THE PALEOCENE-EOCENE FLAGSTAFF FORMATION IN THE SIXMILE CANYON AREA OF THE WASATCH PLATEAU, CENTRAL UTAH

A Thesis

Presented in Partial Fulfillment of the Requirements
for the Degree Bachelor of Science

by

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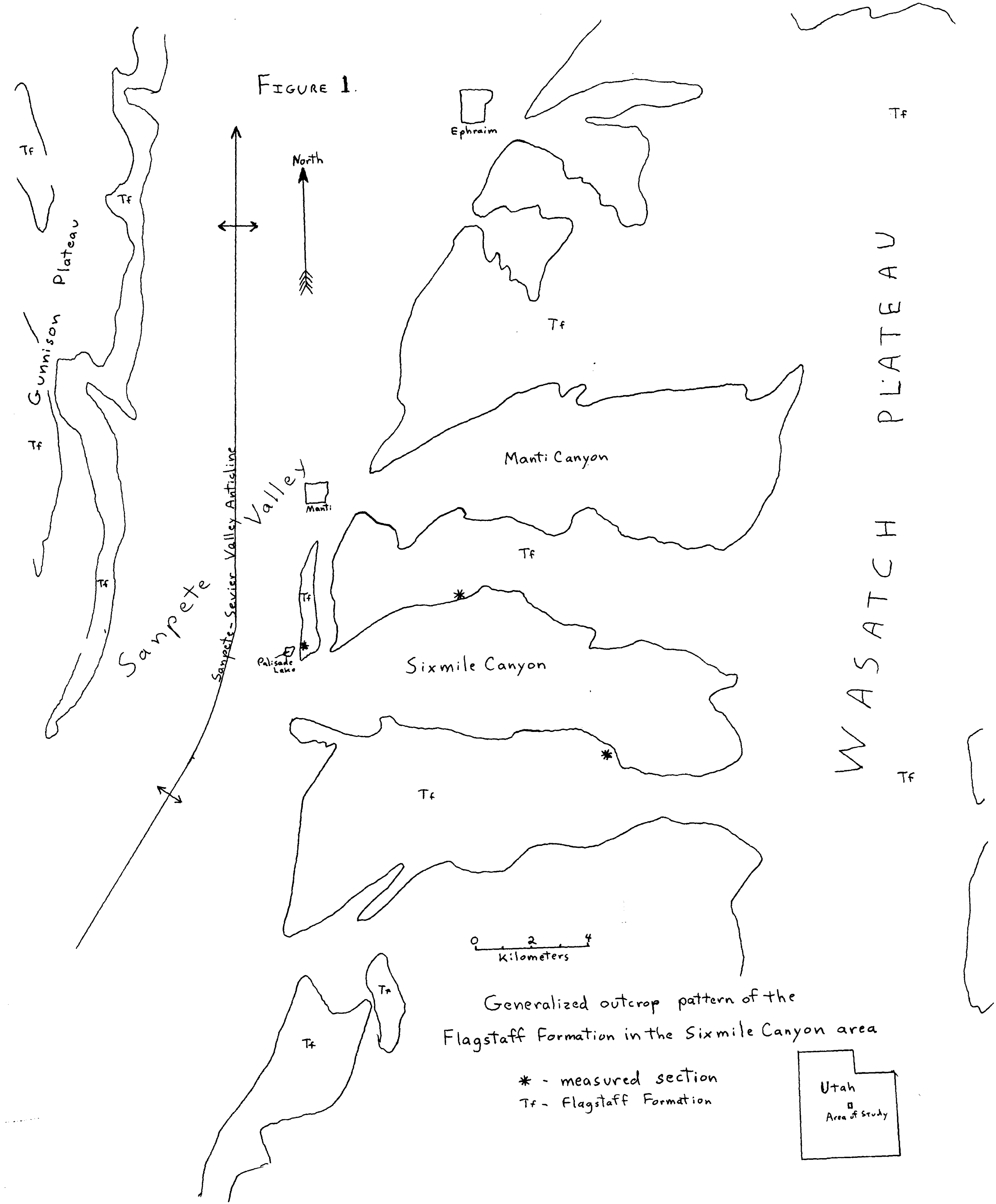
INTRODUCTION

The Flagstaff Formation of central Utah has been the subject of study by many individuals since the latter 19th century. E. M. Spieker and J. B. Reeside first studied and mapped the Wasatch Plateau and surrounding area, and in 1925 named these lacustrine sediments as a seperate geologic unit. A detailed study of the molluscan fauna in the Flagstaff lake sediments by Aurèle LaRocque (1960), has revealed the presence of three stages of development of the lake, as well as age correlation of the fossils present. During the summer of 1976, the Flagstaff Formation was examined in the type area of Flagstaff Peak at the southern end of the Wasatch Plateau, by Lon A. McCullough and Neil Wells. Their investigation of the rocks revealed the presence of playa-lake sediments related to the middle stage of the lake, which had not been previously reported in this area. During their work, fourteen sections were measured in detail and sampled in the type area on the Wasatch Plateau, in the Gunnison Plateau, and along the monocline, which forms the western flank of the Wasatch Plateau; Three of these sections, from the Sixmile Canyon area, are the subject of this report (see fig.1).

Of the samples collected in the Sixmile Canyon area, lithologic variations and various mineral constituents were examined in thin section and hand specimen, and by x-ray powder diffraction analysis, in order to interpret the depositional environment of the Flagstaff Formation in this area. Sixmile Canyon is located on the western flank of the Wasatch Monocline, where Upper Cretaceous and Tertiary sedimentary rocks plunge

FIGURE 1.



Generalized outcrop pattern of the Flagstaff Formation in the Sixmile Canyon area westward from their horizontal attitude on top of the plateau, flattening out again to dip gently beneath the alluvium of the Sanpete and Sevier Valleys.

GENERAL STRATIGRAPHY AND STRUCTURE

During the early Paleocene, 63 million years ago, crustal movements in what is now central Utah formed the Flagstaff lake basin. Prior to this time, at least six periods of tectonic activity have been recognized, forming uplifts, thrust faults, folds, and depressions into which freshwater streams discharged (Weber, 1964). In the Sixmile Canyon area along the plateau front, highly folded Middle Jurassic through Upper Cretaceous sediments rise out of the valley floor to heights of 250-310 metres. This older complex of folded rocks is truncated sharply by an even erosion surface which is overlain at the base of the monocline by the Flagstaff Formation in angular unconformity. Just east of these outer foothills, the Flagstaff Formation rises on the monocline with the Price River and North Horn Formations appearing beneath it, also in angular unconformity with both the older Cretaceous rocks of the Sixmile Canyon Formation of the Indianola Group, as well as with the Flagstaff itself. Farther eastward, the Price River and the North Horn Formations flatten out to parallel the Flagstaff beneath the main body of the plateau (Spieker, 1949), (see fig.2).

The older folded strata form an anticline which trends north-south beneath the Sanpete and Sevier Valleys for at least 105-113 km.. The anticline is a result of compression during the early Laramide orogeny (Gunderson and Gilliland, 1967).

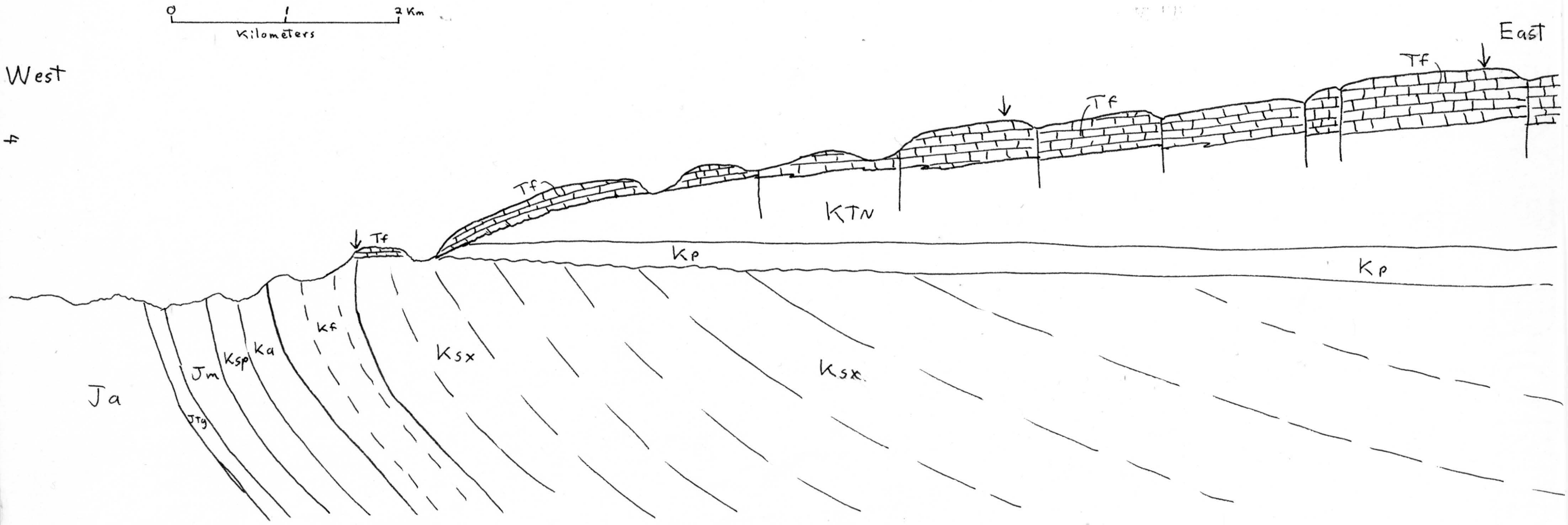
Generalized Stratigraphic and Structur Relations of Bedrock in Sixmile Canyon area

FIGURE 2.

