NO.	Fox Hills	WASH SIEVE	Yes
SOIL DESCR.	RR Section	DRY SIEVE	No

MOISTURE DATA

HYGROSCOPIC	Yes
NATURAL	No
Wt. Wet Soil & Pan (g)	56.37
Wt. Dry Soil & Pan (g)	56.13
Wt. Lost Moisture (g)	0.24
Wt. of Pan Only (g)	3.74
Wt. of Dry Soil (g)	52.39
Moisture Content %	0.5
Wt. Hydrom. Sample Wet (g)	80.01
Wt. Hydrom. Sample Dry (g)	79.65

WASH SIEVE ANALYSIS

Wt. Total Sample Wet (g)	80.01
Weight of + #10 Before Washing (g)	0.00
Weight of + #10 After Washing (g)	0.00
Weight of - #10 Wet (g)	80.01
Weight of - #10 Dry (g)	79.65
Wt. Total Sample Dry (g)	79.65
Calc. Wt. "W" (g)	79.65
Calc. Mass + #10	0.00

Sieve Number (Size)	Pan Weight (g)	Indiv. Wt. + Pan (g)	Indiv. Wt. Retain.	Cum. Wt. Retain.	Cum. % Retain.	% Finer By Wt.
1 1/2"	0.00	0.00	0.00	0.00	0.0	100.0
3/4"	0.00	0.00	0.00	0.00	0.0	100.0
3/8"	0.00	0.00	0.00	0.00	0.0	100.0
#4	0.00	0.00	0.00	0.00	0.0	100.0
#10	0.00	0.00	0.00	0.00	0.0	100.0
#20	3.68	3.75	0.07	0.07	0.1	99.9
#40	3.81	5.44	1.63	1.70	2.1	97.9
#60	3.78	10.87	7.09	8.79	11.0	89.0
#100	3.68	34.71	31.03	39.82	50.0	50.0
#200	3.68	21.16	17.48	57.30	71.9	28.1

MECHANICAL ANALYSIS - SIEVE TEST DATA

CLIENT ASI

JOB NO. 2081-03

BORING NO.	KT24-W	SAMPLED	--
DEPTH	--	DATE TESTED	10-28-91 TNU
SAMPLE NO.	Fox Hills	WASH SIEVE	Yes
SOIL DESCR.	RR Section	DRY SIEVE	No

MOISTURE DATA

HYGROSCOPIC Yes

NATURAL No

Wt. Wet Soil & Pan (g)	61.36
Wt. Dry Soil & Pan (g)	61.08
Wt. Lost Moisture (g)	0.28
Wt. of Pan Only (g)	3.78
Wt. of Dry Soil (g)	57.30
Moisture Content %	0.5
Wt. Hydrom. Sample Wet (g)	75.02
Wt. Hydrom. Sample Dry (g)	74.66

WASH SIEVE ANALYSIS

Wt. Total Sample Wet (g)	75.02
Weight of + #10 Before Washing (g)	0.00
Weight of + #10 After Washing (g)	0.00
Weight of - #10 Wet (g)	75.02
Weight of - #10 Dry (g)	74.66
Wt. Total Sample Dry (g)	74.66
Calc. Wt. "W" (g)	74.66
Calc. Mass + #10	0.00

Sieve Number (Size)	Pan Weight (g)	Indiv. Wt. + Pan (g)	Indiv. Wt. Retain.	Cum. Wt. Retain.	Cum. % Retain.	% Finer By Wt.
1 1/2"	0.00	0.00	0.00	0.00	0.0	100.0
3/4"	0.00	0.00	0.00	0.00	0.0	100.0
3/8"	0.00	0.00	0.00	0.00	0.0	100.0
#4	0.00	0.00	0.00	0.00	0.0	100.0
#10	0.00	0.00	0.00	0.00	0.0	100.0
#20	1.30	1.33	0.03	0.03	0.0	100.0
#40	1.32	4.23	2.91	2.94	3.9	96.1
#60	1.33	4.13	2.80	5.74	7.7	92.3
#100	1.33	9.75	8.42	14.16	19.0	81.0
#200	1.52	35.73	34.21	48.37	64.8	35.2

MECHANICAL ANALYSIS - SIEVE TEST DATA

CLIENT	ASI	JOB NO.	2081-03
BORING NO.	MV4-W	SAMPLED	--
DEPTH	--	DATE TESTED	10-30-91 SR
SAMPLE NO.	Fox Hills	WASH SIEVE	Yes
SOIL DESCR.	RFP - Clay Pit	DRY SIEVE	No

MOISTURE DATA

HYGROSCOPIC	Yes
NATURAL	No
Wt. Wet Soil & Pan (g)	64.32
Wt. Dry Soil & Pan (g)	64.26
Wt. Lost Moisture (g)	0.06
Wt. of Pan Only (g)	3.69
Wt. of Dry Soil (g)	60.57
Moisture Content %	0.1
Wt. Hydrom. Sample Wet (g)	75.00
Wt. Hydrom. Sample Dry (g)	74.93

WASH SIEVE ANALYSIS

Wt. Total Sample Wet (g)	75.00
Weight of + #10 Before Washing (g)	0.00
Weight of + #10 After Washing (g)	0.00
Weight of - #10 Wet (g)	75.00
Weight of - #10 Dry (g)	74.93
Wt. Total Sample Dry (g)	74.93
Calc. Wt. "W" (g)	74.93
Calc. Mass + #10	0.00

Sieve Number (Size)	Pan Weight (g)	Indiv. Wt. + Pan (g)	Indiv. Wt. Retain.	Cum. Wt. Retain.	Cum. % Retain.	% Finer By Wt.
1 1/2"	0.00	0.00	0.00	0.00	0.0	100.0
3/4"	0.00	0.00	0.00	0.00	0.0	100.0
3/8"	0.00	0.00	0.00	0.00	0.0	100.0
#4	0.00	0.00	0.00	0.00	0.0	100.0
#10	0.00	0.00	0.00	0.00	0.0	100.0
#20	3.80	5.20	1.40	1.40	1.9	98.1
#40	3.65	6.44	2.79	4.19	5.6	94.4
#60	3.83	18.53	14.70	18.89	25.2	74.8
#100	3.59	28.63	25.04	43.93	58.6	41.4
#200	3.76	13.01	9.25	53.18	71.0	29.0

MECHANICAL ANALYSIS - SIEVE TEST DATA

CLIENT ASI

JOB NO. 2081-03

BORING NO.	MV38-N	SAMPLED	--
DEPTH	--	DATE TESTED	10-31-91 SR
SAMPLE NO.	Fox Hills	WASH SIEVE	Yes
SOIL DESCR.	Eggleston Reservoir	DRY SIEVE	No

MOISTURE DATA

HYGROSCOPIC Yes

NATURAL No

Wt. Wet Soil & Pan	(g)	49.69
Wt. Dry Soil & Pan	(g)	49.57
Wt. Lost Moisture	(g)	0.12
Wt. of Pan Only	(g)	3.69
Wt. of Dry Soil	(g)	45.88
Moisture Content	%	0.3
Wt. Hydrom. Sample Wet	(g)	80.00
Wt. Hydrom. Sample Dry	(g)	79.79

WASH SIEVE ANALYSIS

Wt. Total Sample Wet (g)	80.01
Weight of + #10 Before Washing (g)	0.00
Weight of + #10 After Washing (g)	0.00
Weight of - #10 Wet (g)	80.01
Weight of - #10 Dry (g)	79.80
Wt. Total Sample Dry (g)	79.80
Calc. Wt. "W" (g)	79.79
Calc. Mass + #10	0.00

Sieve Number (Size)	Pan Weight (g)	Indiv. Wt. + Pan (g)	Indiv. Wt. Retain.	Cum. Wt. Retain.	Cum. % Retain.	% Finer By Wt.
1 1/2"	0.00	0.00	0.00	0.00	0.0	100.0
3/4"	0.00	0.00	0.00	0.00	0.0	100.0
3/8"	0.00	0.00	0.00	0.00	0.0	100.0
#4	0.00	0.00	0.00	0.00	0.0	100.0
#10	0.00	0.00	0.00	0.00	0.0	100.0
#20	3.70	3.74	0.04	0.04	0.1	99.9
#40	3.60	3.63	0.03	0.07	0.1	99.9
#60	3.83	5.52	1.69	1.76	2.2	97.8
#100	3.65	34.52	30.87	32.63	40.9	59.1
#200	3.80	33.13	29.33	61.96	77.7	22.3

ADVANCED TERRA TESTING, INC.

MECHANICAL ANALYSIS - SIEVE TEST DATA

CLIENT	ASI	JOB NO.	2081-03
BORING NO.	KT33-N	SAMPLED	--
DEPTH	--	DATE TESTED	10-30-91 SR
SAMPLE NO.	U. Laramie	WASH SIEVE	Yes
SOIL DESCR.	Superior/Broomfield	DRY SIEVE	No

MOISTURE DATA

HYGROSCOPIC	Yes
NATURAL	No
Wt. Wet Soil & Pan (g)	67.96
Wt. Dry Soil & Pan (g)	67.81
Wt. Lost Moisture (g)	0.15
Wt. of Pan Only (g)	3.74
Wt. of Dry Soil (g)	64.07
Moisture Content %	0.2
Wt. Hydrom. Sample Wet (g)	75.00
Wt. Hydrom. Sample Dry (g)	74.83

WASH SIEVE ANALYSIS

Wt. Total Sample Wet (g)	75.00
Weight of + #10 Before Washing (g)	0.00
Weight of + #10 After Washing (g)	0.00
Weight of - #10 Wet (g)	75.00
Weight of - #10 Dry (g)	74.83
Wt. Total Sample Dry (g)	74.83
Calc. Wt. "W" (g)	74.83
Calc. Mass + #10	0.00

Sieve Number (Size)	Pan Weight (g)	Indiv. Wt. + Pan (g)	Indiv. Wt. Retain.	Cum. Wt. Retain.	Cum. % Retain.	% Finer By Wt.
1 1/2"	0.00	0.00	0.00	0.00	0.0	100.0
3/4"	0.00	0.00	0.00	0.00	0.0	100.0
3/8"	0.00	0.00	0.00	0.00	0.0	100.0
#4	0.00	0.00	0.00	0.00	0.0	100.0
#10	0.00	0.00	0.00	0.00	0.0	100.0
#20	3.69	3.74	0.05	0.05	0.1	99.9
#40	3.77	3.82	0.05	0.10	0.1	99.9
#60	3.72	3.86	0.14	0.24	0.3	99.7
#100	3.64	4.83	1.19	1.43	1.9	98.1
#200	3.70	37.93	34.23	35.66	47.7	52.3

ADVANCED TERRA TESTING, INC.

MECHANICAL ANALYSIS - SIEVE TEST DATA

CLIENT ASI

JOB NO. 2081-03

BORING NO.	KT60-N	SAMPLED	--
DEPTH	--	DATE TESTED	10-30-91 SR
SAMPLE NO.	U. Laramie	WASH SIEVE	Yes
SOIL DESCR.	McCaslin Blvd.	DRY SIEVE	No

MOISTURE DATA

HYGROSCOPIC Yes

NATURAL No

Wt. Wet Soil & Pan (g)	62.06
Wt. Dry Soil & Pan (g)	61.99
Wt. Lost Moisture (g)	0.07
Wt. of Pan Only (g)	3.59
Wt. of Dry Soil (g)	58.40
Moisture Content %	0.1
Wt. Hydrom. Sample Wet (g)	80.01
Wt. Hydrom. Sample Dry (g)	79.92

WASH SIEVE ANALYSIS

Wt. Total Sample Wet (g)	80.01
Weight of + #10 Before Washing (g)	0.00
Weight of + #10 After Washing (g)	0.00
Weight of - #10 Wet (g)	80.01
Weight of - #10 Dry (g)	79.92
Wt. Total Sample Dry (g)	79.92
Calc. Wt. "W" (g)	79.92
Calc. Mass + #10	0.00

Sieve Number (Size)	Pan Weight (g)	Indiv. Wt. + Pan (g)	Indiv. Wt. Retain.	Cum. Wt. Retain.	Cum. % Retain.	% Finer By Wt.
1 1/2"	0.00	0.00	0.00	0.00	0.0	100.0
3/4"	0.00	0.00	0.00	0.00	0.0	100.0
3/8"	0.00	0.00	0.00	0.00	0.0	100.0
#4	0.00	0.00	0.00	0.00	0.0	100.0
#10	0.00	0.00	0.00	0.00	0.0	100.0
#20	3.71	4.13	0.42	0.42	0.5	99.5
#40	3.69	5.65	1.96	2.38	3.0	97.0
#60	3.69	38.72	35.03	37.41	46.8	53.2
#100	3.67	30.07	26.40	63.81	79.8	20.2
#200	3.67	9.69	6.02	69.83	87.4	12.6

MECHANICAL ANALYSIS - SIEVE TEST DATA

CLIENT	ASI		JOB NO.	2081-03
BORING NO.	KT61-N		SAMPLED	--
DEPTH	--		DATE TESTED	10-31-91 SR
SAMPLE NO.	U. Laramie		WASH SIEVE	Yes
SOIL DESCR.	McCaslin Blvd.		DRY SIEVE	No

MOISTURE DATA

HYGROSCOPIC	Yes
NATURAL	No
Wt. Wet Soil & Pan (g)	65.17
Wt. Dry Soil & Pan (g)	65.10
Wt. Lost Moisture (g)	0.07
Wt. of Pan Only (g)	3.74
Wt. of Dry Soil (g)	61.36
Moisture Content %	0.1
Wt. Hydrom. Sample Wet (g)	80.00
Wt. Hydrom. Sample Dry (g)	79.91

WASH SIEVE ANALYSIS

Wt. Total Sample Wet (g)	80.00
Weight of + #10 Before Washing (g)	0.00
Weight of + #10 After Washing (g)	0.00
Weight of - #10 Wet (g)	80.00
Weight of - #10 Dry (g)	79.91
Wt. Total Sample Dry (g)	79.91
Calc. Wt. "W" (g)	79.91
Calc. Mass + #10	0.00

Sieve Number (Size)	Pan Weight (g)	Indiv. Wt. + Pan (g)	Indiv. Wt. Retain.	Cum. Wt. Retain.	Cum. % Retain.	% Finer By Wt.
1 1/2"	0.00	0.00	0.00	0.00	0.0	100.0
3/4"	0.00	0.00	0.00	0.00	0.0	100.0
3/8"	0.00	0.00	0.00	0.00	0.0	100.0
#4	0.00	0.00	0.00	0.00	0.0	100.0
#10	0.00	0.00	0.00	0.00	0.0	100.0
#20	3.73	24.91	21.18	21.18	26.5	73.5
#40	3.69	12.58	8.89	30.07	37.6	62.4
#60	3.68	10.54	6.86	36.93	46.2	53.8
#100	3.60	17.35	13.75	50.68	63.4	36.6
#200	3.67	14.72	11.05	61.73	77.3	22.7

MECHANICAL ANALYSIS - SIEVE TEST DATA

CLIENT ASI

JOB NO. 2081-03

BORING NO.	MV9-E	SAMPLED	--
DEPTH	--	DATE TESTED	10-30-91 SR
SAMPLE NO.	U. Laramie	WASH SIEVE	Yes
SOIL DESCR.	McCaslin Blvd.	DRY SIEVE	No

MOISTURE DATA

HYGROSCOPIC	Yes
NATURAL	No
Wt. Wet Soil & Pan (g)	50.29
Wt. Dry Soil & Pan (g)	49.82
Wt. Lost Moisture (g)	0.47
Wt. of Pan Only (g)	3.72
Wt. of Dry Soil (g)	46.10
Moisture Content %	1.0
Wt. Hydrom. Sample Wet (g)	47.17
Wt. Hydrom. Sample Dry (g)	46.70

WASH SIEVE ANALYSIS

Wt. Total Sample Wet (g)	47.17
Weight of + #10 Before Washing (g)	0.00
Weight of + #10 After Washing (g)	0.00
Weight of - #10 Wet (g)	47.17
Weight of - #10 Dry (g)	46.70
Wt. Total Sample Dry (g)	46.70
Calc. Wt. "W" (g)	46.70
Calc. Mass + #10	0.00

Sieve Number (Size)	Pan Weight (g)	Indiv. Wt. + Pan (g)	Indiv. Wt. Retain.	Cum. Wt. Retain.	Cum. % Retain.	% Finer By Wt.
1 1/2"	0.00	0.00	0.00	0.00	0.0	100.0
3/4"	0.00	0.00	0.00	0.00	0.0	100.0
3/8"	0.00	0.00	0.00	0.00	0.0	100.0
#4	0.00	0.00	0.00	0.00	0.0	100.0
#10	0.00	0.00	0.00	0.00	0.0	100.0
#20	3.63	3.65	0.02	0.02	0.0	100.0
#40	3.75	3.79	0.04	0.06	0.1	99.9
#60	3.73	3.83	0.10	0.16	0.3	99.7
#100	3.66	3.73	0.07	0.23	0.5	99.5
#200	3.65	3.72	0.07	0.30	0.6	99.4

MECHANICAL ANALYSIS - SIEVE TEST DATA

CLIENT ASI

JOB NO. 2081-03

BORING NO.	MV10-E	SAMPLED	--
DEPTH	--	DATE TESTED	10-30-91 SR
SAMPLE NO.	U. Laramie	WASH SIEVE	Yes
SOIL DESCR.	McCaslin Blvd.	DRY SIEVE	No

MOISTURE DATA

HYGROSCOPIC Yes

NATURAL No

Wt. Wet Soil & Pan	(g)	55.25
Wt. Dry Soil & Pan	(g)	55.19
Wt. Lost Moisture	(g)	0.06
Wt. of Pan Only	(g)	3.68
Wt. of Dry Soil	(g)	51.51
Moisture Content	%	0.1
Wt. Hydrom. Sample Wet	(g)	80.01
Wt. Hydrom. Sample Dry	(g)	79.91

WASH SIEVE ANALYSIS

Wt. Total Sample Wet (g)	80.01
Weight of + #10 Before Washing (g)	0.00
Weight of + #10 After Washing (g)	0.00
Weight of - #10 Wet (g)	80.01
Weight of - #10 Dry (g)	79.91
Wt. Total Sample Dry (g)	79.91
Calc. Wt. "W" (g)	79.91
Calc. Mass + #10	0.00

Sieve Number (Size)	Pan Weight (g)	Indiv. Wt. + Pan (g)	Indiv. Wt. Retain.	Cum. Wt. Retain.	Cum. % Retain.	% Finer By Wt.
1 1/2"	0.00	0.00	0.00	0.00	0.0	100.0
3/4"	0.00	0.00	0.00	0.00	0.0	100.0
3/8"	0.00	0.00	0.00	0.00	0.0	100.0
#4	0.00	0.00	0.00	0.00	0.0	100.0
#10	0.00	0.00	0.00	0.00	0.0	100.0
#20	0.00	0.22	0.22	0.22	0.3	99.7
#40	0.00	1.37	1.37	1.59	2.0	98.0
#60	0.00	46.45	46.45	48.04	60.1	39.9
#100	0.00	17.62	17.62	65.66	82.2	17.8
#200	0.00	4.39	4.39	70.05	87.7	12.3

ADVANCED TERRA TESTING, INC.

MECHANICAL ANALYSIS - SIEVE TEST DATA

CLIENT ASI

JOB NO. 2081-03

BORING NO.	MV11-E	SAMPLED	--
DEPTH	--	DATE TESTED	10-31-91 SR
SAMPLE NO.	U. Laramie	WASH SIEVE	Yes
SOIL DESCR.	McCaslin Blvd.	DRY SIEVE	No

MOISTURE DATA

HYGROSCOPIC	Yes
NATURAL	No
Wt. Wet Soil & Pan (g)	56.11
Wt. Dry Soil & Pan (g)	56.05
Wt. Lost Moisture (g)	0.06
Wt. of Pan Only (g)	3.78
Wt. of Dry Soil (g)	52.27
Moisture Content %	0.1
Wt. Hydrom. Sample Wet (g)	60.02
Wt. Hydrom. Sample Dry (g)	59.95

WASH SIEVE ANALYSIS

Wt. Total Sample Wet (g)	60.02
Weight of + #10 Before Washing (g)	0.00
Weight of + #10 After Washing (g)	0.00
Weight of - #10 Wet (g)	60.02
Weight of - #10 Dry (g)	59.95
Wt. Total Sample Dry (g)	59.95
Calc. Wt. "W" (g)	59.95
Calc. Mass + #10	0.00

Sieve Number (Size)	Pan Weight (g)	Indiv. Wt. + Pan (g)	Indiv. Wt. Retain.	Cum. Wt. Retain.	Cum. % Retain.	% Finer By Wt.
1 1/2"	0.00	0.00	0.00	0.00	0.0	100.0
3/4"	0.00	0.00	0.00	0.00	0.0	100.0
3/8"	0.00	0.00	0.00	0.00	0.0	100.0
#4	0.00	0.00	0.00	0.00	0.0	100.0
#10	0.00	0.00	0.00	0.00	0.0	100.0
#20	3.68	3.70	0.02	0.02	0.0	100.0
#40	3.68	3.72	0.04	0.06	0.1	99.9
#60	3.84	4.00	0.16	0.22	0.4	99.6
#100	3.77	4.65	0.88	1.10	1.8	98.2
#200	3.59	36.45	32.86	33.96	56.6	43.4

MECHANICAL ANALYSIS - SIEVE TEST DATA

CLIENT ASI

JOB NO. 2081-03

BORING NO.	KT32-W	SAMPLED	--
DEPTH	--	DATE TESTED	10-28-91 TNU
SAMPLE NO.	L. Laramie	WASH SIEVE	Yes
SOIL DESCR.	RR Section	DRY SIEVE	No

MOISTURE DATA

HYGROSCOPIC	Yes
NATURAL	No
Wt. Wet Soil & Pan (g)	68.63
Wt. Dry Soil & Pan (g)	68.58
Wt. Lost Moisture (g)	0.05
Wt. of Pan Only (g)	3.72
Wt. of Dry Soil (g)	64.86
Moisture Content %	0.1
Wt. Hydrom. Sample Wet (g)	75.01
Wt. Hydrom. Sample Dry (g)	74.95

WASH SIEVE ANALYSIS

Wt. Total Sample Wet (g)	75.01
Weight of + #10 Before Washing (g)	0.00
Weight of + #10 After Washing (g)	0.00
Weight of - #10 Wet (g)	75.01
Weight of - #10 Dry (g)	74.95
Wt. Total Sample Dry (g)	74.95
Calc. Wt. "W" (g)	74.95
Calc. Mass + #10	0.00

Sieve Number (Size)	Pan Weight (g)	Indiv. Wt. + Pan (g)	Indiv. Wt. Retain.	Cum. Wt. Retain.	Cum. % Retain.	% Finer By Wt.
1 1/2"	0.00	0.00	0.00	0.00	0.0	100.0
3/4"	0.00	0.00	0.00	0.00	0.0	100.0
3/8"	0.00	0.00	0.00	0.00	0.0	100.0
#4	0.00	0.00	0.00	0.00	0.0	100.0
#10	0.00	0.00	0.00	0.00	0.0	100.0
#20	3.61	19.11	15.50	15.50	20.7	79.3
#40	3.72	11.11	7.39	22.89	30.5	69.5
#60	3.97	11.36	7.39	30.28	40.4	59.6
#100	3.71	21.85	18.14	48.42	64.6	35.4
#200	3.68	17.71	14.03	62.45	83.3	16.7

ADVANCED TERRA TESTING, INC.

MECHANICAL ANALYSIS - SIEVE TEST DATA

CLIENT ASI

JOB NO. 2081-03

BORING NO.	KT33-W	SAMPLED	--
DEPTH	--	DATE TESTED	10-29-91 SR
SAMPLE NO.	L. Laramie	WASH SIEVE	Yes
SOIL DESCR.	RR Section	DRY SIEVE	No

MOISTURE DATA

HYGROSCOPIC	Yes
NATURAL	No
Wt. Wet Soil & Pan (g)	58.12
Wt. Dry Soil & Pan (g)	55.06
Wt. Lost Moisture (g)	3.06
Wt. of Pan Only (g)	3.06
Wt. of Dry Soil (g)	52.00
Moisture Content %	5.9
Wt. Hydrom. Sample Wet (g)	75.01
Wt. Hydrom. Sample Dry (g)	70.84

WASH SIEVE ANALYSIS

Wt. Total Sample Wet (g)	75.01
Weight of + #10 Before Washing (g)	0.00
Weight of + #10 After Washing (g)	0.00
Weight of - #10 Wet (g)	75.01
Weight of - #10 Dry (g)	70.84
Wt. Total Sample Dry (g)	70.84
Calc. Wt. "W" (g)	70.84
Calc. Mass + #10	0.00

Sieve Number (Size)	Pan Weight (g)	Indiv. Wt. + Pan (g)	Indiv. Wt. Retain.	Cum. Wt. Retain.	Cum. % Retain.	% Finer By Wt.
1 1/2"	0.00	0.00	0.00	0.00	0.0	100.0
3/4"	0.00	0.00	0.00	0.00	0.0	100.0
3/8"	0.00	0.00	0.00	0.00	0.0	100.0
#4	0.00	0.00	0.00	0.00	0.0	100.0
#10	0.00	0.00	0.00	0.00	0.0	100.0
#20	3.76	14.50	10.74	10.74	15.2	84.8
#40	3.64	4.69	1.05	11.79	16.6	83.4
#60	3.79	5.88	2.09	13.88	19.6	80.4
#100	3.75	9.22	5.47	19.35	27.3	72.7
#200	3.75	22.15	18.40	37.75	53.3	46.7

ADVANCED TERRA TESTING, INC.

