U.S. DEPARTMENT OF THE INTERIOR

U.S. GEOLOGICAL SURVEY

Measured Section of the Pennsylvanian Hermosa Group Near Ouray, Colorado

by

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Open-File Report 93-712

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Introduction

A comprehensive study of the Paradox Basin, located in southeastern Utah and southwestern Colorado, is being conducted from 1989-1994 under the U.S. Geological Survey's Evolution of Sedimentary Basins Program. As part of the investigation of the Pennsylvanian System in the Paradox Basin, sections were measured in detail at various locations along the Pennsylvanian outcrop belt in southwestern Colorado. These sections were measured to establish better correlations between outcrops of Pennsylvanian strata in the area that formed the active, eastern, basin margin of the Pennsylvanian Paradox Basin; to establish better correlations from the eastern margin to the center of the basin; and to better define depositional processes on the basin's active margin. This report shows the measured section of the Pennsylvanian Molas Formation and Hermosa Group at Ouray, Colorado (fig. 1). Open-File Report 92-689 (Franczyk, 1992) contains the detailed measured section of the Hermosa Group at Hermosa Mountain, which is about 20 km (12 mi) north of Durango, Colorado (fig. 1).

The Pennsylvanian rocks in the Ouray, Colorado, area are the most northern exposures, and the most proximal to the Uncompahgre uplift, of Pennsylvanian outcrops along the area that formed the southeastern margin of the Pennsylvanian Paradox Basin. South of Ouray erosion has removed Paleozoic rocks for a distance of 32 km (20 mi). Pennyslvanian rocks crop out again south of Silverton, Colorado, and form a continuous outcrop belt southward to the Hermosa Mountain area. Extensive vegetation cover, talus deposits, and local glacial deposits prohibit detailed correlations and resolution of lithofacies geometries along this outcrop belt.

There are no published measured sections of Pennsylvanian strata at Ouray. However, Fetzner (1960) and Wengerd and Strickland (1954) used their unpublished measured sections at Ouray as data points in isopach maps and cross sections; both workers recorded about 305 m (1000 ft) of Pennsylvanian rock. Luedke and Burbank (1962) mapped the Ouray Quadrangle and, based on structural cross sections, estimated 442 m (1450 ft) of Pennsylvanian strata. The measured section of this report shows 305 m (1000 ft) inclusive of both the Pennsylvanian Molas Formation and Hermosa Group. The Triassic Dolores Formation unconformably overlies the Hermosa Group at the measured section locality. This unconformity rises stratigraphically to the north, and an additional 60-120 m (200-400 ft) of Hermosa Group may be present north of the measured section location.

This report presents the lithologic descriptions, macroscopic observations, and interpretations of depositional environments from the Ouray measured section. The format used here enables more detail to be shown than would be possible in a standard manuscript figure or appendix. Ongoing studies of clastic and carbonate petrography and of brachiopod assemblages from this measured section will be integrated with similar outcrop data from other localities and compiled in future reports.

Methods

The Ouray measured section (fig.1), located on the Ouray 7.5 minute quadrangle map (Ouray County, Colorado), is comprised of two segments (fig. 2). The lower segment, named the Ouray segment, begins in section 31, T. 44 N., R. 7 W. (projected location in unsurveyed area) and extends into section 36, T. 44 N., R. 7 W. The upper segment, named the Cascade Falls segment, begins in section 31 and extends into section 32, T. 44 N., R 7 W. (projected location in unsurveyed area). The lower segment begins at the top of the Mississippian Leadville Limestone and ends at 119 m (391 ft) at the top of a thick sandstone unit above which is extensive cover. The upper segment begins with the lowest exposed strata at Cascade Falls and follows the southeast-trending contact between the talus and cliffs up through the Hermosa Group. The basal 59 m (195 ft) of the Cascade Falls segment duplicates the upper part of the Ouray segment. The duplicated section is included to show the lithologic changes that occur over the 1.6 km (1 mi) that separate these two segments.

Along the line of section, an angular unconformity separates the Hermosa Group from the Triassic Dolores Formation. This unconformity rises stratigraphically to the north where it separates the Permian Cutler Formation from the overlying Dolores. Shear, inaccessible cliffs prohibit examination of the Hermosa-Cutler contact where it is exposed. From a distance, this contact looks conformable and gradational.

The section was measured with a Jacobs staff and Abney level; in high, cliff-forming exposures a tape was dropped from the top of the cliff. There is excellent exposure in both the Ouray and Cascade Falls segments resulting in documentation of both the finer-grained units and the contacts between units. Field descriptions were recorded at a scale of 1 in. to 5 ft. or 1 in. to 10 ft (1 cm to .6 m or 1 cm to 1.2 m). These descriptions were simplified to the 1 in. to 20 ft (1 cm to 2.4 m) scale presented in this report.

Both sandstone and carbonate beds were sampled and thin sections prepared for petrographic analysis. Petrographic analysis in the clastic units will document changes in mineralogy through the section and in the carbonate units will determine faunal assemblages and abundances and diagenetic history. The faunal types shown in the accessories column of figures 4 and 5 are based on macroscopic field observations and will be expanded with the final analysis of these carbonate samples. Samples of dark-gray claystone, mudstone, and shale throughout the section were also collected for organic-geochemistry analysis to determine total organic content and thermal maturation levels.

Figure 3 provides the explanation for the measured section diagrams, and figures 4 (Ouray segment) and 5 (Cascade Falls segment) show the measured section data. Part or all of the unit at the top of each page on figures 4 and 5 is repeated at the base of the succeeding page to facilitate splicing the section into a continuous vertical column. The profile on the left side of the lithology column shows the grain size for clastic units. The lithologic profile for carbonate units is arbitrarily assigned to the medium-grained interval; the texture of the carbonate unit is shown in the carbonate fabric column. An interpretation of depositional environments for units or packages of units is listed on the far left side of figures 4 and 5. Based on the interpreted environments, a relative sea level curve was constructed. Marine carbonate and marine clastic units are considered to represent the highest relative sea level and alluvial units the lowest. Abrupt changes from high or intermediate relative sea level to low correspond to a period of base level drop and subaerial exposure.

Geologic notes

Pennsylvanian strata in the Ouray area can be separated into two units: the Molas Formation and the overlying Hermosa Group. The Molas, 18 m (60 ft) thick, unconformably overlies the Mississippian Leadville Limestone. Red sandstone to siltstone matrix surrounding karstified limestone characterizes the lowest part of the Molas. This lithology is replaced upward by red conglomerate and pebbly sandstone beds. A color change from dominantly red to dominantly olive gray and a slight decrease in grain size marks the gradational contact between the alluvial deposits of the Molas Formation and those of the overlying Hermosa Group. The Pinkerton Trail Formation, a marine carbonate unit at the base of the Hermosa Group throughout the Paradox basin, is absent (possibly due to nondeposition) in the Ouray area. The first marine carbonate unit overlies 30 m (100 ft) of alluvial deposits in the Hermosa Group.

Luedke and Burbank (1962) informally separated the Hermosa Group at Ouray into three parts based on lithologic characteristics. Their lower part is about 137 m (450 ft) thick and consists of gray, green, and red calcareous sandstone, siltstone, and shale interbedded with gray fossiliferous limestone. The middle part is about 213 m (700 ft) thick and is characterized by pink to red, generally cliff-forming, thick (15-24 m (50-80 ft)) sandstone units interbedded with thin, red to gray limestone and fossiliferous shale units. The upper part is about 91 m (300 ft) thick and contains red sandstone and conglomerate beds that are thinner than those in the underlying middle part. These coarse-grained clastic beds are interbedded with fossiliferous gray limestone and gray to red shale units. Luedke and Burbank (1962) interpreted a gradational and conformable contact between the Hermosa and the Cutler; they arbitrarily chose the contact between these two units to be 40 m (130 ft) above the uppermost fossiliferous zone within the Hermosa.

This measured section shows a similar three-fold subdivision but slight differences in thickness. The lower part, 104 m (340 ft) thick, contains overall thinner lithologic units than in the overlying parts. Beds of sandstone, siltstone, shale, and limestone ranging from less than 3 m to 9 m (10 ft to 30 ft) thick characterize the lower part. The middle part, which is 154 m (505 ft) thick, contains cliff-forming channel-sandstone units that are locally up to 27 m (90 ft) and generally greater than 12 m (40 ft) thick. Fossiliferous, subtidal limestone units ranging from 0.6-3 m (2-10 ft) thick overlie these channel sandstones above a sharp contact. Only 27 m (90 ft) of the upper part was measured along the line of section because of erosion below the angular unconformity at the base of the Triassic. Thinner units, more fine-grained clastic intervals, and less well developed limestone beds differentiate it from the underlying middle part. Lithologically, with the exception of limestone in the Hermosa, the upper part of the Hermosa is identical to the overlying basal part of the Cutler where the Cutler has not been removed below the unconformity surface (Luedke and Burbank, 1962).

Luedke and Burbank (1962) did not apply the name Rico Formation in the Ouray area to the interval that contains thin, poorly developed limestone beds at the top of the Hermosa Group. They did note that the limestone beds in the upper part of the Hermosa contain a greater ratio of molluscs to brachiopods than in the underlying parts. Cross and Spencer (1900) used this increase in mollusc abundance to differentiate the limestones in the Rico Formation from those in the underlying Hermosa in the Rico, Colorado, area. Based on the greater abundance of molluscs in upper part of the Hermosa at Ouray, Luedke and Burbank (1962) suggested that this part of the Hermosa "may be an approximate equivalent of the Rico Formation" at Rico, Colorado. Cross and Spencer (1900, p. 65), citing personal communition from Girty, reported fossils from the Rico Formation having "both Permian and Carboniferous affinities, but if this unit must be assigned to only one of these ages, it would be placed in the Carboniferous (Pennsylvanian)". Blodgett (1984, p. 68) stated that upper Desmoinesian fussulinids were found in the uppermost limestone beds in the Rico area, indicating the Hermosa/Rico section is no younger than Pennsylvanian.

Ongoing paleontologic study of the faunal assemblages at Ouray indicates the Hermosa Group is no younger than Pennsylvanian, and probably no younger than the DesMoinesian stage of the Pennsylvanian (Germaine Clark, USGS, 1993, oral communication). The apparent conformable and gradational contact with the overlying Cutler Formation suggests that the Cutler is of both Pennsylvanian and Permian age.

Correlations of the Hermosa Group between Ouray, Silverton, and Hermosa Mountain present interesting questions. Figure 6 shows the great increase in thickness in the Hermosa Group between the Ouray and Silverton areas. Additionally, the gross, regionally extensive lithologic packages that can be correlated from Hermosa Mountain to the Silverton area (fig. 6) can not be identified in the Ouray area. Because the Pennyslvanian rocks south of Ouray area are eroded, the cause of these changes is uncertain. A stratigraphic rise in the Hermosa-Cutler contact from Ouray to Silverton is possible, or there may be an unconformity spanning a large part of the DesMoinesian within the Hermosa Group at Ouray. The interpretation shown in figure 6 is that numerous unconformities within the Hermosa at Ouray and a slight stratigraphic rise in the Hermosa-Cutler contact account for the observed thickness differences. The sharp, scour contacts that locally show a few meters of relief at the base of thick channel sandstone units in the middle part of the Hermosa Group at Ouray are probably the sites of these unconformities. Ouray's close proximity to the Uncompahgre uplift may have made this area more sensitive to tectonically induced base-level changes that resulted in long periods of erosion and nondeposition. Ongoing paleontologic analysis of the faunal assemblages may provide more precise chronostratigraphic correlations between Ouray and areas to the south.

Trough cross-stratification within deltaic marine and nonmarine fluvial sandstones throughout the Hermosa Group in the Ouray area yield radial (southwest to north) paleocurrent indicators that produce an average mean vector of 281° (fig. 7). This westerly direction differs from the southwesterly orientation (230°) obtained from the Hermosa Group in both the Molas Lake (Spoelhof, 1974) and the Hermosa Mountain areas (Franczyk, 1992).

Acknowledgements

The long, arduous, and often tedious job of section measuring was ably and good-naturedly assisted by George Wigman and Doug Brew.

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Wengerd, S.A., and Strickland, J.W., 1954, Pennsylvanian stratigraphy of Paradox salt basin, Four Corners region, Colorado and Utah: American Association of Petroleum Geologists Bulletin, v. 38, no. 10, p. 2157-2199.

Figure Captions

Figure 1. Location map showing the Paradox Basin, shown here by the solid, heavy line that corresponds to the maximum extent of salt in the Paradox Formation, and surrounding geologic features. The star shows the location of the Ouray measured section. Line of section shows location of stratigraphic cross section illustrated in figure 6.

Figure 2. Location map of the Ouray measured section. The Ouray segment includes the Molas Formation and lowest part of the Hermosa Group. The Cascade Falls segment includes the remainder of the Hermosa Group. At the top of the measured section, the Triassic Dolores Formation unconformably overlies the Hermosa. Base map from Luedke and Burbank's (1962) geologic map of the Ouray 7.5 minute quadrangle map.

Figure 3. Explanation for figures 4 and 5.

Figure 4. Ouray segment of the Ouray measured section. Part or all of the unit at the top of each page is repeated at the base of the succeeding page to facilitate splicing the section into a continuous vertical column.

Figure 5. Cascade Falls segment of the Ouray measured section. The basal 59 m (195 ft) of the Cascade Falls segment duplicates the upper part of the Ouray segment. Part or all of the unit at the top of each page is repeated at the base of the succeeding page to facilitate splicing the section into a continuous vertical column.

Figure 6. Stratigraphic correlation diagram of the Molas Formation (IPm), Pinkerton Trail Formation (IPpt), and Hermosa Group (IPh) between Ouray to the north and Hermosa Mountain to the south. Line of section is shown on figure 1. Spoelhof (1974) refers to the Hermosa Group above the Pinkerton Trail Formation as the Honaker Trail Formation (IPht). The middle member of the Honaker Trail of Spoelhof is a carbonate-rich interval that can be traced from the Silverton area southward to Hermosa Mountain; this interval can not be identified in the Ouray area. Ml-Mississippian Leadville Limestone; PC-Precambrian; TRd-Triassic Dolores Formation; IPPc-Pennsylvanian/Permian Cutler Formation. Equivalent (eq.) members of the Paradox Formation of the Hermosa Group are shown in column on right: AG-Alkali Gulch; BC-Barker Creek; A-Akah; DC-Desert Creek; I-Ismay.