Tertiary	TF	Flagstaff Fm.
Cretaceous	KTN	North Horn Fm.
	Kp	Price River fm.
	Ksx	Sixmile Canyon fm.
	Kf	Funk Valley fm.
	Ka	Allen Valley fm.
	Ksp	Sanpete Fm.
Jurassic	Jm	Morrison fm.
	JTg	Twist Gulch fm.
	Ja	Arapien Shale

〰 unconformity

↓ – measured section



Isopachous mapping of the Flagstaff and adjacent formations by Gunderson and Gilliland indicates that the anticline was a positive belt almost continuously since the initial exposure of the Jurassic Arapien Shale. The later Cretaceous and early Tertiary strata thin markedly toward the anticline, which remained topographically positive throughout the North Horn and Flagstaff depositions. Evidence for this probable island in the Sixmile Canyon area can be seen in the Flagstaff Formation by the high percentage of sandstone and conglomerate at the base of the Flagstaff where it rests directly on the vertical beds of the Funk Valley Formation in the lower Sixmile Canyon section near Palisade Lake. Farther to the east, the clastics die out where the Flagstaff lake was probably deeper, and only carbonates were deposited. The presence of oncolites and oolites (see photo D) near the basal Flagstaff in the vicinity of the mouth of Sixmile Canyon, also serves as an indication of shallow-water, high energy, near-shore lacustrine deposition (Weiss, 1969). As stated earlier, the unconformity between the Flagstaff and the underlying North Horn Formations dies out toward the east, indicating movement on the anticline just prior to early Flagstaff deposition.

Early Flagstaff deposition consisted of alternating, relatively thin-bedded, micritic and intraclastic limestone, and carbonaceous, highly calcareous shale, mudstone, and siltstone. An abundance of Paleocene gastropods and pelecypods, both whole and fragmented, indicative of a shallow, freshwater, and low shore-line environment, occurs in many of the limestones and some shale (LaRocque, 1960).

Rocks ofthe second lake stage show a variety of features that are quite different from the first and last stages. The chemical composition of the water changed toward more saline conditions, causing the scarcity of freshwater mollusks, and the presence of dolomite and evaporite mineral deposits (LaRocque, 1960). In addition to this, sedimentary features indicative of shallow-water deposition and dessication suggest that the rocks of the middle lake stage were deposited in a playa-lake complex (McCullough, 1977). Only the presence of ostracods, which were more tolerant of the higher salinity, and the occurrence of a few land snails washed into the lake from the surrounding land area, make up the faunal record of the middle stage rocks (LaRocque, 1960). A couple periods of temporary freshening of the lake waters can be seen by the presence of a few horizons containing stunted mollusks, during the early playa-lake deposition (McCullough, 1977).

Rocks of the third lake stage are very similar in lithology to those of the first stage, except that some of the limestones have been heavily silicified (McCullough, 1977), and the dating of the abundant molluscan fauna points to deposition during the Eocene (LaRocque, 1960).

DESCRIPTION OF SECTIONS

The three stratigraphic sections of the Flagstaff Formation that were measured, collected, and examined, were taken from locations in the upper Sixmile Canyon, middle Sixmile Canyon, and lower Sixmile Canyon (see fig.1, and Appendix). These sections are samples of the sediments deposited in fairly deep water, shallow water, and very shallow, near-shore environments respectively.

The upper Sixmile Canyon section (see fig.3), representing deeper water deposition, consists of thin to moderately thick-bedded micrite, biomicrite, and intramicrite (photo A), alternating with thin-bedded carbonaceous shale, grading upward into thicker bedded micrite, dolomicrite, and thick-bedded shale, shaly limestone, and shaly dolomite (photo B). The lower half of the section contains a noticably higher percentage of fossils, which generally decrease (throughout the section), as the dolomite in the rock increases in proportion to calcite (see fig.4).

The middle Sixmile Canyon section (see fig.5), deposited nearer to shore than the latter section, is made up of basal sandstone, mudstone, and siltstone, commonly conglomeratic, and containing sandstone intraclasts. This clastic sequence fines upward in the section, and becomes more calcareous. In the upper half of the section, the rocks become less silty, more muddy, and highly dolomitic (see fig.6). Fossils consist of a few burrows in the lower sandstone and siltstone beds.

The lower Sixmile Canyon section represents a very near-shore environment of deposition (see fig.7). A thick-bedded sequence of massive sandstone and conglomerate, with thin beds of shale and siltstone becomes finer grain, and more calcareous, grading upward into silty limestone. The section becomes highly dolomitic (see fig.8) toward the upper one-quarter of its thickness. The uppermost beds exposed are thin to moderately thick-bedded pisolitic and oolitic, fossiliferous limestone, with some white chert nodules (photo D). The lower third of the section contains the most fossils which are mostly ostracods, a few burrows and some round, broken, and downward-cupped oncolites in conglomerate.

ENVIRONMENTS OF DEPOSITION

As previously stated, the upper Sixmile Canyon section was deposited away from the western shore of the island produced by the Sanpete-Sevier Valley anticline. It is at a distance of roughly 10 km. from the paleo-shoreline, but because a large variety of mollusks and ostracods lived at or near this location during early Flagstaff time, these early stage sediments were probably deposited in relatively shallow water, as suggested by the food and environmental requirements of the organisms. The intraclastic nature of many of the limestone beds indicates a shallow enough lake bottom for wave action to occasionally rip up and move around the then loosely consolidated sediments, and the rounded nature of many of the intraclasts points out a small amount of transportation before re-deposition. One of the samples (6M-41),(photo B), shows some of these characteristics well: Subrounded intraclasts occur mostly at the base and the rock then is densely laminated with ostracod shells, which decrease in abundance upward as the percentage of dolomite increases.

The rocks from the middle Sixmile Canyon section most likely represent deposition during the lower and middle playa-lake stage of Lake Flagstaff. Being nearer to the shore of the island, approximately 6 km., more clastic particles reached this location than did the latter. As the island became slowly inundated by the lake waters, which probably became much more extensive near the time of the early playa-lake conditions (LaRocque, 1960), fewer clastics were washed in because the source was covered by finer and finer sediments.

This stratigraphic column shows clastic grain size decreasing upward in section, as well as increased carbonate deposition indicating deeper water deposition. The high amount of dolomite as cement in the lower sandstone beds and near the top of the section, as well as the absence af fossils, most likely indicates that the rocks were deposited during more saline conditions. The intraclastic nature of some of the carbonates again shows that even when the lake waters were deeper, bottom sediments were still within reach of occasional disturbance by wave action.

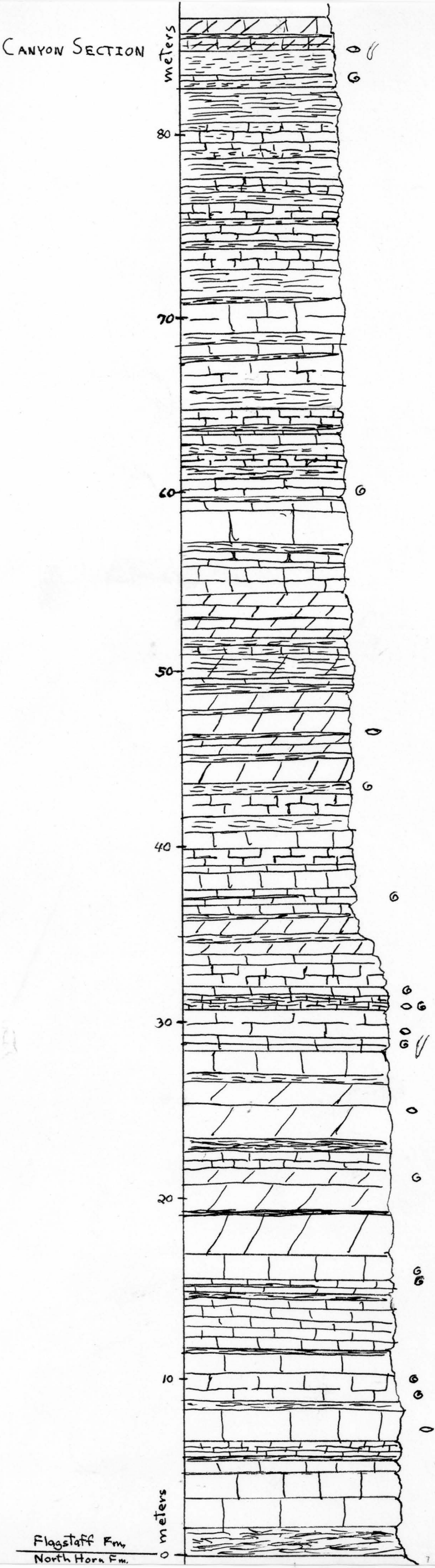
The near-shore depositional environment of the lower Sixmile Canyon section is apparent just by looking at the similarity between the basal sandstone and the sandstones that make up the folded Cretaceous source rocks; the Funk Valley and Sixmile Canyon Formations. Cross-bedding and oncolites in the redeposited sands indicate current movements, possibly in a near-shore deltaic environment.