MECHANICAL ANALYSIS - SIEVE TEST DATA

CLIENT ASI

JOB NO. 2081-03

BORING NO.	KT35a-w	SAMPLED	--
DEPTH	--	DATE TESTED	10-29-91 SR
SAMPLE NO.	L Laramie	WASH SIEVE	Yes
SOIL DESCR.	RR Section	DRY SIEVE	No

MOISTURE DATA

HYGROSCOPIC	Yes
NATURAL	No
Wt. Wet Soil & Pan (g)	71.94
Wt. Dry Soil & Pan (g)	71.87
Wt. Lost Moisture (g)	0.07
Wt. of Pan Only (g)	3.67
Wt. of Dry Soil (g)	68.20
Moisture Content %	0.1
Wt. Hydrom. Sample Wet (g)	80.01
Wt. Hydrom. Sample Dry (g)	79.93

WASH SIEVE ANALYSIS

Wt. Total Sample Wet (g)	594.44
Weight of + #10 Before Washing (g)	10.85
Weight of + #10 After Washing (g)	10.02
Weight of - #10 Wet (g)	292.21
Weight of - #10 Dry (g)	292.74
Wt. Total Sample Dry (g)	302.76
Calc. Wt. "W" (g)	82.67
Calc. Mass + #10	2.74

Sieve Number (Size)	Pan Weight (g)	Indiv. Wt. + Pan (g)	Indiv. Wt. Retain.	Cum. Wt. Retain.	Cum. % Retain.	% Finer By Wt.
1 1/2"	0.00	0.00	0.00	0.00	0.0	100.0
3/4"	0.00	0.00	0.00	0.00	0.0	100.0
3/8"	0.00	0.00	0.00	0.00	0.0	100.0
#4	0.00	0.85	0.85	0.85	0.3	99.7
#10	0.00	9.17	9.17	10.02	3.3	96.7
#20	1.41	5.76	4.35	4.35	8.6	91.4
#40	1.31	18.41	17.10	21.45	29.3	70.7
#60	1.32	35.17	33.85	55.30	70.2	29.8
#100	1.31	11.34	10.03	65.33	82.3	17.7
#200	1.29	6.66	5.37	70.70	88.8	11.2

ADVANCED TERRA TESTING, INC.

MECHANICAL ANALYSIS - SIEVE TEST DATA

CLIENT	ASI	JOB NO.	2081-03
BORING NO.	KT35b-W	SAMPLED	--
DEPTH	--	DATE TESTED	10-31-91 SR
SAMPLE NO.	L. Laramie	WASH SIEVE	Yes
SOIL DESCR.	RR Section	DRY SIEVE	No

MOISTURE DATA

HYGROSCOPIC	Yes
NATURAL	No
Wt. Wet Soil & Pan (g)	69.34
Wt. Dry Soil & Pan (g)	69.27
Wt. Lost Moisture (g)	0.07
Wt. of Pan Only (g)	3.78
Wt. of Dry Soil (g)	65.49
Moisture Content %	0.1
Wt. Hydrom. Sample Wet (g)	60.00
Wt. Hydrom. Sample Dry (g)	59.94

WASH SIEVE ANALYSIS

Wt. Total Sample Wet (g)	60.00
Weight of + #10 Before Washing (g)	0.00
Weight of + #10 After Washing (g)	0.00
Weight of - #10 Wet (g)	60.00
Weight of - #10 Dry (g)	59.94
Wt. Total Sample Dry (g)	59.94
Calc. Wt. "W" (g)	59.94
Calc. Mass + #10	0.00

Sieve Number (Size)	Pan Weight (g)	Indiv. Wt. + Pan (g)	Indiv. Wt. Retain.	Cum. Wt. Retain.	Cum. % Retain.	% Finer By Wt.
1 1/2"	0.00	0.00	0.00	0.00	0.0	100.0
3/4"	0.00	0.00	0.00	0.00	0.0	100.0
3/8"	0.00	0.00	0.00	0.00	0.0	100.0
#4	0.00	0.00	0.00	0.00	0.0	100.0
#10	0.00	0.00	0.00	0.00	0.0	100.0
#20	3.67	5.80	2.13	2.13	3.6	96.4
#40	3.68	6.93	3.25	5.38	9.0	91.0
#60	3.73	6.88	3.15	8.53	14.2	85.8
#100	3.70	22.75	19.05	27.58	46.0	54.0
#200	3.65	22.46	18.81	46.39	77.4	22.6

MECHANICAL ANALYSIS - SIEVE TEST DATA

CLIENT ASI

JOB NO. 2081-03

BORING NO.	KT2-S	SAMPLED	--
DEPTH	--	DATE TESTED	10-30-91 SR
SAMPLE NO.	Arapahoe	WASH SIEVE	Yes
SOIL DESCR.	Barbara Gulch	DRY SIEVE	No

MOISTURE DATA

HYGROSCOPIC	Yes
NATURAL	No
Wt. Wet Soil & Pan (g)	55.70
Wt. Dry Soil & Pan (g)	55.64
Wt. Lost Moisture (g)	0.06
Wt. of Pan Only (g)	3.69
Wt. of Dry Soil (g)	51.95
Moisture Content %	0.1
Wt. Hydrom. Sample Wet (g)	53.21
Wt. Hydrom. Sample Dry (g)	53.15

WASH SIEVE ANALYSIS

Wt. Total Sample Wet (g)	53.21
Weight of + #10 Before Washing (g)	0.00
Weight of + #10 After Washing (g)	0.00
Weight of - #10 Wet (g)	53.21
Weight of - #10 Dry (g)	53.15
Wt. Total Sample Dry (g)	53.15
Calc. Wt. "W" (g)	53.15
Calc. Mass + #10	0.00

Sieve Number (Size)	Pan Weight (g)	Indiv. Wt. + Pan (g)	Indiv. Wt. Retain.	Cum. Wt. Retain.	Cum. % Retain.	% Finer By Wt.
1 1/2"	0.00	0.00	0.00	0.00	0.0	100.0
3/4"	0.00	0.00	0.00	0.00	0.0	100.0
3/8"	0.00	0.00	0.00	0.00	0.0	100.0
#4	0.00	0.00	0.00	0.00	0.0	100.0
#10	0.00	0.00	0.00	0.00	0.0	100.0
#20	3.59	3.75	0.16	0.16	0.3	99.7
#40	3.77	3.98	0.21	0.37	0.7	99.3
#60	3.82	16.96	13.14	13.51	25.4	74.6
#100	3.72	31.62	27.90	41.41	77.9	22.1
#200	3.67	10.69	7.02	48.43	91.1	8.9

ADVANCED TERRA TESTING, INC.

MECHANICAL ANALYSIS - SIEVE TEST DATA

CLIENT	ASI	JOB NO.	2081-03
BORING NO.	KT15-E	SAMPLED	--
DEPTH	--	DATE TESTED	10-28-91 TNU
SAMPLE NO.	Arapahoe	WASH SIEVE	Yes
SOIL DESCR.	RFP Protected Area	DRY SIEVE	No

MOISTURE DATA

HYGROSCOPIC	Yes
NATURAL	No
Wt. Wet Soil & Pan (g)	61.48
Wt. Dry Soil & Pan (g)	61.42
Wt. Lost Moisture (g)	0.06
Wt. of Pan Only (g)	3.65
Wt. of Dry Soil (g)	57.77
Moisture Content %	0.1
Wt. Hydrom. Sample Wet (g)	80.03
Wt. Hydrom. Sample Dry (g)	79.95

WASH SIEVE ANALYSIS

Wt. Total Sample Wet (g)	80.03
Weight of + #10 Before Washing (g)	0.00
Weight of + #10 After Washing (g)	0.00
Weight of - #10 Wet (g)	80.03
Weight of - #10 Dry (g)	79.95
Wt. Total Sample Dry (g)	79.95
Calc. Wt. "W" (g)	79.95
Calc. Mass + #10	0.00

Sieve Number (Size)	Pan Weight (g)	Indiv. Wt. + Pan (g)	Indiv. Wt. Retain.	Cum. Wt. Retain.	Cum. % Retain.	% Finer By Wt.
1 1/2"	0.00	0.00	0.00	0.00	0.0	100.0
3/4"	0.00	0.00	0.00	0.00	0.0	100.0
3/8"	0.00	0.00	0.00	0.00	0.0	100.0
#4	0.00	0.00	0.00	0.00	0.0	100.0
#10	0.00	0.00	0.00	0.00	0.0	100.0
#20	1.30	1.58	0.28	0.28	0.4	99.6
#40	1.32	2.35	1.03	1.31	1.6	98.4
#60	1.34	15.78	14.44	15.75	19.7	80.3
#100	1.32	18.12	16.80	32.55	40.7	59.3
#200	1.30	39.92	38.62	71.17	89.0	11.0

ADVANCED TERRA TESTING, INC.

MECHANICAL ANALYSIS - SIEVE TEST DATA

CLIENT ASI

JOB NO. 2081-03

BORING NO.	MV3-E	SAMPLED	--
DEPTH	--	DATE TESTED	10-29-91 SR
SAMPLE NO.	Arapahoe	WASH SIEVE	Yes
SOIL DESCR.	Standley Lake	DRY SIEVE	No

MOISTURE DATA

HYGROSCOPIC	Yes
NATURAL	No
Wt. Wet Soil & Pan (g)	53.80
Wt. Dry Soil & Pan (g)	53.61
Wt. Lost Moisture (g)	0.19
Wt. of Pan Only (g)	3.70
Wt. of Dry Soil (g)	49.91
Moisture Content %	0.4
Wt. Hydrom. Sample Wet (g)	80.00
Wt. Hydrom. Sample Dry (g)	79.70

WASH SIEVE ANALYSIS

Wt. Total Sample Wet (g)	366.31
Weight of + #10 Before Washing (g)	30.32
Weight of + #10 After Washing (g)	26.76
Weight of - #10 Wet (g)	171.04
Weight of - #10 Dry (g)	173.94
Wt. Total Sample Dry (g)	200.70
Calc. Wt. "W" (g)	91.96
Calc. Mass + #10	12.26

Sieve Number (Size)	Pan Weight (g)	Indiv. Wt. + Pan (g)	Indiv. Wt. Retain.	Cum. Wt. Retain.	Cum. % Retain.	% Finer By Wt.
1 1/2"	0.00	0.00	0.00	0.00	0.0	100.0
3/4"	0.00	0.00	0.00	0.00	0.0	100.0
3/8"	0.00	0.00	0.00	0.00	0.0	100.0
#4	0.00	3.87	3.87	3.87	1.9	98.1
#10	0.00	22.89	22.89	26.76	13.3	86.7
#20	3.67	29.88	26.21	26.21	41.8	58.2
#40	3.67	21.64	17.97	44.18	61.4	38.6
#60	3.63	19.07	15.44	59.62	78.2	21.8
#100	3.79	9.48	5.69	65.31	84.4	15.6
#200	3.84	5.79	1.95	67.26	86.5	13.5

MECHANICAL ANALYSIS - SIEVE TEST DATA

CLIENT ASI

JOB NO. 2081-03

BORING NO.	MV28-E	SAMPLED	--
DEPTH	--	DATE TESTED	10-30-91 SR
SAMPLE NO.	Arapahoe	WASH SIEVE	Yes
SOIL DESCR.	Indiana Street	DRY SIEVE	No

MOISTURE DATA

HYGROSCOPIC	Yes
NATURAL	No
Wt. Wet Soil & Pan (g)	46.55
Wt. Dry Soil & Pan (g)	46.51
Wt. Lost Moisture (g)	0.04
Wt. of Pan Only (g)	3.61
Wt. of Dry Soil (g)	42.90
Moisture Content %	0.1
Wt. Hydrom. Sample Wet (g)	80.01
Wt. Hydrom. Sample Dry (g)	79.94

WASH SIEVE ANALYSIS

Wt. Total Sample Wet (g)	80.01
Weight of + #10 Before Washing (g)	0.00
Weight of + #10 After Washing (g)	0.00
Weight of - #10 Wet (g)	80.10
Weight of - #10 Dry (g)	80.03
Wt. Total Sample Dry (g)	80.03
Calc. Wt. "W" (g)	79.94
Calc. Mass + #10	0.00

Sieve Number (Size)	Pan Weight (g)	Indiv. Wt. + Pan (g)	Indiv. Wt. Retain.	Cum. Wt. Retain.	Cum. % Retain.	% Finer By Wt.
1 1/2"	0.00	0.00	0.00	0.00	0.0	100.0
3/4"	0.00	0.00	0.00	0.00	0.0	100.0
3/8"	0.00	0.00	0.00	0.00	0.0	100.0
#4	0.00	0.00	0.00	0.00	0.0	100.0
#10	0.00	0.00	0.00	0.00	0.0	100.0
#20	3.65	6.89	3.24	3.24	4.1	95.9
#40	3.72	19.37	15.65	18.89	23.6	76.4
#60	3.72	46.39	42.67	61.56	77.0	23.0
#100	3.69	13.16	9.47	71.03	88.9	11.1
#200	3.67	6.98	3.31	74.34	93.0	7.0

ADVANCED TERRA TESTING, INC.

MECHANICAL ANALYSIS - SIEVE TEST DATA

CLIENT	ASI	JOB NO.	2081-03
BORING NO.	MV69-N	SAMPLED	--
DEPTH	--	DATE TESTED	10-31-91 SR
SAMPLE NO.	Arapahoe	WASH SIEVE	Yes
SOIL DESCR.	RFP Buffer Zone	DRY SIEVE	No

MOISTURE DATA

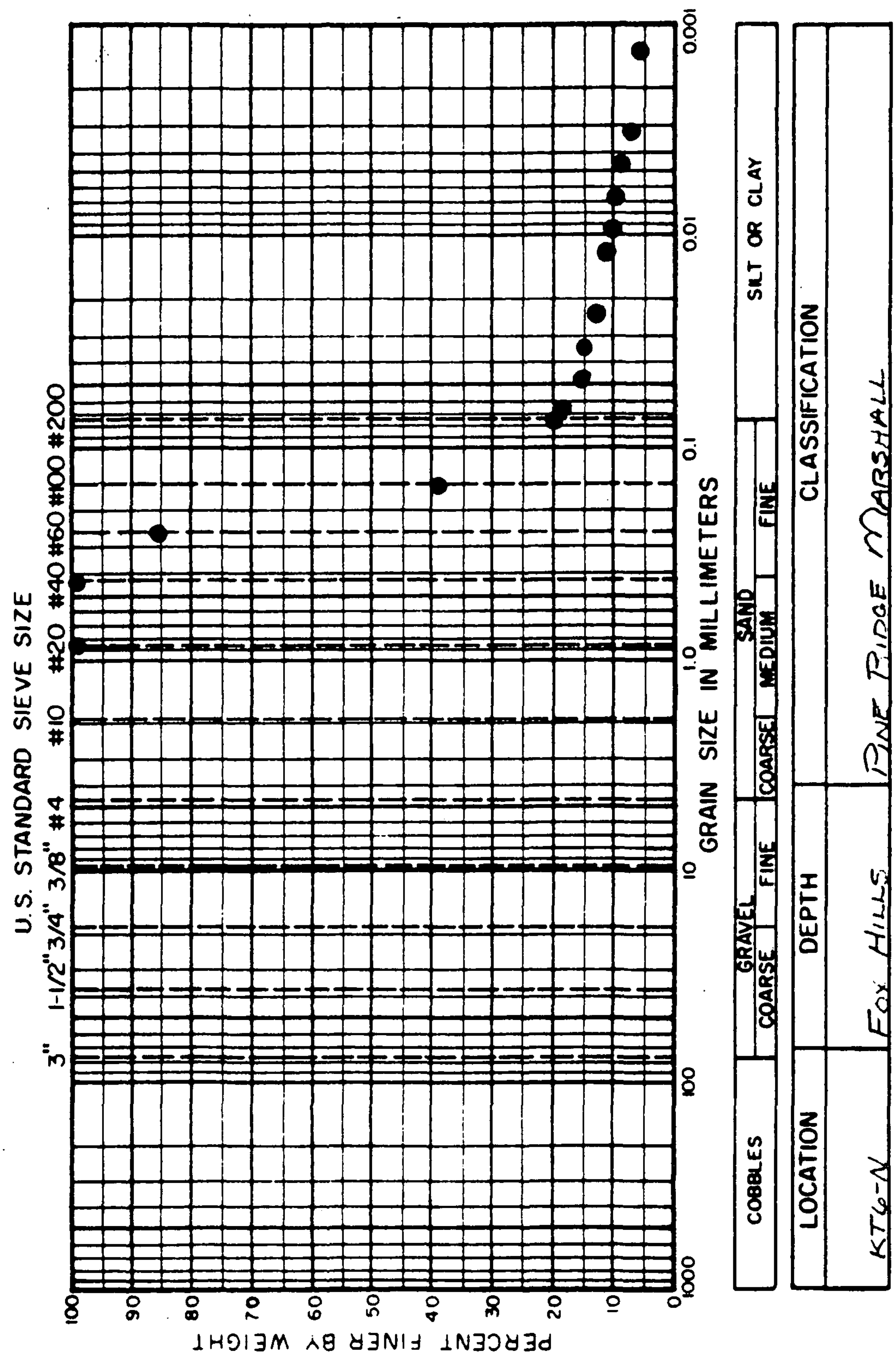
HYGROSCOPIC	Yes
NATURAL	No
Wt. Wet Soil & Pan (g)	54.09
Wt. Dry Soil & Pan (g)	54.07
Wt. Lost Moisture (g)	0.02
Wt. of Pan Only (g)	3.95
Wt. of Dry Soil (g)	50.12
Moisture Content %	0.0
Wt. Hydrom. Sample Wet (g)	80.00
Wt. Hydrom. Sample Dry (g)	79.97

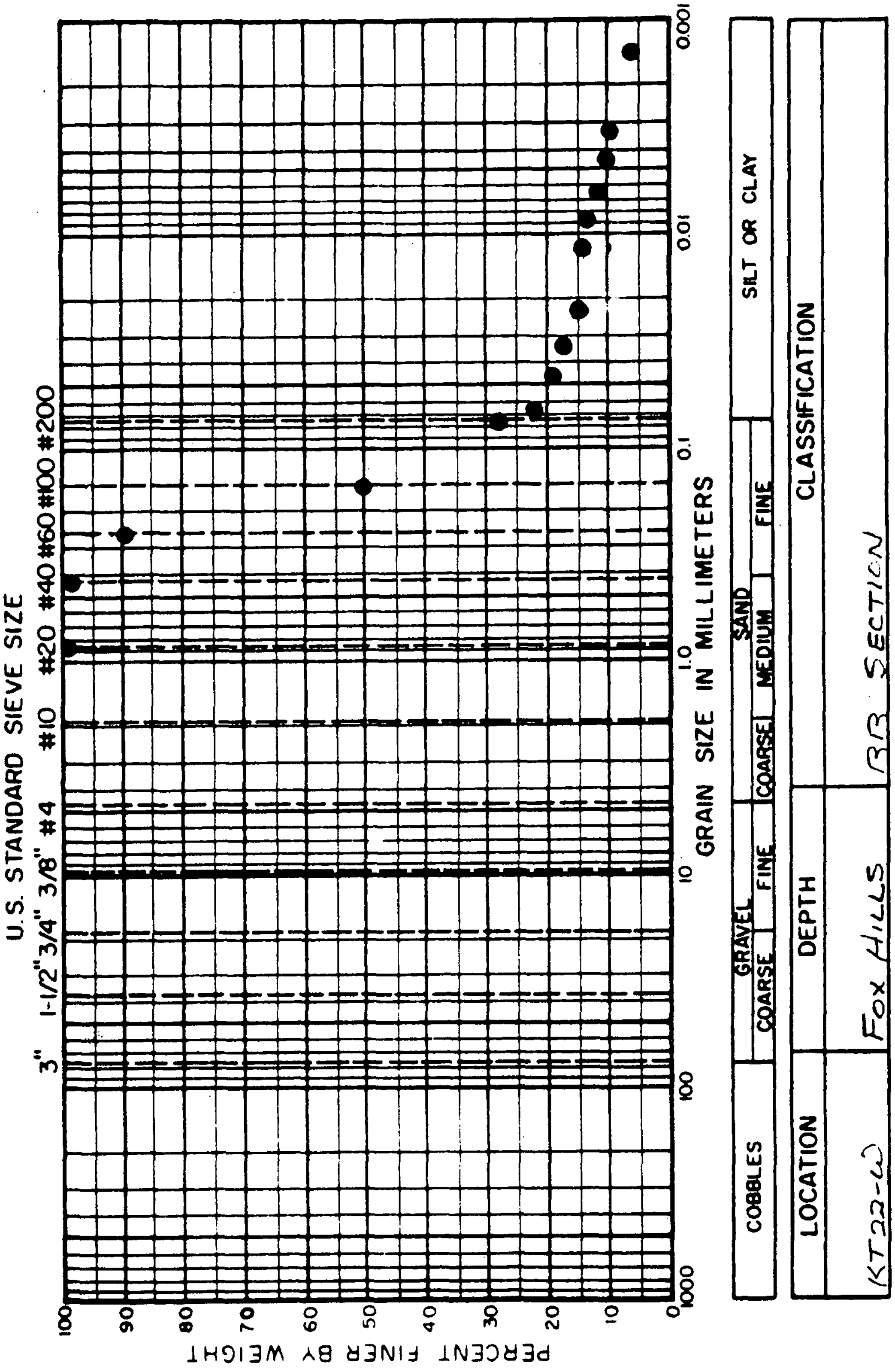
WASH SIEVE ANALYSIS

Wt. Total Sample Wet (g)	80.00
Weight of + #10 Before Washing (g)	0.00
Weight of + #10 After Washing (g)	0.00
Weight of - #10 Wet (g)	80.00
Weight of - #10 Dry (g)	79.97
Wt. Total Sample Dry (g)	79.97
Calc. Wt. "W" (g)	79.97
Calc. Mass + #10	0.00

Sieve Number (Size)	Pan Weight (g)	Indiv. Wt. + Pan (g)	Indiv. Wt. Retain.	Cum. Wt. Retain.	Cum. % Retain.	% Finer By Wt.
1 1/2"	0.00	0.00	0.00	0.00	0.0	100.0
3/4"	0.00	0.00	0.00	0.00	0.0	100.0
3/8"	0.00	0.00	0.00	0.00	0.0	100.0
#4	0.00	0.00	0.00	0.00	0.0	100.0
#10	0.00	0.00	0.00	0.00	0.0	100.0
#20	3.66	8.32	4.66	4.66	5.8	94.2
#40	3.68	18.45	14.77	19.43	24.3	75.7
#60	3.69	45.62	41.93	61.36	76.7	23.3
#100	3.69	12.79	9.10	70.46	88.1	11.9
#200	3.71	9.01	5.30	75.76	94.7	5.3

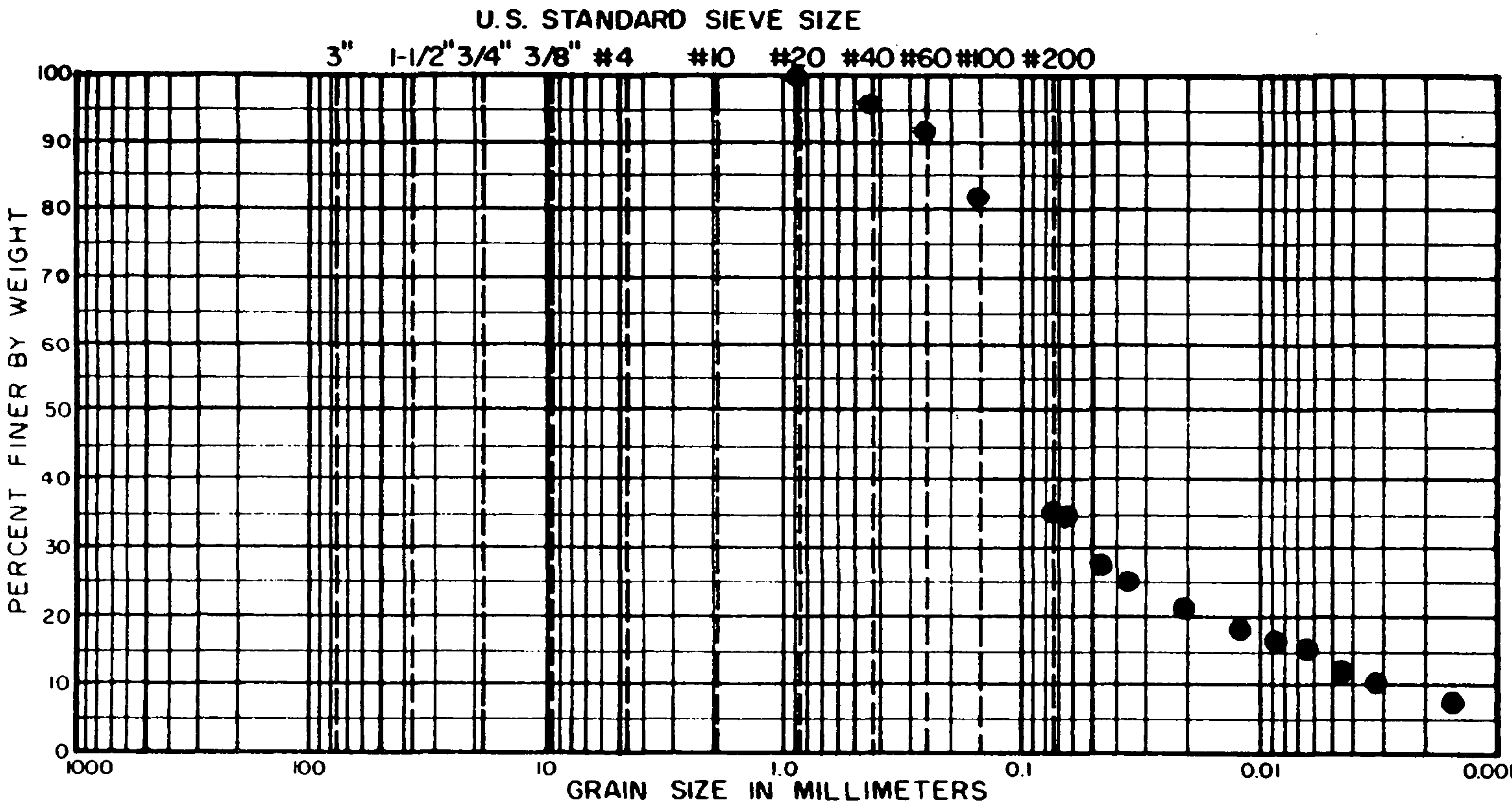
ADVANCED TERRA TESTING, INC.