Figure 7. Rose diagram showing all paleocurrent measurements taken from the Ouray and Cascade Falls segments. Average mean vector direction is 281°; N is the number of readings.

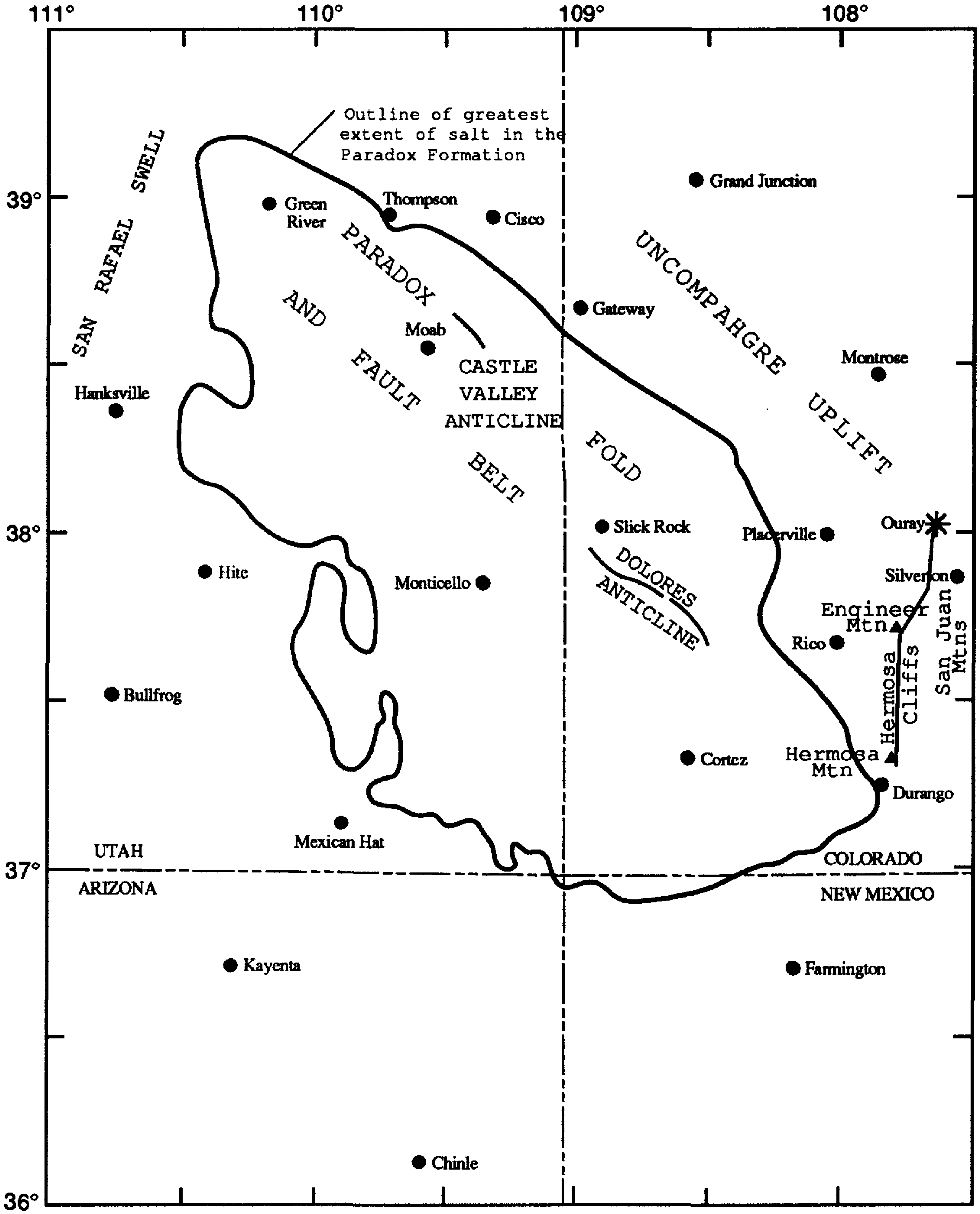
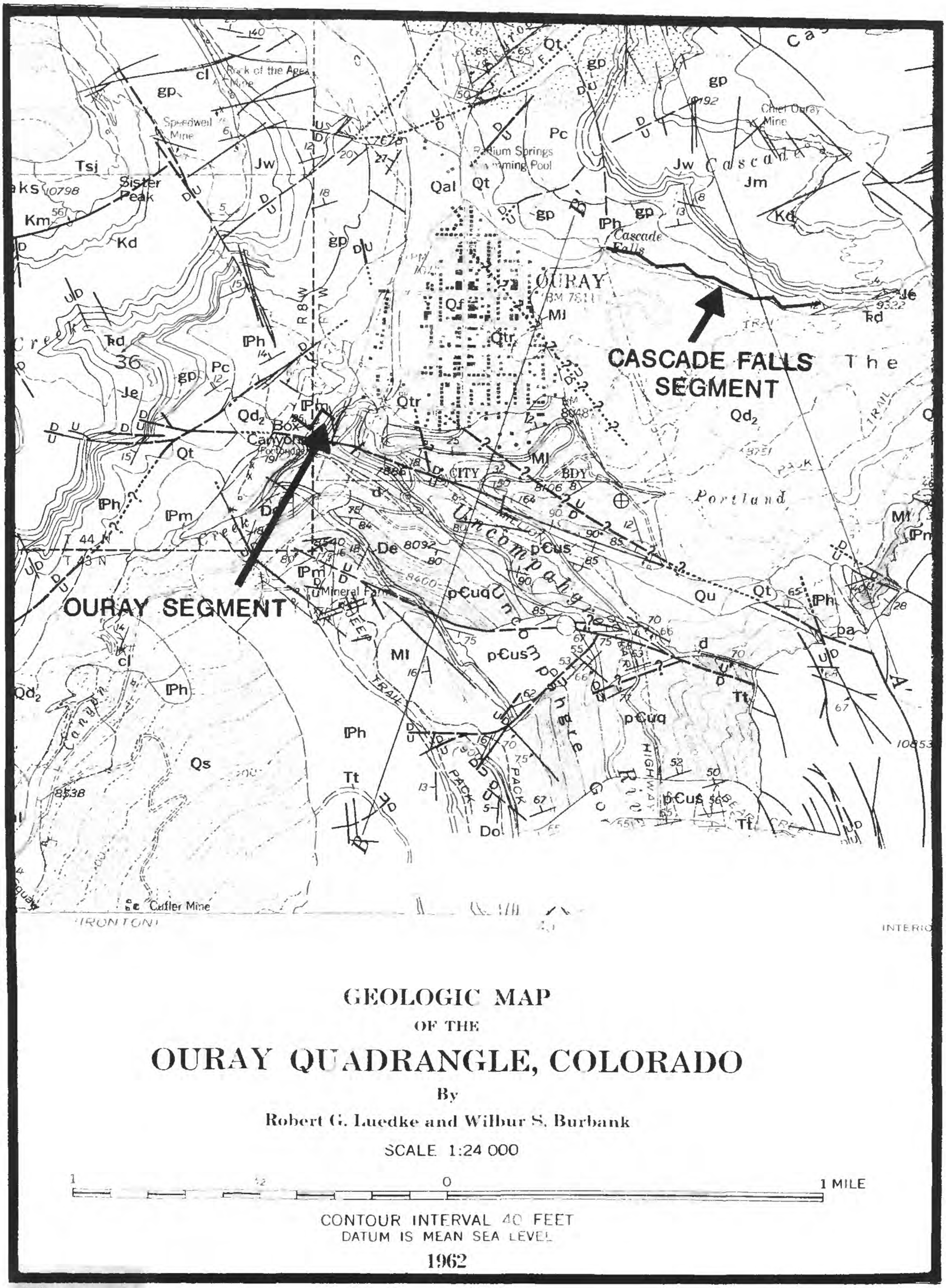

111°
110°
109°
108°
39°
38°
37°
36°
Outline of greatest extent of salt in the Paradox Formation
SAN RAFAEL SWELL
Green River
Thompson
Cisco
Grand Junction
PARADOX
AND
FAULT
BELT
FOLD
Moab
CASTLE VALLEY ANTICLINE
Gateway
UNCOMPAHGRE UPLIFT
Montrose
Hanksville
Slick Rock
Placerville
Ouray
Hite
Monticello
DOLORES ANTICLINE
Silverton
Engineer Mtn
Rico
Hermosa Cliffs
San Juan Mtns
Bullfrog
Cortez
Hermosa Mtn
Durango
Mexican Hat
UTAH
ARIZONA
COLORADO
NEW MEXICO
Kayenta
Farmington
Chinle

Figure 1



CASCADE FALLS SEGMENT
OURAY SEGMENT
OURAY
Box Canyon
Cascade Falls
Chief Ouray Mine
Speedwell Mine
Sister Peak
Radium Springs Swimming Pool
Portland
Uncompahgre River
Cutler Mine
GEOLOGIC MAP
OF THE
OURAY QUADRANGLE, COLORADO
By
Robert G. Luedke and Wilbur S. Burbank
SCALE 1:24 000
1 MILE
CONTOUR INTERVAL 40 FEET
DATUM IS MEAN SEA LEVEL
1962

Figure 2

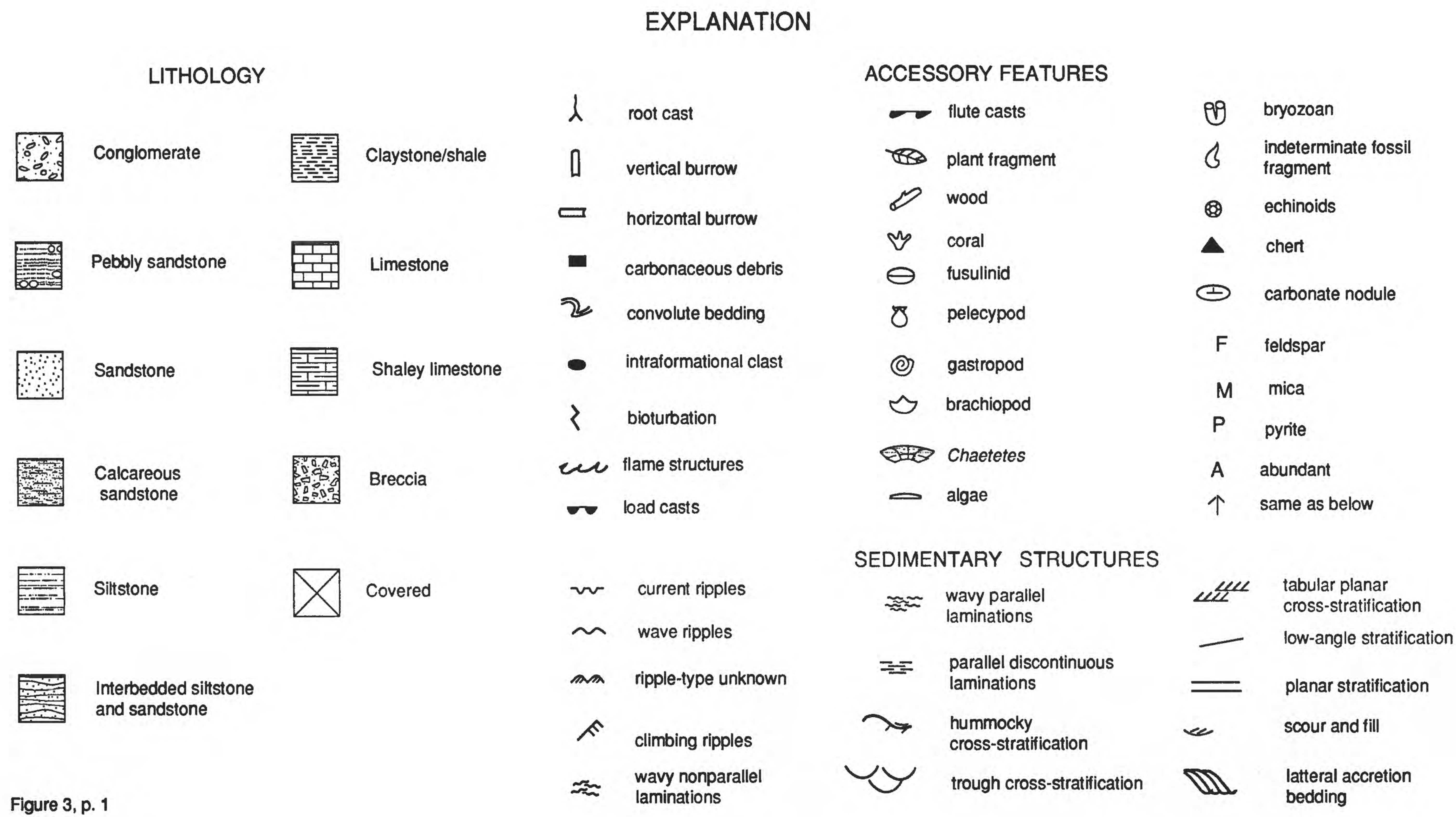

EXPLANATION
LITHOLOGY
Conglomerate
Claystone/shale
Pebbly sandstone
Limestone
Sandstone
Shaley limestone
Calcareous sandstone
Breccia
Siltstone
Covered
Interbedded siltstone and sandstone
root cast
vertical burrow
horizontal burrow
carbonaceous debris
convolute bedding
intraformational clast
bioturbation
flame structures
load casts
current ripples
wave ripples
ripple-type unknown
climbing ripples
wavy nonparallel laminations
ACCESSORY FEATURES
flute casts
plant fragment
wood
coral
fusulinid
pelecypod
gastropod
brachiopod
Chaetetes
algae
bryozoan
indeterminate fossil fragment
echinoids
chert
carbonate nodule
F feldspar
M mica
P pyrite
A abundant
same as below
SEDIMENTARY STRUCTURES
wavy parallel laminations
parallel discontinuous laminations
hummocky cross-stratification
trough cross-stratification
tabular planar cross-stratification
low-angle stratification
planar stratification
scour and fill
latteral accretion bedding