The deposition of carbonate seen in the upper section probably indicates that the island was breached by lake waters similar to that described by Gunderson and Gilliland (1967). The presence of oolites and pisolites show that the positive belt of Cretaceous rocks was not deeply submerged. These upper more fossiliferous limestones could mean that this section was deposited during the upper middle-playa-lake stage, at which time a further expansion of lake waters (LaRocque, 1960) led to the freshening of the water and the breaching of the island.

Figure 3,

UPPER SIX MILE CANYON SECTION

SYMBOLS
G Gastropods
○ Ostracods
// Burrows



Dolomitic, medium to thick bedded sparce biomicrite, with thin brown shale

Varigated, thick bedded shale, and thin bedded intramicrite

medium to thick bedded mudstone, alternating with blocky, argillaceous intramicrite, and biomicrite

interbedded, medium to thick bedded intramicrite, and biomicrite, alternating with mudstone, and thin bedded shale

blocky, thin to medium bedded micrite, one thick bed of shaly mudstone

medium bedded micrite, intramicrite, and biomicrite, alternating with medium bedded shale and mudstone

medium to thick bedded intramicrite and biomicrite (sparfillings), shale partings, and thin interbedded shale and mudstone

Dolomitic medium to thin bedded micrite and intramicrite, with very thin shale

Dolomitic thick to medium bedded shale, and shaly mudstone, alternating with thin bedded clayey micrite

Dolomitic micrite, and intramicrite (some laminated with ostracod shells), alternating with thin bedded, light brown shale, and organic-rich mudstone

medium to thick bedded shale, alternating with massive gray-brown micrite (some intraclastic, some fossiliferous)

thick to medium bedded pure micrite (lithographic) with some light brown biomicrite (calcite veins)

dark brown micrite, some nodular, some fossiliferous, with thin bedded shale

Thick to medium bedded, very light color micrite and dolomitic micrite, some thin bedded shale, and some whole snail shells.

laminated biomicrite (light color, sparfilling of cracks and vugs), medium thick bed of packed biomicrite (laminated with ostracod shells)

Thick bedded, light gray-brown micrite, and medium thick dark biomicrite-intramicrite (calcite veins)

Dolomitec
micrite, dark biomicrite and intramicrite (argillaceous, platy, some fossils and fossil fragments), alternating with thin bedded light gray shale and mudstone

intramicrite, (brecciated clasts, slightly fossiliferous)

light color micrite and biomicrite, with thin shale, and thicker brown shaley mudstone

thin bedded micrite, and biomicrite, sparce biomicrite, some intramicrite, interbedded with very thin shale.

moderately thick bedded micrite (organic rich), alternating with sparce biomicrite and biomicrite, and thin bedded dark shale

Thin bedded, nodular micrite with thin bedded shale

massive micrite

intramicrite and biomicrite

clayey shale

Figure 4

Upper Six Mile Canyon Section
(from Appendix)

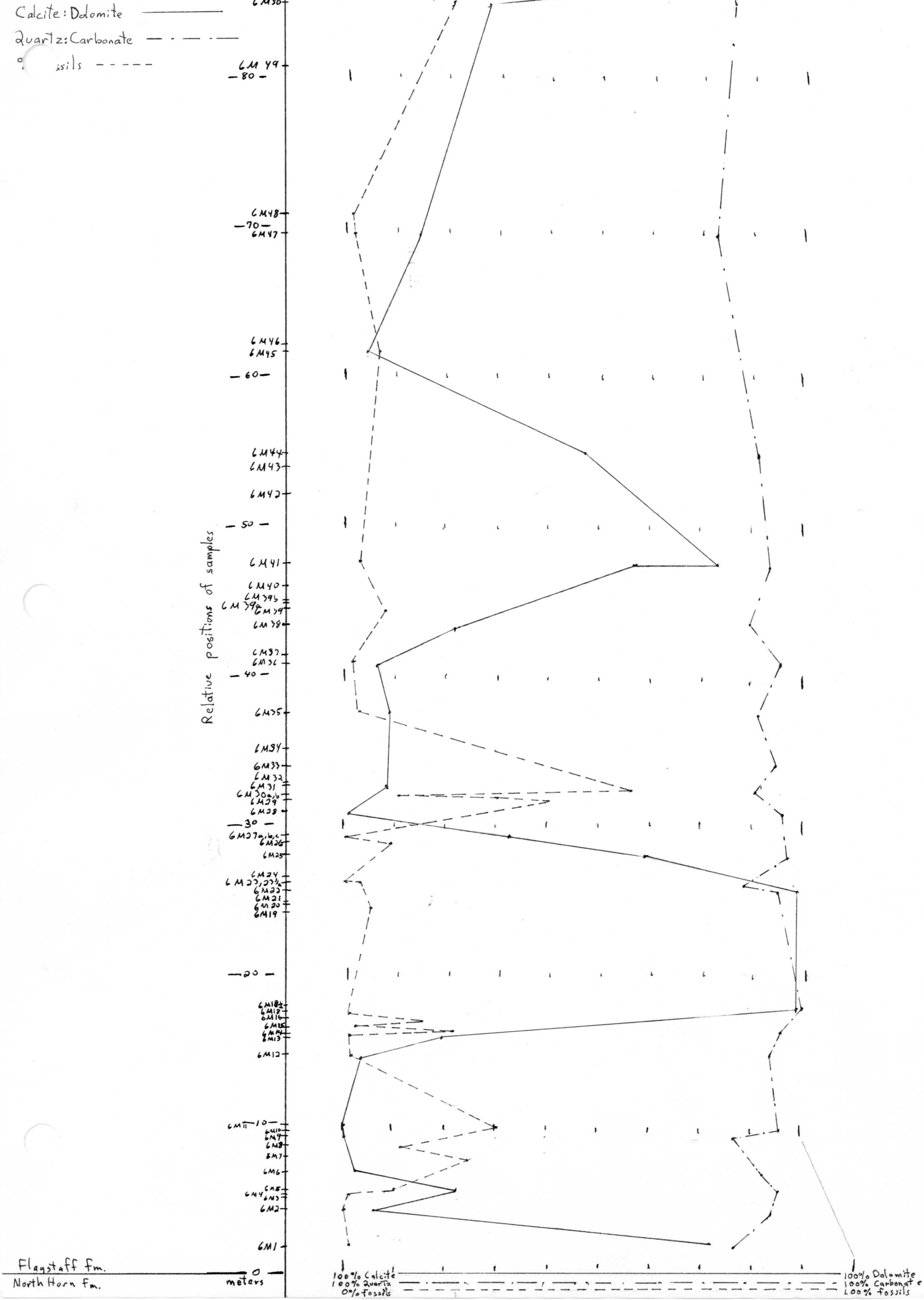


Figure 5.