U.S. STANDARD SIEVE SIZE
3" 1-1/2" 3/4" 3/8" #4 #10 #20 #40 #60 #100 #200
GRAIN SIZE IN MILLIMETERS
1000 100 10 1.0 0.1 0.01 0.001
PERCENT FINER BY WEIGHT
100 90 80 70 60 50 40 30 20 10 0
COBBLES
GRAVEL
COARSE FINE
SAND
COARSE MEDIUM FINE
SILT OR CLAY
LOCATION
DEPTH
CLASSIFICATION
KT6-N
Fox Hills
Pine Ridge Marshall



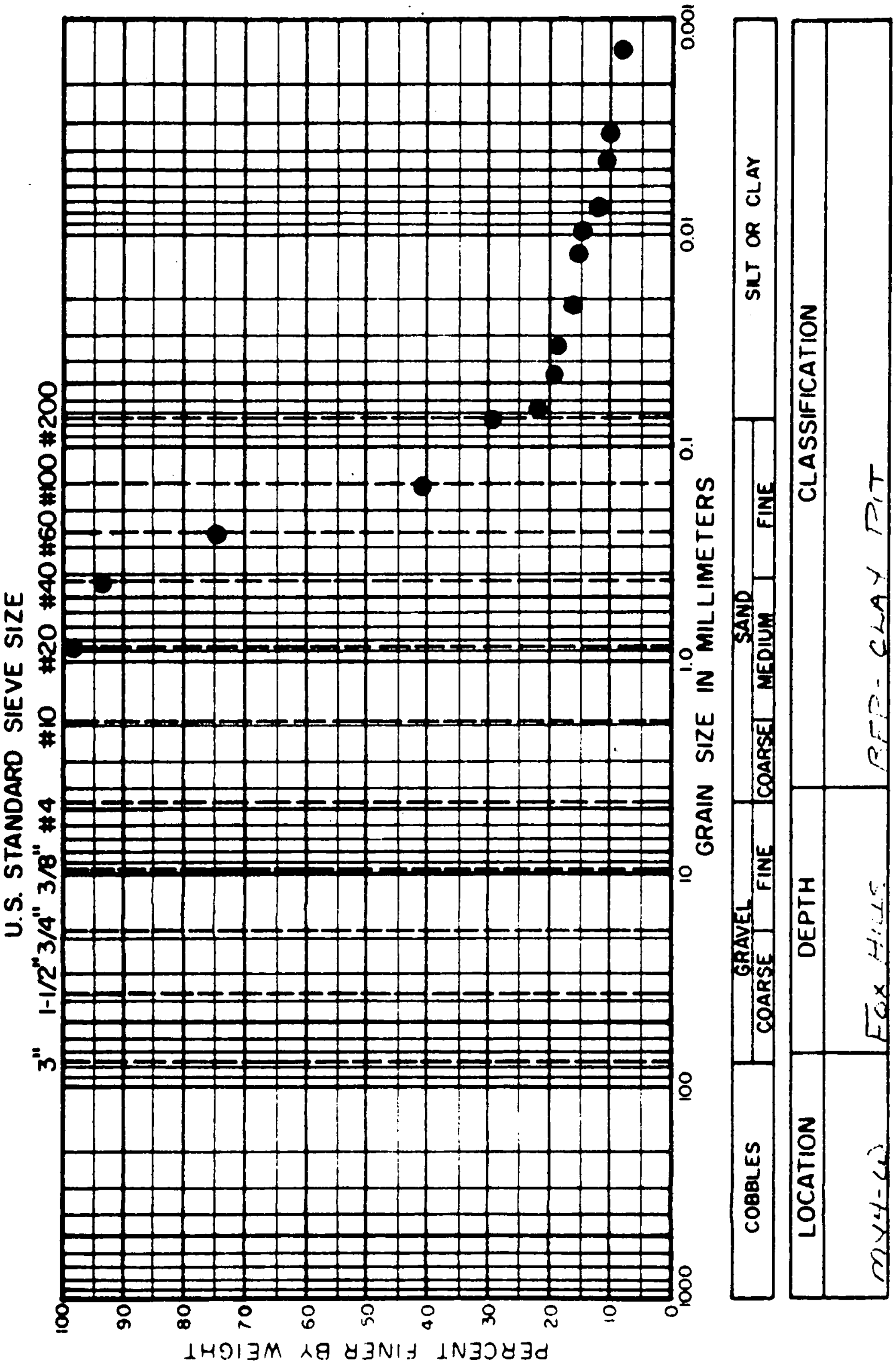
ADVANCED TERRA TESTING inc

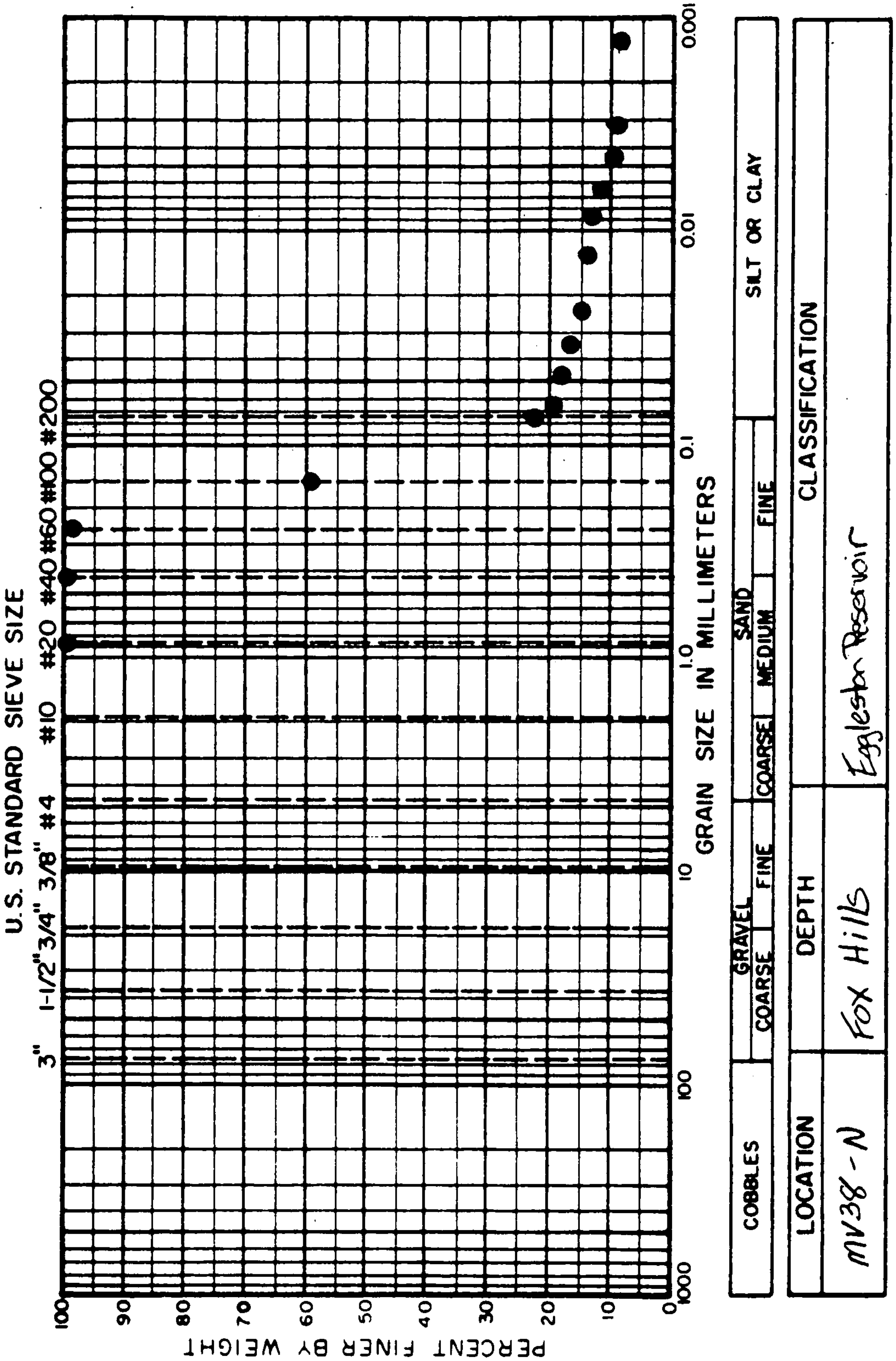
C-24



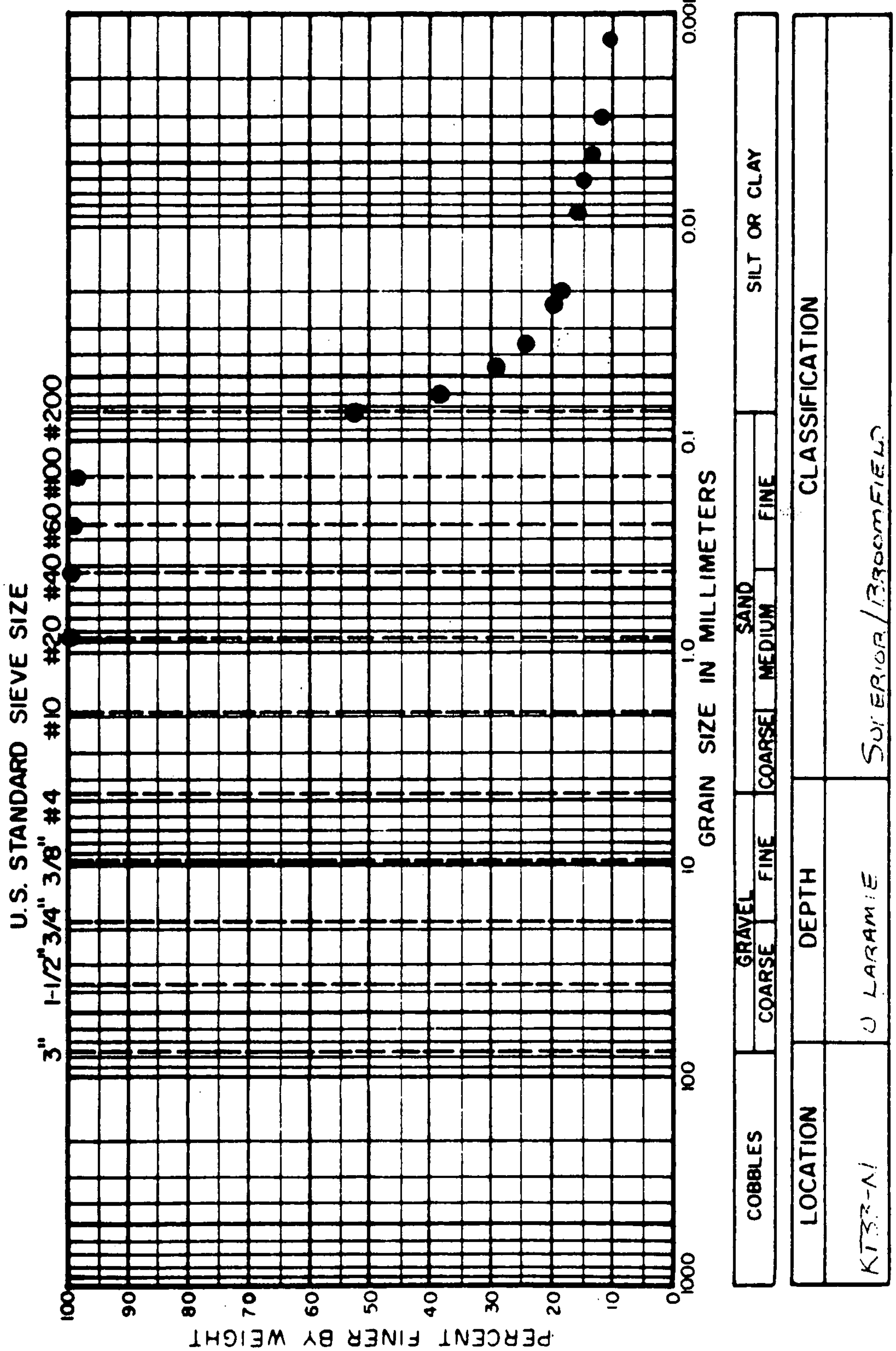
COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

LOCATION	DEPTH	CLASSIFICATION
KT24-W	Fox Hill	B3 Section


U.S. STANDARD SIEVE SIZE
3" 1-1/2" 3/4" 3/8" #4 #10 #20 #40 #60 #100 #200
PERCENT FINER BY WEIGHT
100 90 80 70 60 50 40 30 20 10 0
1000 100 10 1.0 0.1 0.01 0.001
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE FINE
SAND
COARSE MEDIUM FINE
SILT OR CLAY
LOCATION
DEPTH
CLASSIFICATION
Fox Hills
RED-CLAY PIT

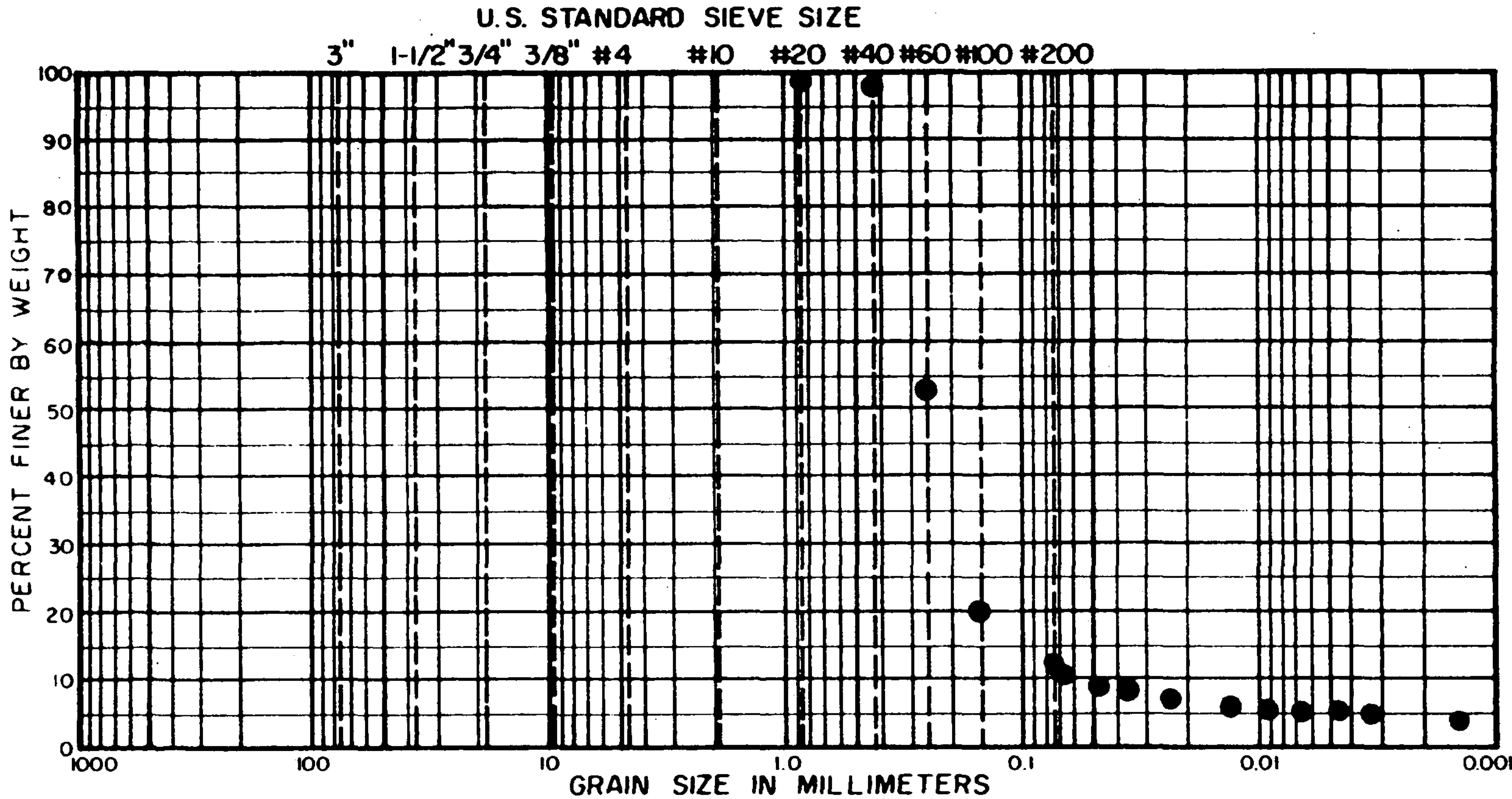


ADVANCED TERRA TESTING inc



C-27

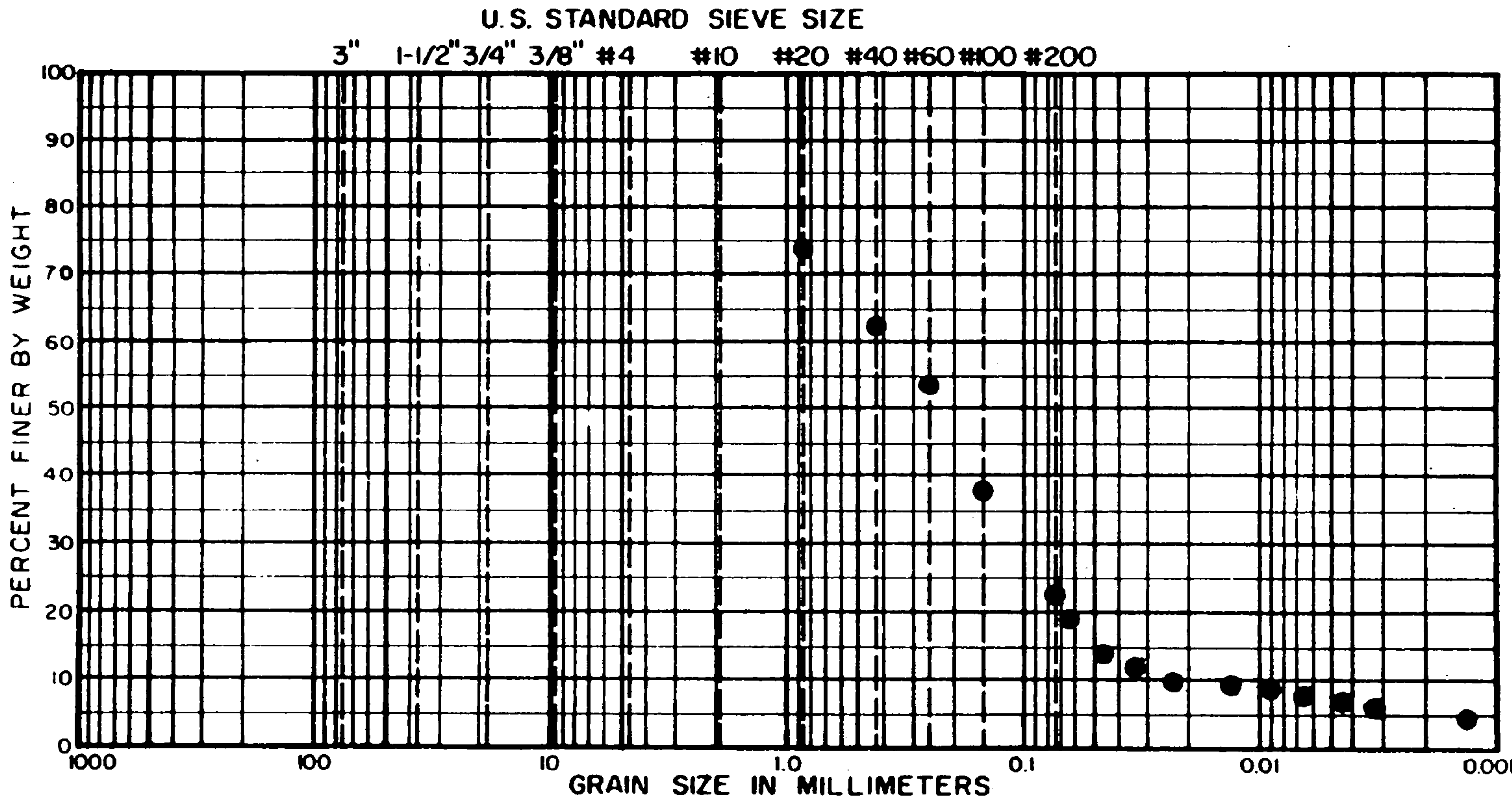
ADVANCED TERRA TESTING



COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

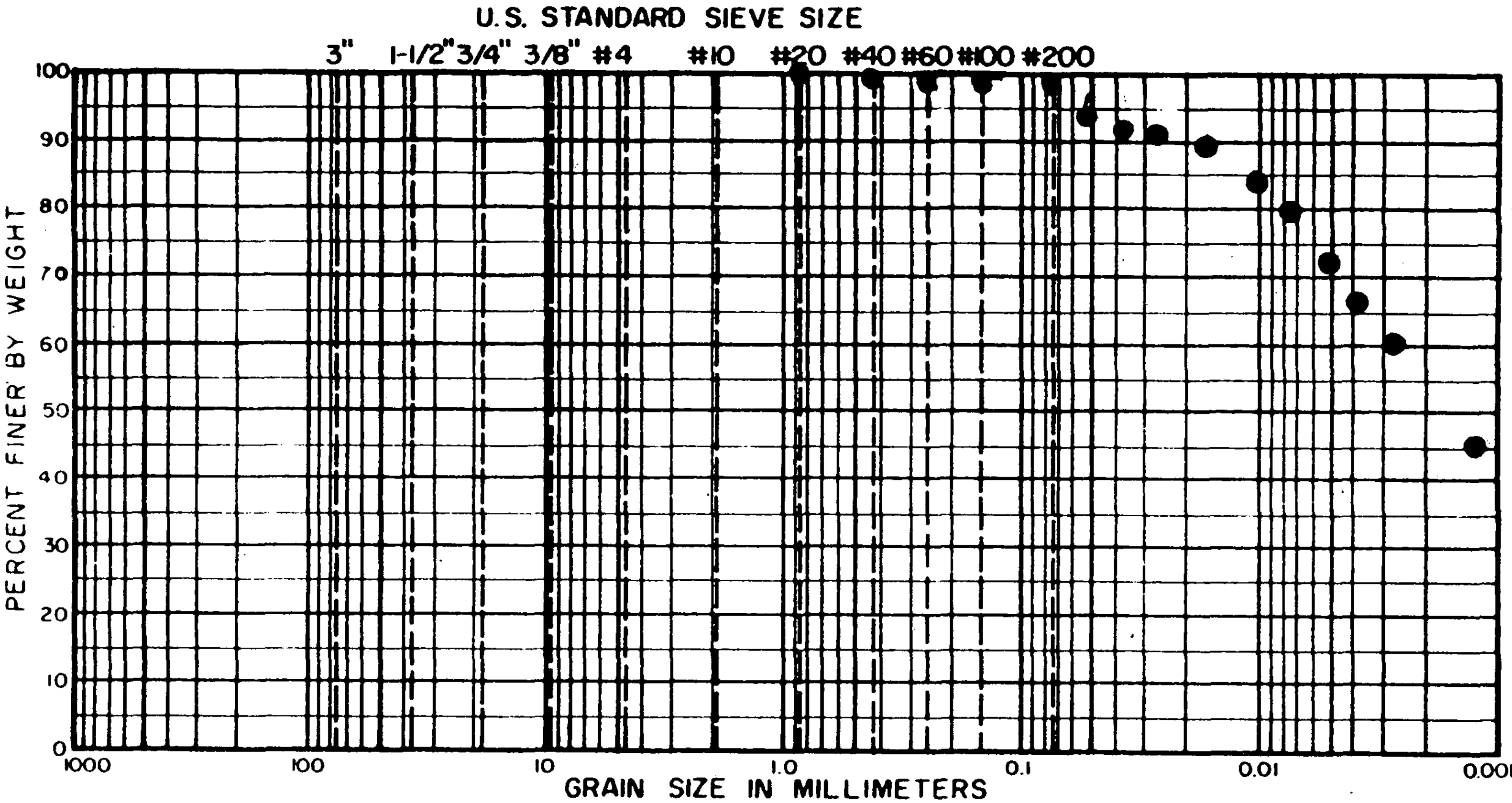
LOCATION	DEPTH	CLASSIFICATION
KTLO-N	() LARAMIE	McCASLIN BLVD.

ADVANCED TERRA TESTING



COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

LOCATION	DEPTH	CLASSIFICATION
KT61-N	U. Laramie	McCaslin Blvd.