Figure 3, p. 1

EXPLANATION

DEPOSITIONAL ENVIRONMENT

NM	Nonmarine
AL	Alluvial
DP	Delta plain
DF	Delta front
SM	Shallow marine
M	Marine

CARBONATE FABRIC

M	Lime mudstone
W	Wackestone
P	Packstone
G	Grainstone
X	Crystalline

BEDDING THICKNESS

VTH	Very thin
TH	Thin
M	Medium
TK	Thick
VTK	Very thick
NA	Not apparent

CONTACT TYPE

S	Sharp
SI	Sharp, irregular
G	Gradational
C	Covered

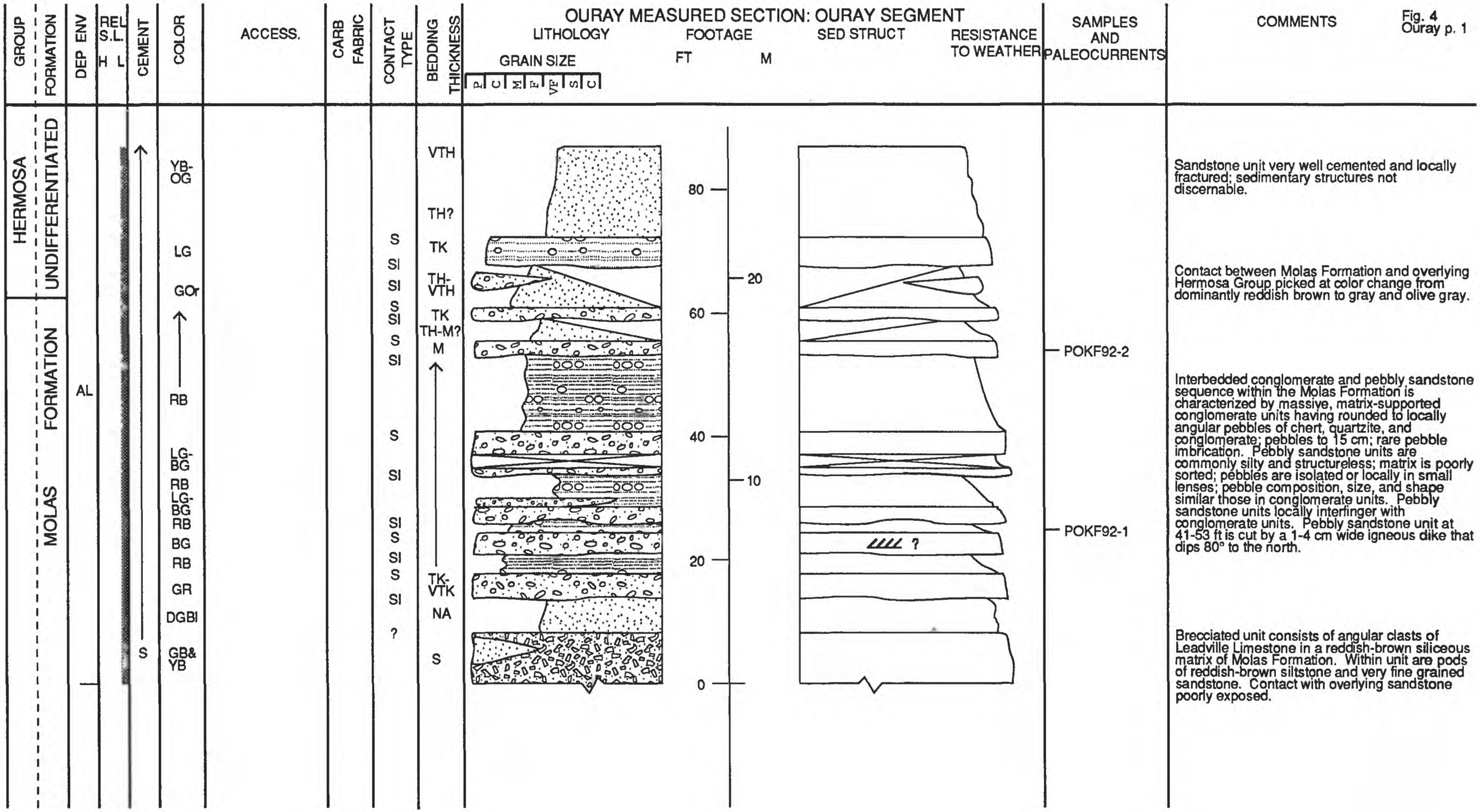
COLOR

B	Brown	Or	Orange	D	Dark
Bl	Black	Pk	Pink	L	Light
G	Gray	R	Red	M	Medium
Gr	Green	Y	Yellow	P	Pale
O	Olive				

CONTACT TYPE

C	Calcareous
S	Siliceous
Sl	Slightly
V	Very
N	Non

Figure 3, p. 2


OURAY MEASURED SECTION: OURAY SEGMENT
Fig. 4
Ouray p. 1
GROUP
FORMATION
DEP ENV
REL S.L.
H L
CEMENT
COLOR
ACCESS.
CARB FABRIC
CONTACT TYPE
BEDDING THICKNESS
LITHOLOGY
GRAIN SIZE
FOOTAGE
FT
M
SED STRUCT
RESISTANCE TO WEATHER
SAMPLES AND PALEOCURRENTS
COMMENTS
HERMOSA
UNDIFFERENTIATED
MOLAS FORMATION
AL
S
YB-OG
LG
GOr
RB
LG-BG
RB
LG-BG
RB
BG
RB
GR
DGBl
GB& YB
VTH
TH?
TK
TH-VTH
TK
TH-M?
M
TK-VTK
NA
S
80
60
40
20
0
20
10
POKF92-2
POKF92-1
Sandstone unit very well cemented and locally fractured; sedimentary structures not discernable.
Contact between Molas Formation and overlying Hermosa Group picked at color change from dominantly reddish brown to gray and olive gray.
Interbedded conglomerate and pebbly sandstone sequence within the Molas Formation is characterized by massive, matrix-supported conglomerate units having rounded to locally angular pebbles of chert, quartzite, and conglomerate; pebbles to 15 cm; rare pebble imbrication. Pebbly sandstone units are commonly silty and structureless; matrix is poorly sorted; pebbles are isolated or locally in small lenses; pebble composition, size, and shape similar those in conglomerate units. Pebbly sandstone units locally interfinger with conglomerate units. Pebbly sandstone unit at 41-53 ft is cut by a 1-4 cm wide igneous dike that dips 80° to the north.
Brecciated unit consists of angular clasts of Leadville Limestone in a reddish-brown siliceous matrix of Molas Formation. Within unit are pods of reddish-brown siltstone and very fine grained sandstone. Contact with overlying sandstone poorly exposed.

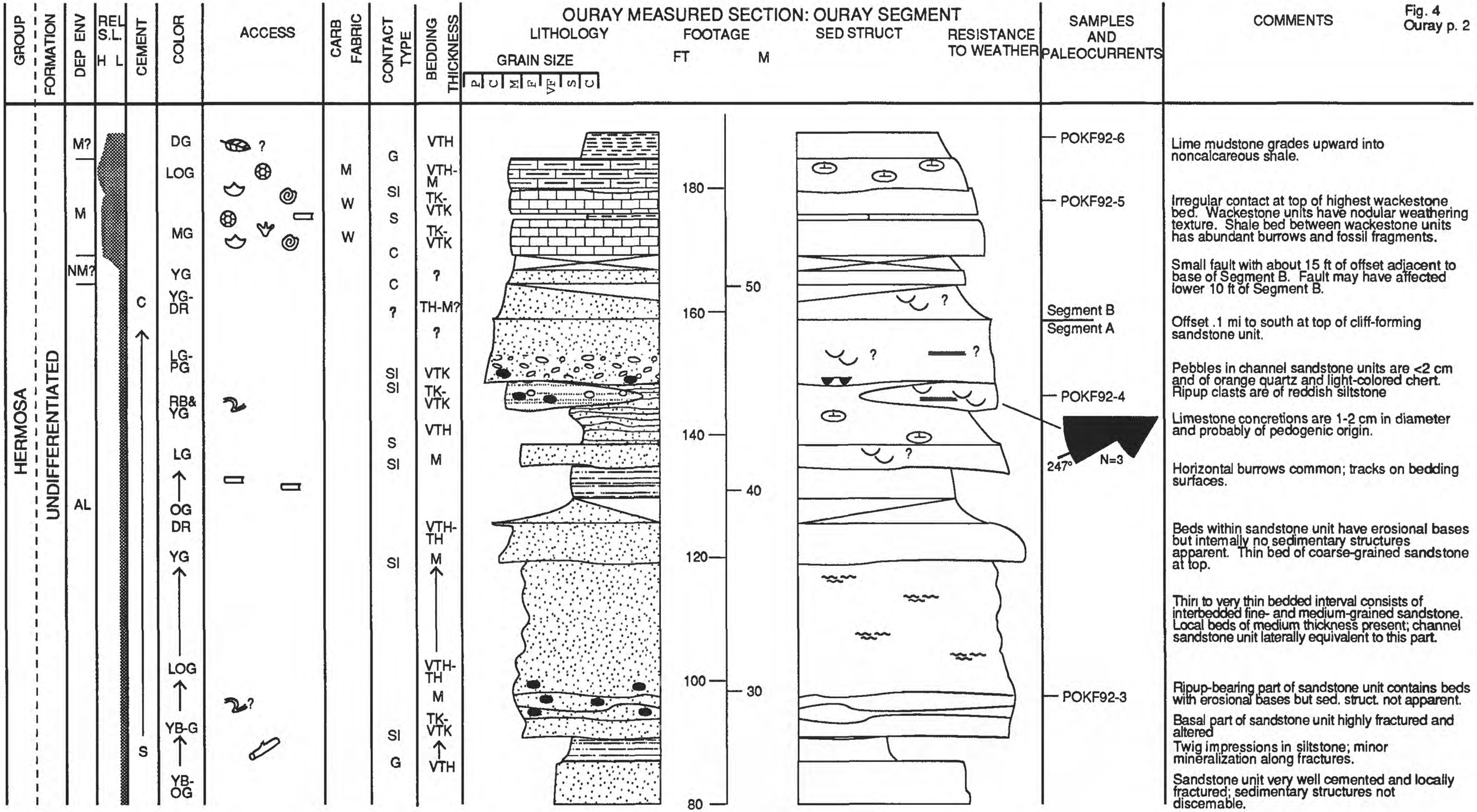
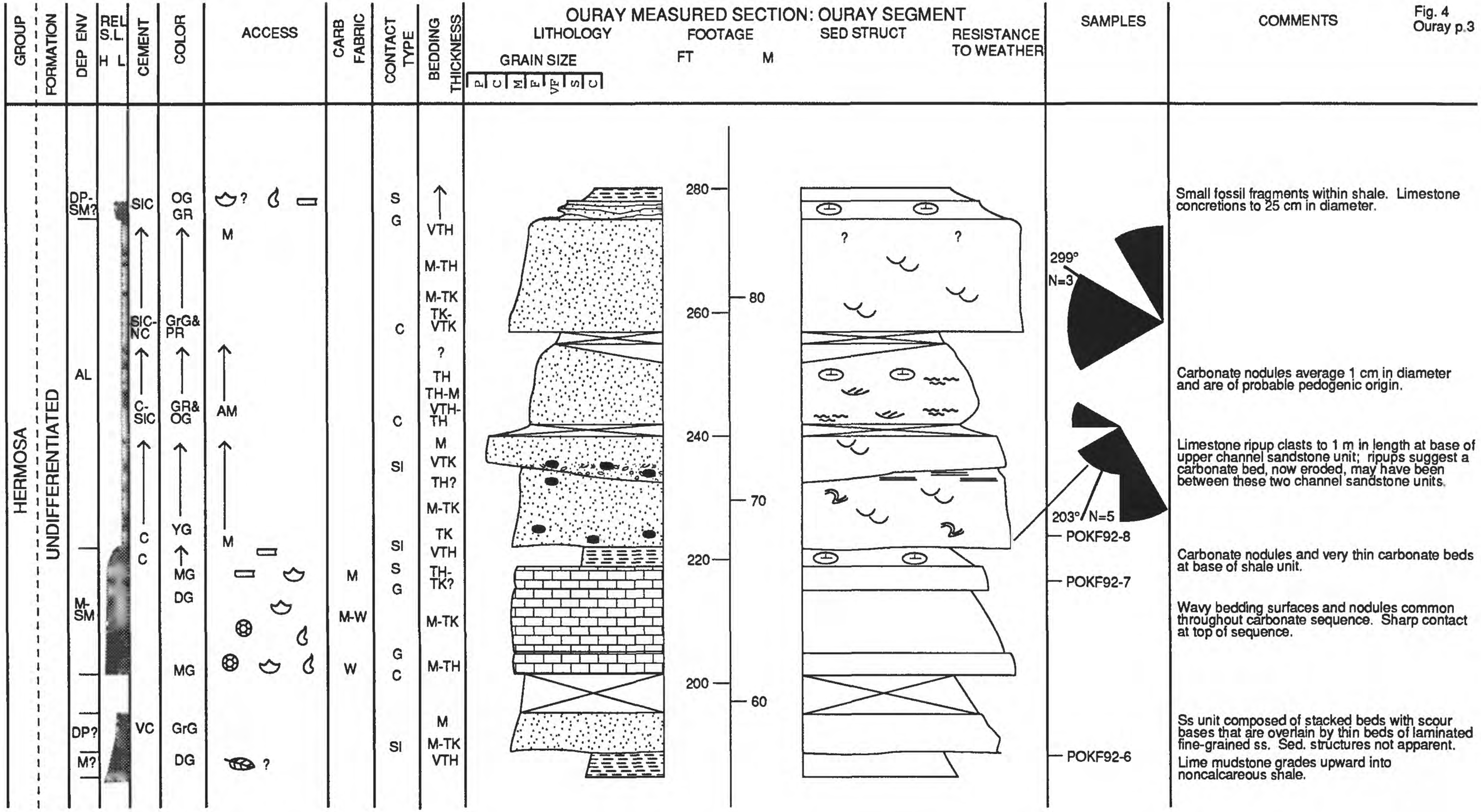