MIDDLE SIX MILE CANYON SECTION

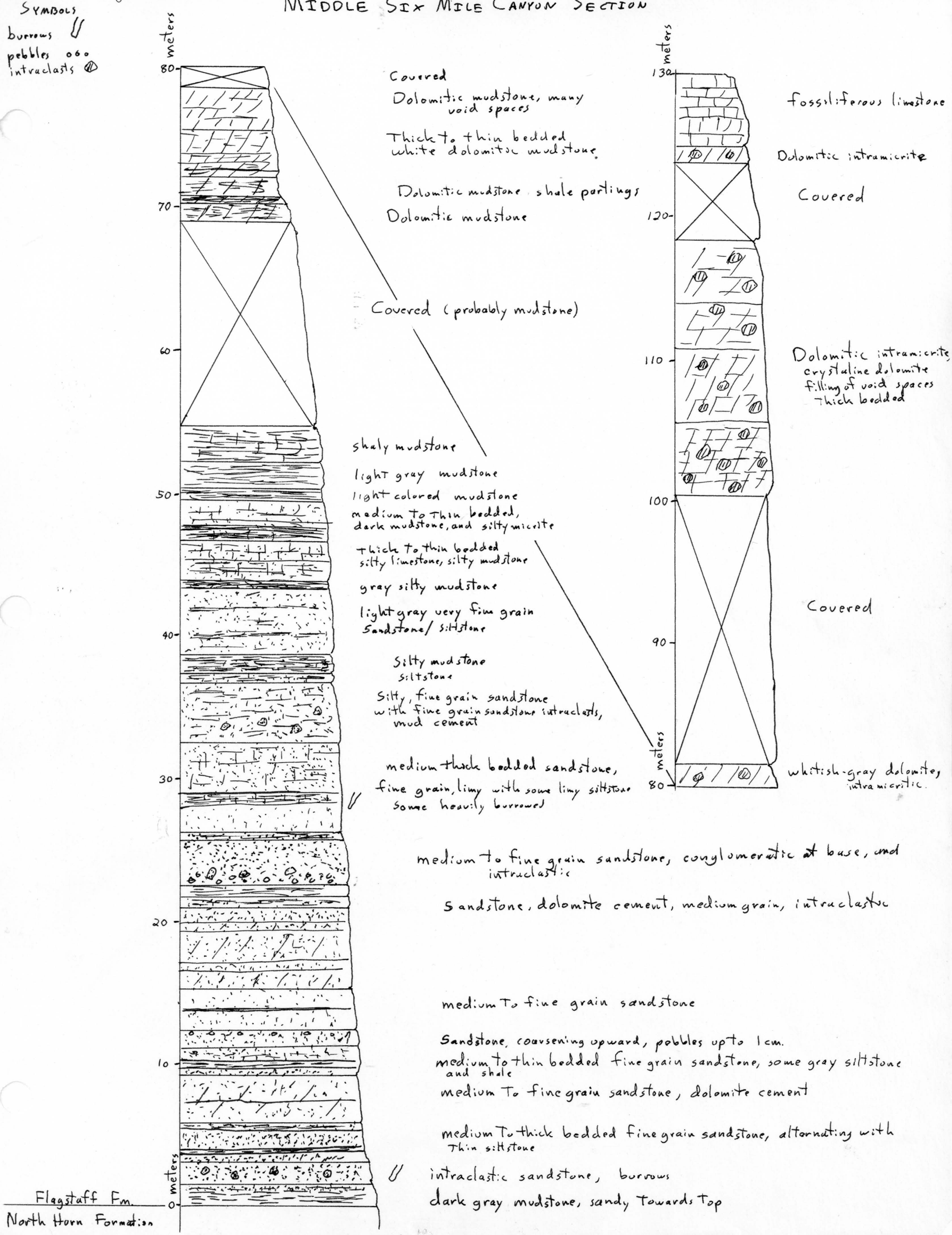


Figure 6.
MIDDLE SIXMILE
CANYON SECTION
(, Appendix)

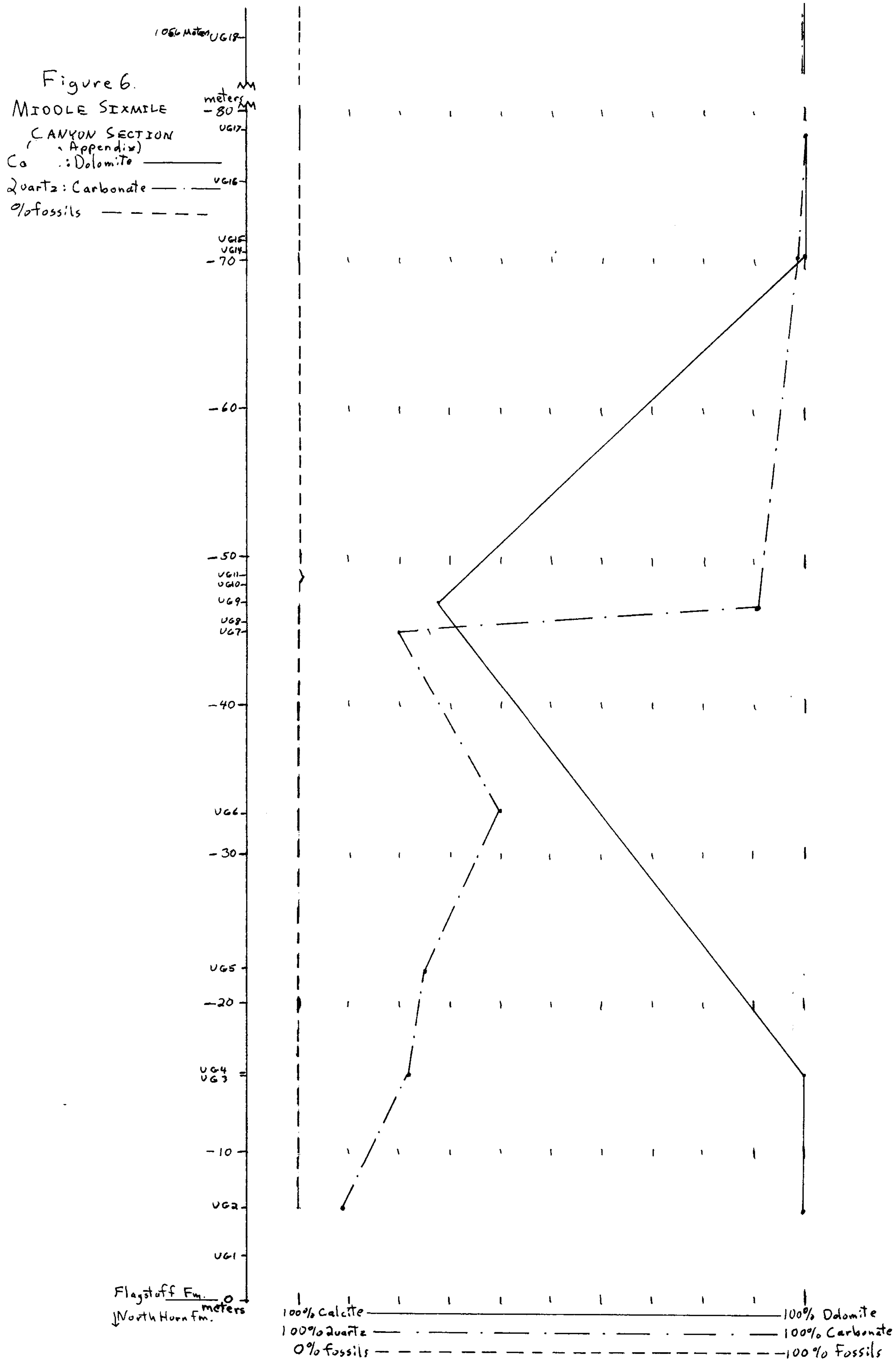


Figure 7.