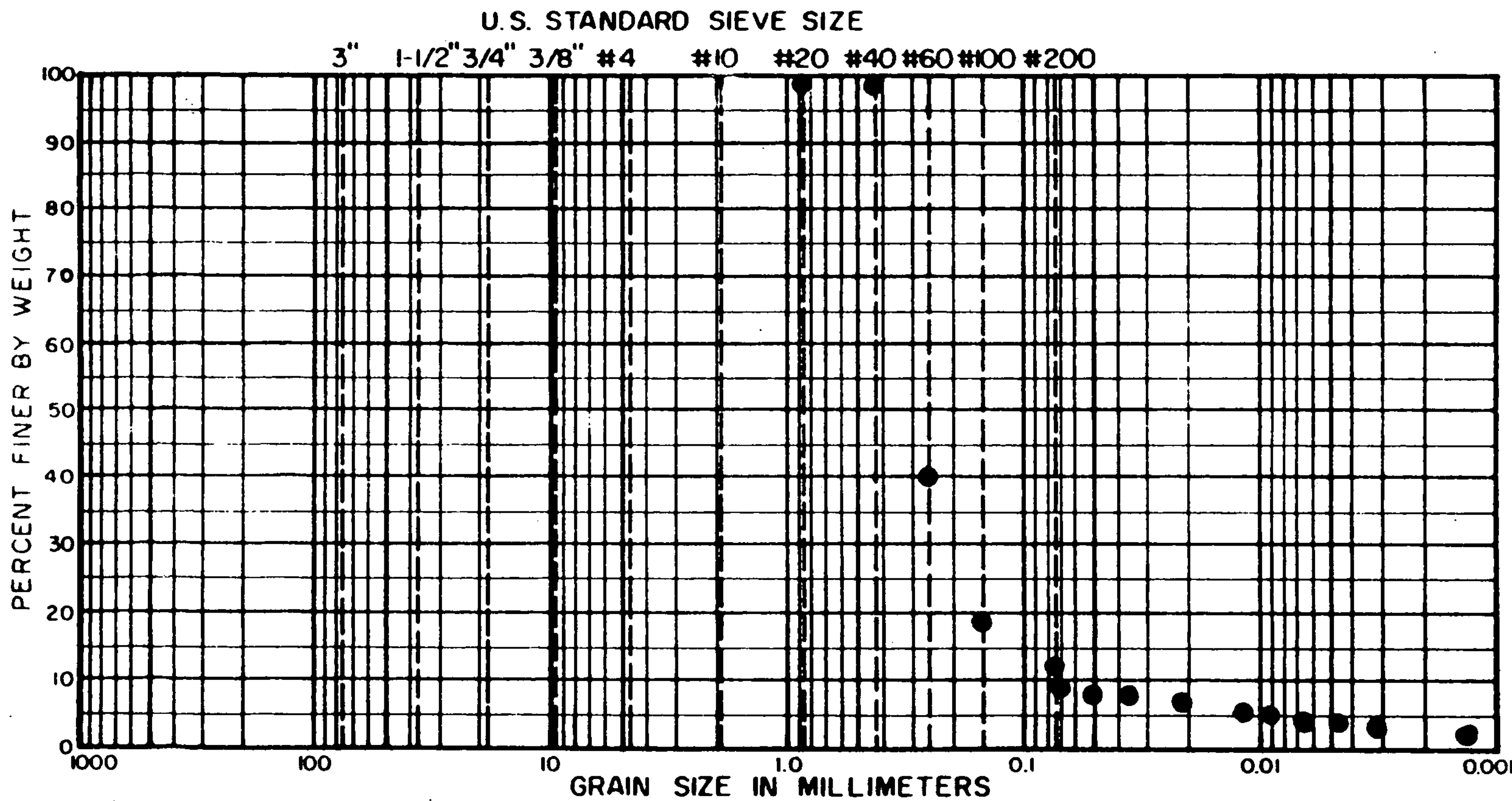


COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

LOCATION	DEPTH	CLASSIFICATION
MV9-E	U. LABAN E	[illegible]

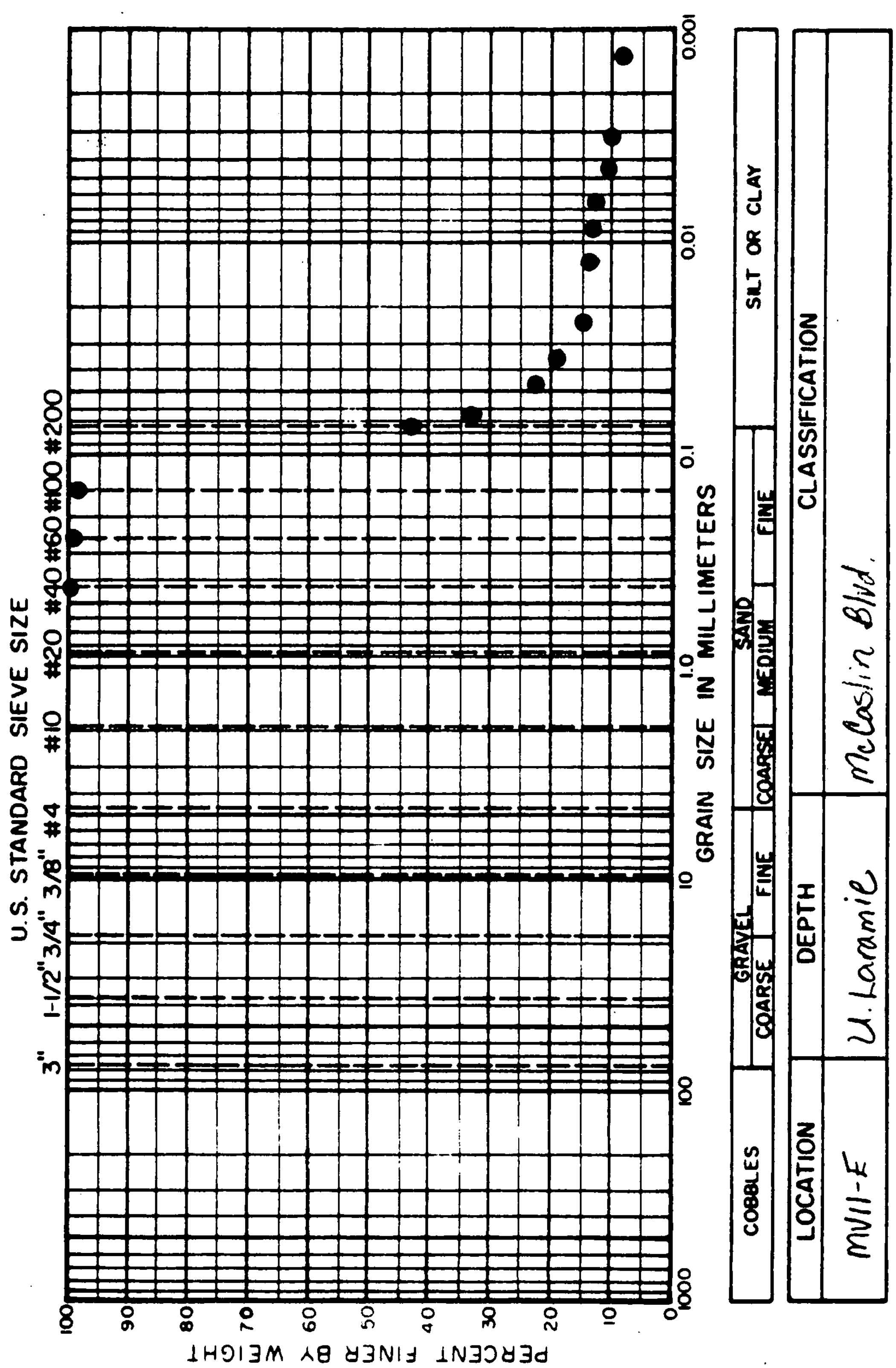
C-30

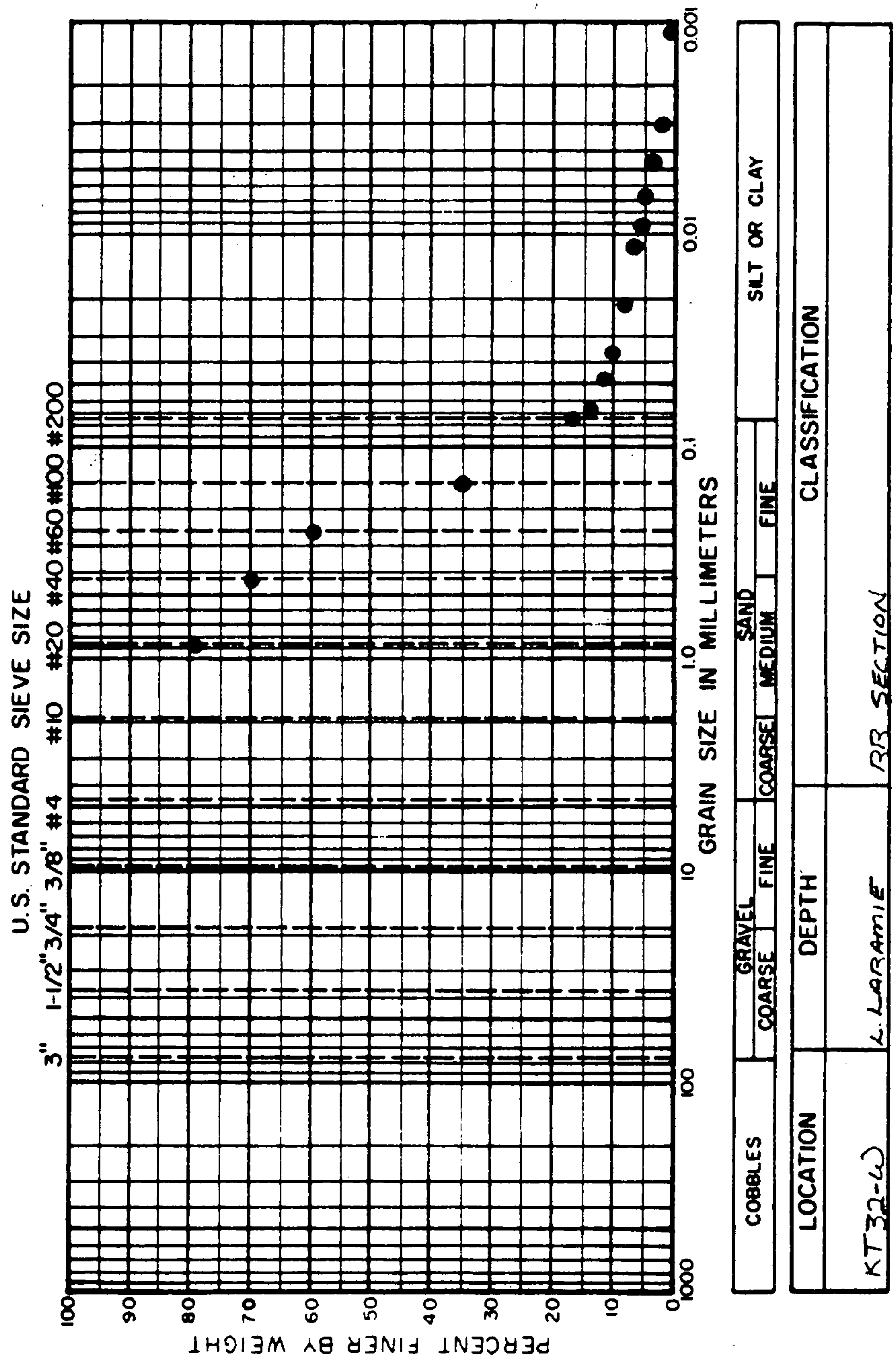
ADVANCED TERRA TESTING

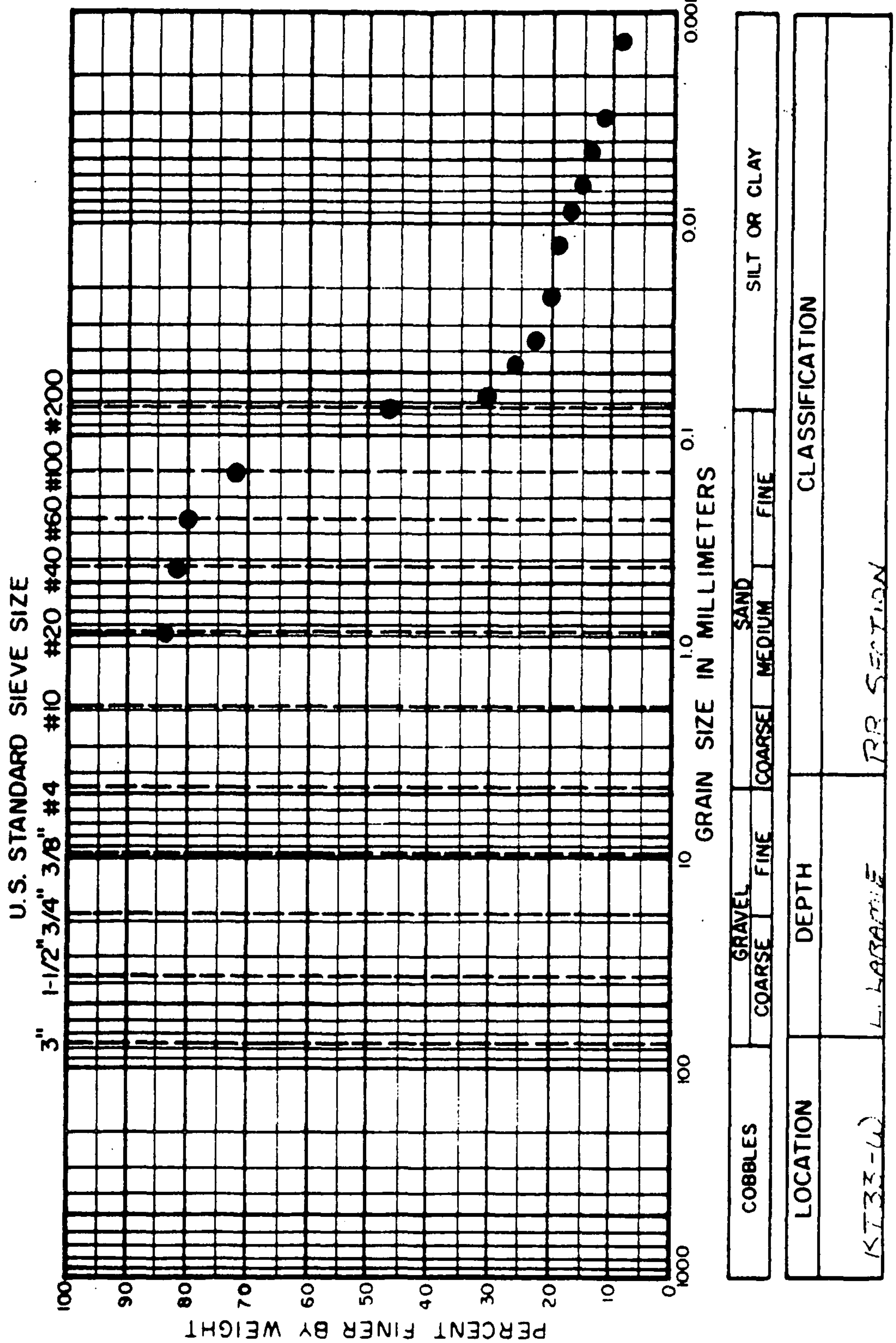


COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

LOCATION	DEPTH	CLASSIFICATION
MV10-E	U. LARAMIE	McCASLIN BLVD.


U.S. STANDARD SIEVE SIZE
3" 1-1/2" 3/4" 3/8" #4 #10 #20 #40 #60 #100 #200
PERCENT FINER BY WEIGHT
100 90 80 70 60 50 40 30 20 10 0
1000 100 10 1.0 0.1 0.01 0.001
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
LOCATION
DEPTH
CLASSIFICATION
MVII-E
U. Laramie
McCaslin Blvd.


U.S. STANDARD SIEVE SIZE
3" 1-1/2" 3/4" 3/8" #4 #10 #20 #40 #60 #100 #200
GRAIN SIZE IN MILLIMETERS
1000 100 10 1.0 0.1 0.01 0.001
PERCENT FINER BY WEIGHT
100 90 80 70 60 50 40 30 20 10 0
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
LOCATION
DEPTH
CLASSIFICATION
KT32-W
L. LARAMIE
RR SECTION



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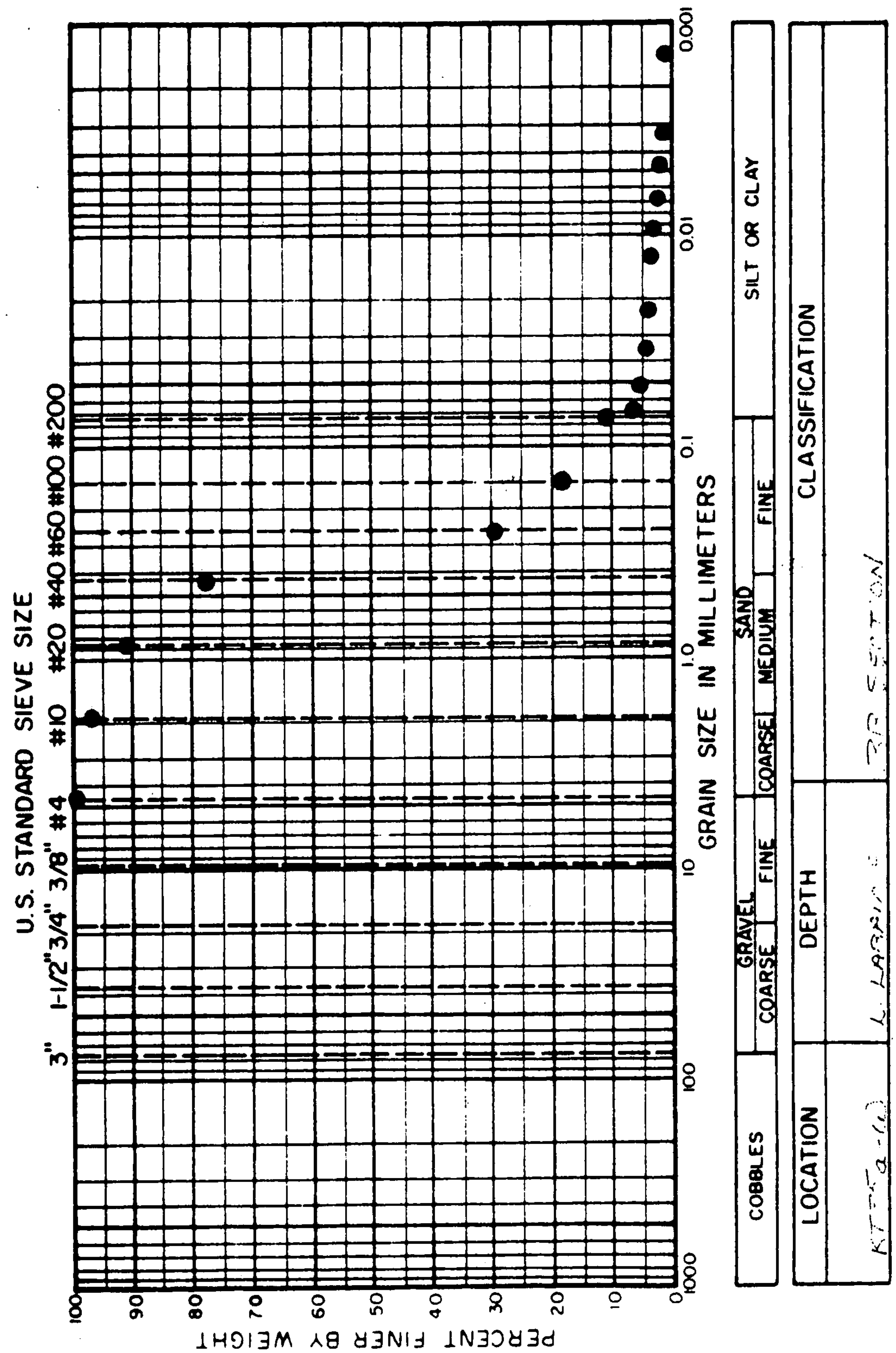

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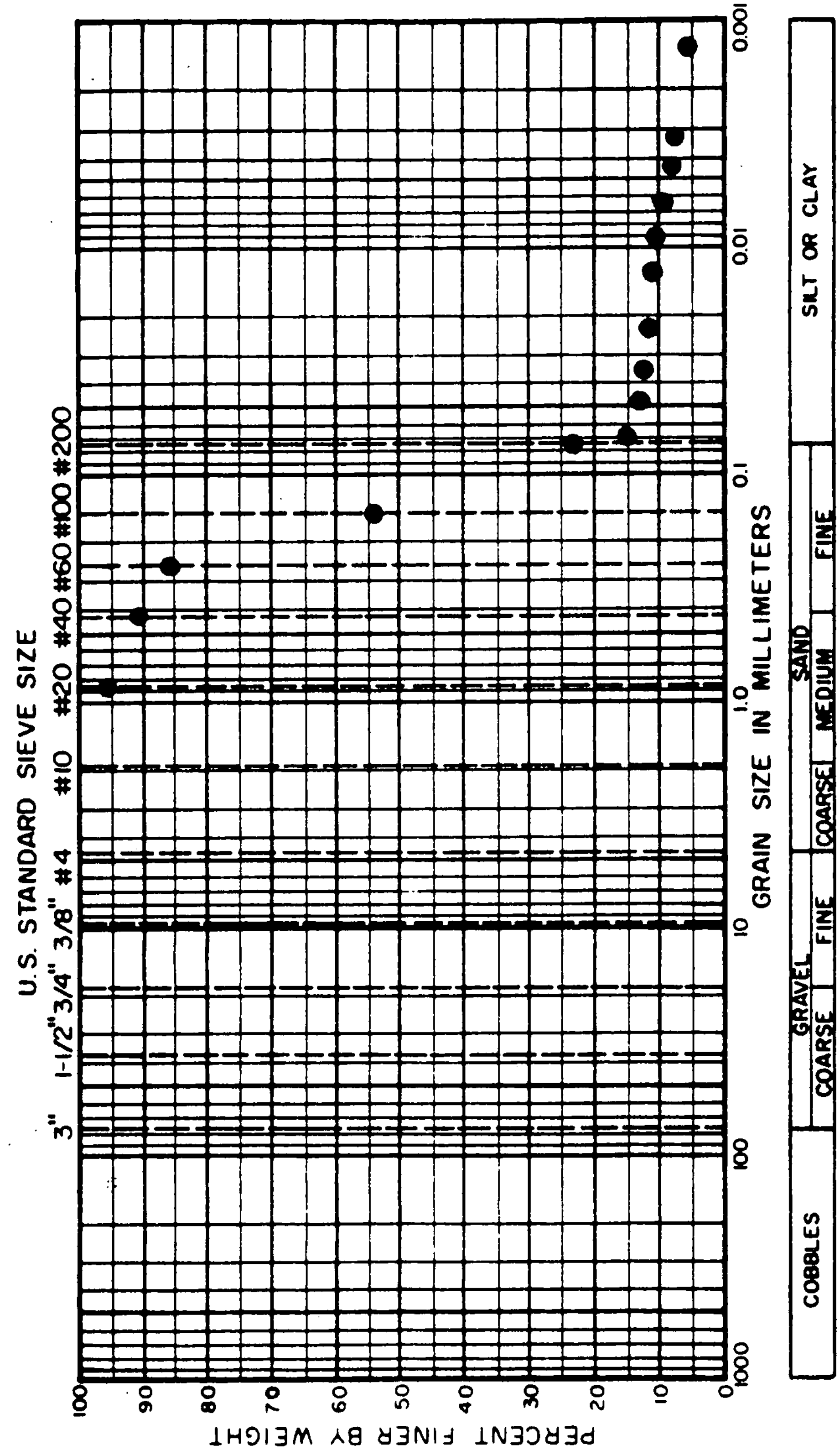
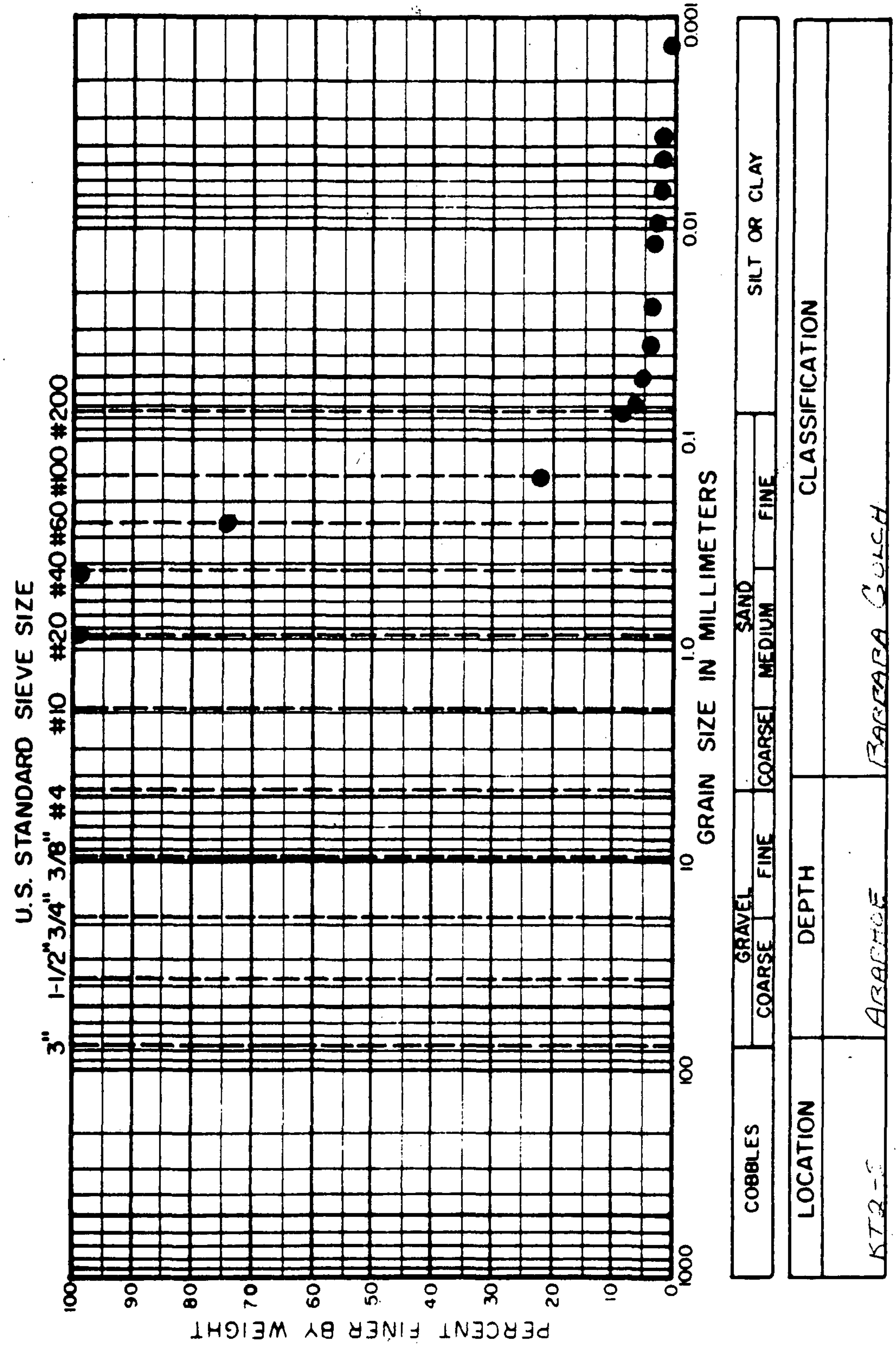