Fig. 4
Ouray p. 2
OURAY MEASURED SECTION: OURAY SEGMENT
GROUP
FORMATION
DEP ENV
REL S.L.
H L
CEMENT
COLOR
ACCESS
CARB FABRIC
CONTACT TYPE
BEDDING THICKNESS
LITHOLOGY
GRAIN SIZE
P C M F VF S C
FOOTAGE
FT
M
SED STRUCT
RESISTANCE TO WEATHER
SAMPLES AND PALEOCURRENTS
COMMENTS
HERMOSA
UNDIFFERENTIATED
M?
M
NM?
AL
C
S
DG
LOG
MG
YG
YG-DR
LG-PG
RB& YG
LG
OG DR
YG
LOG
YB-G
YB-OG
M
W
W
G
SI
S
C
C
?
SI
SI
S
SI
SI
SI
G
VTH
VTH-M
TK-VTK
TK-VTK
?
TH-M?
?
VTK
TK-VTK
VTH
M
VTH-TH
M
VTH-TH
M
TK-VTK
VTH
180
160
140
120
100
80
50
40
30
POKF92-6
POKF92-5
Segment B
Segment A
POKF92-4
247°
N=3
POKF92-3
Lime mudstone grades upward into noncalcareous shale.
Irregular contact at top of highest wackestone bed. Wackestone units have nodular weathering texture. Shale bed between wackestone units has abundant burrows and fossil fragments.
Small fault with about 15 ft of offset adjacent to base of Segment B. Fault may have affected lower 10 ft of Segment B.
Offset .1 mi to south at top of cliff-forming sandstone unit.
Pebbles in channel sandstone units are <2 cm and of orange quartz and light-colored chert. Ripup clasts are of reddish siltstone
Limestone concretions are 1-2 cm in diameter and probably of pedogenic origin.
Horizontal burrows common; tracks on bedding surfaces.
Beds within sandstone unit have erosional bases but internally no sedimentary structures apparent. Thin bed of coarse-grained sandstone at top.
Thin to very thin bedded interval consists of interbedded fine- and medium-grained sandstone. Local beds of medium thickness present; channel sandstone unit laterally equivalent to this part.
Ripup-bearing part of sandstone unit contains beds with erosional bases but sed. struct. not apparent.
Basal part of sandstone unit highly fractured and altered
Twig impressions in siltstone; minor mineralization along fractures.
Sandstone unit very well cemented and locally fractured; sedimentary structures not discernable.



OURAY MEASURED SECTION: OURAY SEGMENT
Fig. 4
Ouray p.3
GROUP
FORMATION
DEP ENV
REL S.L.
H L
CEMENT
COLOR
ACCESS
CARB FABRIC
CONTACT TYPE
BEDDING THICKNESS
LITHOLOGY
GRAIN SIZE
P C M F VF S C
FOOTAGE
FT
M
SED STRUCT
RESISTANCE TO WEATHER
SAMPLES
COMMENTS
HERMOSA
UNDIFFERENTIATED
DP-SM?
AL
M-SM
DP?
M?
SIC
SIC-NC
C-SIC
C
C
VC
OG GR
GrG& PR
GR& OG
YG
MG
DG
MG
GrG
DG
M
AM
M
M
M-W
W
S
G
C
C
SI
SI
S
G
G
C
SI
VTH
M-TH
M-TK
TK-VTK
?
TH
TH-M
VTH-TH
M
VTK
TH?
M-TK
TK
VTH
TH-TK?
M-TK
M-TH
M
M-TK
VTH
280
260
240
220
200
80
70
60
299°
N=3
203°
N=5
POKF92-8
POKF92-7
POKF92-6
Small fossil fragments within shale. Limestone concretions to 25 cm in diameter.
Carbonate nodules average 1 cm in diameter and are of probable pedogenic origin.
Limestone ripup clasts to 1 m in length at base of upper channel sandstone unit; ripups suggest a carbonate bed, now eroded, may have been between these two channel sandstone units.
Carbonate nodules and very thin carbonate beds at base of shale unit.
Wavy bedding surfaces and nodules common throughout carbonate sequence. Sharp contact at top of sequence.
Ss unit composed of stacked beds with scour bases that are overlain by thin beds of laminated fine-grained ss. Sed. structures not apparent.
Lime mudstone grades upward into noncalcareous shale.

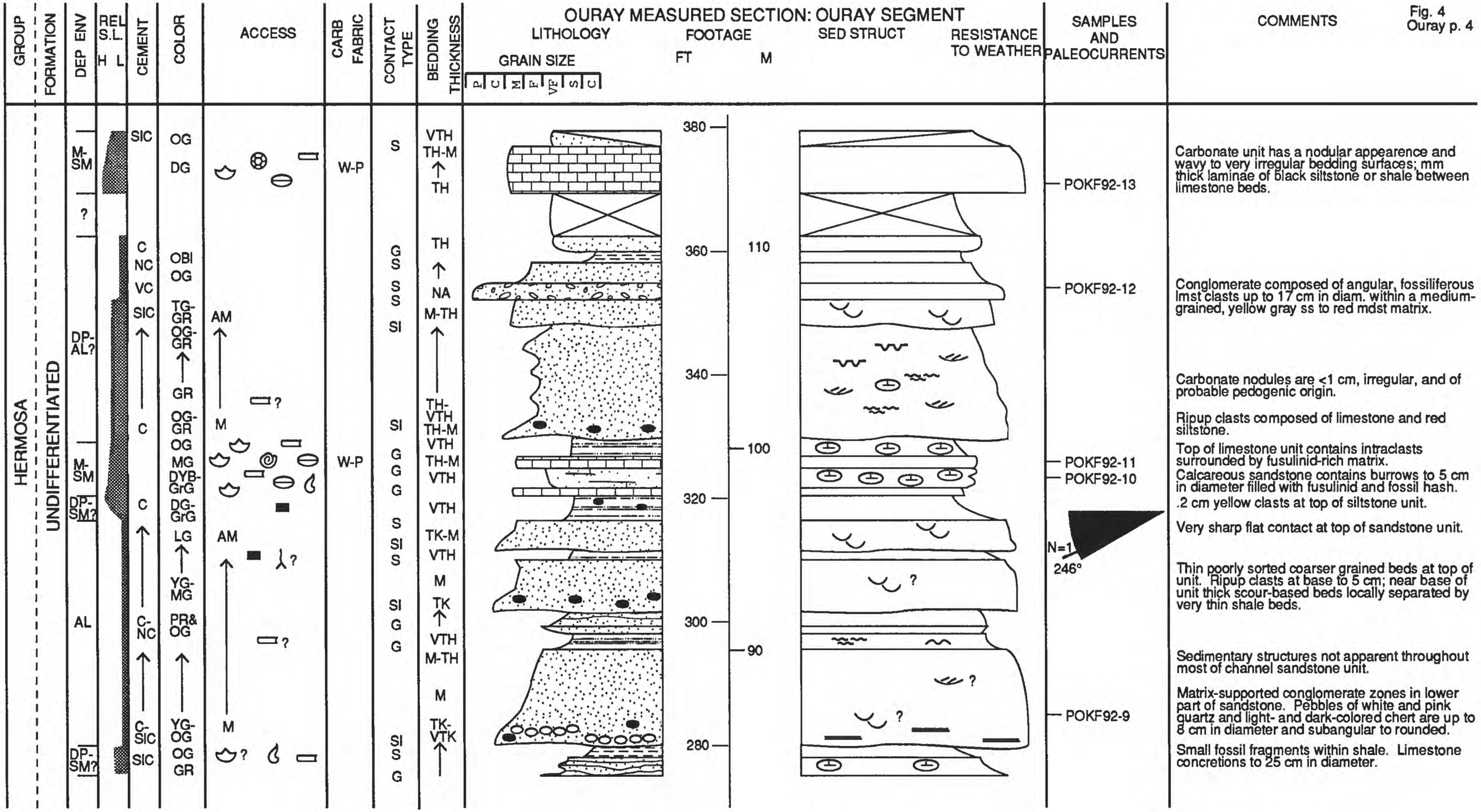
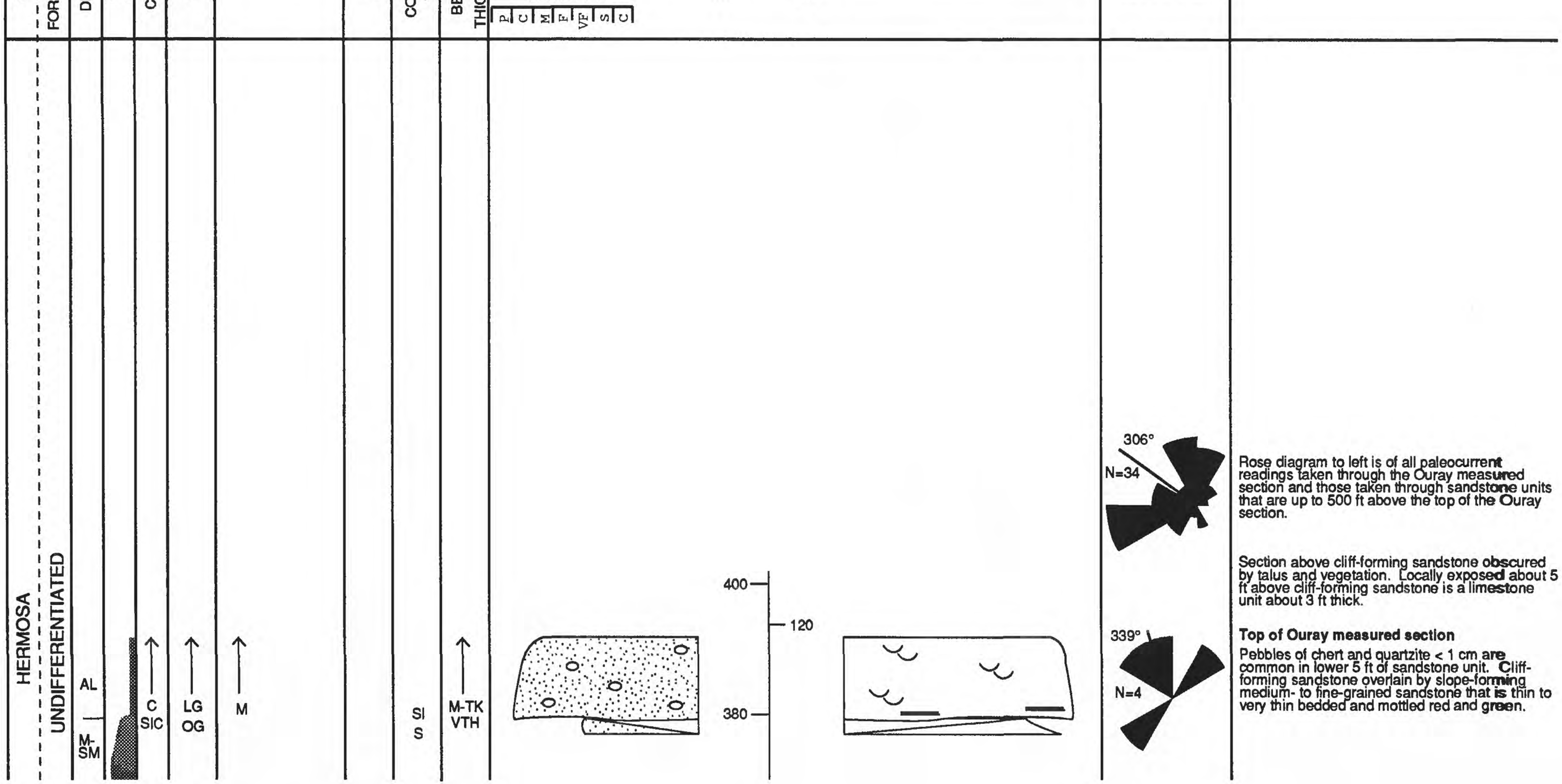
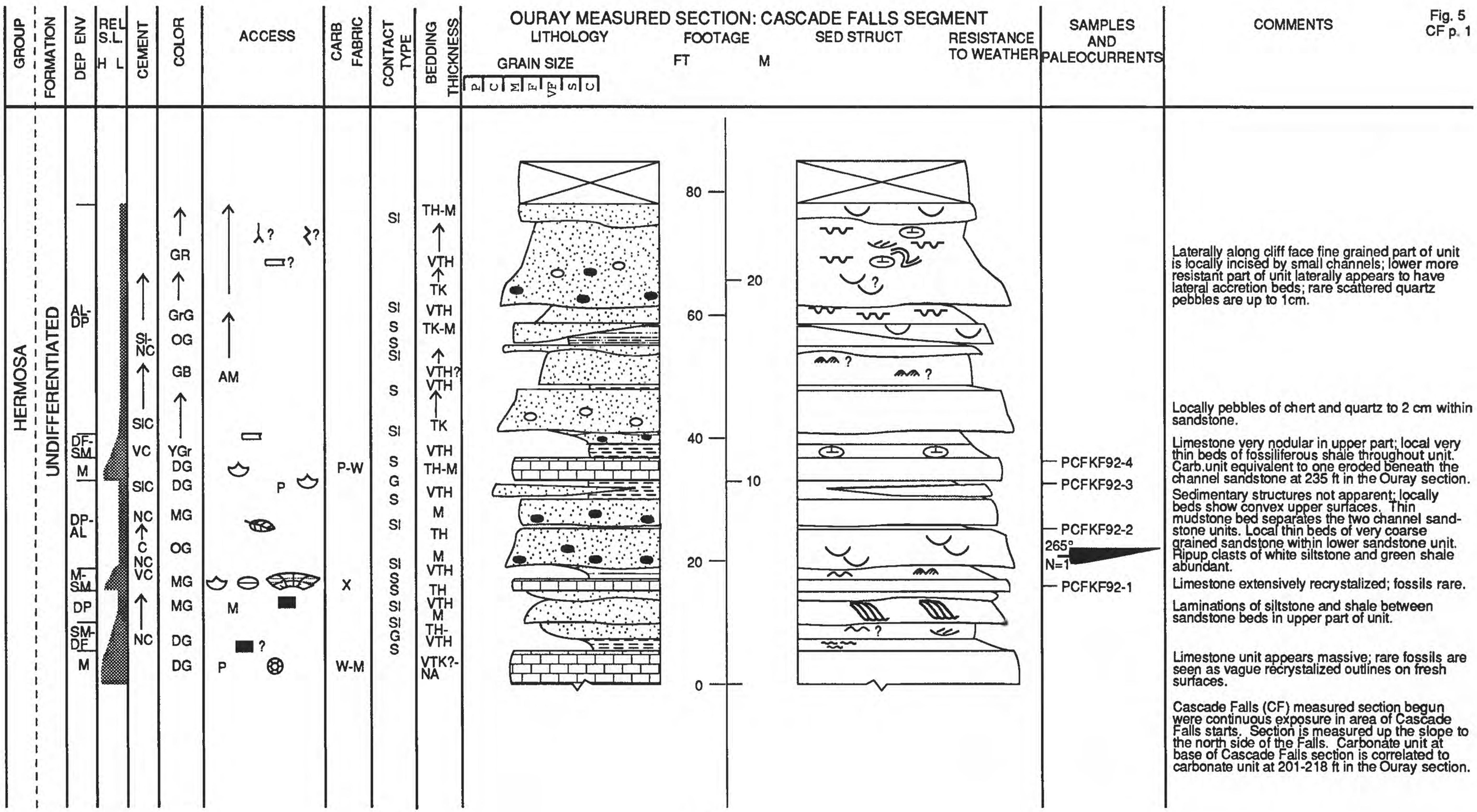