LOWER SIX MILE CANYON SECTION

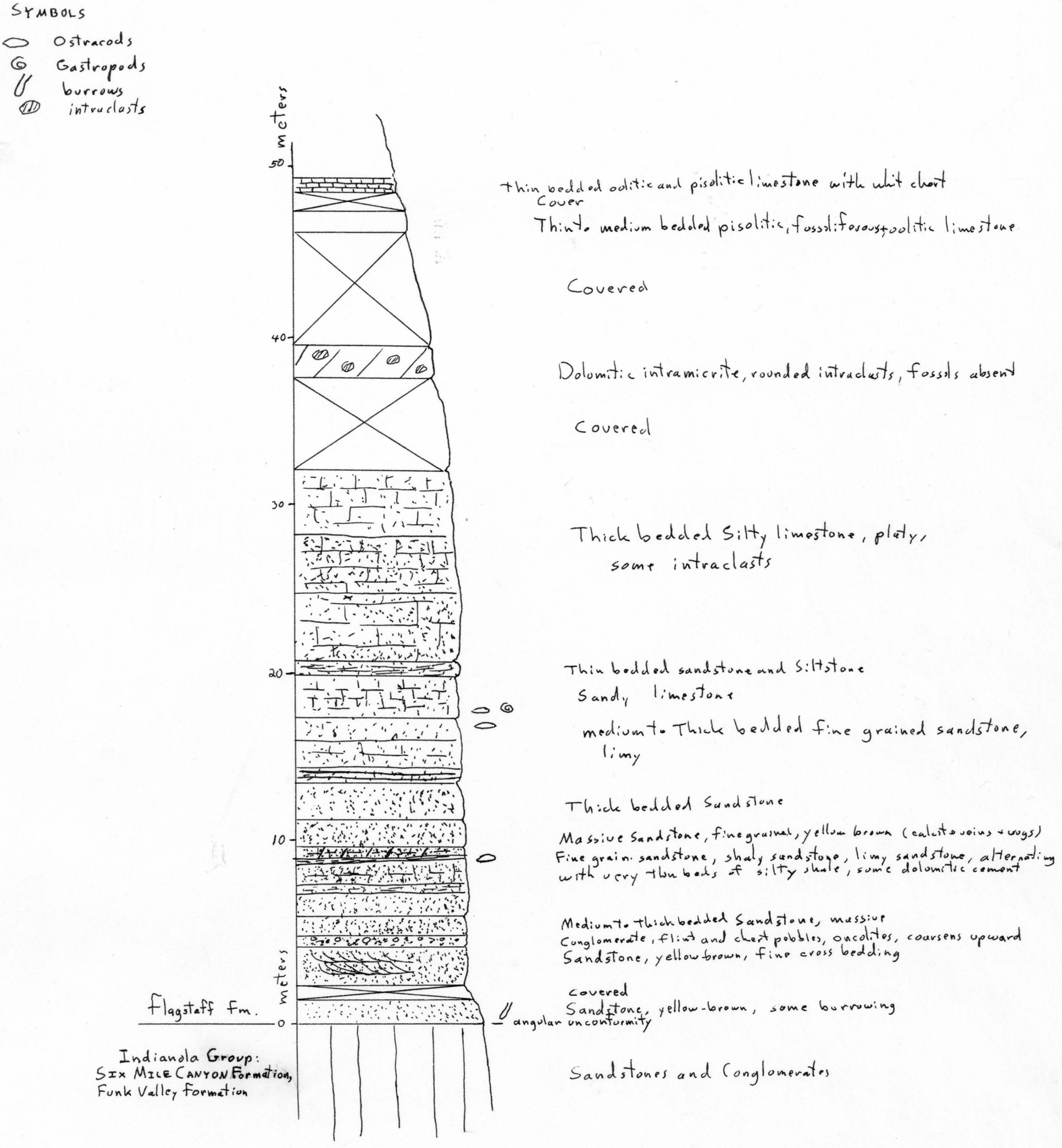


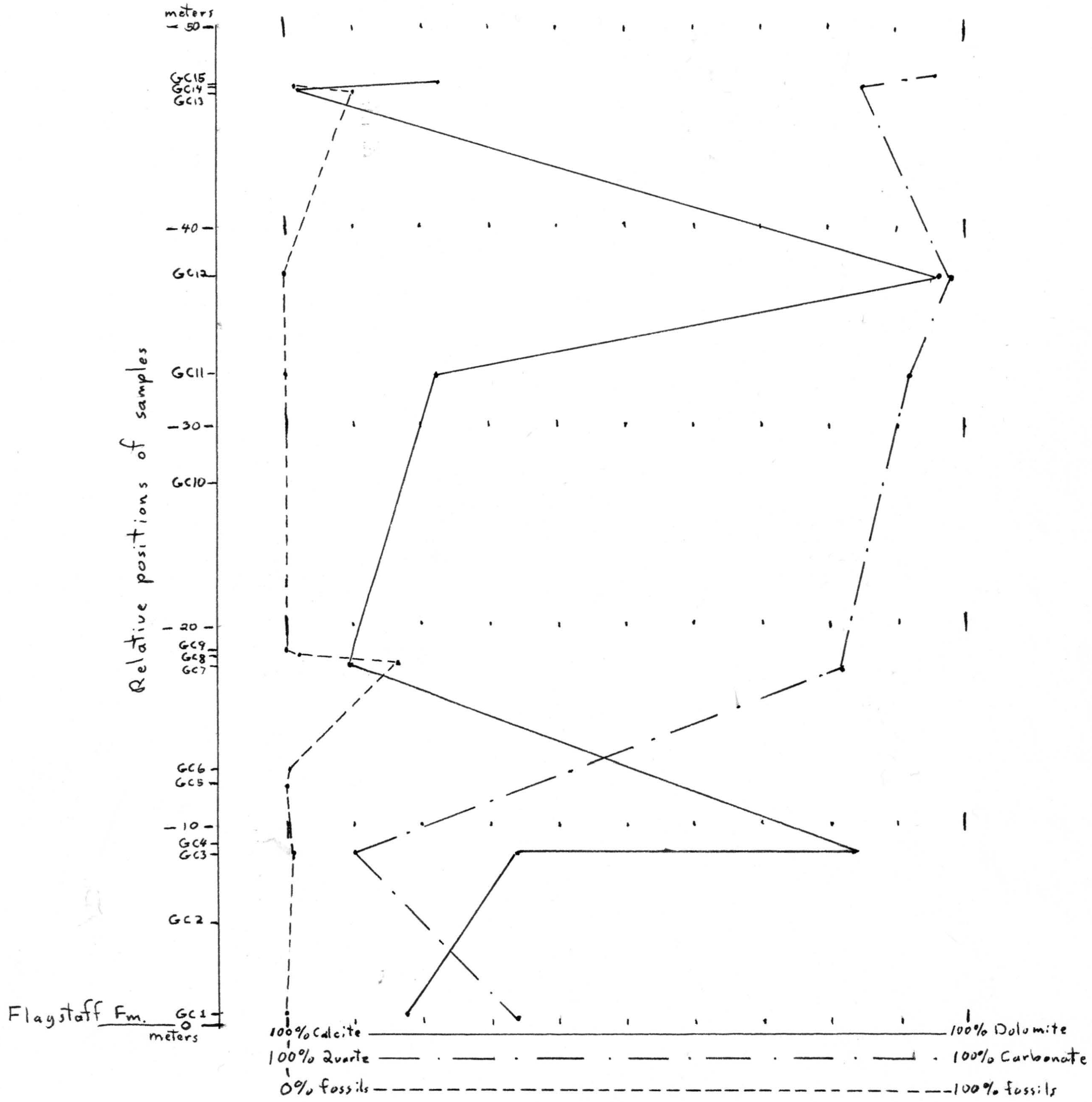
Figure 8.

LOWER SIX MILE CANYON SECTION
(from Appendix)

Calcite : Dolomite ————————

Quartz : Carbonate —— · —— · —— ·

% fossils – – – – – –



CONCLUSION

Close examination of the Flagstaff Formation in the walls of Sixmile Canyon shows good correlation with Flagstaff Lake depositional stages. The presence of an island of folded and upthrown Cretaceous rocks can easily be seen, as well as it's eventual submergence in this area close to the end of the middle playa-lake stage time.

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APPENDIX

Locations, and Information on Measured Sections

Locations:

Upper Sixmile Canyon Section (6M)
Black Mountain Quadrangle
T. 19 S. , R. 3 E.
Section 3, Southeast
lower Flagstaff, 87m.

Middle Sixmile Canyon Section (UG)
Black Mountain Quadrangle
T. 18 S. , R. 3 E.
Section 29, Northwest
lower-middle Flagstaff, 125m.

Lower Sixmile Canyon Section (GC)
Sterling Quadrangle
T. 18 S. , R. 2 E.
Section 26, Southeast
upper-middle Flagstaff, 49.2m.

Thin Section Descriptions

In describing the samples collected, the limestone classification scheme of Robert Folk was used in most cases. Where necessary, descriptions are divided into three groups: Intraclasts, Matrix, and Fossils. Thin section slides were stained using the dual stain method of combined **Alizarin Red-S**, and Potassium ferricyanide, in order to optically distinguish calcite and dolomite, and to try to distinguish the presence of ferron-dolomite and ferron calcite. Each mineral should produce a characteristic color when stained, but in most cases the stain only distinguished calcite, with a characteristic pale pink color, reliably. Difficulty in the use of the stain is possibly due to the microcrystalline nature of these rocks.

Upper Sixmile Canyon Section (6M)

6M-1, fossiliferous intramicrite
- 85% lt. brown-gray micrite intraclasts, three sizes: 50% less than 1mm., subrounded - rounded, 35% 3mm., subangular - subrounded, 15% 1cm., angular - subangular; moderate to poor sorting.
- 12% gray-brown micritic matrix, some spar filling of tiny shell fragments.
- 1-2% sparry shell fragments, mostly broken.

6M-2, intramicrite
- 90% brown-gray micrite intraclasts, 75% angular large clasts, less than 1cm., 25% well rounded tiny clasts, less than 1mm..
- 10%matrix of fine, less than 1mm., very rounded intraclasts, spar-filled cracks and cavities between intraclasts, stylolite.
- less than 1% very few sparry shell fragments, very tiny.

6M-3, fossiliferous intramicrite

- 70% lt. brown-gray micrite intraclasts, **subangular** to subrounded, less than 1mm., 20% 1-2mm, 5% .5-1cm., poor sorting grading up to good sorting.
- 25% gray-brown micrite matrix, grading up to 10% matrix and 85% intraclasts, some lamination due to parallel orientation of flat shell fragments and layers of mud around clasts.
- 2% sparry fossil fragments, a few whole and/or crushed in place, snail shells (1-2mm.), with unstained carbonate? interiors.

6M-5, fossiliferous to sparce biomicrite

- 75% lt. brown micrite intraclasts, two sizes: 20% greater than 1cm., angular to subangular, 80% .5-3mm., rounded to subrounded.
- 15% matrix of rounded to subrounded micrite intraclasts (.5-3mm.) around larger clasts, a few spar-filled cracks.
- 10% fossil fragments, re-crystallized and sparry, a few ostracods (whole and fragmented), with spar shell replacement, unstained central portion.

6M-7, sparce biomicrite

- 2-5% lt. reddish brown intraclasts, 1-1,5mm., subangular to subrounded.
- 80% dark gray-brown micrite matrix.
- 20-25% sparry shell fragments, many whole gastropods (2mm.) with spar-filling (some unstained), also some mud filling.

6M-9, sparce biomicrite

- less than 1% intraclasts.
- 60% dark gray micrite matrix.
- 40% broken shell fragments with distinct parallel allignment, most fragments less than 1mm., many small gastropods (1mm.).

6M-10, fossiliferous intramicrite

- 50-60% lt. brown, well rounded intraclasts, 1-4mm., some limonite stain.
- 35% spar filled cracks, and between intraclasts.
- 10-12% fossils, a few ostracods (spar-filled), and gastropods (1mm.), some shell fragments.

6M-11, sparce biomicrite

- less than .5% intraclasts, 1mm..
- 65% dark gray micrite matrix, possibly very tiny intraclasts (less than .1mm.), very well rounded.
- 30% spar-filled gastropods, 1-3mm., some mud-filled, several **large gastropods,** whole and fragmented (2cm.), original shell material, spar and mud filled.