LOCATION	DEPTH	CLASSIFICATION
KT35bW	L. Laramie	RR Section



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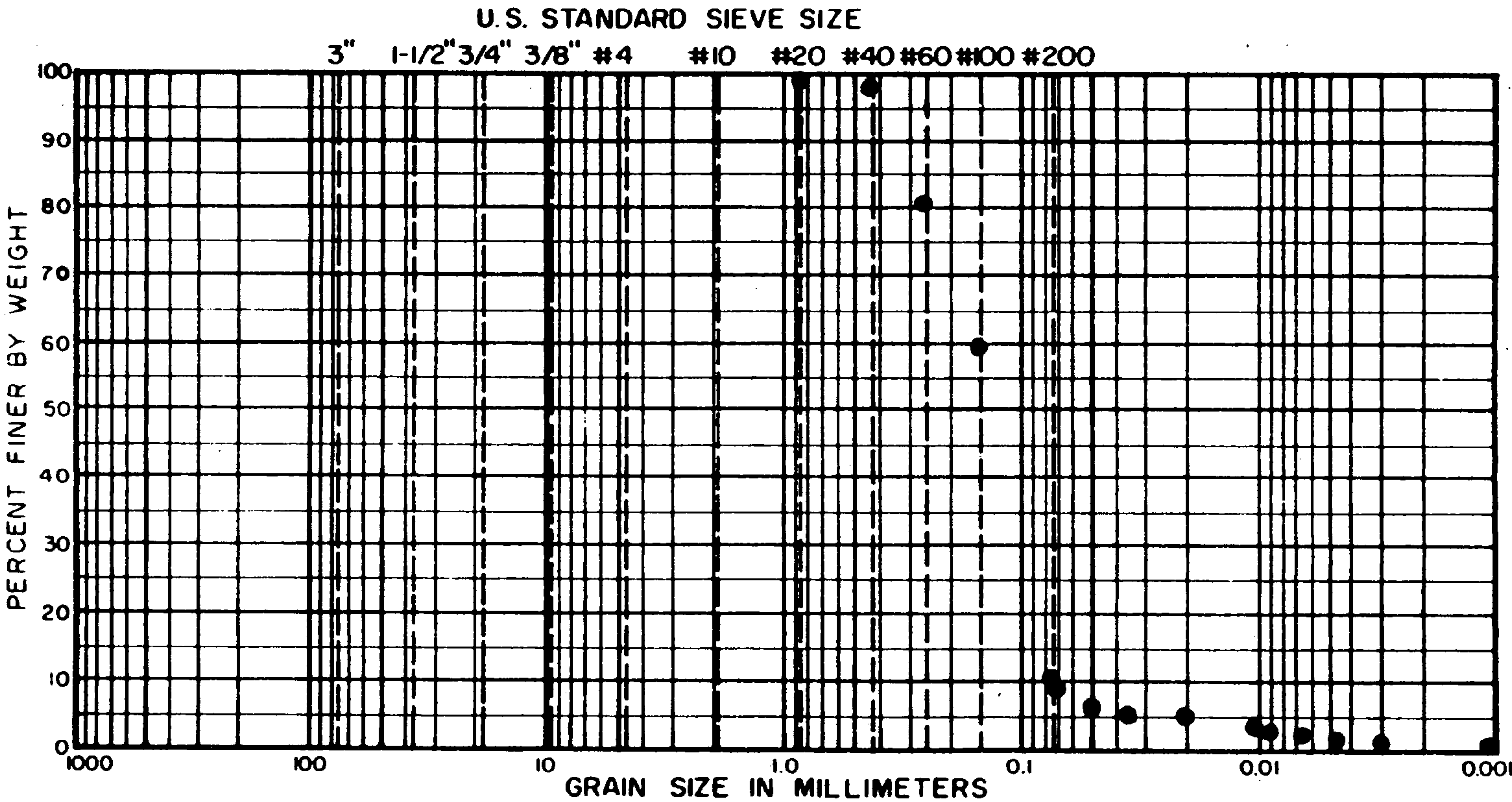
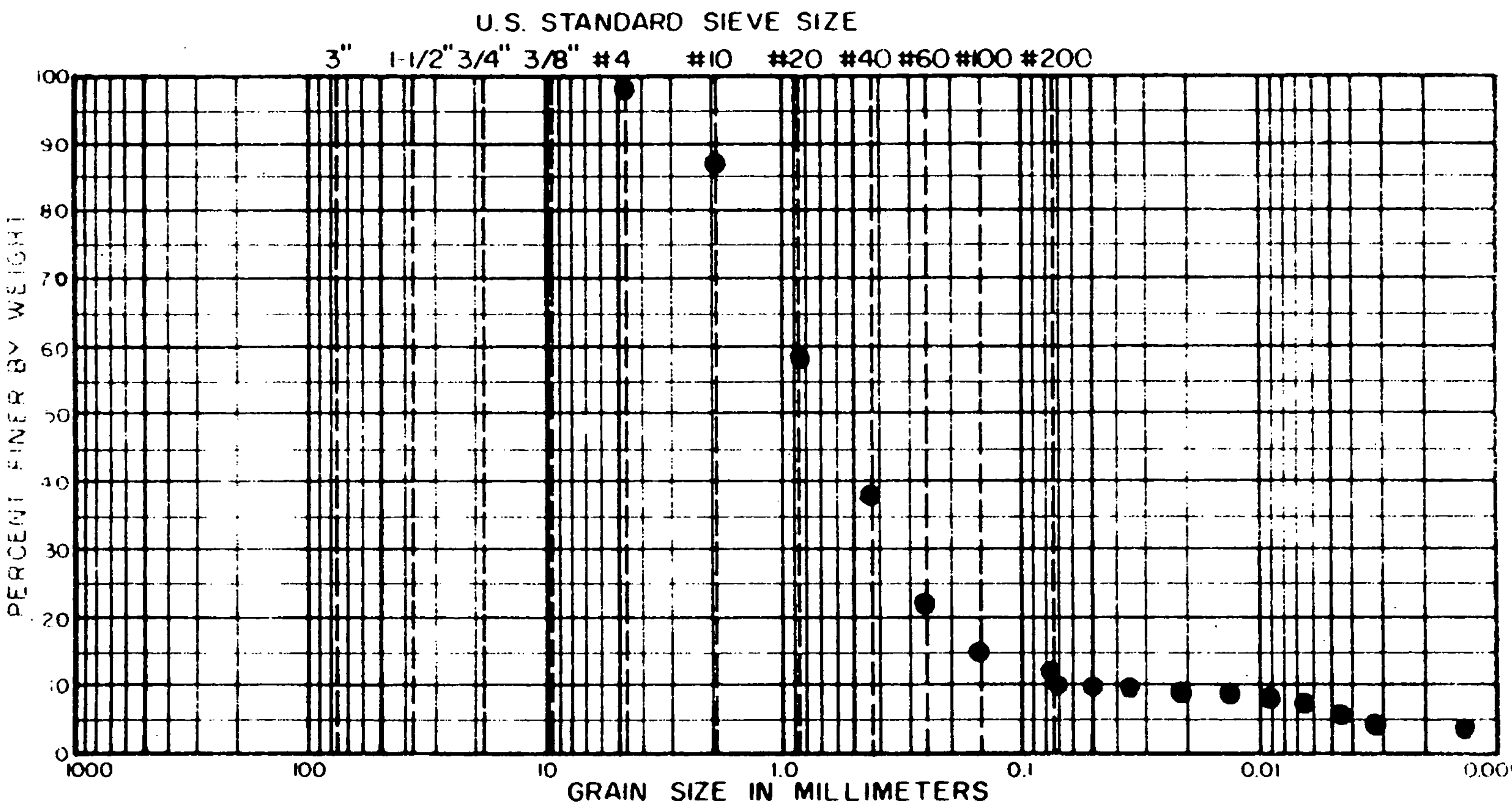


COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

LOCATION	DEPTH	CLASSIFICATION
KT15-E	ARAPAHOE	RFP PROTECTED AREA

ADVANCED TERRA TESTING INC



COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

LOCATION	DEPTH	CLASSIFICATION
[illegible]	[illegible]	[illegible]

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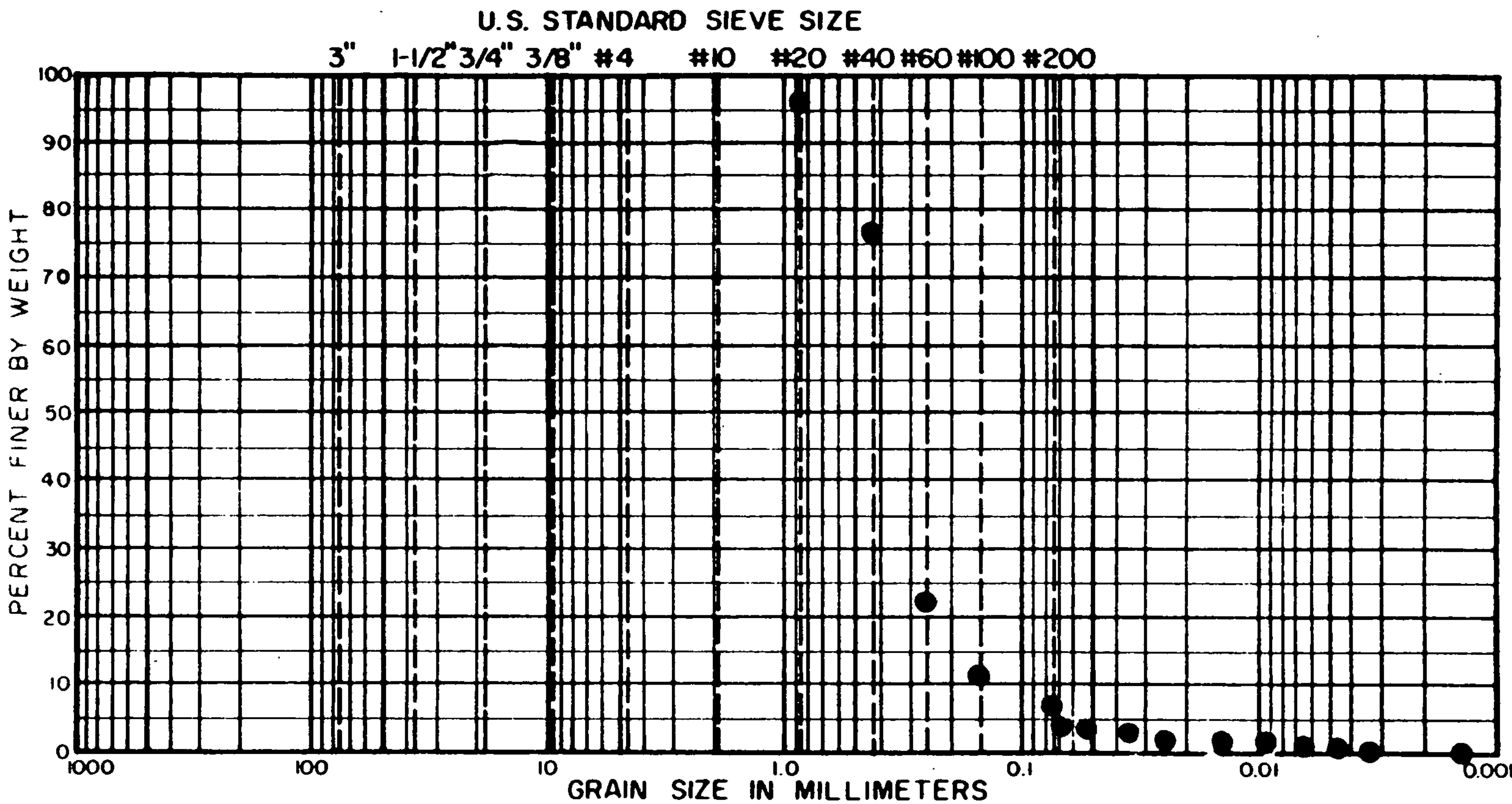
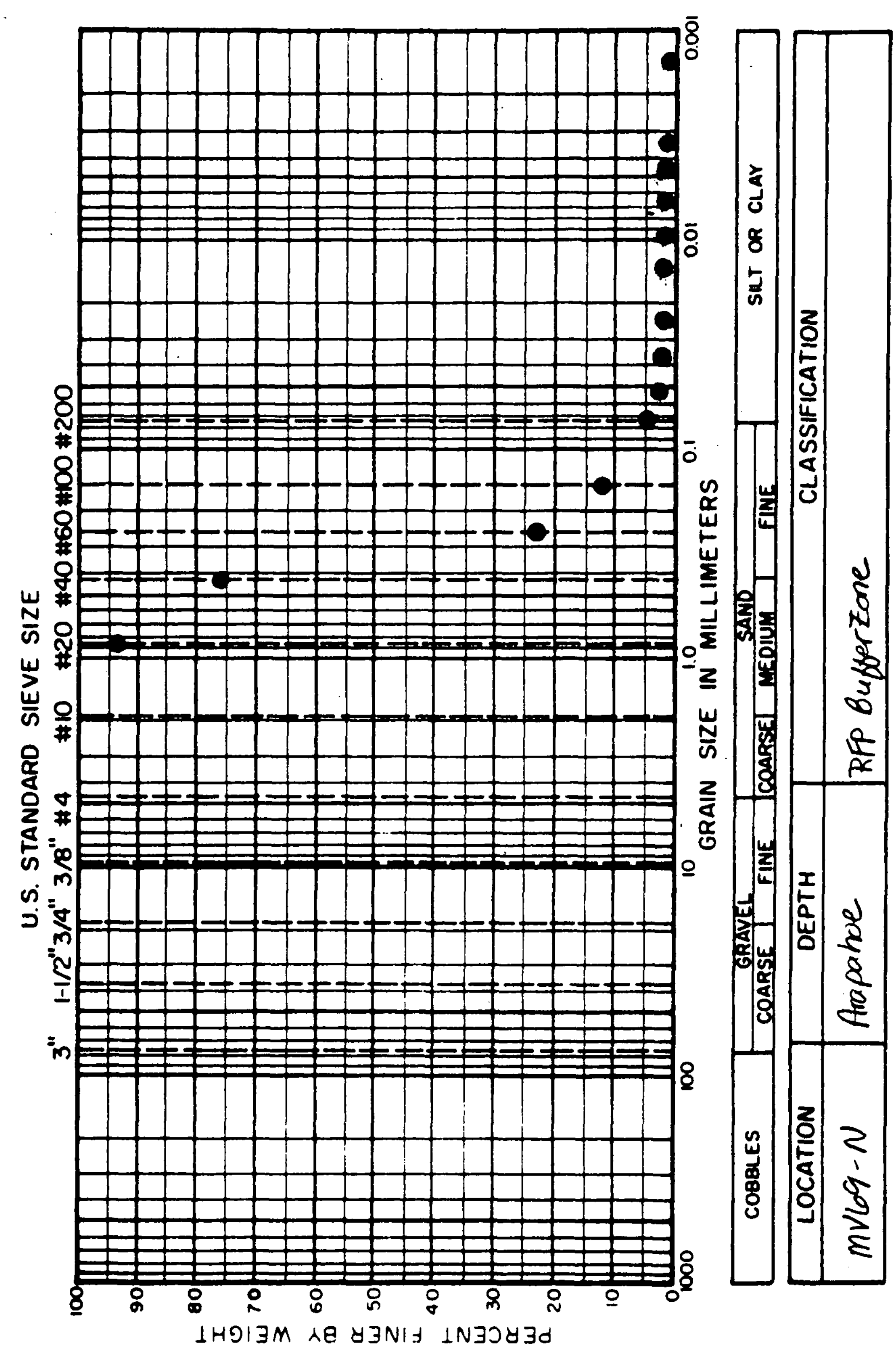
ADVANCED TERRA TESTING



COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

LOCATION	DEPTH	CLASSIFICATION
mV2x E	Arapahoe	Indiana Street



ADVANCED TERRA TESTING INC

HYDROMETER ANALYSIS - SEDIMENTATION DATA

CLIENT ASI

JOB NO. 2081-03

BORING NO.	KT6-N	SAMPLED	--
DEPTH	--	DATE TESTED	10-28-91 TNU
SAMPLE NO.	Fox Hills	WASH SIEVE	Yes
SOIL DESCR.	Pine Ridge Marshall	DRY SIEVE	No

Hydrometer #	ASTM 152 H	Temp., Deg. C	22.0
Sp. Gr. of Soil	2.71	Temp. Coef. K	0.01308
Value of "a"	0.99	Wt. Dry Sample "W"	79.785
Deflocculant	Sodium Hexametaphosphate	% of Total Sample	100.0
Defloc. Corr'n	5.0		
Meniscus Corr'n	-1.0		

T Elapsed Time (min)	Hydrometer Reading Original	Hydrometer Reading Corrected "R"	100Ra/W	% Total Sample	Effecitve Depth L	Grain Diameter (mm)
0.0	--	--	--	--	--	--
0.5	21.00	15.00	18.6	18.6	12.85	0.0663
1.0	19.00	13.00	16.1	16.1	13.17	0.0475
2.0	18.50	12.50	15.5	15.5	13.26	0.0337
5.0	17.00	11.00	13.6	13.6	13.50	0.0215
15.0	16.00	10.00	12.4	12.4	13.67	0.0125
30.0	15.00	9.00	11.1	11.1	13.83	0.0089
60.0	14.00	8.00	9.9	9.9	13.99	0.0063
120.0	13.00	7.00	8.7	8.7	14.16	0.0045
250.0	12.00	6.00	7.4	7.4	14.32	0.0031
1440.0	11.50	5.50	6.8	6.8	14.40	0.0013

Grain Diameter = K*(SQRT(L/T))

HYDROMETER ANALYSIS - SEDIMENTATION DATA

CLIENT	ASI	JOB NO.	2081-03
BORING NO.	KT22-W	SAMPLED	--
DEPTH	--	DATE TESTED	10-29-91 SR
SAMPLE NO.	Fox Hills	WASH SIEVE	Yes
SOIL DESCR.	RR Section	DRY SIEVE	No

Hydrometer #	ASTM 152 H	Temp., Deg. C	22.5
Sp. Gr. of Soil	2.71	Temp. Coef. K	0.01301
Value of "a"	0.99	Wt. Dry Sample "W"	79.648
Deflocculant	Sodium Hexametaphosphate	% of Total Sample	100.0
Defloc. Corr'n	5.0		
Meniscus Corr'n	-1.0		

T Elapsed Time (min)	Hydrometer Reading Original	Corrected "R"	100Ra/W	% Total Sample	Effecitve Depth L	Grain Diameter (mm)
0.0	--	--	--	--	--	--
0.5	25.00	19.00	23.6	23.6	12.19	0.0642
1.0	22.00	16.00	19.8	19.8	12.68	0.0463
2.0	20.00	14.00	17.4	17.4	13.01	0.0332
5.0	18.25	12.25	15.2	15.2	13.30	0.0212
15.0	18.00	12.00	14.9	14.9	13.34	0.0123
30.0	17.75	11.75	14.6	14.6	13.38	0.0087
60.0	15.75	9.75	12.1	12.1	13.71	0.0062
120.0	14.50	8.50	10.5	10.5	13.91	0.0044
250.0	13.25	7.25	9.0	9.0	14.12	0.0031
1440.0	11.00	5.00	6.2	6.2	14.49	0.0013

Grain Diameter = K*(SQRT(L/T))

HYDROMETER ANALYSIS - SEDIMENTATION DATA

CLIENT	ASI	JOB NO.	2081-03
BORING NO.	KT24-W	SAMPLED	--
DEPTH	--	DATE TESTED	10-28-91 TNU
SAMPLE NO.	Fox Hills	WASH SIEVE	Yes
SOIL DESCR.	RR Section	DRY SIEVE	No

Hydrometer #	ASTM 152 H	Temp., Deg. C	22.0
Sp. Gr. of Soil	2.73	Temp. Coef. K	0.01301
Value of "a"	0.98	Wt. Dry Sample "W"	74.659
Deflocculant	Sodium Hexametaphosphate	% of Total Sample	100.0
Defloc. Corr'n	5.0		
Meniscus Corr'n	-1.0		

T Elapsed Time (min)	Hydrometer Reading Original	Corrected "R"	100Ra/W	% Total Sample	Effecitve Depth L	Grain Diameter (mm)
0.0	--	--	--	--	--	--
0.5	33.00	27.00	35.6	35.6	10.88	0.0607
1.0	27.00	21.00	27.7	27.7	11.86	0.0448
2.0	25.00	19.00	25.0	25.0	12.19	0.0321
5.0	22.50	16.50	21.7	21.7	12.60	0.0207
15.0	20.00	14.00	18.5	18.5	13.01	0.0121
30.0	19.00	13.00	17.1	17.1	13.17	0.0086
60.0	17.50	11.50	15.2	15.2	13.42	0.0062
120.0	15.50	9.50	12.5	12.5	13.75	0.0044
250.0	14.00	8.00	10.5	10.5	13.99	0.0031
1440.0	12.00	6.00	7.9	7.9	14.32	0.0013

Grain Diameter = K*(SQRT(L/T))

ADVANCED TERRA TESTING, INC.

HYDROMETER ANALYSIS - SEDIMENTATION DATA

CLIENT ASI

JOB NO. 2081-03

BORING NO.	MV4-W	SAMPLED	--
DEPTH	--	DATE TESTED	10-30-91 SR
SAMPLE NO.	Fox Hills	WASH SIEVE	Yes
SOIL DESCR.	RFP - Clay Pit	DRY SIEVE	No

Hydrometer #	ASTM 152 H	Temp., Deg. C	22.5
Sp. Gr. of Soil	2.73	Temp. Coef. K	0.01294
Value of "a"	0.98	Wt. Dry Sample "W"	74.930
Deflocculant	Sodium Hexametaphosphate	% of Total Sample	100.0
Defloc. Corr'n	4.5		
Meniscus Corr'n	-1.0		

T Elapsed Time (min)	Hydrometer Reading Original	Corrected "R"	100Ra/W	% Total Sample	Effecitve Depth L	Grain Diameter (mm)
0.0	--	--	--	--	--	--
0.5	23.00	17.50	23.0	23.0	12.52	0.0647
1.0	20.00	14.50	19.0	19.0	13.01	0.0467
2.0	20.00	14.50	19.0	19.0	13.01	0.0330
5.0	18.00	12.50	16.4	16.4	13.34	0.0211
15.0	17.50	12.00	15.8	15.8	13.42	0.0122
30.0	17.25	11.75	15.4	15.4	13.46	0.0087
60.0	15.75	10.25	13.5	13.5	13.71	0.0062
120.0	14.50	9.00	11.8	11.8	13.91	0.0044
250.0	13.75	8.25	10.8	10.8	14.04	0.0031
1440.0	12.00	6.50	8.5	8.5	14.32	0.0013

Grain Diameter = K*(SQRT(L/T))

HYDROMETER ANALYSIS - SEDIMENTATION DATA

CLIENT ASI

JOB NO. 2081-03

BORING NO. MV38-N
DEPTH --
SAMPLE NO. Fox Hills
SOIL DESCR. Eggleston Reservoir

SAMPLED --
DATE TESTED 10-31-91 SR
WASH SIEVE Yes
DRY SIEVE No

Hydrometer # ASTM 152 H
Sp. Gr. of Soil 2.69
Value of "a" 0.99
Deflocculant Sodium Hexametaphosphate
Defloc. Corr'n 4.0
Meniscus Corr'n -1.0

Temp., Deg. C 22.5
Temp. Coef. K 0.01320
Wt. Dry Sample "W" 79.792
% of Total Sample 100.0

T Elapsed Time (min)	Hydrometer Reading Original	Corrected "R"	100Ra/W	% Total Sample	Effecitve Depth L	Grain Diameter (mm)
0.0	--	--	--	--	--	--
0.5	20.00	15.00	18.6	18.6	13.01	0.0673
1.0	19.75	14.75	18.3	18.3	13.05	0.0477
2.0	19.00	14.00	17.4	17.4	13.17	0.0339
5.0	17.00	12.00	14.9	14.9	13.50	0.0217
15.0	16.75	11.75	14.6	14.6	13.54	0.0125
30.0	16.25	11.25	14.0	14.0	13.63	0.0089
60.0	15.00	10.00	12.4	12.4	13.83	0.0063
120.0	13.25	8.25	10.3	10.3	14.12	0.0045
250.0	13.25	8.25	10.3	10.3	14.12	0.0031
1440.0	11.25	6.25	7.8	7.8	14.45	0.0013

Grain Diameter = K*(SQRT(L/T))

HYDROMETER ANALYSIS - SEDIMENTATION DATA

CLIENT	ASI	JOB NO.	2081-03
BORING NO.	KT33-N	SAMPLED	--
DEPTH	--	DATE TESTED	10-30-91 SR
SAMPLE NO.	U. Laramie	WASH SIEVE	Yes
SOIL DESCR.	Superior/Broomfield	DRY SIEVE	No

Hydrometer #	ASTM 152 H	Temp., Deg. C	22.5
Sp. Gr. of Soil	2.71	Temp. Coef. K	0.01301
Value of "a"	0.99	Wt. Dry Sample "W"	74.828
Deflocculant	Sodium Hexametaphosphate	% of Total Sample	100.0
Defloc. Corr'n	5.0		
Meniscus Corr'n	-1.0		

T Elapsed Time (min)	Hydrometer Reading Original	Corrected "R"	100Ra/W	% Total Sample	Effecitve Depth L	Grain Diameter (mm)
0.0	--	--	--	--	--	--
0.5	35.00	29.00	38.3	38.3	10.55	0.0598
1.0	27.75	21.75	28.7	28.7	11.74	0.0446
2.0	24.00	18.00	23.8	23.8	12.35	0.0323
5.0	20.50	14.50	19.1	19.1	12.93	0.0209
15.0	20.25	14.25	18.8	18.8	12.97	0.0121
30.0	18.25	12.25	16.2	16.2	13.30	0.0087
60.0	18.25	12.25	16.2	16.2	13.30	0.0061
120.0	17.00	11.00	14.5	14.5	13.50	0.0044
250.0	16.00	10.00	13.2	13.2	13.67	0.0030
1440.0	14.50	8.50	11.2	11.2	13.91	0.0013

Grain Diameter = K*(SQRT(L/T))

HYDROMETER ANALYSIS - SEDIMENTATION DATA

CLIENT	ASI	JOB NO.	2081-03
BORING NO.	KT60-N	SAMPLED	--
DEPTH	--	DATE TESTED	10-30-91 SR
SAMPLE NO.	U. Laramie	WASH SIEVE	Yes
SOIL DESCR.	McCaslin Blvd.	DRY SIEVE	No

Hydrometer #	ASTM 152 H	Temp., Deg. C	22.5
Sp. Gr. of Soil	2.73	Temp. Coef. K	0.01294
Value of "a"	0.98	Wt. Dry Sample "W"	79.915
Deflocculant	Sodium Hexametaphosphate	% of Total Sample	100.0
Defloc. Corr'n	4.5		
Meniscus Corr'n	-1.0		

T Elapsed Time (min)	Hydrometer Reading Original	Corrected "R"	100Ra/W	% Total Sample	Effecitve Depth L	Grain Diameter (mm)
0.0	--	--	--	--	--	--
0.5	14.00	8.50	10.5	10.5	13.99	0.0685
1.0	13.00	7.50	9.2	9.2	14.16	0.0487
2.0	12.00	6.50	8.0	8.0	14.32	0.0346
5.0	11.50	6.00	7.4	7.4	14.40	0.0220
15.0	11.00	5.50	6.8	6.8	14.49	0.0127
30.0	11.00	5.50	6.8	6.8	14.49	0.0090
60.0	10.50	5.00	6.2	6.2	14.57	0.0064
120.0	10.50	5.00	6.2	6.2	14.57	0.0045
250.0	10.25	4.75	5.8	5.8	14.61	0.0031
1440.0	9.00	3.50	4.3	4.3	14.81	0.0013

Grain Diameter = K*(SQRT(L/T))

ADVANCED TERRA TESTING, INC.