OURAY MEASURED SECTION: OURAY SEGMENT
Fig. 4
Ouray p. 4
GROUP
FORMATION
DEP ENV
REL S.L.
H L
CEMENT
COLOR
ACCESS
CARB FABRIC
CONTACT TYPE
BEDDING THICKNESS
LITHOLOGY
GRAIN SIZE
FOOTAGE
FT
M
SED STRUCT
RESISTANCE TO WEATHER
SAMPLES AND PALEOCURRENTS
COMMENTS
HERMOSA
UNDIFFERENTIATED
POKF92-13
POKF92-12
POKF92-11
POKF92-10
N=1
246°
POKF92-9
Carbonate unit has a nodular appearence and wavy to very irregular bedding surfaces; mm thick laminae of black siltstone or shale between limestone beds.
Conglomerate composed of angular, fossiliferous lmst clasts up to 17 cm in diam. within a medium-grained, yellow gray ss to red mdst matrix.
Carbonate nodules are <1 cm, irregular, and of probable pedogenic origin.
Ripup clasts composed of limestone and red siltstone.
Top of limestone unit contains intraclasts surrounded by fusulinid-rich matrix.
Calcareous sandstone contains burrows to 5 cm in diameter filled with fusulinid and fossil hash.
.2 cm yellow clasts at top of siltstone unit.
Very sharp flat contact at top of sandstone unit.
Thin poorly sorted coarser grained beds at top of unit. Ripup clasts at base to 5 cm; near base of unit thick scour-based beds locally separated by very thin shale beds.
Sedimentary structures not apparent throughout most of channel sandstone unit.
Matrix-supported conglomerate zones in lower part of sandstone. Pebbles of white and pink quartz and light- and dark-colored chert are up to 8 cm in diameter and subangular to rounded.
Small fossil fragments within shale. Limestone concretions to 25 cm in diameter.

Fig. 4
Ouray p. 5.

OURAY MEASURED SECTION: OURAY SEGMENT




OURAY MEASURED SECTION: CASCADE FALLS SEGMENT
Fig. 5
CF p. 1
GROUP
FORMATION
DEP ENV
REL S.L.
H L
CEMENT
COLOR
ACCESS
CARB FABRIC
CONTACT TYPE
BEDDING THICKNESS
LITHOLOGY
GRAIN SIZE
P C M F VF S C
FOOTAGE
FT
M
SED STRUCT
RESISTANCE TO WEATHER
SAMPLES AND PALEOCURRENTS
COMMENTS
HERMOSA
UNDIFFERENTIATED
AL-DP
DF-SM
M
DP-AL
M-SM
DP
SM-DF
M
SI-NC
SIC
VC
SIC
NC
C
NC
VC
NC
GR
GrG
OG
GB
YGr
DG
DG
MG
OG
MG
MG
DG
DG
AM
P
M
P
P-W
X
W-M
SI
SI
S
S
SI
S
SI
S
G
S
SI
SI
S
S
SI
SI
G
S
TH-M
VTH
TK
VTH
TK-M
VTH?
VTH
TK
VTH
TH-M
VTH
M
TH
M
VTH
TH
VTH
M
TH-
VTH
VTK?-
NA
80
60
40
20
0
20
10
PCFKF92-4
PCFKF92-3
PCFKF92-2
265°
N=1
PCFKF92-1
Laterally along cliff face fine grained part of unit is locally incised by small channels; lower more resistant part of unit laterally appears to have lateral accretion beds; rare scattered quartz pebbles are up to 1cm.
Locally pebbles of chert and quartz to 2 cm within sandstone.
Limestone very nodular in upper part; local very thin beds of fossiliferous shale throughout unit. Carb.unit equivalent to one eroded beneath the channel sandstone at 235 ft in the Ouray section.
Sedimentary structures not apparent; locally beds show convex upper surfaces. Thin mudstone bed separates the two channel sandstone units. Local thin beds of very coarse grained sandstone within lower sandstone unit. Ripup clasts of white siltstone and green shale abundant.
Limestone extensively recrystalized; fossils rare.
Laminations of siltstone and shale between sandstone beds in upper part of unit.
Limestone unit appears massive; rare fossils are seen as vague recrystalized outlines on fresh surfaces.
Cascade Falls (CF) measured section begun were continuous exposure in area of Cascade Falls starts. Section is measured up the slope to the north side of the Falls. Carbonate unit at base of Cascade Falls section is correlated to carbonate unit at 201-218 ft in the Ouray section.

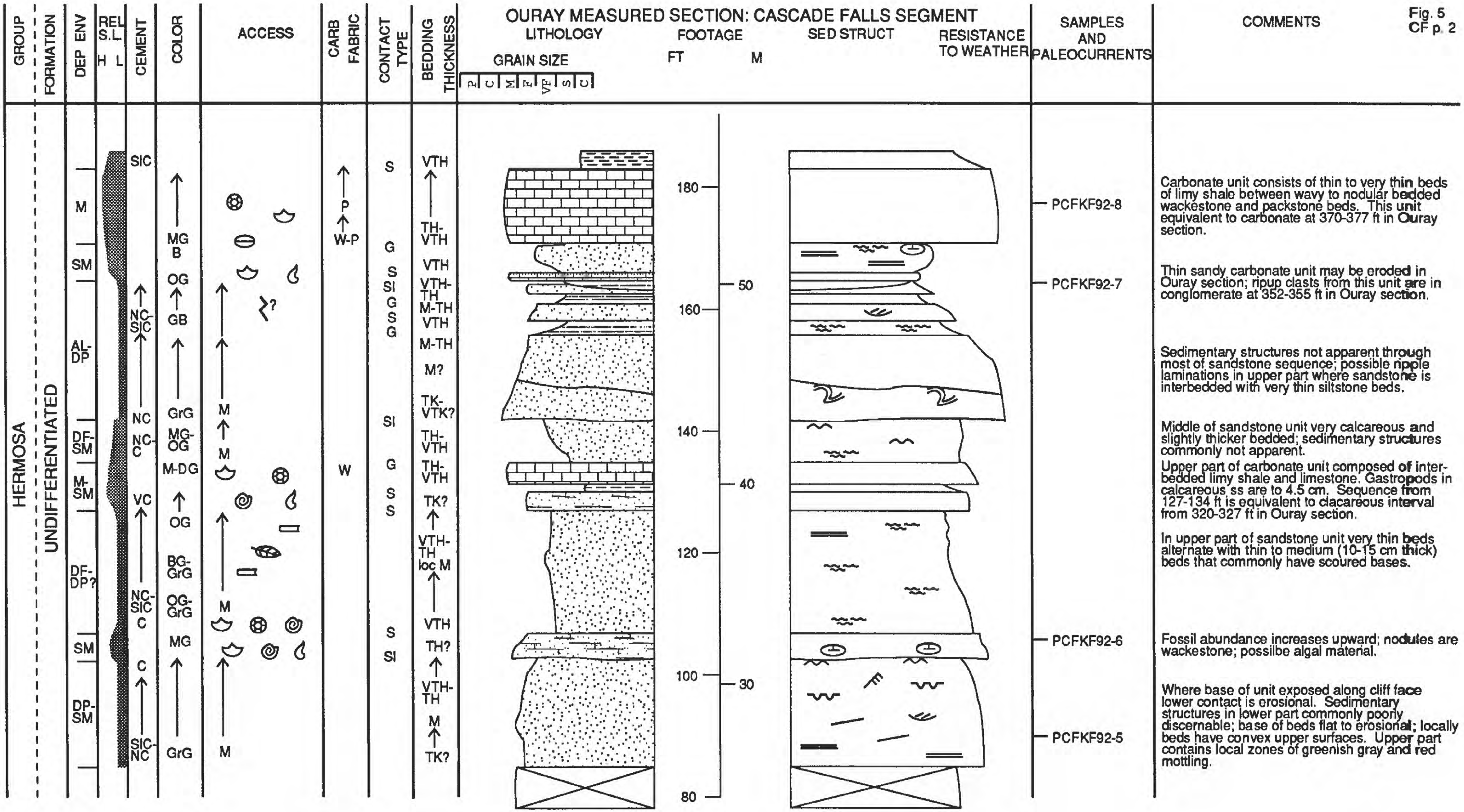
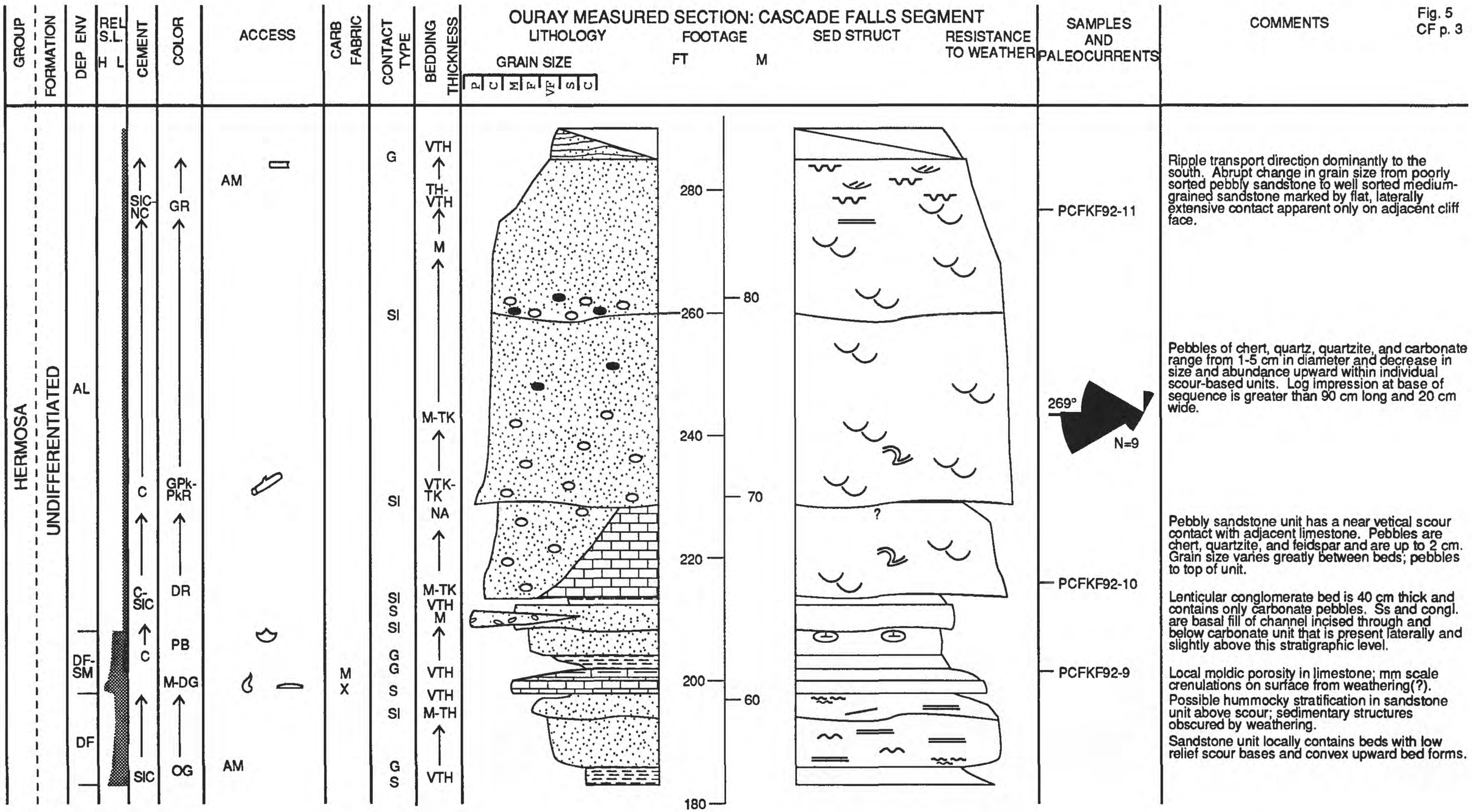
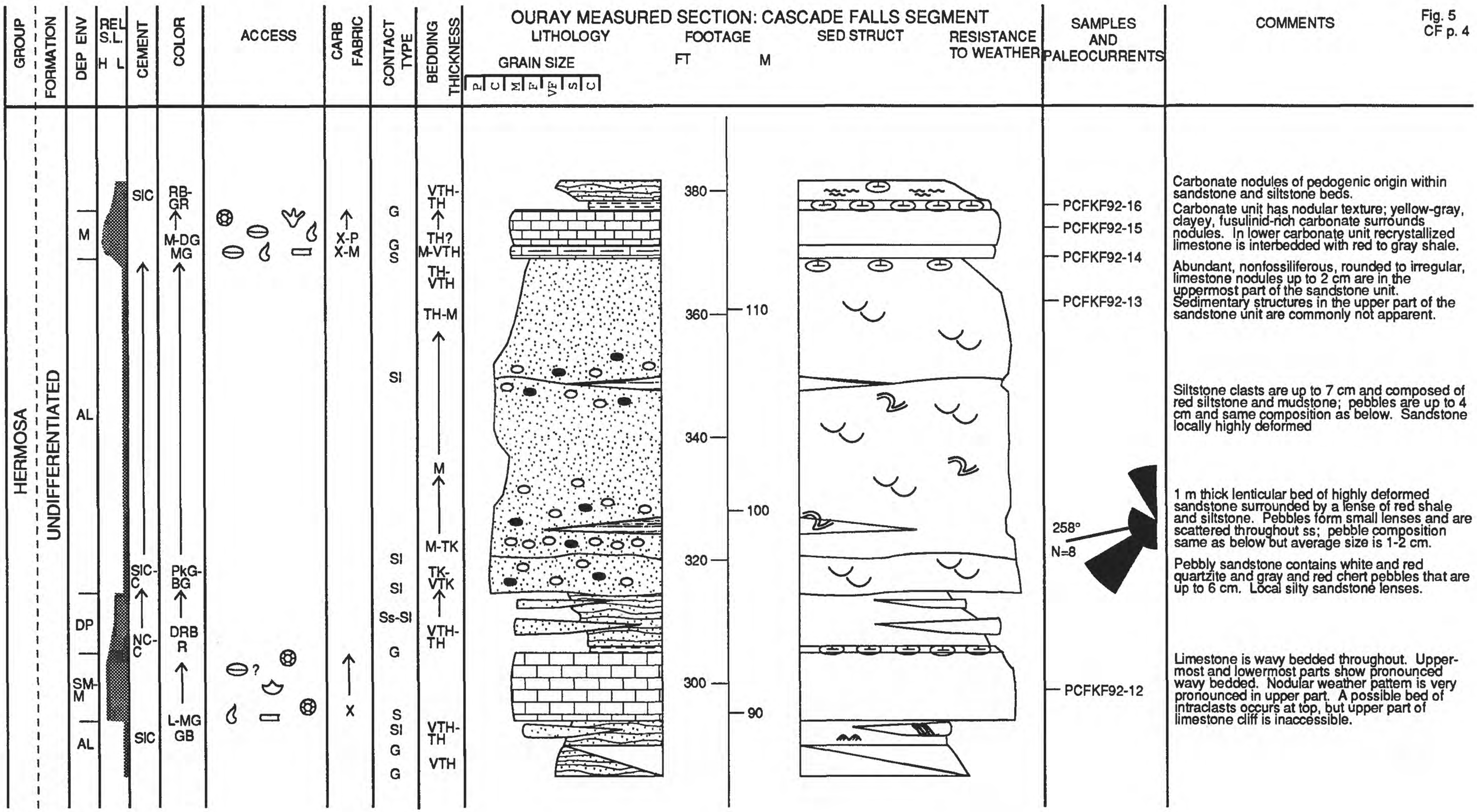