6M-12, intrapelmicrite

- 50% yellowish-brown pelleted intraclasts, up to 2cm., subangular to subrounded, some smaller, well rounded, 1-2mm. clasts.
- 45% dark gray brown pelleted matrix, much spar-filling between clasts, a very few thin laminations of dark organic matter.

- 1% broken snail shells, up to 2mm., some fragments of larger snails.

6M-13, intramicrite
- 80% very lt. brown intraclasts, subangular to well rounded, less than 1mm. up to several centimeters.
- 15% sparry calcite filling of cracks and spaces between intraclasts.
- less than .1% spar filled ostracods, 1mm..

6M-14, intramicrite with sparce biomicrite matrix
- 75% lt. brown-gray intraclasts, very large, and almost continuous,
- 20-25% dark gray-brown matrix filling void spaces, fossil-hash.
- 15% of matrix (4% of rock) is finely broken shells, less than 1mm., several gastropods (whole and fragments), .8mm., spar-filled, one mud-filled, spar-replaced gastropod, 9mm..

6M-15, sparce biomicrite, grading up to fossiliferous intramicrite (photo A)
- 2% intraclasts at base, grading up to 98% intraclasts (2-5mm.) at top, very lt. brown, subangular-subrounded.
- 65% matrix at base to 5-6% at top, micrite matrix, spar-filled cracks.
- 20-25% fossils at base decreasing in number and fragment size upward, (5-8% at top), some whole and/or crushed in place gastropod shells, 1-2mm., spar-filled and replaced, filling stained more bluish-red (cracks too) than lt. pink shell, tiny fragments toward top (less than 1mm.).

6M-16, sparce biomicrite, probably dolomitic
- 20% brown and lt. brown intraclasts, well rounded, avg. 1.5mm. soft, almost chalky.
- 60% lt. whitish-brown micrite matrix
- 15% mostly snail shell fragments up to 3mm., a few whole snail shells (1mm.).

6M-181/2, intramicrite, probably dolomitic
- 88% very lt. whitish-tan micritic intraclasts, subangular-subrounded, smaller intraclasts well rounded
- 12% matrix, some spar filling between clasts, many unfilled void spaces.
- fossils absent

6M-19, intramicrite
- 35% very lt. tan micrite matrix, subrounded-rounded, little to no quartz, also some dark gray-brown fossiliferous micrite intraclasts, subangular to subrounded, 1-4mm. (mostly larger than lt. colored intraclasts), more quartz grains.
- 60% lt. brown micrite matrix, darker toward base, and faintly laminated.
- 5% shell fragments, 2-4mm..

6M-23, dolomitic intramicrite
- 30% very lt. brown, and gray brown micrite intraclasts, well rounded, avg. .5-2mm..
- 60% whitish-brown at base, to slightly darker gray-brown matrix at top, dolomicrite, faintly laminated.
- 3-5% ostracods, whole and fragmented.

6M-23 1/2, intramicrite, probably dolomitic
- 30-35% mostly lt. tan, well rounded micrite intraclasts, .5-3mm., one-third lt. gray-brown micrite intraclasts, 1-1.5mm., generally elongated.
- 65% gray-brown micrite matrix, distinct laminations around intraclasts.
- fossils absent.

6M-26, fossiliferous micrite
- 3% lt. tan small intraclasts, 1-2mm., small and clumped together, stylolite with lt. intraclasts clumps above and mud below.
- 85% mictite-mud matrix, dark brown, some spar-filling of voids and fossils
- 10% long spiraled gastropods, up to 4mm., and spar-filled, a few larger gastropods (1.3cm.), some ostracods (spar-filled).

6M-27a, micrite
- 99% very lt. gray-brown micrite, spar-filling of void spaces and fossils.
- 1% ostracods, whole and broken, spar-filled, .8mm..

6M-27b, micrite
- less than 1% dark brown-gray intraclasts.
- mostly brown-gray-brown micrite matrix, difficult to distinguish from intraclasts, spar-filled cracks.
- less than 1% broken ostracod shells.

6M-27c, micrite
- 89% very lt. gray-brown micrite, with up to 10% spar-filled cracks.
  less than 1% ostracod fragments, possibly some small gastropod shell fragments.

6M-30a, fossiliferous micrite
- a few percent towards the center of sample(intraclasts), where mixed with laminated ostracod shell fragments.
- 90% lt. yellow-brown micrite mud matrix at base, grading up to more and more laminated with shell fragments (darker color lamelli).
- a few gastropods and ostracods (whole and fragmented) becoming more abundant toward middle, grading up into parallel aligned ostracod fragments with a few scattered fragments of larger gastropods, up to 40% ostracods toward top, mud supported.

6M-30b, fossiliferous micrite
- 10% brown-gray micrite intraclasts, clumped together.
- 75% dark gray-brown micrite matrix, laminations.
- 12% fossils, a few gastropods up to 1cm., some slightly crushed in place, many smaller snails, and a very few ostracod fragments.

6M-31, packed biomicrite
- 3% very lt. brown micritic intraclasts, well rounded, 1-2mm..
- 40% dark gray-brown micrite matrix.
- 50-60% stongly aligned parallel to bedding gastropods, both whole and fragmented, 1-2mm., some crushed in place, mud supported.

6M-35, micrite
- 6% very lt. brown micrite intraclasts, well rounded,1mm., clumped together in void spaces in matrix.
- 92% dark brown-gray micrite mud matrix, spar-filling of cracks and small void spaces.
- 2% whole and broken snail shells, 2-4mm., spar and mud filled.

6M-36, micrite
- 91% lt. brown-gray micrite matrix, with about 8% spar-filling of cracks.
- less than 1% fossil fragments, with one or two ostracod valves.

6M-39a, fossiliferous micrite
- 8-10% lt. brown and dark brown-gray intraclasts, subangular to well rounded, .5-2mm..
- 81% brownish micrite
- 5-8% shell fragments, less than 1mm., a few whole snail shells, many very tiny fragments.

6M-41, micrite (photo B)
- 3% very lt. brown micrite intraclasts, in base only, subangular to subrounded, poorly sorted, three sizes; less than 1mm., 1-2mm., and up to 2cm..
- 96% brownish-gray micrite, strongly laminated above base, intraclastic at base, micritic in upper 2/3 (slightly darker).
- 1-2% parallel oriented ostracod shell fragments make up laminated zone, decreasing in abundance upward.

6M-45, intramicrite
- 40% dark gray-brown intraclasts, changing to gray-brown(and lighter color), angular to subangular, 2mm.-2cm..
- 61% gray brown micrite matrix, difficult to tell from intraclasts, some spar-filling of void spaces.
- 4% a few whole snails, 3-7mm., some 1-2mm. fragments of larger gastropods.

6M-48, intramicrite
- 80% very lt. brown, and gray-brown micrite intraclasts, 1-3mm and rounded, and 1cm. and angular to subangular, respectively.
- 12% gray-brown micrite matrix.
- less than 1% very tiny thin shell fragments, possibly ostracod, one whole ostracod.

6M-50, sparce biomicrite
- 5% very lt. tan micrite intraclasts, 2-3mm., subrounded to rounded.
- 70% brownish-gray micrite matrix, mixed with fossil fragments.
- 20% fossil hash, broken shell fragments, rounded, a few whole snails 2mm..

6M-50 1/2, sparce biomicrite, very dark-highly organic, approaching oil-shale. (photo C)

- 15% very light tan micrite intraclasts (dolomitic) at base, 1mm.-several cm., changes quickly upward to very dark brown-black, highly organic zone, burrowed.
- 65% very dark brown-black zone(upper 3/4 of rock), lacks intraclasts(except at base).
- 22-30% fossils, whole snails 2-3mm., some crushed in place, fossil hash filling burrow. (see photo C)

6M-51, intramicrite

- 60% lt. gray-brown micritic intraclasts, well rounded and large, 3mm., 8mm., 3cm., imbricate orientation.
- 40% very lt. gray-brown micrite matrix, some spar-filling of void spaces.
- less than .5% ostracod shell fragments, one whole ostracod.

Middle Sixmile Canyon Section (UG)

UG-2, medium to fine grain sandstone, 80-85% quartz grains, .2mm., carbonate cement (dolomite), a little iron oxide stain.

UG-3, medium to fine grain sandstone, 40% quartz, .2-.3mm., and less than .1mm., moderate sorting, micritic(dolomitic) cement up to 50%, micritic intraclasts up to 6mm. (subangular-rounded), poorly consolidated rock.

UG-4, medium grain sandstone, rounded to well rounded quartz up to .7mm. 75%, and up to 20% mud between grains.

UG-5, medium to very fine grain sandstone, 70-75% quartz, .7mm., and less than .1mm. quartz grains subangular to subround, poor to moderate sorting, a few intraclasts containing quartz grains and minute fossil fragments, some sparry-filling of void spaces.

UG-6, medium to fine grain sandstone, with fine grain sandstone intraclasts(.5-1cm.) which are up to 55% quartz, loosely consolidated, 60% quartz grains, subrounded-rounded, mud cement.

UG-7, fine grain sandstone, 80-85% quartz, .1-.5mm., subrounded to rounded, a few grains of colloidal silica, micritic cement.

UG-8, 60-70% sand sized rhombic/wedge shaped grains(stained pink), possibly dolomite, 5-10% quartz grains, subangular to subrounded, a few micritic intraclasts(2%).