HYDROMETER ANALYSIS - SEDIMENTATION DATA

CLIENT	ASI	JOB NO.	2081-03
BORING NO.	KT61-N	SAMPLED	--
DEPTH	--	DATE TESTED	10-31-91 SR
SAMPLE NO.	U. Laramie	WASH SIEVE	Yes
SOIL DESCR.	McCaslin Blvd.	DRY SIEVE	No

Hydrometer #	ASTM 152 H	Temp., Deg. C	22.5
Sp. Gr. of Soil	2.71	Temp. Coef. K	0.01301
Value of "a"	0.99	Wt. Dry Sample "W"	79.909
Deflocculant	Sodium Hexametaphosphate	% of Total Sample	100.0
Defloc. Corr'n	4.0		
Meniscus Corr'n	-1.0		

T Elapsed Time (min)	Hydrometer Reading Original	Corrected "R"	100Ra/W	% Total Sample	Effecitve Depth L	Grain Diameter (mm)
0.0	--	--	--	--	--	--
0.5	20.00	15.00	18.5	18.5	13.01	0.0664
1.0	16.50	11.50	14.2	14.2	13.58	0.0480
2.0	15.00	10.00	12.4	12.4	13.83	0.0342
5.0	13.00	8.00	9.9	9.9	14.16	0.0219
15.0	13.00	8.00	9.9	9.9	14.16	0.0126
30.0	12.25	7.25	9.0	9.0	14.28	0.0090
60.0	11.00	6.00	7.4	7.4	14.49	0.0064
120.0	10.75	5.75	7.1	7.1	14.53	0.0045
250.0	10.25	5.25	6.5	6.5	14.61	0.0031
1440.0	9.00	4.00	4.9	4.9	14.81	0.0013

Grain Diameter = K*(SQRT(L/T))

ADVANCED TERRA TESTING, INC.

HYDROMETER ANALYSIS - SEDIMENTATION DATA

CLIENT ASI

JOB NO. 2081-03

BORING NO.	MV9-E	SAMPLED	--
DEPTH	--	DATE TESTED	10-30-91 SR
SAMPLE NO.	U. Laramie	WASH SIEVE	Yes
SOIL DESCR.	McCaslin Blvd.	DRY SIEVE	No

Hydrometer #	ASTM 152 H	Temp., Deg. C	22.5
Sp. Gr. of Soil	2.71	Temp. Coef. K	0.01301
Value of "a"	0.99	Wt. Dry Sample "W"	46.698
Deflocculant	Sodium Hexametaphosphate	% of Total Sample	100.0
Defloc. Corr'n	4.5		
Meniscus Corr'n	-1.0		

T Elapsed Time (min)	Hydrometer Reading Original	Hydrometer Reading Corrected "R"	100Ra/W	% Total Sample	Effecitve Depth L	Grain Diameter (mm)
0.0	--	--	--	--	--	--
0.5	50.00	44.50	94.1	94.1	8.09	0.0523
1.0	49.50	44.00	93.1	93.1	8.17	0.0372
2.0	49.00	43.50	92.0	92.0	8.25	0.0264
5.0	48.00	42.50	89.9	89.9	8.42	0.0169
15.0	45.50	40.00	84.6	84.6	8.83	0.0100
30.0	43.00	37.50	79.3	79.3	9.24	0.0072
60.0	40.00	34.50	73.0	73.0	9.73	0.0052
120.0	37.00	31.50	66.6	66.6	10.22	0.0038
250.0	34.00	28.50	60.3	60.3	10.71	0.0027
1440.0	27.00	21.50	45.5	45.5	11.86	0.0012

Grain Diameter = K*(SQRT(L/T))

ADVANCED TERRA TESTING, INC.

HYDROMETER ANALYSIS - SEDIMENTATION DATA

CLIENT ASI

JOB NO. 2081-03

BORING NO.	MV10-E	SAMPLED	--
DEPTH	--	DATE TESTED	10-30-91 SR
SAMPLE NO.	U. Laramie	WASH SIEVE	Yes
SOIL DESCR.	McCaslin Blvd.	DRY SIEVE	No

Hydrometer #	ASTM 152 H	Temp., Deg. C	22.5
Sp. Gr. of Soil	2.73	Temp. Coef. K	0.01294
Value of "a"	0.98	Wt. Dry Sample "W"	79.915
Deflocculant	Sodium Hexametaphosphate	% of Total Sample	100.0
Defloc. Corr'n	4.5		
Meniscus Corr'n	-1.0		

T Elapsed Time (min)	Hydrometer Reading Original	Corrected "R"	100Ra/W	% Total Sample	Effecitve Depth L	Grain Diameter (mm)
0.0	--	--	--	--	--	--
0.5	12.00	6.50	8.0	8.0	14.32	0.0693
1.0	11.50	6.00	7.4	7.4	14.40	0.0491
2.0	11.50	6.00	7.4	7.4	14.40	0.0347
5.0	11.00	5.50	6.8	6.8	14.49	0.0220
15.0	10.00	4.50	5.5	5.5	14.65	0.0128
30.0	10.00	4.50	5.5	5.5	14.65	0.0090
60.0	9.00	3.50	4.3	4.3	14.81	0.0064
120.0	8.50	3.00	3.7	3.7	14.90	0.0046
250.0	8.00	2.50	3.1	3.1	14.98	0.0032
1440.0	7.75	2.25	2.8	2.8	15.02	0.0013

Grain Diameter = K*(SQRT(L/T))

HYDROMETER ANALYSIS - SEDIMENTATION DATA

CLIENT ASI

JOB NO. 2081-03

BORING NO.	MV11-E	SAMPLED	--
DEPTH	--	DATE TESTED	10-31-91 SR
SAMPLE NO.	U. Laramie	WASH SIEVE	Yes
SOIL DESCR.	McCaslin Blvd.	DRY SIEVE	No

Hydrometer #	ASTM 152 H	Temp., Deg. C	22.5
Sp. Gr. of Soil	2.71	Temp. Coef. K	0.01301
Value of "a"	0.99	Wt. Dry Sample "W"	59.947
Deflocculant	Sodium Hexametaphosphate	% of Total Sample	100.0
Defloc. Corr'n	4.0		
Meniscus Corr'n	-1.0		

T Elapsed Time (min)	Hydrometer Reading Original	Corrected "R"	100Ra/W	% Total Sample	Effecitve Depth L	Grain Diameter (mm)
0.0	--	--	--	--	--	--
0.5	25.00	20.00	33.0	33.0	12.19	0.0642
1.0	18.50	13.50	22.2	22.2	13.26	0.0474
2.0	16.75	11.75	19.4	19.4	13.54	0.0339
5.0	14.25	9.25	15.2	15.2	13.95	0.0217
15.0	14.00	9.00	14.8	14.8	13.99	0.0126
30.0	13.00	8.00	13.2	13.2	14.16	0.0089
60.0	12.75	7.75	12.8	12.8	14.20	0.0063
120.0	11.75	6.75	11.1	11.1	14.36	0.0045
250.0	11.00	6.00	9.9	9.9	14.49	0.0031
1440.0	10.00	5.00	8.2	8.2	14.65	0.0013

Grain Diameter = K*(SQRT(L/T))

ADVANCED TERRA TESTING, INC.

HYDROMETER ANALYSIS - SEDIMENTATION DATA

CLIENT ASI

JOB NO. 2081-03

BORING NO.	KT32-W	SAMPLED	--
DEPTH	--	DATE TESTED	10-28-91 TNU
SAMPLE NO.	L. Laramie	WASH SIEVE	Yes
SOIL DESCR.	RR Section	DRY SIEVE	No

Hydrometer #	ASTM 152 H	Temp., Deg. C	22.0
Sp. Gr. of Soil	2.71	Temp. Coef. K	0.01308
Value of "a"	0.99	Wt. Dry Sample "W"	74.947
Deflocculant	Sodium Hexametaphosphate	% of Total Sample	100.0
Defloc. Corr'n	5.0		
Meniscus Corr'n	-1.0		

T Elapsed Time (min)	Hydrometer Reading Original	Corrected "R"	100Ra/W	% Total Sample	Effecitve Depth L	Grain Diameter (mm)
0.0	--	--	--	--	--	--
0.5	17.00	11.00	14.5	14.5	13.50	0.0680
1.0	15.00	9.00	11.9	11.9	13.83	0.0486
2.0	14.00	8.00	10.5	10.5	13.99	0.0346
5.0	13.00	7.00	9.2	9.2	14.16	0.0220
15.0	11.50	5.50	7.3	7.3	14.40	0.0128
30.0	10.50	4.50	5.9	5.9	14.57	0.0091
60.0	10.00	4.00	5.3	5.3	14.65	0.0065
120.0	9.00	3.00	4.0	4.0	14.81	0.0046
250.0	8.00	2.00	2.6	2.6	14.98	0.0032
1440.0	8.00	2.00	2.6	2.6	14.98	0.0013

Grain Diameter = K*(SQRT(L/T))

ADVANCED TERRA TESTING, INC.

HYDROMETER ANALYSIS - SEDIMENTATION DATA

CLIENT	ASI	JOB NO.	2081-03
BORING NO.	KT33-W	SAMPLED	--
DEPTH	--	DATE TESTED	10-29-91 SR
SAMPLE NO.	L. Laramie	WASH SIEVE	Yes
SOIL DESCR.	RR Section	DRY SIEVE	No

Hydrometer #	ASTM 152 H	Temp., Deg. C	22.5
Sp. Gr. of Soil	2.73	Temp. Coef. K	0.01294
Value of "a"	0.98	Wt. Dry Sample "W"	70.837
Deflocculant	Sodium Hexametaphosphate	% of Total Sample	100.0
Defloc. Corr'n	5.0		
Meniscus Corr'n	-1.0		

T Elapsed Time (min)	Hydrometer Reading Original	Corrected "R"	100Ra/W	% Total Sample	Effecitve Depth L	Grain Diameter (mm)
0.0	--	--	--	--	--	--
0.5	28.00	22.00	30.6	30.6	11.70	0.0626
1.0	25.25	19.25	26.7	26.7	12.15	0.0451
2.0	23.00	17.00	23.6	23.6	12.52	0.0324
5.0	20.75	14.75	20.5	20.5	12.89	0.0208
15.0	20.00	14.00	19.4	19.4	13.01	0.0121
30.0	18.75	12.75	17.7	17.7	13.22	0.0086
60.0	17.00	11.00	15.3	15.3	13.50	0.0061
120.0	16.00	10.00	13.9	13.9	13.67	0.0044
250.0	14.75	8.75	12.2	12.2	13.87	0.0030
1440.0	12.25	6.25	8.7	8.7	14.28	0.0013

Grain Diameter = K*(SQRT(L/T))

 ADVANCED TERRA TESTING, INC.

HYDROMETER ANALYSIS - SEDIMENTATION DATA

CLIENT	ASI	JOB NO.	2081-03
BORING NO.	KT35a-w	SAMPLED	--
DEPTH	--	DATE TESTED	10-29-91 SR
SAMPLE NO.	L Laramie	WASH SIEVE	Yes
SOIL DESCR.	RR Section	DRY SIEVE	No

Hydrometer #	ASTM 152 H	Temp., Deg. C	22.5
Sp. Gr. of Soil	2.69	Temp. Coef. K	0.01321
Value of "a"	0.99	Wt. Dry Sample "W"	82.666
Deflocculant	Sodium Hexametaphosphate	% of Total Sample	100.0
Defloc. Corr'n	5.0		
Meniscus Corr'n	-1.0		

T Elapsed Time (min)	Hydrometer Reading Original	Corrected "R"	100Ra/W	% Total Sample	Effecitve Depth L	Grain Diameter (mm)
0.0	--	--	--	--	--	--
0.5	11.50	5.50	6.6	6.6	14.40	0.0709
1.0	11.00	5.00	6.0	6.0	14.49	0.0503
2.0	10.00	4.00	4.8	4.8	14.65	0.0358
5.0	9.75	3.75	4.5	4.5	14.69	0.0226
15.0	9.50	3.50	4.2	4.2	14.73	0.0131
30.0	9.25	3.25	3.9	3.9	14.77	0.0093
60.0	9.00	3.00	3.6	3.6	14.81	0.0066
120.0	8.75	2.75	3.3	3.3	14.86	0.0046
250.0	8.00	2.00	2.4	2.4	14.98	0.0032
1440.0	8.00	2.00	2.4	2.4	14.98	0.0013

Grain Diameter = K*(SQRT(L/T))

ADVANCED TERRA TESTING, INC.

HYDROMETER ANALYSIS - SEDIMENTATION DATA

CLIENT	ASI	JOB NO.	2081-03
BORING NO.	KT35b-W	SAMPLED	--
DEPTH	--	DATE TESTED	10-31-91 SR
SAMPLE NO.	L. Laramie	WASH SIEVE	Yes
SOIL DESCR.	RR Section	DRY SIEVE	No

Hydrometer #	ASTM 152 H	Temp., Deg. C	22.5
Sp. Gr. of Soil	2.71	Temp. Coef. K	0.01301
Value of "a"	0.99	Wt. Dry Sample "W"	59.937
Deflocculant	Sodium Hexametaphosphate	% of Total Sample	100.0
Defloc. Corr'n	4.0		
Meniscus Corr'n	-1.0		

T Elapsed Time (min)	Hydrometer Reading Original	Corrected "R"	100Ra/W	% Total Sample	Effecitve Depth L	Grain Diameter (mm)
0.0	--	--	--	--	--	--
0.5	14.00	9.00	14.8	14.8	13.99	0.0688
1.0	13.00	8.00	13.2	13.2	14.16	0.0490
2.0	12.50	7.50	12.4	12.4	14.24	0.0347
5.0	12.25	7.25	12.0	12.0	14.28	0.0220
15.0	12.00	7.00	11.5	11.5	14.32	0.0127
30.0	11.50	6.50	10.7	10.7	14.40	0.0090
60.0	10.50	5.50	9.1	9.1	14.57	0.0064
120.0	10.00	5.00	8.2	8.2	14.65	0.0045
250.0	9.75	4.75	7.8	7.8	14.69	0.0032
1440.0	8.75	3.75	6.2	6.2	14.86	0.0013

Grain Diameter = K*(SQRT(L/T))

ADVANCED TERRA TESTING, INC.

HYDROMETER ANALYSIS - SEDIMENTATION DATA

CLIENT	ASI	JOB NO.	2081-03
BORING NO.	KT2-S	SAMPLED	--
DEPTH	--	DATE TESTED	10-30-91 SR
SAMPLE NO.	Arapahoe	WASH SIEVE	Yes
SOIL DESCR.	Barbara Gulch	DRY SIEVE	No

Hydrometer #	ASTM 152 H	Temp., Deg. C	22.5
Sp. Gr. of Soil	2.73	Temp. Coef. K	0.01294
Value of "a"	0.98	Wt. Dry Sample "W"	53.151
Deflocculant	Sodium Hexametaphosphate	% of Total Sample	100.0
Defloc. Corr'n	4.5		
Meniscus Corr'n	-1.0		

T Elapsed Time (min)	Hydrometer Reading Original	Corrected "R"	100Ra/W	% Total Sample	Effecitve Depth L	Grain Diameter (mm)
0.0	--	--	--	--	--	--
0.5	9.00	3.50	6.5	6.5	14.81	0.0704
1.0	8.75	3.25	6.0	6.0	14.86	0.0499
2.0	8.00	2.50	4.6	4.6	14.98	0.0354
5.0	8.00	2.50	4.6	4.6	14.98	0.0224
15.0	8.00	2.50	4.6	4.6	14.98	0.0129
30.0	7.75	2.25	4.2	4.2	15.02	0.0092
60.0	7.25	1.75	3.2	3.2	15.10	0.0065
120.0	7.25	1.75	3.2	3.2	15.10	0.0046
250.0	7.25	1.75	3.2	3.2	15.10	0.0032
1440.0	6.75	1.25	2.3	2.3	15.18	0.0013

Grain Diameter = K*(SQRT(L/T))

ADVANCED TERRA TESTING, INC.

HYDROMETER ANALYSIS - SEDIMENTATION DATA

CLIENT	ASI	JOB NO.	2081-03
BORING NO.	KT15-E	SAMPLED	--
DEPTH	--	DATE TESTED	10-28-91 TNU
SAMPLE NO.	Arapahoe	WASH SIEVE	Yes
SOIL DESCR.	RFP Protected Area	DRY SIEVE	No

Hydrometer #	ASTM 152 H	Temp., Deg. C	22.0
Sp. Gr. of Soil	2.71	Temp. Coef. K	0.01308
Value of "a"	0.99	Wt. Dry Sample "W"	79.947
Deflocculant	Sodium Hexametaphosphate	% of Total Sample	100.0
Defloc. Corr'n	5.0		
Meniscus Corr'n	-1.0		

T Elapsed Time (min)	Hydrometer Reading Original	Corrected "R"	100Ra/W	% Total Sample	Effecitve Depth L	Grain Diameter (mm)
0.0	--	--	--	--	--	--
0.5	14.00	8.00	9.9	9.9	13.99	0.0692
1.0	11.00	5.00	6.2	6.2	14.49	0.0498
2.0	11.00	5.00	6.2	6.2	14.49	0.0352
5.0	10.00	4.00	4.9	4.9	14.65	0.0224
15.0	9.50	3.50	4.3	4.3	14.73	0.0130
30.0	9.00	3.00	3.7	3.7	14.81	0.0092
60.0	9.00	3.00	3.7	3.7	14.81	0.0065
120.0	8.50	2.50	3.1	3.1	14.90	0.0046
250.0	8.00	2.00	2.5	2.5	14.98	0.0032
1440.0	8.00	2.00	2.5	2.5	14.98	0.0013

Grain Diameter = K*(SQRT(L/T))

HYDROMETER ANALYSIS - SEDIMENTATION DATA

CLIENT	ASI	JOB NO.	2081-03
BORING NO.	MV3-E	SAMPLED	--
DEPTH	--	DATE TESTED	10-29-91 SR
SAMPLE NO.	Arapahoe	WASH SIEVE	Yes
SOIL DESCR.	Standley Lake	DRY SIEVE	No

Hydrometer #	ASTM 152 H	Temp., Deg. C	22.5
Sp. Gr. of Soil	2.69	Temp. Coef. K	0.01321
Value of "a"	0.99	Wt. Dry Sample "W"	91.961
Deflocculant	Sodium Hexametaphosphate	% of Total Sample	100.0
Defloc. Corr'n	5.0		
Meniscus Corr'n	-1.0		

T Elapsed Time (min)	Hydrometer Reading Original	Corrected "R"	100Ra/W	% Total Sample	Effecitve Depth L	Grain Diameter (mm)
0.0	--	--	--	--	--	--
0.5	16.00	10.00	10.8	10.8	13.67	0.0691
1.0	15.50	9.50	10.2	10.2	13.75	0.0490
2.0	15.25	9.25	10.0	10.0	13.79	0.0347
5.0	15.00	9.00	9.7	9.7	13.83	0.0220
15.0	15.00	9.00	9.7	9.7	13.83	0.0127
30.0	14.00	8.00	8.6	8.6	13.99	0.0090
60.0	13.00	7.00	7.6	7.6	14.16	0.0064
120.0	11.75	5.75	6.2	6.2	14.36	0.0046
250.0	10.50	4.50	4.9	4.9	14.57	0.0032
1440.0	10.00	4.00	4.3	4.3	14.65	0.0013

Grain Diameter = K*(SQRT(L/T))

ADVANCED TERRA TESTING, INC.

HYDROMETER ANALYSIS - SEDIMENTATION DATA

CLIENT	ASI	JOB NO.	2081-03
BORING NO.	MV28-E	SAMPLED	--
DEPTH	--	DATE TESTED	10-30-91 SR
SAMPLE NO.	Arapahoe	WASH SIEVE	Yes
SOIL DESCR.	Indiana Street	DRY SIEVE	No

Hydrometer #	ASTM 152 H	Temp., Deg. C	22.5
Sp. Gr. of Soil	2.71	Temp. Coef. K	0.01301
Value of "a"	0.99	Wt. Dry Sample "W"	79.938
Deflocculant	Sodium Hexametaphosphate	% of Total Sample	100.0
Defloc. Corr'n	4.5		
Meniscus Corr'n	-1.0		

T Elapsed Time (min)	Hydrometer Reading Original	Corrected "R"	100Ra/W	% Total Sample	Effecitve Depth L	Grain Diameter (mm)
0.0	--	--	--	--	--	--
0.5	9.00	3.50	4.3	4.3	14.81	0.0708
1.0	8.25	2.75	3.4	3.4	14.94	0.0503
2.0	8.25	2.75	3.4	3.4	14.94	0.0356
5.0	7.75	2.25	2.8	2.8	15.02	0.0225
15.0	7.75	2.25	2.8	2.8	15.02	0.0130
30.0	7.75	2.25	2.8	2.8	15.02	0.0092
60.0	7.00	1.50	1.9	1.9	15.14	0.0065
120.0	6.50	1.00	1.2	1.2	15.22	0.0046
250.0	6.25	0.75	0.9	0.9	15.27	0.0032
1440.0	6.25	0.75	0.9	0.9	15.27	0.0013

Grain Diameter = K*(SQRT(L/T))

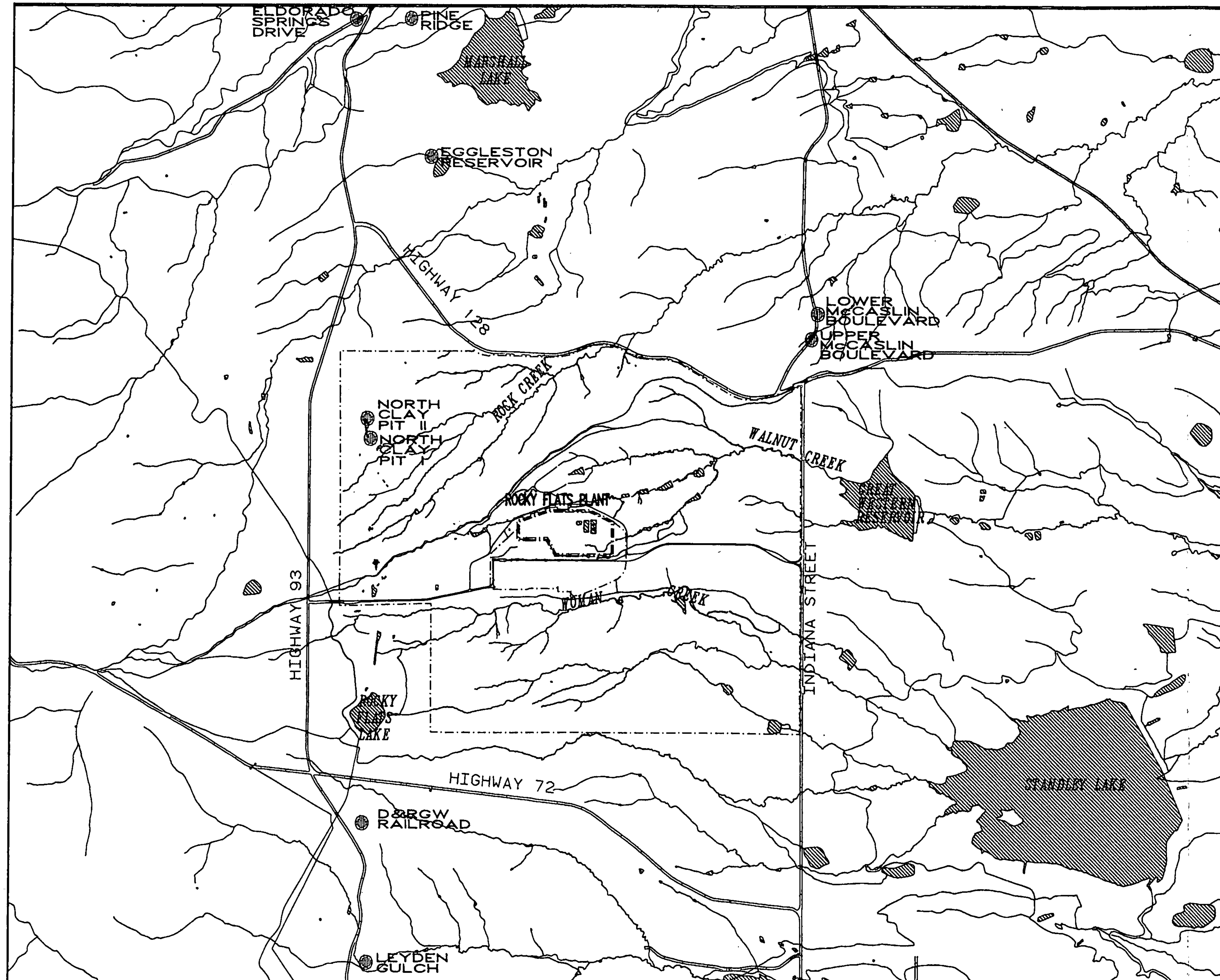
HYDROMETER ANALYSIS - SEDIMENTATION DATA

CLIENT	ASI	JOB NO.	2081-03
BORING NO.	MV69-N	SAMPLED	--
DEPTH	--	DATE TESTED	10-31-91 SR
SAMPLE NO.	Arapahoe	WASH SIEVE	Yes
SOIL DESCR.	RFP Buffer Zone	DRY SIEVE	No

Hydrometer #	ASTM 152 H	Temp., Deg. C	22.5
Sp. Gr. of Soil	2.69	Temp. Coef. K	0.01320
Value of "a"	0.99	Wt. Dry Sample "W"	79.971
Deflocculant	Sodium Hexametaphosphate	% of Total Sample	100.0
Defloc. Corr'n	4.0		
Meniscus Corr'n	-1.0		

T Elapsed Time (min)	Hydrometer Reading Original	Corrected "R"	100Ra/W	% Total Sample	Effecitve Depth L	Grain Diameter (mm)
0.0	--	--	--	--	--	--
0.5	8.00	3.00	3.7	3.7	14.98	0.0722
1.0	7.00	2.00	2.5	2.5	15.14	0.0514
2.0	7.00	2.00	2.5	2.5	15.14	0.0363
5.0	7.00	2.00	2.5	2.5	15.14	0.0230
15.0	7.00	2.00	2.5	2.5	15.14	0.0133
30.0	7.00	2.00	2.5	2.5	15.14	0.0094
60.0	6.75	1.75	2.2	2.2	15.18	0.0066
120.0	6.75	1.75	2.2	2.2	15.18	0.0047
250.0	6.25	1.25	1.6	1.6	15.27	0.0033
1440.0	6.25	1.25	1.6	1.6	15.27	0.0014

Grain Diameter = K*(SQRT(L/T))

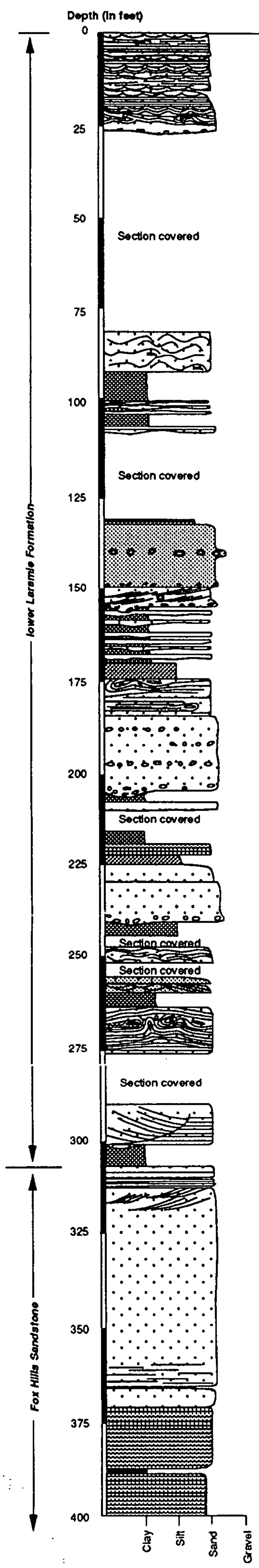


EG&G Rocky Flats, Inc.