Fig. 5
CF p. 2
OURAY MEASURED SECTION: CASCADE FALLS SEGMENT
GROUP
FORMATION
DEP ENV
REL S.L.
H L
CEMENT
COLOR
ACCESS
CARB FABRIC
CONTACT TYPE
BEDDING THICKNESS
LITHOLOGY
GRAIN SIZE
P C M F VF S C
FOOTAGE
FT
M
SED STRUCT
RESISTANCE TO WEATHER
SAMPLES AND PALEOCURRENTS
COMMENTS
HERMOSA
UNDIFFERENTIATED
M
SM
AL-DP
DF-SM
M-SM
DF-DP?
SM
DP-SM
SIC
NC-SIC
NC
NC-C
VC
NC-SIC C
C
SIC-NC
MG B
OG
GB
GrG
MG-OG
M-DG
OG
BG-GrG
OG-GrG
MG
GrG
M
M
M
M
?
P
W-P
W
S
G
S
SI
G
S
G
SI
G
S
S
S
SI
VTH
TH-VTH
VTH
VTH-TH
M-TH
VTH
M-TH
M?
TK-VTK?
TH-VTH
TH-VTH
TK?
VTH-TH loc M
VTH
TH?
VTH-TH
M
TK?
180
160
140
120
100
80
50
40
30
PCFKF92-8
PCFKF92-7
PCFKF92-6
PCFKF92-5
Carbonate unit consists of thin to very thin beds of limy shale between wavy to nodular bedded wackestone and packstone beds. This unit equivalent to carbonate at 370-377 ft in Ouray section.
Thin sandy carbonate unit may be eroded in Ouray section; ripup clasts from this unit are in conglomerate at 352-355 ft in Ouray section.
Sedimentary structures not apparent through most of sandstone sequence; possible ripple laminations in upper part where sandstone is interbedded with very thin siltstone beds.
Middle of sandstone unit very calcareous and slightly thicker bedded; sedimentary structures commonly not apparent.
Upper part of carbonate unit composed of inter-bedded limy shale and limestone. Gastropods in calcareous ss are to 4.5 cm. Sequence from 127-134 ft is equivalent to clacareous interval from 320-327 ft in Ouray section.
In upper part of sandstone unit very thin beds alternate with thin to medium (10-15 cm thick) beds that commonly have scoured bases.
Fossil abundance increases upward; nodules are wackestone; possilbe algal material.
Where base of unit exposed along cliff face lower contact is erosional. Sedimentary structures in lower part commonly poorly discernable; base of beds flat to erosional; locally beds have convex upper surfaces. Upper part contains local zones of greenish gray and red mottling.



OURAY MEASURED SECTION: CASCADE FALLS SEGMENT
Fig. 5
CF p. 3
GROUP
FORMATION
DEP ENV
REL S.L.
H L
CEMENT
COLOR
ACCESS
CARB FABRIC
CONTACT TYPE
BEDDING THICKNESS
LITHOLOGY
GRAIN SIZE
P C M F VF S C
FOOTAGE
FT
M
SED STRUCT
RESISTANCE TO WEATHER
SAMPLES AND PALEOCURRENTS
COMMENTS
HERMOSA
UNDIFFERENTIATED
AL
DF-SM
DF
SIC-NC
C
C-SIC
C
SIC
GR
GPk-PkR
DR
PB
M-DG
OG
AM
AM
M
X
G
SI
SI
SI
S
SI
G
G
S
SI
G
S
VTH
TH-VTH
M
M-TK
VTK-TK
NA
M-TK
VTH
M
VTH
VTH
M-TH
VTH
280
260
240
220
200
180
80
70
60
?
PCFKF92-11
269°
N=9
PCFKF92-10
PCFKF92-9
Ripple transport direction dominantly to the south. Abrupt change in grain size from poorly sorted pebbly sandstone to well sorted medium-grained sandstone marked by flat, laterally extensive contact apparent only on adjacent cliff face.
Pebbles of chert, quartz, quartzite, and carbonate range from 1-5 cm in diameter and decrease in size and abundance upward within individual scour-based units. Log impression at base of sequence is greater than 90 cm long and 20 cm wide.
Pebbly sandstone unit has a near vetical scour contact with adjacent limestone. Pebbles are chert, quartzite, and feldspar and are up to 2 cm. Grain size varies greatly between beds; pebbles to top of unit.
Lenticular conglomerate bed is 40 cm thick and contains only carbonate pebbles. Ss and congl. are basal fill of channel incised through and below carbonate unit that is present laterally and slightly above this stratigraphic level.
Local moldic porosity in limestone; mm scale crenulations on surface from weathering(?).
Possible hummocky stratification in sandstone unit above scour; sedimentary structures obscured by weathering.
Sandstone unit locally contains beds with low relief scour bases and convex upward bed forms.


OURAY MEASURED SECTION: CASCADE FALLS SEGMENT
Fig. 5
CF p. 4
GROUP
FORMATION
DEP ENV
REL S.L.
H L
CEMENT
COLOR
ACCESS
CARB FABRIC
CONTACT TYPE
BEDDING THICKNESS
LITHOLOGY
GRAIN SIZE
P C M F VF S C
FOOTAGE
FT
M
SED STRUCT
RESISTANCE TO WEATHER
SAMPLES AND PALEOCURRENTS
COMMENTS
HERMOSA
UNDIFFERENTIATED
M
AL
DP
SM-M
AL
SIC
SIC-C
NC-C
SIC
RB-GR
M-DG MG
PkG-BG
DRB R
L-MG GB
X-P
X-M
X
G
G
S
SI
SI
SI
Ss-SI
G
S
SI
G
G
VTH-TH
TH?
M-VTH
TH-VTH
TH-M
M
M-TK
TK-VTK
VTH-TH
VTH-TH
VTH
380
360
340
320
300
110
100
90
PCFKF92-16
PCFKF92-15
PCFKF92-14
PCFKF92-13
258°
N=8
PCFKF92-12
Carbonate nodules of pedogenic origin within sandstone and siltstone beds.
Carbonate unit has nodular texture; yellow-gray, clayey, fusulinid-rich carbonate surrounds nodules. In lower carbonate unit recrystallized limestone is interbedded with red to gray shale.
Abundant, nonfossiliferous, rounded to irregular, limestone nodules up to 2 cm are in the uppermost part of the sandstone unit. Sedimentary structures in the upper part of the sandstone unit are commonly not apparent.
Siltstone clasts are up to 7 cm and composed of red siltstone and mudstone; pebbles are up to 4 cm and same composition as below. Sandstone locally highly deformed
1 m thick lenticular bed of highly deformed sandstone surrounded by a lense of red shale and siltstone. Pebbles form small lenses and are scattered throughout ss; pebble composition same as below but average size is 1-2 cm.
Pebbly sandstone contains white and red quartzite and gray and red chert pebbles that are up to 6 cm. Local silty sandstone lenses.
Limestone is wavy bedded throughout. Uppermost and lowermost parts show pronounced wavy bedded. Nodular weather pattern is very pronounced in upper part. A possible bed of intraclasts occurs at top, but upper part of limestone cliff is inaccessible.