UG-9, 55-60% micritic intraclasts(2-5mm.), 5% quartz grains(subrounded), 30% rhombic/wedge shaped crystals, between intraclasts.

UG-10, yellowish-brown micrite, iron oxide stain around cracks, some spar filling, 8% quartz grains (less than .1mm., and subangular).

UG-11, 85% micrite, with 8% subangular quartz (less than .1mm.), 5% intraclasts, and one or two shell fragments (well rounded, possibly snails, less than .01%).

UG-14, dolomitic mudrock, less than 1% very fine grain quartz (less than .1mm.), also less than 1% hematite in tiny accumulations, salty taste.

UG-16, dolomitic mudrock, many void spaces (up to 15%).

UG-17, dolomitic mudrock, 15-20% void spaces, very tiny(less than .1mm.) crystaline dolomite.

UG-18, dolomitic mudrock, 15% small rounded intraclasts, with crystaline dolomite filling voids and cracks (up to 45%), up to 25-30% mud.

Lower Sixmile Canyon Section (GC)

GC-1, fine grain sandstone, 50% quartz, less than .1mm., subangular to subrounded, well sorted, up to .7% clusters of hematite from less than .05mm. to .2mm., also some iron oxide stain.

GC-2, conglomerate, very poorly sorted with sand/mud matrix, very coarse grains up to 1.5cm., some colloidal silica.

GC-3, fine grain sandstone grading up to coarse grain sandstone, fine grained: 70% quartz, avg. .1mm., subangular to rounded, well sorted, laminated toward base with ostracod shells and fragments, matrix whitish with reflected light.
coarse grained: (grades in gradually over .5mm transition zone of larger grains surrounded by finer ones), large grains .4mm., well sorted, subrounded to rounded, a few grains of chert, or calcedony, some calcite between quartz grains.

GC-4, very fine grain sandstone/siltstone, well sorted, some calcite cement and filling of voids, iron oxide stain/cement, a few hematite crystals.

GC-5, very fine grain sandstone/siltstone, well sorted, 70% quartz, subangular to rounded, 15% calcite filling of void spaces, one feldspar(microcline) grain, some colloidal silica grains.

GC-6, medium to fine grain sandstone, grains avg. .2mm. and up to .5mm. well sorted and well rounded, 30-40% quartz, 60% micrite intraclasts, 3% void spaces, a couple of shell fragments(well rounded), and a couple of ostracods, some small intraclasts (sand sized), and some ostracod shells have faintly concentric deposition of carbonate.

GC-7, very fine grain micritic sandstone/siltstone, 45% micrite, 10-12% subrounded to rounded quartz, 15-20% ostracod shells which are mostly broken, a few small gastropod shells, precipitated calcium carbonate on quartz and ostracod fragments, slightly pisolitic.

GC-8, 80% micrite, 8% spar-filling of void spaces, 2% ostracod shell fragments (a few whole, spar-filled), 10-12% euhedral hematite, a few (.7-.8mm.), grains of colloidal silica, 1% sand sized quartz grains(very fine grain).

GC-9, 95% yellow-brown micritic mud, 2% euhedral hematite, iron oxide stain throughout, a few very tiny quartz grains.

GC-11, 70% well rounded micrite intraclasts, some stained darker and some have higher percentage of quartz, intraclasts up to 4mm., 20% spar-filling between intraclasts, less than 1% very tiny quartz grains.

GC-12, 85% well rounded micritic intraclasts, looks pelleted in spots, very little quartz, 3% spar-filling of voids, some deposition of carbonate around clasts(.2-.5mm.), fossils absent.

GC-14, pisolitic limestone, up to 10% fossils, spar-replaced snail shell fragments(central spire of one), quartz grains at center of pisolites (up to 5% quartz, subangular to subrounded, .2mm.), 20% spar-filling between clasts (fine grained clasts), ostracod shells both whole and fragmented(spar-filled).

GC-15, oolitic limestone, upper part is 80% oolites (1.5mm.), laminated toward base with iron oxide and ostracod shell fragments(12%), 2% spar-filling of ostracod shells, some fine grained quartz at base(absent at top). (photo D)

X-Ray Powder Diffraction Data

The x-ray machine used was a Diano Corp. XR D-6. Powdered samples were run at 45Kvp, 15ma., through a 1° beam slit, Ni filter, and a Cu target, with a xenon-filled geiger tube.

Samples were analyzed for the presence of quartz, calcite, and dolomite, and the data was calculated from strip-chart results. 2θ angles for calcite and dolomite were figured in relation to the quartz peak, and the intensities of the individual peaks were measured in centimeters in order to find the relative percentages of these minerals. The standard 2θ angles for quartz, calcite, and dolomite are 26.66, 29.43. and30.99 respectively (from: Chao, G. Y., 2θ(Cu) Table for Common Minerals, Geological Paper 69.2). My results showed that the vast majority of dolomite 2θ angles were depressed toward the ferron-dolomite angle of 30.84, and that the calcite angles were elevated toward the angle characteristic of magnesium rich calcite(2θ 30.30). I make no attempt in this study to propose a meaning for these results.

X-ray data for the Upper Sixmile Canyon section
(scale factor - 1000 for all samples)

	Quartz		Calcite		Dolomite	
sample #	2θ	I (cm)	2θ	I (cm)	2θ	I (cm)
6M-1	26.6	1.72	29.40	1.94	30.72	8.87
6M-2	"	1.1	29.49	15.71	30.80	.92
6M-5	"	.51	29.50	7.6	30.80	2.12
6M-6	"	1.4	29.52	17.68	30.79	.31
6M-9	"	2.96	29.5	18.75		
6M-11	"	.9	29.52	18.18		
6M-12	"	1.17	29.53	15.97	30.87	.55
6M-14	"	.47	29.58	8.39	30.89	1.93
6M-18 1/2	"	.1	29.6	.2	30.79	16.07
6M-22	"	.81	29.52	.2	30.82	14.76
6M-23d	"	2.31	29.73	.24	30.81	11.35
6M-23L	"	1.07			30.81	9.35
6M-25	"	.3	29.51	3.07	30.81	4.36
6M-27c	"	.62	29.52	11.45	30.84	8.37
6M-28	"	.65	29.45	12.39	30.83	.1
6M-31d	"	1.98	29.52	15.92	30.84	1.46
6M-31L	"	.68	29.50	8.28	30.79	5.95
6M-33	"	.7	29.50	3.47	30.81	9.25
6M-35	"	1.1	29.48	10.1	30.81	1.0
6M-36	"	.78	29.49	13.94	30.81	.9
6M-38	"	1.4	29.46	9.03	30.74	2.45
6M-41 base	"	.55	29.46	2.5	30.73	5.02
6M-41 top	"	.57	29.47	1.34	30.76	6.34
6M-44	"	1.75	29.52	7.0	30.79	9.26
6M-45	"	1.52	29.48	10.96	30.92	.45
6M-47	"	3.2	29.50	12.72	30.82	2.2
6M-50	"	1.91	29.51	7.26	30.82	4.34
6M-50 1/2 L	"	.91	29.47	6.7	30.78	13.68
6M-50 1/2 d	"	1.87	29.47	12.15	30.79	.71

X-ray data for the Middle Sixmile Canyon section

sample #	2θ	I (cm)	2θ	I (cm)	2θ	I (cm)
(scale factor)	(quartz)		(calcite)		(dolomite)	
UG-2 (2000)	26.6	21.37			30.87	2.16
UG-4 (2000)	"	20.96			30.88	5.59
UG-9 (2000)	"	1.05	29.47	7.32	30.88	2.9
UG-9 (1000)	"	2.4	29.48	14.2	30.89	4.99
UG-14 (1000)	"	.15			30.88	21.0
UG-17 (1000)	"				30.90	16.07

X-ray data for the Lower Sixmile Canyon section

sample # (scale factor)	Quartz		Calcite		Dolomite	
	2θ	I (cm)	2θ	I (cm)	2θ	I (cm)
GC-1 (2000)	26.66	13.3	29.48	5.2	30.9	1.11
GC-3L (2000)	"	23.71	29.43	1.5	30.95	.73
GC-3d (2000)	"	39.7	29.45	.95	30.96	4.2
GC-7 (2000)	"	2.45	29.45	9.85	30.85	.97
GC-7 (1000)	"	3.86	29.48	17.4	30.86	2.81
GC-11 (1000)	"	1.32	29.51	11.83	30.90	3.29
GC-12 (1000)	"	.2	29.52	.41	30.95	17.85
GC-14 (1000)	"	2.4	29.43	15.3	30.81	.1
GC-15 (1000)	"	.65	29.52	13.78	30.91	3.9

Ratios of Calcite : Dolomite, and Quartz : Carbonate Percentages calculated from preceeding x-ray data.