Figure 1-2

MEASURED SECTION LOCATIONS

March, 1992



Lithologic Description	Sedimentary Structures
Yellowish-orange to light olive-gray, medium- to fine-grained sandstone and fine to very fine silty sandstone	Four distinct fining-upward sequences; planar bedding, ripple laminations, and convolute, soft-sediment deformation
Light olive-gray, very fine silty sandstone to fine-grained sandstone	Medium to thick beds and laminations draped over casts of plant material
Yellowish-gray silty claystone	
Yellowish-gray silty claystone with interfingering yellowish-brown very fine-grained sandstone; light olive-gray, fine- to medium-grained sandstone at base	Laminated sands with convoluted bedding; bases of sand beds are sharp, irregular boundaries; contains wood imprints and burrows; basal sand is a single bed with discontinuous laminations
Brownish-gray to light brown, very fine-grained silty sandstone	Very thin to thin planar laminations; dendritic manganese-oxide staining on some bedding planes
Light olive-gray to light brown, very fine-grained silty sandstone	Massive; contains 2-3 inch ironstone concretions
Llight olive-gray, very fine- to fine-grained sandstone; abundant siltstone rip-up clasts	Scour/erosional base; planar tangential cross-bedding
Six thin, light olive-gray, very fine- to fine-grained sandstones within pale red to brownish-gray silty claystone	Massive; sands contain ring-shaped iron stains at base; apparent moldic porosity
Brownish-gray siltstone	Massive
Light olive-gray to blackish-red, very fine- to fine-grained sandstone	Discontinuous planar to convolute bedding; some burrows, bedding-plane dissolution
Light olive-gray, medium- to fine-grained sandstone with claystone near base; calcite cement; abundant siltstone rip-up clasts	Massive; irregular scoured base
Dusky-red to medium-gray claystone	Massive
Red to brown to olive-gray, very fine- to fine-grained sandstone with interbedded siltstones	Thin, discontinuous planar bedding; wood imprints
Brownish-gray to light olive-gray sandy siltstone	
Light olive-gray, fine-grained sandstone	Fining-upward, massive; grades into overlying siltstone
Yellowish-orange, fine- to medium-grained sandstone; contains siltstone rip-up clasts	Erosional lower bounding surface; massive
Brownish-gray siltstone	
Light olive-gray, fine- to very fine-grained sandstone	Fining-upward sequence with thin to medium wavy bedding; leaf imprints
Light olive-gray, very fine-grained silty sandstone	Fining-upward, massive beds separated by silts; upper portion contains root casts, non-parallel planar bedding at base
Light brownish-gray silty claystone	
Yellowish-gray, very fine-grained sandstone	Medium-bedded to laminated; soft-sediment deformed convolute laminae; plant imprints
Yellowish-gray, very fine- to fine-grained friable sandstone	Parallel planar bedding and low-angle planar cross-bedding with erosional lower bounding surface
Olive-gray claystone	Massive; coarsening-upward
Light olive-gray, very fine- to fine-grained sandstone	Medium-bedded
Light olive-gray, very fine- to fine-grained sandstone in light brownish-gray claystone matrix	Sandstone lenses in fissile shale
Yellowish-gray, very fine- to fine-grained sandstone	Discontinuous planar beds near base; massive in center; tangential planar cross-bedding near top
Yellowish-gray, very fine- tofine-grained sandstone underlying a thin, light olive-gray clayey siltstone	Massive
Dusky-yellow, very fine- to fine-grained friable sandstone with some silt	Very thin to thin planar bedding; thin shale beds in lower 2 feet
Dusky-yellow, very fine-grained silty sandstone	Very thin-bedded to laminated; planar bedding

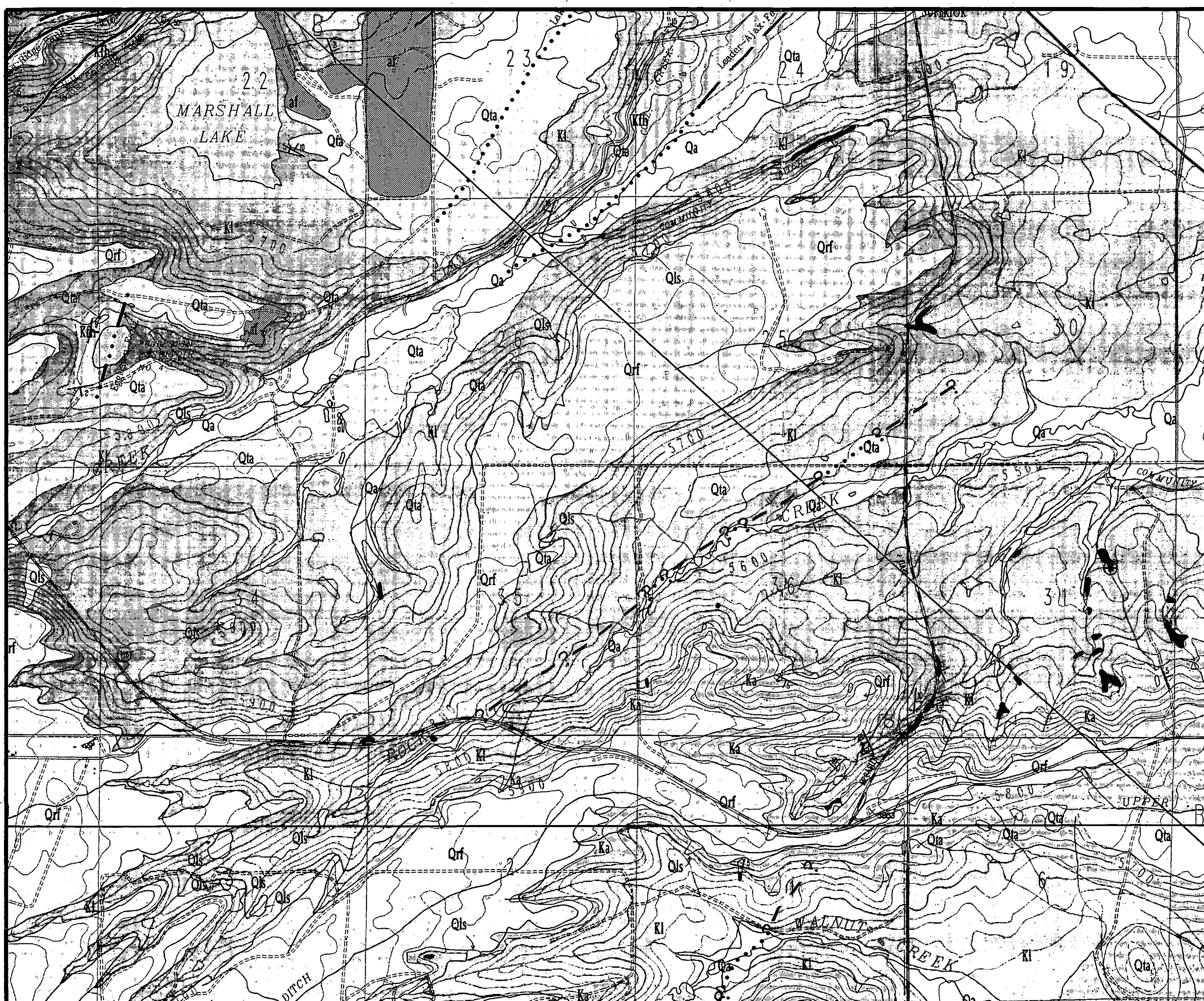
LEGEND

- Sandstone
- Sandstone with organic material and coal
- Sandstone with siltstone rip-up clasts
- Silty sandstone with ironstone concretions
- Silty sandstone
- Siltstone
- Claystone
- Coal

EG&G Rocky Flats Plant, Inc. March 1992

Figure 4-28

Denver & Rio Grande Western Railroad Measured Section



EXPLANATION

af	Artificial Fill (RECENT)
Qa	Valley Fill Alluvium (RECENT)
Qls	Landslide Slump (RECENT)
Qta	Undiff. Terrace Alluvium (PLEISTOCENE)
Qrf	Rocky Flats Alluvium (PLEISTOCENE)
Ka	Arapahoe Formation (CRETACEOUS)
Kl	Laramie Formation (CRETACEOUS)
Kfh	Fox Hills Sandstone (CRETACEOUS)
Kp	Pierre Shale (CRETACEOUS)

Strike and dip of bedding planes in bedrock

50 inclined — vertical — 20 overturned — horizontal

Gravel, sand, or clay pit — BM Benchmark

Area of bedrock exposure

Contact
dashed where approx. located;
dotted where concealed

Fault
dashed where approx. located;
dotted where concealed
U, upthrown side; D, downthrown side

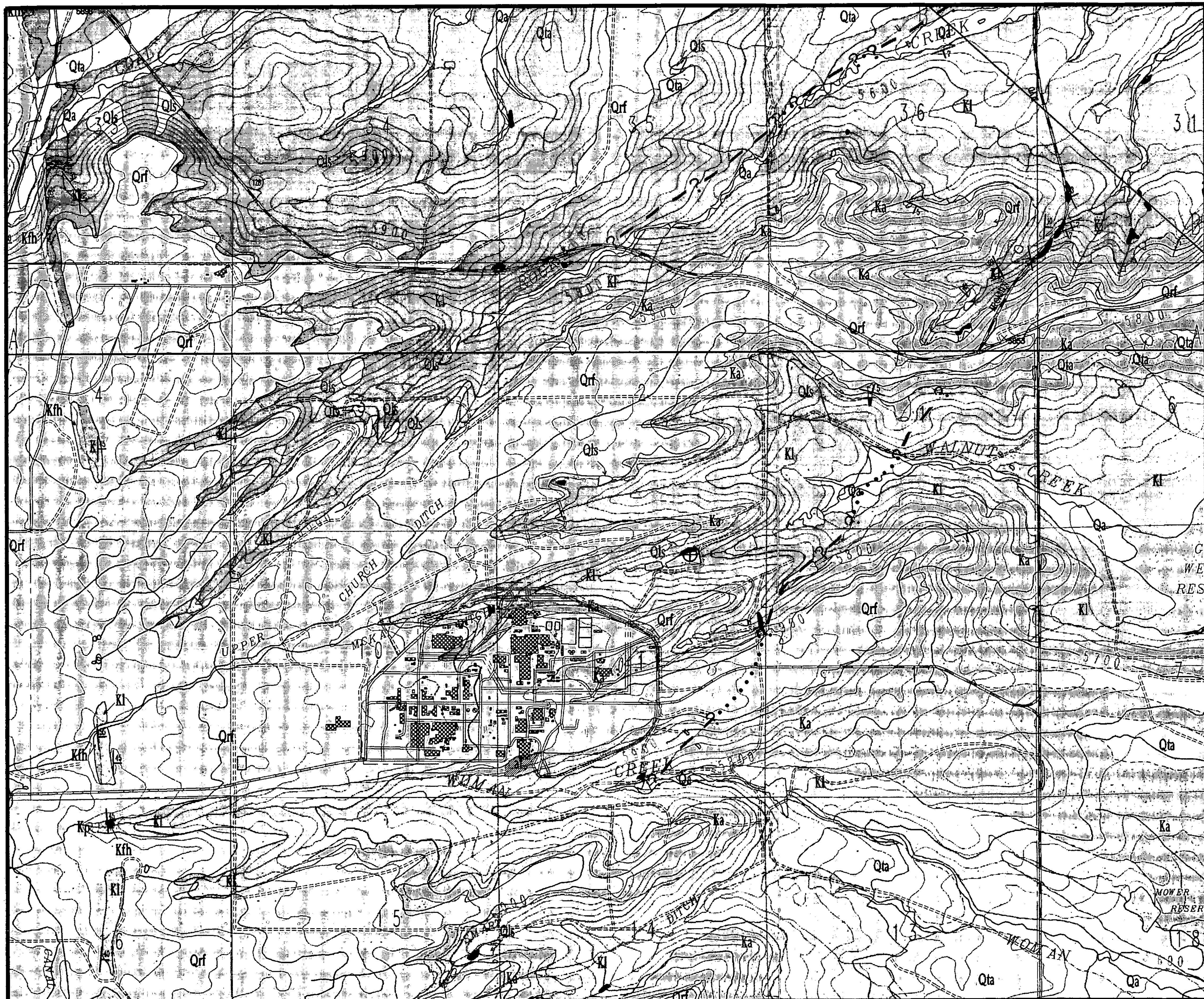
SCALE 1" = 2000'

2000' 0 2000'

E.G. & G. ROCKY FLATS, INC. MARCH, 1992

ROCK CREEK STRUCTURE

Figure 5 - 17



EXPLANATION

- af — Artificial Fill (RECENT)
- Qa — Valley Fill Alluvium (RECENT)
- Qls — Landslide Slump (RECENT)
- Qta — Undiff. Terrace Alluvium (PLEISTOCENE)
- Qrf — Rocky Flats Alluvium (PLEISTOCENE)
- Ka — Arapahoe Formation (CRETACEOUS)
- Kl — Laramie Formation (CRETACEOUS)
- Kfh — Fox Hills Sandstone (CRETACEOUS)
- Kp — Pierre Shale (CRETACEOUS)

Strike and dip of bedding planes in bedrock

50 inclined — vertical — 20 overturned — horizontal

Gravel, sand, or clay pit — BM Benchmark

Area of bedrock exposure

Contact
dashed where approx. located;
dotted where concealed

Fault
D
U
dashed where approx. located;
dotted where concealed
U, upthrown side; D, downthrown side

SCALE 1" = 2000'

2000' 0 2000'

N

E.G. & G. ROCKY FLATS, INC. MARCH, 1992

WALNUT CREEK STRUCTURE

Figure 5 - 18

Table A-3. Summary of Sample and Core Descriptions by Formation

	Elevation *	GRAIN SIZE							SORTING			ROUNDNESS					FROSTING		TEXTURAL MATURITY				ϕ	MATRIX		CEMENT					FRIABILITY				COMPOSITION															
		Very fine sand	Fine Sand	Medium Sand	Coarse Sand	Fine Pebble	Medium Pebble	Coarse Pebble	Well	Moderate	Poor	Angular	Subangular	Subrounded	Rounded	Well Rounded	No Frosted Grains	Frosted Grains	Immature	Submature	Mature	Supermature	Porosity	Silt	Clay	Silica	Calcite	Siderite	Pyrite	Clay	Highly	Moderately	Slightly	Non-Friable	Quartz	Feldspar	Chert	Metamorphic RF	Sedimentary RF	Volcanic RF	Carbonaceous Fragments	Ironstone	Biotite	Muscovite	Glauconite	Zircon	Tourmaline	Garnet	Magnetite	Thin Section
ARAPAHOE																																																		
Coarse Basal SS																																																		
KT 52-N	5730*		X	X	(X)	X					X		X	X	X	X		X	X				10	3	5		15				X				80	4	1	8	7										tr	
KT 56-N	5740		X	X	(X)	X	X	X			X		X	X	X	X		X	X					5	3		25	tr						X	55	2	5	10	10			18								X
KT 1-E	5535			X	(X)	X	X				X		X	X	X	X		X	X				10	3	5		15				X				80	5		8	7				tr	tr					tr	
KT 2-E	5535			X	(X)	X					X		X	X	X	X		X	X				10	3	5		15				X				78	5		8	7				2						tr	
MV 63-N	5445		X	X	(X)	X	X	X			X			X	X	X		X	X					6	7		20							X	75	tr	tr	8	7		tr	15								
MV 64-N	5445		X	X	(X)	X	X	X			X		X	X	X	X		X	X					3	5		25							X	78	tr		5	5		2	10								
MV 65-N	5435	X	X	(X)	X	X					X		X	X	X	X		X		X			5	5			23							X	93	2	4	1												X
MV 70-N	5670		X	X	(X)	X	X				X			X	X	X		X	X					6	7		20							X	78	1		5			1	15								
MV 71b-N	5660		X	X	(X)	X	X				X		X	X	X			X	X					6	7		20							X	70		5	8	7			10								
MV 73-N	5920*		X	X	(X)	X					X		X	X	X	X		X		X			5	3	2			23						X	80	1	10	5				4								X
MV 74-N	5920			X	(X)	X	X				X		X	X	X	X		X	X				5	3	8		15					X			84	tr	10	6												X
MV 3-E	5530			X	(X)	X					X		X	X	X	X		X	X				15	1	7		10				X				73	5	2	10	10				tr						tr	X
0987 BH (29.3)	5937		X	(X)	X	X	X	X			X			X	X	X		X		X			30	2	1										74	1	5		20							tr				X
0987 BH (30)	5936		X	(X)	X	X	X	X			X			X	X	X		X		X			30	1	2						X				85	tr	10		5											X
0987 BH (30.2)	5936		X	(X)	X					X				X	X	X		X		X			22	3	3			5							88	2	10									tr				X
3187 BR (128)	5817		X	(X)	X	X					X		X	X	X	X		X	X				15	8	10						X				90	1	3		3		3									X
3687 BR (45)	5904		X	(X)	X	X	X				X		X	X	X	X		X	X				5	8	20						X				80	tr	15		5											X
4287 BH (38.7)	5912		X	(X)	X					X	X			X	X	X		X			X		30	3	tr						X				90		8		2											X
5289(33.5)B217089	5877		X	(X)	X	X	X				X		X	X	X	X		X		X			25	5	3							X			92				8											X
5689(43)B217489	5918		X	(X)	X	X				X	X		X	X	X	X		X		X			30	2	1						X				82	1	10		7											X
Frosted Basal SS																																																		
KT 53-N	5730*		X	(X)	X					X			X	X	X	X		X		X			10	2	1		20							X	98	1		1												
KT 54-N	5775		X	(X)					X				X	X	X	X		X			X		15	3			15							X	98	1		1												
KT 55-N	5765*	X	X	(X)						X				X	X	X		X		X				5	3		25							X	98	1		1											tr	
KT 57-N	5740	X	X	(X)						X			X	X	X	X		X			X		10	3			20							X	98	1		1											tr	
KT 11-E	5810	X	(X)	X						X			X	X	X	X		X		X			20	5	3		5				X				92	2	4	1												X
MV 69-N	5780		X	(X)	X					X			X	X	X	X		X		X	X		20	3			10						X		97	2		1												
MV 71a-N	5660		X	(X)						X			X	X	X	X		X		X				5	3		25							X	97	tr	3	tr	tr										tr	
MV 28E	5640		X	(X)						X				X	X	X		X			X		30		3						X				96	tr	4	tr	tr											X
0386 BR (14.5)	5656	X	X	(X)						X				X	X	X		X		X			25	5	3						X				95	tr	1	2	2											X

RF = Rock Fragments; tr = trace amount (0-5%)

*elevations in feet, starred elevations refer to float samples.

◯ indicates grain size mode

Table A-3. Summary of Sample and Core Descriptions by Formation (continued)

Sample	Elevation *	Grain Size: Very fine sand	Fine Sand	Medium Sand	Coarse Sand	Fine Pebble	Medium Pebble	Coarse Pebble	Sorting: Well	Moderate	Poor	Roundness: Angular	Subangular	Subrounded	Rounded	Well Rounded	Frosting: No Frosted Grains	Frosted Grains	Textural Maturity: Immature	Submature	Mature	Supermature	ϕ Porosity
ARAPAHOE																							
Medium Grained SS																							
KT 50-N	5815		X	(X)						X			X	X	X	X		X			X		25
KT 2-5	6025		X	(X)					X				X	X	X	X		X			X		25
MV 67-N	5520		X	(X)						X			X	X			X			X			20
MV 2-S	5990		X	(X)	X					X			X	X			X			X			20
MV 3-S	5990		X	(X)						X			X	X	X			X	X				5
MV 5-S	6020		X	(X)	X					X			X	X			X			X			20
MV 1-E	5795	X	X	(X)						X			X	X	X		X			X			20
MV 2-E	5620		X	(X)					X	X			X	X	X			X			X		25
1387 BR (20.50)	5835	(X)	X	(X)							X		X	X	X			X	X				5
1487 BR (10.5)	5845	X	(X)							X			X	X			X		X	X			18
1487 BR (20)	5835	X	X	(X)						X			X	X	X	X		X	X	X			20
Fine Grained SS																							
KT 32-N	5410	(X)	X						X	X			X				X		X				15
KT 51-N	5815	X	(X)	X						X			X	X	X			X		X			
KT 1-S	5845	X	(X)							X			X	X			X			X			
KT 5-S	6085	X	(X)	X						X			X	X	X			X	X				15
KT 10-E	5935	X	(X)							X			X	X			X			X			15
KT 13-E	5935	X	(X)						X				X				X			X			2
6286 (55.3)	5842	X	(X)	X						X			X	X	X			X	X				10
0987 BH (20.3)	5946	X	(X)						X				X	X	X		X			X			30

Sample	Matrix: Silt	Clay	Cement: Silica	Calcite	Siderite	Pyrite	Clay	Friability: Highly	Moderately	Slightly	Non-Friable	Composition: Quartz	Feldspar	Chert	Metamorphic RF	Sedimentary RF	Volcanic RF	Carbonaceous Fragments	Ironstone	Biotite	Muscovite	Glauconite	Zircon	Tourmaline	Garnet	Magnetite	Thin Section
ARAPAHOE																											
Medium Grained SS																											
KT 50-N	8								X			98	tr	1		1										tr	
KT 2-5	5	3						X				98	tr		1	1											
MV 67-N	10	3								X		98	1	tr		1											
MV 2-S	3				10					X		94	2	2	1	1										tr	
MV 3-S	6	7		15							X	95	1	3		1					tr						X
MV 5-S	3				10					X		94	2	2	1	1											
MV 1-E	8			5				X	X			98	tr	1		1											
MV 2-E	8									X		98		tr	1	1										tr	
1387 BR (20.50)	15	10			3							91		6						3							X
1487 BR (10.5)	8	7										85	tr	10						5							X
1487 BR (20)	6	7										90			4	4				2							X
Fine Grained SS																											
KT 32-N	10	8								X		78	tr		1	1		20			tr						
KT 51-N	10	5		18							X	97	2			1					tr					tr	
KT 1-S	8	5		20							X	97	2	tr		1										tr	
KT 5-S	10	5		3						X		96	2		1	1					tr						
KT 10-E					18			X	X			62	8	25	2	3				tr							X
KT 13-E						30			X	X	X	85	3	12						tr							X
6286 (55.3)	10	13										88	3		4	4				1							X
0987 BH (20.3)	3											77	3	15	2	3			tr				tr				X

RF = Rock Fragments; tr = trace amount (0-5%)

* elevations in feet, starred elevations refer to float samples.

◯ indicates grain size mode

Table A-3. Summary of Sample and Core Descriptions by Formation (continued)

Sample	Elevation*	Grain Size: Very fine sand	Grain Size: Fine Sand	Grain Size: Medium Sand	Grain Size: Coarse Sand	Grain Size: Fine Pebble	Grain Size: Medium Pebble	Grain Size: Coarse Pebble	Sorting: Well	Sorting: Moderate	Sorting: Poor	Roundness: Angular	Roundness: Subangular	Roundness: Subrounded	Roundness: Rounded	Roundness: Well Rounded	Frosting: No Frosted Grains	Frosting: Frosted Grains	Textural Maturity: Immature	Textural Maturity: Submature	Textural Maturity: Mature	Textural Maturity: Supermature	Porosity
UPPER LARAMIE																							
Medium Grained SS																							
KT 31-N	5560	X	X	(X)						X			X	X	X	X		X		X			10
KT 58-N	6505	X	X	(X)						X			X	X			X			X			5
KT 60-N	5645		X	(X)	X	X	X				X		X	X	X			X		X			25
KT 61-N	5645	X	X	(X)						X			X	X	X		X			X			5
KT 6-S	5855	X	X	(X)						X			X	X	X			X		X			15
KT 8-S	6160		X	(X)						X			X	X	X		X			X			20
Fine Grained SS																							
KT 33-N	5355	X	(X)						X				X				X		X				15
KT 34-N	5885	X	(X)	X						X			X	X			X			X			10
MV 1-S	5860	(X)	X						X				X				X			X			20
MV 4-S	5910	(X)	X						X				X	X			X			X			10
0987 BH (33.0)	5933	X	(X)						X				X				X		X				10
1687 BR (137)	5832	X	(X)						X			X	X				X		X				20
1887 BR (112)	5855	X	(X)						X			X	X				X		X				12
3287 BH (9.7)	5962	X	(X)	X						X			X	X			X		X				5
3387 BH (14.8)	5953	(X)	X	X						X			X	X			X		X				15
4287 BH (55)	5896	X	(X)	X						X			X	X	X	X	X		X				15
4587 BH (23.8)	5929	X	(X)						X				X				X		X				20

Sample	Matrix: Silt	Matrix: Clay	Cement: Silica	Cement: Calcite	Cement: Siderite	Cement: Pyrite	Cement: Clay	Friability: Highly	Friability: Moderately	Friability: Slightly	Friability: Non-Friable	Quartz	Feldspar	Chert	Metamorphic RF	Sedimentary RF	Volcanic RF	Carbonaceous Fragments	Ironstone	Biotite	Muscovite	Glauconite	Zircon	Tourmaline	Garnet	Magnetite	Thin Section
UPPER LARAMIE																											
Medium Grained SS																											
KT 31-N	5	3		15							X	98	1		1											tr	
KT 58-N	8	5		15							X	97	2		1					tr						tr	
KT 60-N	5	3							X			85	1	6	3	2		3								tr	X
KT 61-N	10	3		20							X	92	1	5	1	1		tr			tr						X
KT 6-S	5	3		10						X		95	2	1	1	1										tr	
KT 8-S	5	3	5								X	92	3		3	2											
Fine Grained SS																											
KT 33-N	12	6							X			94	1		2	1		2								tr	X
KT 34-N	5	3		15					X			98			1			1			tr						
MV 1-S	5	3		5					X			94	2					3		1		?					
MV 4-S	5	3		15							X	93	1		2			2		2							
0987 BH (33.0)	8	15										90	1		3	2		tr			4		tr				X
1687 BR (137)	8	5								X		90	tr	5	2	1				tr							X
1887 BR (112)	3	5		13						X		83	1	7	2	1		5		1							X
3287 BH (9.7)	10	18										90	2		3	3					2						X
3387 BH (14.8)		15			3							85		3	3	2				7							X
4287 BH (55)	5	13										90	2	3	3	2				tr							X
4587 BH (23.8)	tr	13										85	2	8	2					3							X

RF = Rock Fragments; tr = trace amount (0-5%)

* elevations in feet, starred elevations refer to float samples.