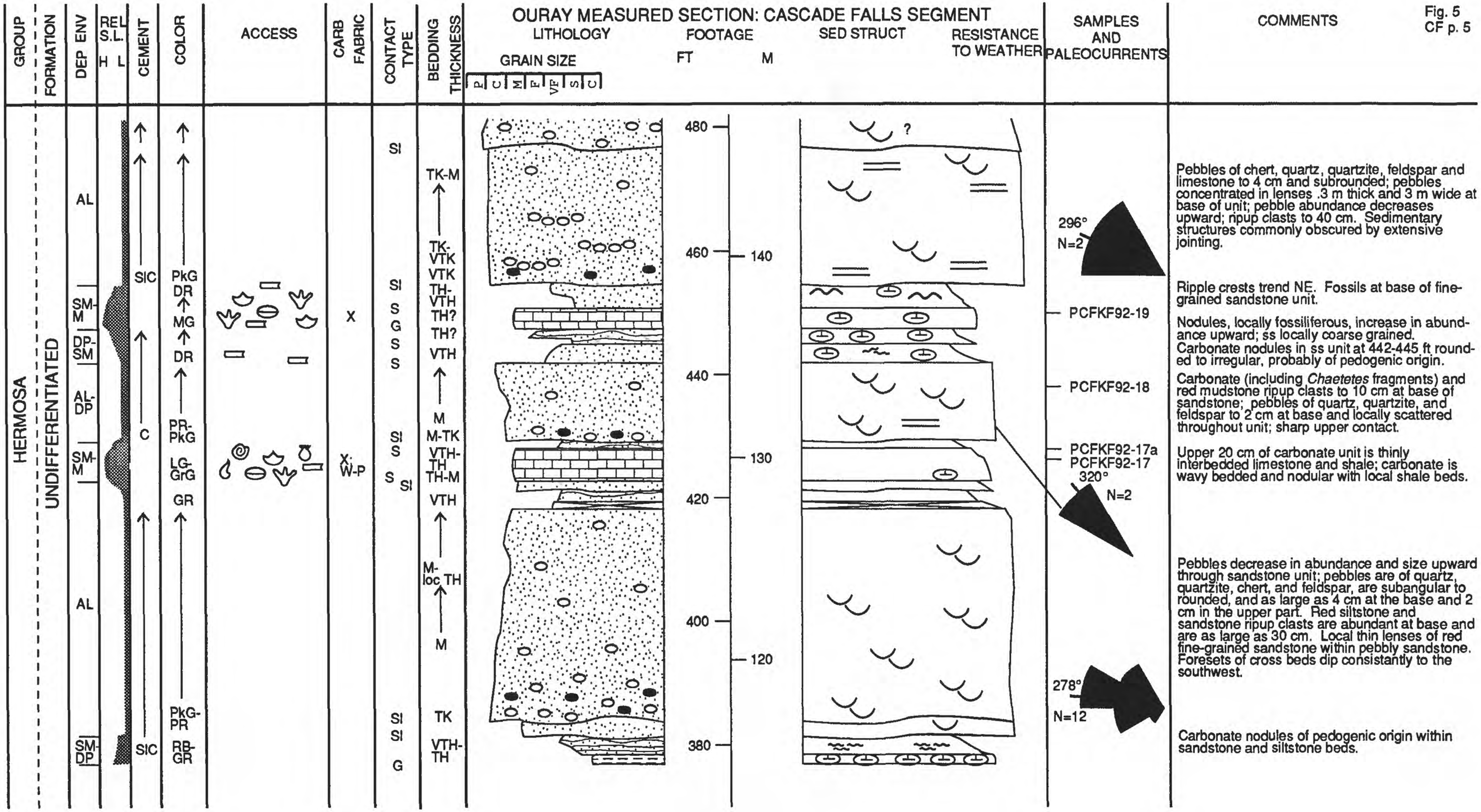
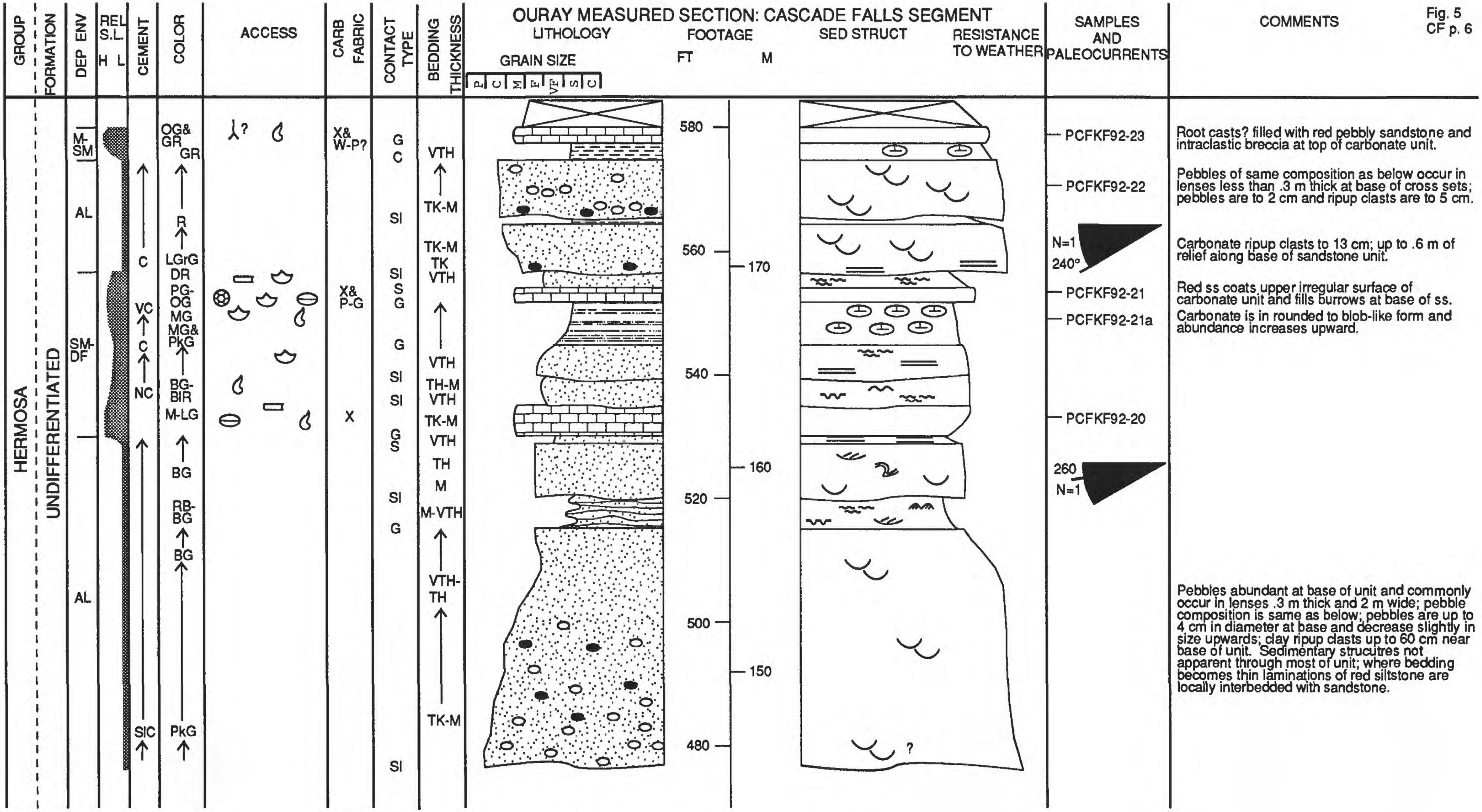
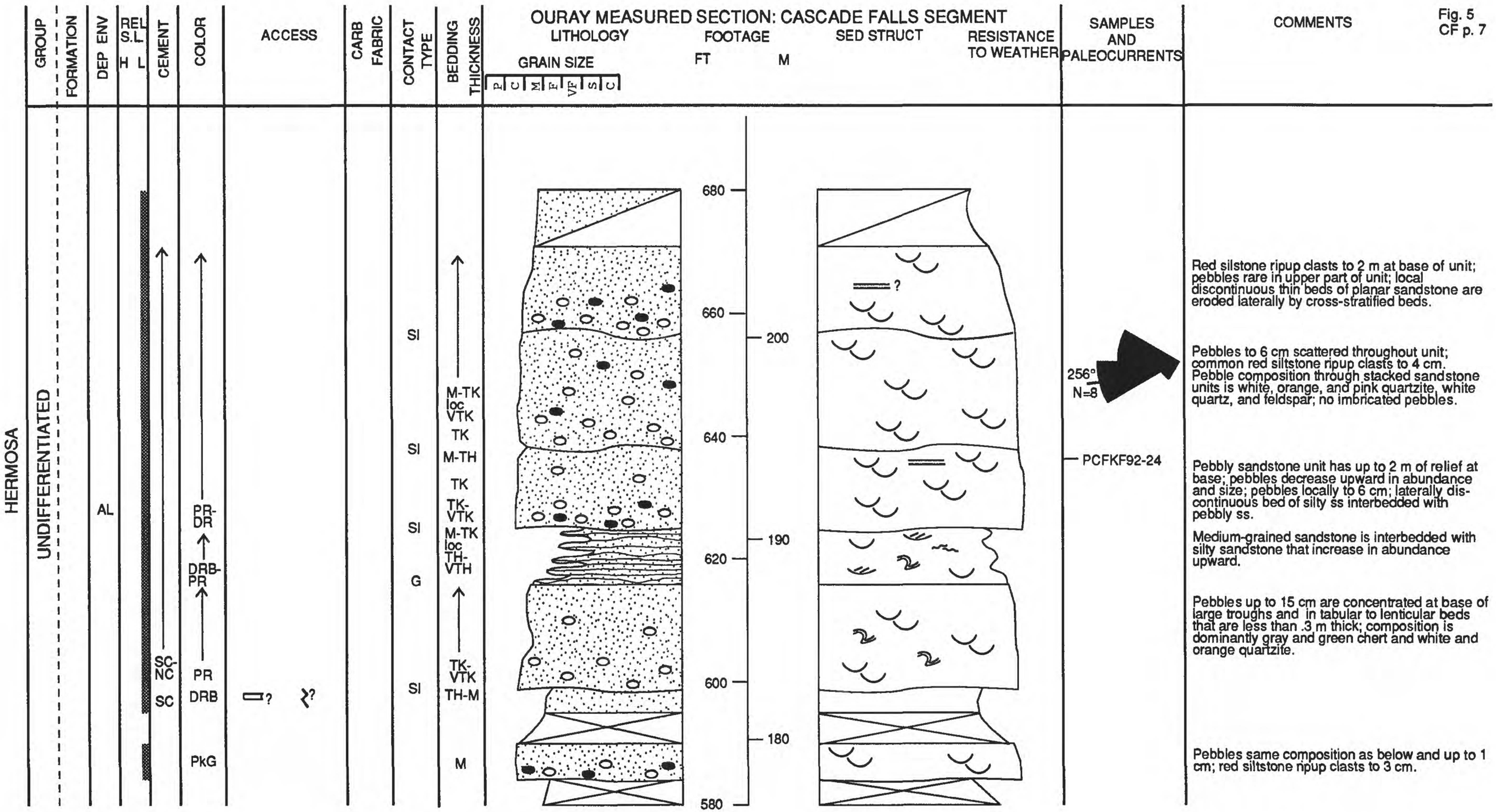


Fig. 5
CF p. 5
OURAY MEASURED SECTION: CASCADE FALLS SEGMENT
GROUP
FORMATION
DEP ENV
REL S.L.
H L
CEMENT
COLOR
ACCESS
CARB FABRIC
CONTACT TYPE
BEDDING THICKNESS
LITHOLOGY
GRAIN SIZE
P C M F VF S C
FOOTAGE
FT
M
SED STRUCT
RESISTANCE TO WEATHER
SAMPLES AND PALEOCURRENTS
COMMENTS
HERMOSA
UNDIFFERENTIATED
AL
SM-M
DP-SM
AL-DP
SM-M
AL
SM-DP
SIC
C
SIC
PkG
DR
MG
DR
PR-PkG
LG-GrG
GR
PkG-PR
RB-GR
X
X;W-P
Sl
Sl
S
G
S
S
Sl
S
S Sl
Sl
Sl
G
TK-M
TK-VTK
VTK
TH-VTH
TH?
TH?
VTH
M
M-TK
VTH-TH
TH-M
VTH
M-loc TH
M
TK
VTH-TH
480
460
440
420
400
380
140
130
120
296°
N=2
PCFKF92-19
PCFKF92-18
PCFKF92-17a
PCFKF92-17
320°
N=2
278°
N=12
Pebbles of chert, quartz, quartzite, feldspar and limestone to 4 cm and subrounded; pebbles concentrated in lenses .3 m thick and 3 m wide at base of unit; pebble abundance decreases upward; ripup clasts to 40 cm. Sedimentary structures commonly obscured by extensive jointing.
Ripple crests trend NE. Fossils at base of fine-grained sandstone unit.
Nodules, locally fossiliferous, increase in abundance upward; ss locally coarse grained.
Carbonate nodules in ss unit at 442-445 ft rounded to irregular, probably of pedogenic origin.
Carbonate (including Chaetetes fragments) and red mudstone ripup clasts to 10 cm at base of sandstone; pebbles of quartz, quartzite, and feldspar to 2 cm at base and locally scattered throughout unit; sharp upper contact.
Upper 20 cm of carbonate unit is thinly interbedded limestone and shale; carbonate is wavy bedded and nodular with local shale beds.
Pebbles decrease in abundance and size upward through sandstone unit; pebbles are of quartz, quartzite, chert, and feldspar, are subangular to rounded, and as large as 4 cm at the base and 2 cm in the upper part. Red siltstone and sandstone ripup clasts are abundant at base and are as large as 30 cm. Local thin lenses of red fine-grained sandstone within pebbly sandstone. Foresets of cross beds dip consistantly to the southwest.
Carbonate nodules of pedogenic origin within sandstone and siltstone beds.


OURAY MEASURED SECTION: CASCADE FALLS SEGMENT
Fig. 5
CF p. 6
GROUP
FORMATION
DEP ENV
REL S.L.
H L
CEMENT
COLOR
ACCESS
CARB FABRIC
CONTACT TYPE
BEDDING THICKNESS
LITHOLOGY
GRAIN SIZE
P C M F VF S C
FOOTAGE
FT
M
SED STRUCT
RESISTANCE TO WEATHER
SAMPLES AND PALEOCURRENTS
COMMENTS
HERMOSA
UNDIFFERENTIATED
M-SM
AL
SM-DF
AL
C
VC
C
NC
SIC
OG&
GR
GR
R
LGrG
DR
PG-
OG
MG
MG&
PkG
BG-
BIR
M-LG
BG
RB-
BG
BG
PkG
X&
W-P?
X&
P-G
X
G
C
SI
SI
S
G
G
SI
SI
G
S
SI
G
SI
VTH
TK-M
TK-M
TK
VTH
VTH
TH-M
VTH
TK-M
VTH
TH
M
M-VTH
VTH-
TH
TK-M
580
560
540
520
500
480
170
160
150
PCFKF92-23
PCFKF92-22
N=1
240°
PCFKF92-21
PCFKF92-21a
PCFKF92-20
260
N=1
Root casts? filled with red pebbly sandstone and intraclastic breccia at top of carbonate unit.
Pebbles of same composition as below occur in lenses less than .3 m thick at base of cross sets; pebbles are to 2 cm and ripup clasts are to 5 cm.
Carbonate ripup clasts to 13 cm; up to .6 m of relief along base of sandstone unit.
Red ss coats upper irregular surface of carbonate unit and fills burrows at base of ss.
Carbonate is in rounded to blob-like form and abundance increases upward.
Pebbles abundant at base of unit and commonly occur in lenses .3 m thick and 2 m wide; pebble composition is same as below; pebbles are up to 4 cm in diameter at base and decrease slightly in size upwards; clay ripup clasts up to 60 cm near base of unit. Sedimentary strucutres not apparent through most of unit; where bedding becomes thin laminations of red siltstone are locally interbedded with sandstone.


OURAY MEASURED SECTION: CASCADE FALLS SEGMENT
Fig. 5
CF p. 7
GROUP
FORMATION
DEP ENV
REL S.L.
H L
CEMENT
COLOR
ACCESS
CARB FABRIC
CONTACT TYPE
BEDDING THICKNESS
LITHOLOGY
GRAIN SIZE
P C M F VF S C
FOOTAGE
FT
M
SED STRUCT
RESISTANCE TO WEATHER
SAMPLES AND PALEOCURRENTS
COMMENTS
HERMOSA
UNDIFFERENTIATED
AL
SC-NC
SC
PR-DR
DRB-PR
PR
DRB
PkG
SI
SI
SI
G
SI
M-TK loc VTK
TK
M-TH
TK
TK-VTK
M-TK loc TH-VTH
TK-VTK
TH-M
M
680
660
640
620
600
580
200
190
180
256°
N=8
PCFKF92-24
Red silstone ripup clasts to 2 m at base of unit; pebbles rare in upper part of unit; local discontinuous thin beds of planar sandstone are eroded laterally by cross-stratified beds.
Pebbles to 6 cm scattered throughout unit; common red siltstone ripup clasts to 4 cm. Pebble composition through stacked sandstone units is white, orange, and pink quartzite, white quartz, and feldspar; no imbricated pebbles.
Pebbly sandstone unit has up to 2 m of relief at base; pebbles decrease upward in abundance and size; pebbles locally to 6 cm; laterally discontinuous bed of silty ss interbedded with pebbly ss.
Medium-grained sandstone is interbedded with silty sandstone that increase in abundance upward.
Pebbles up to 15 cm are concentrated at base of large troughs and in tabular to lenticular beds that are less than .3 m thick; composition is dominantly gray and green chert and white and orange quartzite.
Pebbles same composition as below and up to 1 cm; red siltstone ripup clasts to 3 cm.