Upper Sixmile Canyon section

sample #	Carbonate Calcite : Dolomite	Carbonate : Quartz
6M-1	17.9 : 82.1	86.3 : 13.7
6M-2	94.47 : 5.53	93.8 : 6.2
6M-5	78.2 : 21.8	95.01 : 4.99
6M-6	98.3 : 1.7	92.8 : 7.2
6M-9	100.0 : ——	86.4 : 13.6
6M-11	100.0 : ——	95.3 : 4.7
6M-12	96.7 : 3.3	93.4 : 6.6
6M-14	81.3 : 18.7	95.6 : 4.4
6M-18 1/2	1.2 : 98.8	99.4 : 0.6
6M-22	1.3 : 98.7	94.9 : 5.1
6M-23d	2.1 : 97.9	83.4 : 16.6
6M-23L	—— : 100.0	89.7 : 10.3
6M-25	41.3 : 58.7	96.1 : 3.9
6M-27c	57.8 : 42.2	96.96 : 3.04
6M-28	99.2 : 0.8	95.1 : 4.9
6M-31L	58.2 : 41.8	95.4 : 4.6
6M-31d	91.6 : 8.4	89.9 : 10.1
6M-33	27.3 : 72.7	94.8 : 5.2
6M-35	90.99 : 9.01	90.98 : 9.02
6M-36	93.9 : 6.1	95.0 : 5.0

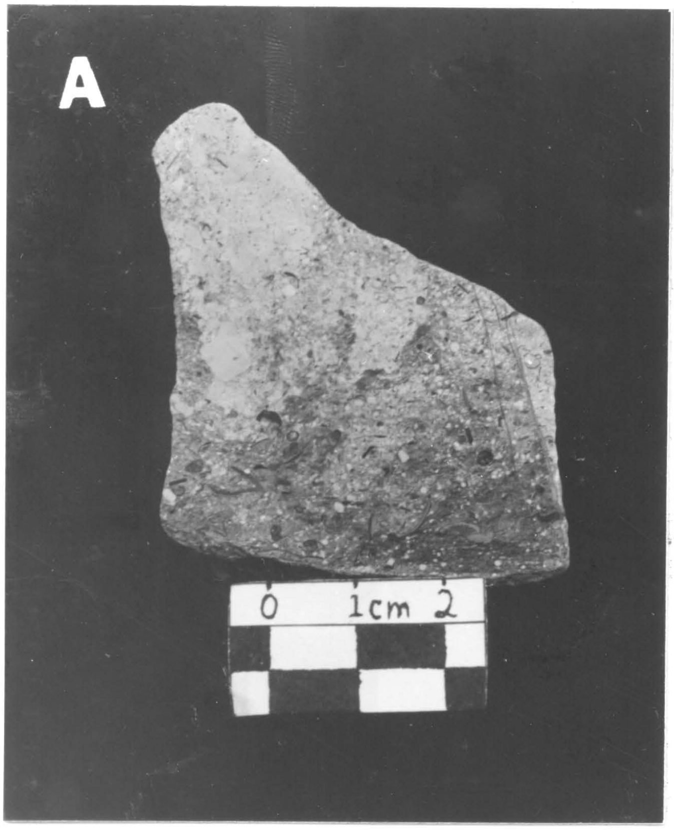
	Calcite : Dolomite	Carbonate : Quartz
6M-38	78.7 : 21.3	89.1 : 10.0
6M-41 base	33.2 : 66.8	93.2 : 6.8
6M-41 top	17.4 : 82.6	93.1 : 6.9
6M-44	43.1 : 56.9	90.3 : 9.7
6M-45	96.1 : 3.9	88.2 : 11.8
6M-47	85.3 : 14.7	82.3 : 17.7
6M-50	62.6 : 37.4	85.0 : 14.1
6M-50 1/2Light	32.9 : 67.1	95.7 : 4.3
6M-50 1/2dark	94.5 : 5.5	87.3 : 12.7

Middle Sixmile Canyon section

sample #	Calcite : Dolomite	Carbonate : Quartz
UG-2	—— :100.0	9.2 : 90.8
UG-4	—— :100.0	21.1 : 78.9
UG-9	71.6 : 28.4	90.7 : 9.3
UG-9	74.0 : 26.0	88.9 : 11.1
UG-14	—— :100.0	99.3 : 0.7
UG-17	—— :100.0	100.0 : ——

Lower Sixmile Canyon section

sample #	Calcite : Dolomite	Carbonate : Quartz
GC-1	82.4 : 17.6	32.1 : 67.9
GC-3Light	67.3 : 32.7	8.6 : 91.4
GC-3dark	18.4 : 81.6	11.5 : 88.5
GC-7	91.1 : 8.9	81.5 : 18.5
GC-7	86.1 : 13.9	83.9 : 16.1
GC-11	78.2 : 21.8	91.9 : 8.1
GC-12	2.2 : 97.8	98.9 : 1.1
GC-14	99.4 : 0.6	86.5 : 13.5
GC-15	77.9 : 22.1	96.5 : 3.5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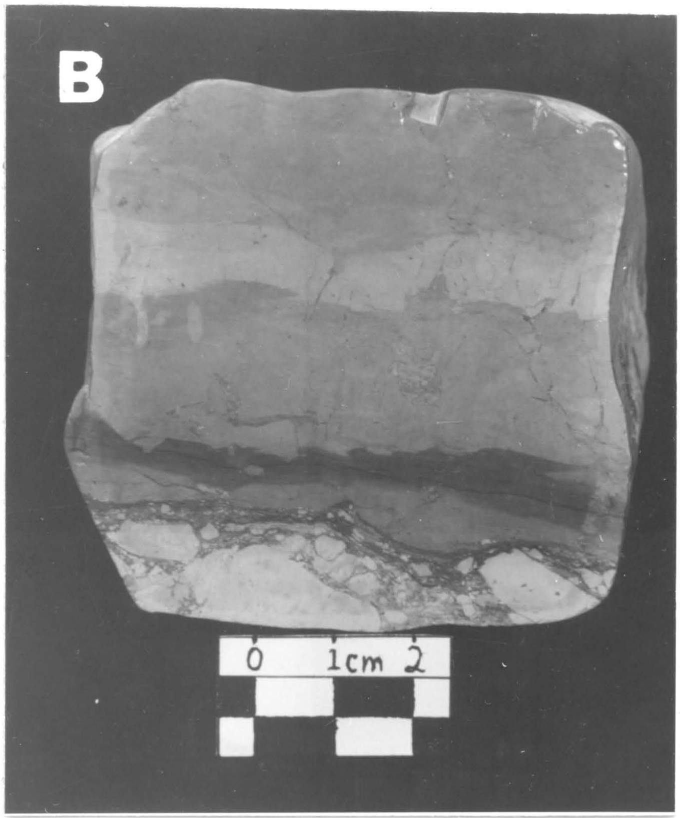
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C
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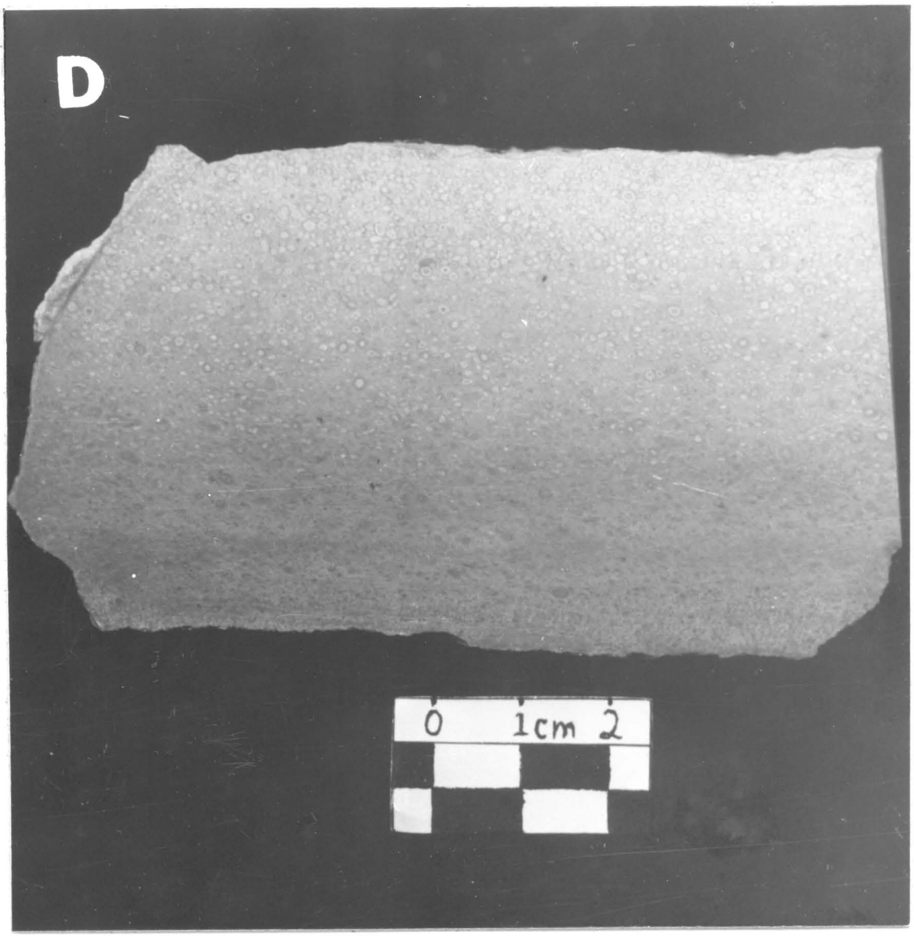
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