(X) ○ indicates grain size mode

Table A-3. Summary of Sample and Core Descriptions by Formation (continued)

	GRAIN SIZE								SORTING			ROUNDNESS					FROSTING		TEXTURAL MATURITY				ϕ
	Elevation *	Very fine sand	Fine Sand	Medium Sand	Coarse Sand	Fine Pebble	Medium Pebble	Coarse Pebble	Well	Moderate	Poor	Angular	Subangular	Subrounded	Rounded	Well Rounded		Frosted Grains	Immature	Submature	Mature	Supermature	Porosity
LOWER LARAMIE																							
KT 15-N	5715	(X)							X				X				X		X				10
KT 1-W	6130	(X)	X						X	X			X				X		X				
KT 2-W	6140	X	X	(X)	X						X		X	X	X		X			X			5
KT 3-W	6140	X	X	(X)						X			X	X			X			X			10
KT 6-W	6070	X	(X)							X			X	X			X			X			5
KT 10-W	6070	X	(X)						X	X			X				X			X	X		5
KT 11-W	6080	(X)	X						X	X			X				X			X	X		5
KT 12-W	6080	(X)							X				X				X		X				
KT 13-W	6085	X	X	(X)						X			X	X			X		X				20
KT 14-W	5925	X	X	(X)						X			X	X	X		X			X			10
KT 15-W	5925	X	X	(X)						X			X	X			X			X			15
KT 16-W	5925	X	(X)	X						X			X	X			X			X			10
KT 17-W	5925	X	(X)							X			X	X	X		X			X			10
MV 2-N	5570	X	(X)	X						X			X	X			X			X			15
MV 3-N	5590	X	(X)	X						X			X	X			X			X			20
MV 12-N	5650	X	(X)						X	X			X	X	X		X			X			20
MV 21-N	5670	(X)	X							X			X				X			X			20
MV 46-N	5660	X	X	(X)						X			X	X			X			X			
MV 50-N	5730	(X)	X						X				X	X			X		X				15
MV 1-W	6140	X	X	(X)						X			X	X			X			X			5
MV 2-W	6140	X	X	(X)						X			X	X	X		X			X			5
MV 3-W	6080	(X)	X							X			X	X			X			X			
MV 5-W	6150	(X)	X						X	X			X				X		X				
MV 6-W	6150	X	(X)	X						X			X	X			X			X			5
MV 7-W	6150	X	(X)	X	X	X	X	X		X	X		X	X			X		X				
MV 14-W	5930		X	(X)	X					X			X	X	X		X			X			20
MV 16-W	5930	(X)	X	X						X			X				X		X				
MV 17-W	5930	(X)	X						X	X			X				X		X				5
MV 18-W	5930	X	(X)	X						X			X				X		X				

	MATRIX		CEMENT					FRIABILITY				COMPOSITION															
	Silt	Clay	Silica	Calcite	Siderite	Pyrite	Clay	Highly	Moderately	Slightly	Non-Friable	Quartz	Feldspar	Chert	Metamorphic RF	Sedimentary RF	Volcanic RF	Carbonaceous Fragments	Ironstone	Biotite	Muscovite	Glauconite	Zircon	Tourmaline	Garnet	Magnetite	Thin Section
LOWER LARAMIE																											
KT 15-N	15	8	tr								X	97	1		2			tr			tr						
KT 1-W	15	13	5								X	97	1					2			tr						
KT 2-W	5	3	20								X	95	2			3										tr	
KT 3-W	5	3	15								X	95	1	1		3					tr						
KT 6-W	5	3	20								X	93	2		3	2		tr								tr	
KT 10-W	5	3	20							X		98	1		1						tr					tr	
KT 11-W	5	3	20								X	97	1		2												
KT 12-W	15	8	10								X	99	tr		1												
KT 13-W	8	5							X			75	1	2	2	20					tr		tr				X
KT 14-W	10	3	10								X	95	1	1		3					tr						
KT 15-W	5	3	10							X		94	2			4		tr			tr						
KT 16-W	10	3	10							X		92	3		3	2		tr					?			tr	
KT 17-W	10	3	10							X		92	2		2	1		3								tr	
MV 2-N	10	3	5							X		94	2		2	1		1			tr						
MV 3-N	3		10						X			97	1		2						tr						
MV 12-N	5	3	5						X			97	1		2			tr		tr				?			
MV 21-N	10	3							X			96	1		1			2			tr						
MV 46-N	10	3	20								X	96	tr	2	2			tr									X
MV 50-N	10	8								X		98		1	1												
MV 1-W	5	3	20								X	92	3	tr	3	2					tr						
MV 2-W	5	3	20								X	97		2	1						tr					tr	
MV 3-W	10	3	20								X	98	1		1			tr	tr								
MV 5-W	15	8	10								X	94		3	2	1					tr						X
MV 6-W	5	3	20								X	97	1	tr	2						tr						
MV 7-W	7	6	20								X	80	1		1	18											
MV 14-W	5	3	5							X		95	1		2			2									
MV 16-W	7	6	20								X	98	tr					2			tr						
MV 17-W	7	6	15								X	96			1			2		1	tr						
MV 18-W	10	13	10								X	98	1								1						

RF = Rock Fragments; tr = trace amount (0-5%)

* elevations in feet, starred elevations refer to float samples.

◯ indicates grain size mode

Table A-3. Summary of Sample and Core Descriptions by Formation (continued)

	Elevation *	GRAIN SIZE: Very fine sand	Fine Sand	Medium Sand	Coarse Sand	Fine Pebble	Medium Pebble	Coarse Pebble	SORTING: Well	Moderate	Poor	ROUNDNESS: Angular	Subangular	Subrounded	Rounded	Well Rounded	FROSTING: No Frosted Grains	Frosted Grains
FOX HILLS																		
KT 4a-N	5575	X	(X)	X						X			X	X			X	
KT 18-N	5930	X	(X)	X						X			X	X	X		X	
KT 22-N	5530	X	(X)	X						X			X	X	X		X	
KT 23-N	5530	X	X	(X)						X		X	X	X			X	
KT 24-N	5540	X	(X)	X						X			X	X	X		X	
KT 25-N	5550	X	(X)	X						X		X	X	X			X	
KT 26-N	5555	X	(X)	X						X			X	X	X		X	
KT 28-N	5560	X	(X)						X				X	X			X	
KT 29-N	5560	X	(X)	X						X			X	X	X		X	
MV 4-N	5600	X	(X)	X						X		X	X	X			X	
MV 5-N	5600	X	(X)	X						X			X	X	X		X	
MV 6-N	5600	X	(X)	X						X		X	X	X			X	
MV 37-N	5840	X	(X)						X				X	X			X	
MV 38-N	5840	X	(X)						X				X	X			X	
MV 39-N	5840	X	(X)	X						X			X	X	X		X	
MV 4-W	6080	X	(X)						X				X	X			X	
MV 8-W	6140	X	(X)	X						X			X	X	X		X	

	TEXTURAL MATURITY: Immature	Submature	Mature	Supermature	ϕ Porosity	MATRIX: Silt	Clay	CEMENT: Silica	Calcite	Siderite	Pyrite	Clay	FRIABILITY: Highly	Moderately	Slightly	Non-Friable
FOX HILLS																
KT 4a-N		X			20	10	3								X	
KT 18-N	X				15	10	8							X		
KT 22-N	X				20	8	5						X			
KT 23-N	X				5	14	14							X		
KT 24-N		X			20	10	3							X		
KT 25-N		X			20	10	3							X		
KT 26-N	X				20	7	6							X		
KT 28-N		X			20	10	3								X	
KT 29-N		X			25	6	2						X			
MV 4-N		X			20	10	3								X	
MV 5-N	X				15	10	8							X		
MV 6-N		X			10	15	5	3						X		
MV 37-N		X			25	6	2						X			
MV 38-N		X			25	6	2						X			
MV 39-N		X			25	6	2						X			
MV 4-W	X					20	8	5								X
MV 8-W	X				15	10	8							X		

	COMPOSITION: Quartz	Feldspar	Chert	Metamorphic RF	Sedimentary RF	Volcanic RF	Carbonaceous Fragments	Ironstone	Biotite	Muscovite	Glauconite	Zircon	Tourmaline	Garnet	Magnetite	Thin Section
FOX HILLS																
KT 4a-N	85	tr	4	5	5				1							
KT 18-N	90	tr	3	4	3				tr	tr	tr					
KT 22-N	85	tr	5	5	5				tr		tr	?				
KT 23-N	80		5	3	2		10		tr							
KT 24-N	85		10	3	2				tr	tr			?			
KT 25-N	85	1	3	5	5				1		tr					
KT 26-N	85	1	10	2	2				tr							
KT 28-N	90	tr	4	3	3		tr			tr						
KT 29-N	90	tr	3	4	3				tr	tr	tr	?				
MV 4-N	80	1	5	5	5				3		1					X
MV 5-N	85	2	3	5	5				tr		tr	tr				
MV 6-N	88	2	4	.3	3				tr		tr					X
MV 37-N	85	1	2	5	5				1	1	tr	?				
MV 38-N	90	tr	4	3	3				tr	tr						
MV 39-N	90	1	3	3	2		tr		1		tr					
MV 4-W	90		1	4	3						2		tr	tr		
MV 8-W	90	tr	3	4	3					tr	tr					

RF = Rock Fragments; tr = trace amount (0-5%)

* elevations in feet, starred elevations refer to float samples.

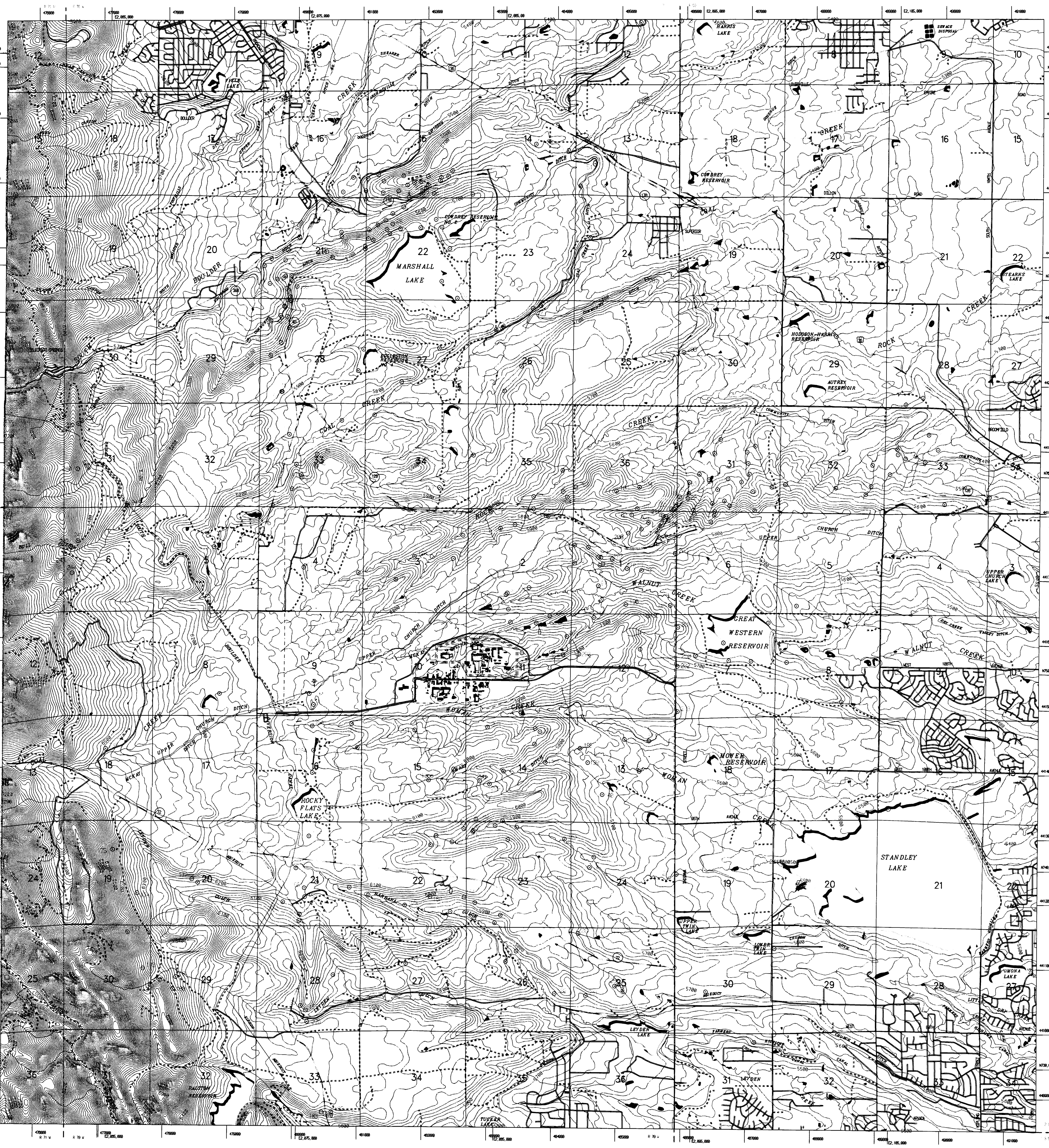
◯ indicates grain size mode

E.G. & G. ROCKY FLATS, INC. MARCH, 1992

Figure 5-2

Cross-Section B - B'

SW-A-000307



EXPLANATION

- STREAMS, DITCHES, DRAINAGE FEATURES
- HEAVY-DUTY ROADS
- MEDIUM-DUTY ROADS
- LIGHT-DUTY ROADS
- UNIMPROVED DIRT ROADS
- RFP BOUNDARY AND PROTECTED AREA
- SURFACE WATER IMPOUNDMENTS
- RFP BUILDINGS
- ⊙ STATION LOCATIONS

CONTOUR INTERVAL = 20 FEET

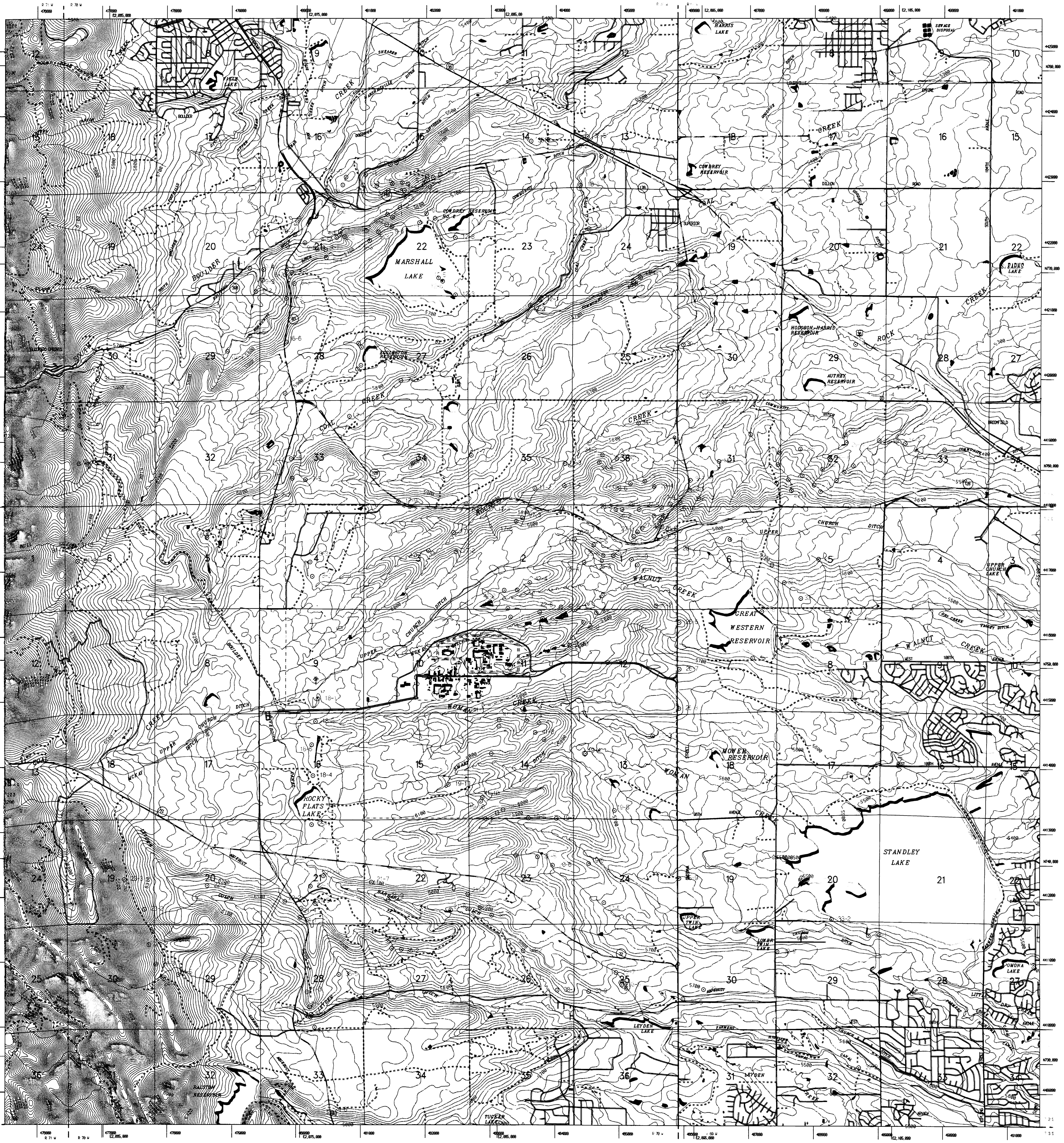
EG&G Rocky Flats, Inc.

STATION LOCATION MAP

PLATE B11

March, 1992

SW-A-000307



EXPLANATION

- STREAMS, DITCHES, DRAINAGE FEATURES
- HEAVY-DUTY ROADS
- MEDIUM-DUTY ROADS
- LIGHT-DUTY ROADS
- UNIMPROVED DIRT ROADS
- RFP BOUNDARY AND PROTECTED AREA
- SURFACE WATER IMPOUNDMENTS
- RFP BUILDINGS
- ⊙ STATION LOCATIONS

0 feet 2000 4000 8000

CONTOUR INTERVAL = 20 FEET

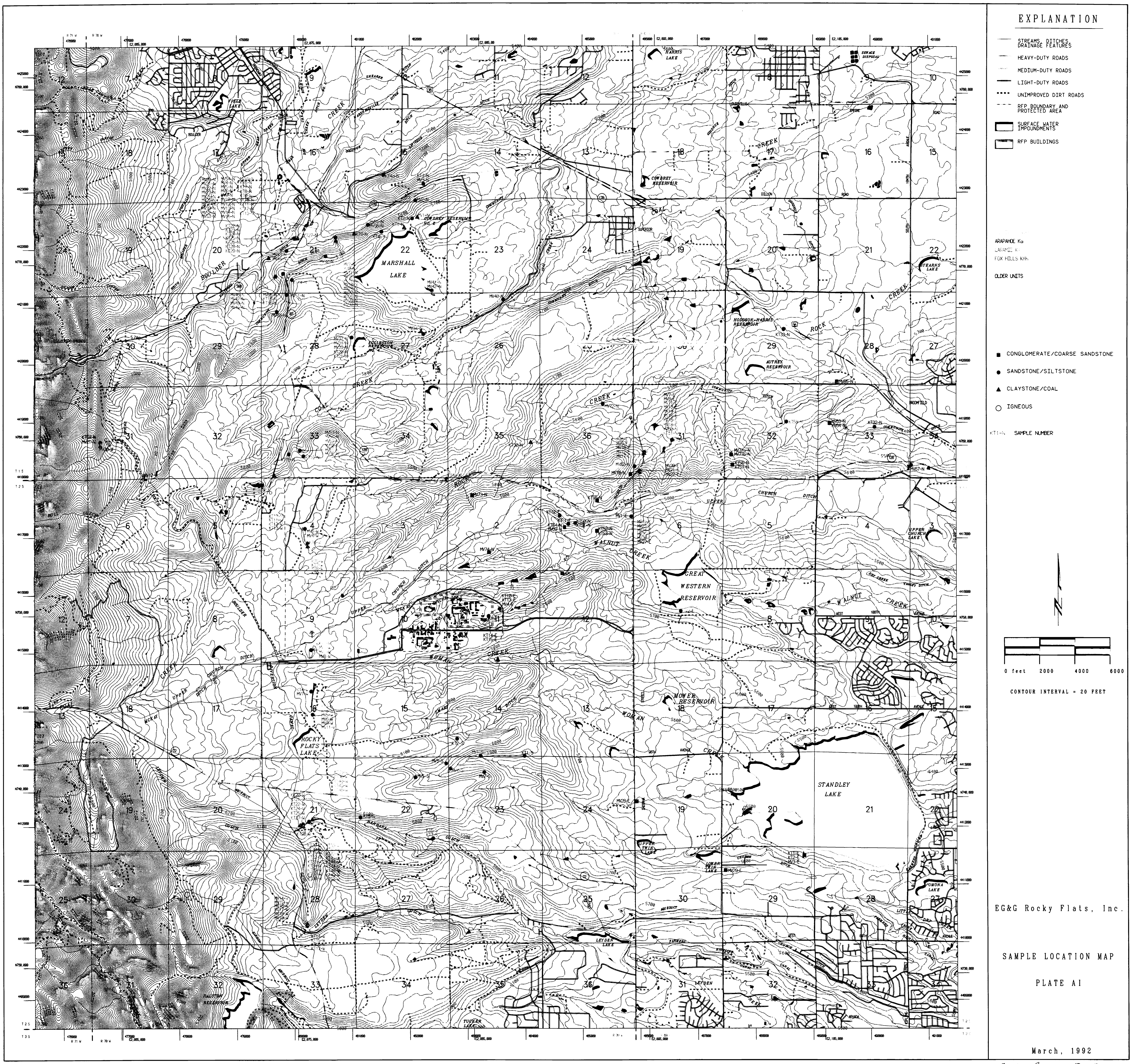
EG&G Rocky Flats, Inc.

STATION LOCATION MAP

PLATE B1

March, 1992

SW-A-000307


EXPLANATION
STREAMS, DITCHES, DRAINAGE FEATURES
HEAVY-DUTY ROADS
MEDIUM-DUTY ROADS
LIGHT-DUTY ROADS
UNIMPROVED DIRT ROADS
RFP BOUNDARY AND PROTECTED AREA
SURFACE WATER IMPOUNDMENTS
RFP BUILDINGS
ARAPAHOE Ka
LARAMIE Kl
FOX HILLS Kfh
OLDER UNITS
CONGLOMERATE/COARSE SANDSTONE
SANDSTONE/SILTSTONE
CLAYSTONE/COAL
IGNEOUS
SAMPLE NUMBER
0 feet 2000 4000 6000
CONTOUR INTERVAL = 20 FEET
MARSHALL LAKE
GREAT WESTERN RESERVOIR
STANDLEY LAKE
ROCKY FLATS LAKE
MOWER RESERVOIR
WALNUT CREEK
WOMAN CREEK
COAL CREEK
BOULDER
EG&G Rocky Flats, Inc.
SAMPLE LOCATION MAP
PLATE A1
March, 1992
SW-A-000307

EXPLANATION

SURFICIAL DEPOSITS

QUATERNARY

RECENT
- af — artificial fill

UNCONFORMITY

- Qa — Valley-fill alluvium
- Qaf — Alluvial fan
- Qls — Landslide, slump

UNCONFORMITY

PLEISTOCENE
- Qta — Undifferentiated Terrace Alluvium includes Broadway, Louviers, Slocum and Verdos Alluvium

UNCONFORMITY

- Qrf — Rocky Flats Alluvium

UNCONFORMITY

PLEISTOCENE (?)
- Qpr — Pre-Rocky Flats Alluvium

ANGULAR UNCONFORMITY

IGNEOUS ROCKS

CRETACEOUS OR (?) TERTIARY — TERTIARY
- TKi — Alkali basalt intrusion

SEDIMENTARY ROCKS

CRETACEOUS

UPPER CRETACEOUS
- Ka — Arapahoe Formation
- Kl — Laramie Formation
- Kfh — Fox Hills Sandstone
- Kp — Pierre Shale
- Kn — Niobrara Formation includes Smokey Hill Shale member and Fort Hayes Limestone member

UNCONFORMITY

LOWER CRETACEOUS
- Kb — Benton Shale
- Dakota Group

JURASSIC

UNCONFORMITY

UPPER JURASSIC
- Jm — Morrison Formation

UNCONFORMITY

- Jrc — Ralston Creek Formation

PERMIAN AND TRIASSIC (?)

UNCONFORMITY

- TrPl — Lykins Formation

PERMIAN

UNCONFORMITY

- Ply — Lyons Sandstone

PENNSYLVANIAN AND PERMIAN

UNCONFORMITY

- PPf — Fountain Formation

ANGULAR UNCONFORMITY

PRECAMBRIAN
- pC — Undivided, interlayered gneisses and mica schist

MAP SYMBOLS

Contact

dashed where approximately located; dotted where concealed

Fault: showing dip

dashed where approximately located, dotted where concealed. U, upthrown side, D, downthrown side

inclined — vertical — overturned — horizontal

Strike and dip of bedding planes in bedrock

Area of bedrock exposure

Gravel, sand, or clay pit

ROAD CLASSIFICATION
- Heavy-duty
- Medium-duty
- Light-duty
- Unimproved dirt
- Trails

Buildings

PLATE 1

FINAL

GEOLOGIC MAP OF ROCKY FLATS PLANT AND VICINITY
JEFFERSON AND BOULDER COUNTIES, COLORADO

March, 1992

Prepared for EG. & G. Rocky Flats, Inc.

SCALE 1:24000

(1 inch = 2000 feet)

0 1000 2000 3000 4000 FEET

Projection: UTM Zone 13

CONTOUR INTERVAL 20 FEET

SW-A-000307

E.G. & G. ROCKY FLATS, INC. MARCH, 1992

Figure 5-1

Cross-Section A - A'

SW-A-000307