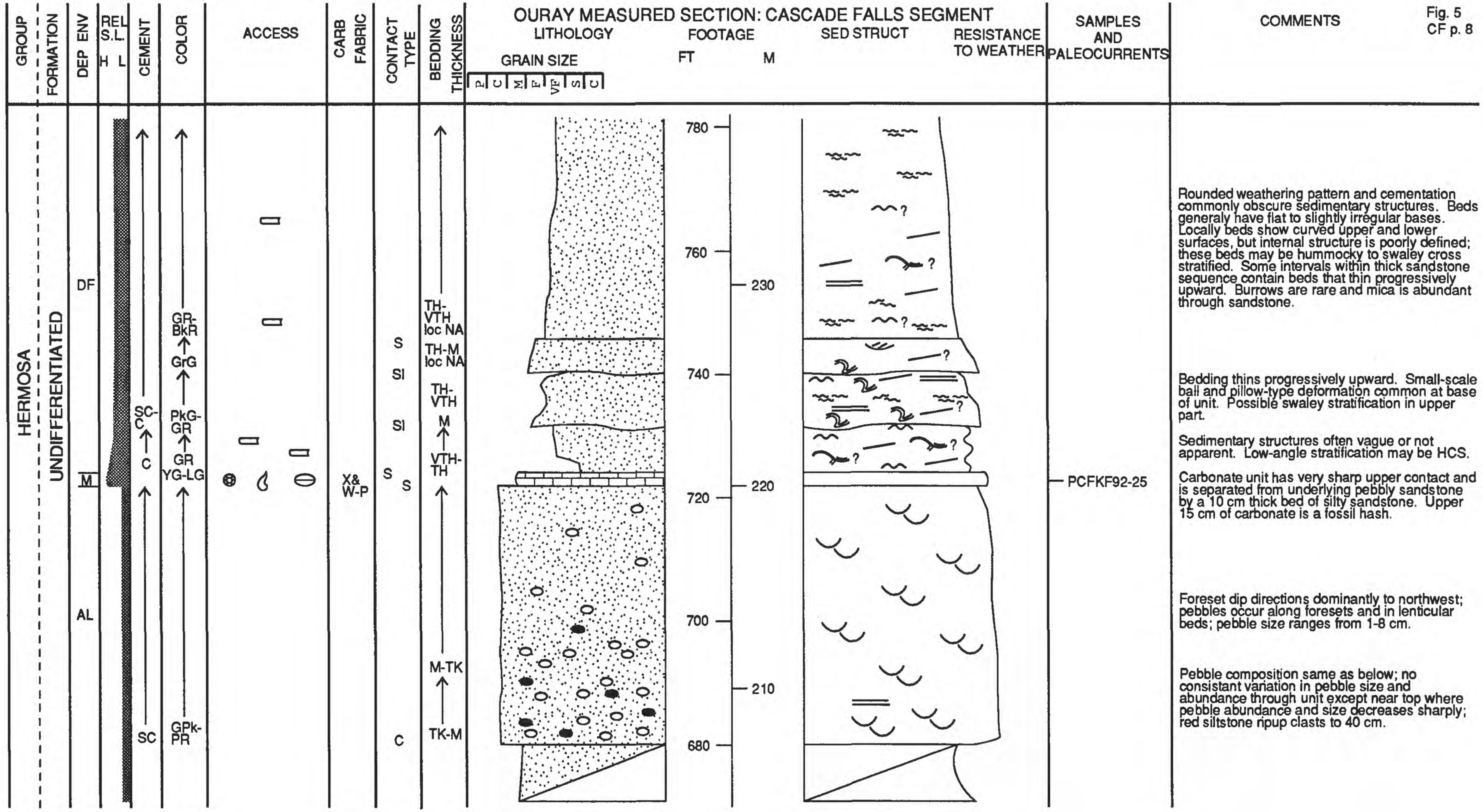
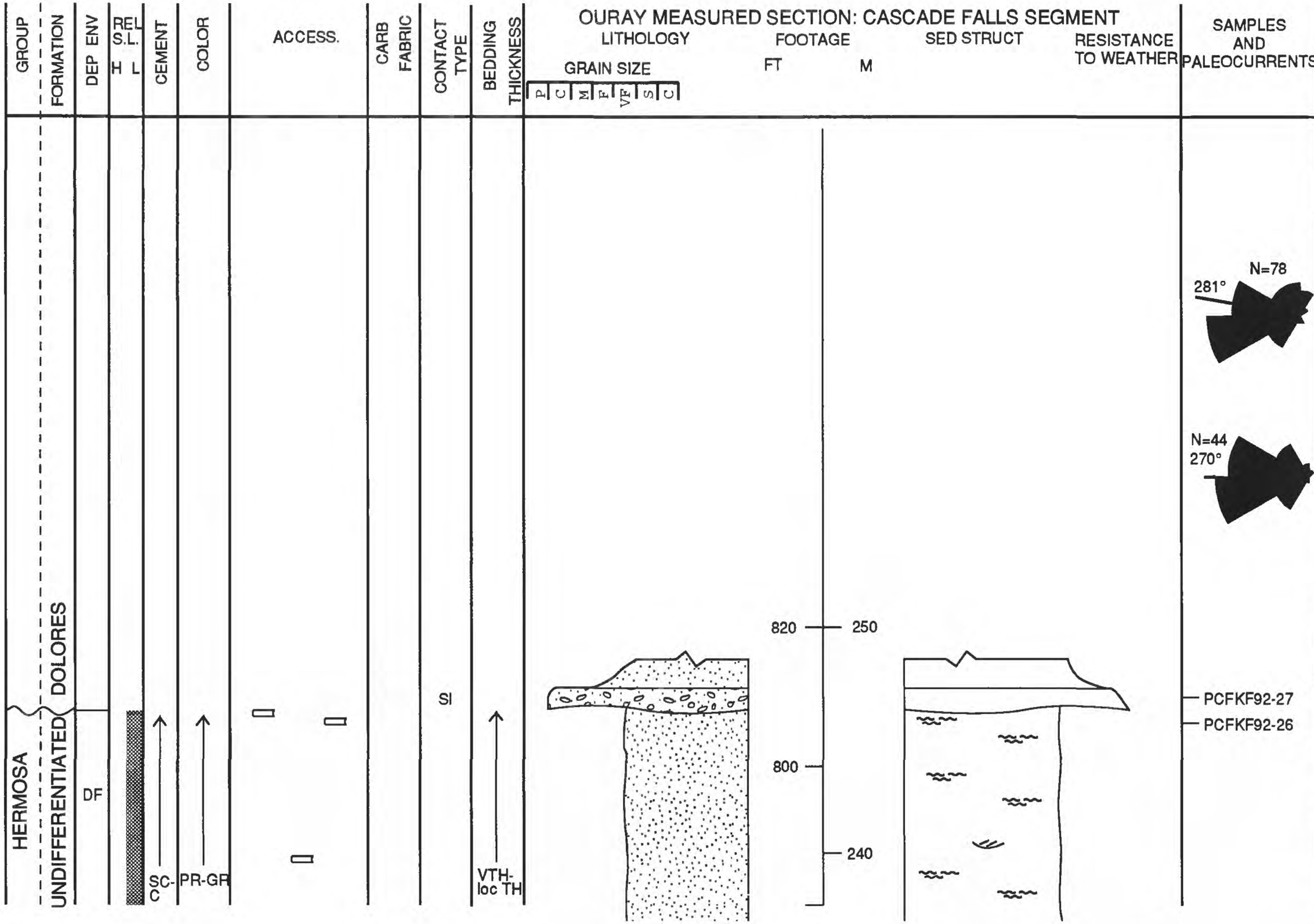

OURAY MEASURED SECTION: CASCADE FALLS SEGMENT
Fig. 5
CF p. 8
GROUP
FORMATION
DEP ENV
REL S.L.
H L
CEMENT
COLOR
ACCESS
CARB FABRIC
CONTACT TYPE
BEDDING THICKNESS
LITHOLOGY
GRAIN SIZE
P C M F VF S C
FOOTAGE
FT
M
SED STRUCT
RESISTANCE TO WEATHER
SAMPLES AND PALEOCURRENTS
COMMENTS
HERMOSA
UNDIFFERENTIATED
DF
M
AL
SC-C
C
SC
GR-BkR
GrG
PkG-GR
GR
YG-LG
GPk-PR
X& W-P
S
SI
SI
S
S
C
TH-VTH loc NA
TH-M loc NA
TH-VTH
M
VTH-TH
M-TK
TK-M
780
760
740
720
700
680
230
220
210
PCFKF92-25
Rounded weathering pattern and cementation commonly obscure sedimentary structures. Beds generaly have flat to slightly irregular bases. Locally beds show curved upper and lower surfaces, but internal structure is poorly defined; these beds may be hummocky to swaley cross stratified. Some intervals within thick sandstone sequence contain beds that thin progressively upward. Burrows are rare and mica is abundant through sandstone.
Bedding thins progressively upward. Small-scale ball and pillow-type deformation common at base of unit. Possible swaley stratification in upper part.
Sedimentary structures often vague or not apparent. Low-angle stratification may be HCS.
Carbonate unit has very sharp upper contact and is separated from underlying pebbly sandstone by a 10 cm thick bed of silty sandstone. Upper 15 cm of carbonate is a fossil hash.
Foreset dip directions dominantly to northwest; pebbles occur along foresets and in lenticular beds; pebble size ranges from 1-8 cm.
Pebble composition same as below; no consistant variation in pebble size and abundance through unit except near top where pebble abundance and size decreases sharply; red siltstone ripup clasts to 40 cm.

Fig. 5
CF p. 9

OURAY MEASURED SECTION: CASCADE FALLS SEGMENT



COMMENTS

Rose diagram to left shows all paleocurrent readings taken from both the Ouray and Cascade Falls sections.

Rose diagram to left shows all paleocurrent readings from the Cascade Falls section.

The angular unconformity between the Dolores and Hermosa rises stratigraphically to the north of the Cascade Falls line of section. About 200 ft of the Hermosa Group has been cut out by this unconformity. This 200 ft of section is only exposed on cliff faces, and it appears to consist of alternating marine and nonmarine sequences.

An angular unconformity separates the Triassic Dolores Formation from the underlying Hermosa Group. About 300 ft to the north of the line of section, discontinuous, fossiliferous limestone beds are within the very fine grained sandstone at the top of the Hermosa. Sample PCFKF92-26 is from these limestone beds.

Rare bioturbated to deformed beds; burrows are generally rare through this interval; Locally beds have a nodular weathering appearance and contain blebs and stringers of sparry calcite, but no apparent fossils. Sedimentary structures are the same as below.

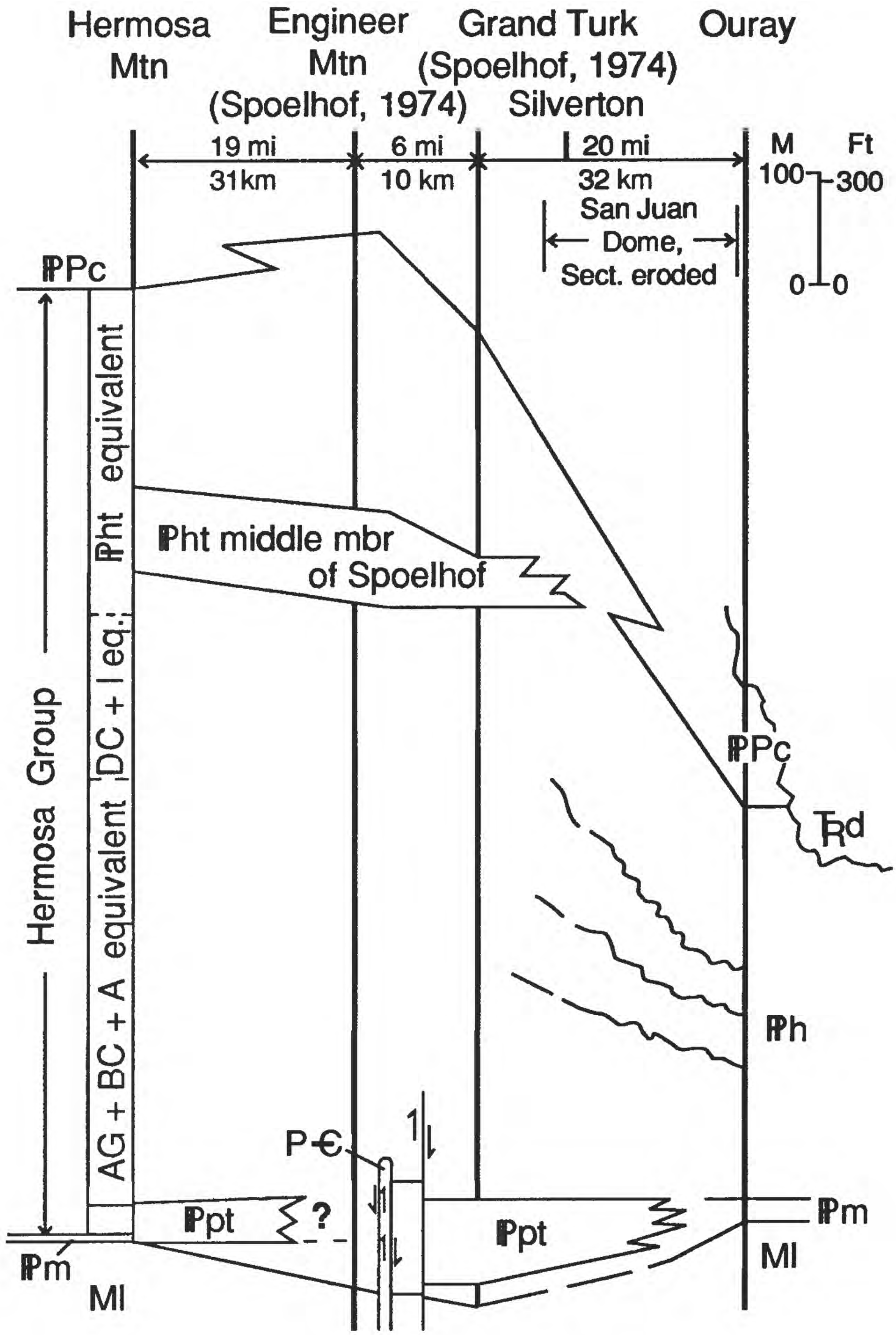

Hermosa Mtn
Engineer Mtn (Spoelhof, 1974)
Grand Turk (Spoelhof, 1974) Silverton
Ouray
19 mi 31km
6 mi 10 km
20 mi 32 km
San Juan Dome, Sect. eroded
M Ft
100 300
0 0
PPc
Pht equivalent
Pht middle mbr of Spoelhof
DC + I eq.
AG + BC + A equivalent
Hermosa Group
Ppt
?
P-€
Pm
Ml
PPc
Rd
Ph
Pm
Ml

Figure 6

Figure 7