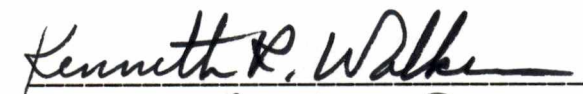


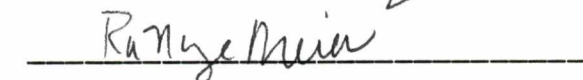
To the Graduate Council :

I am submitting herewith a thesis written by Joseph A. McReynolds entitled "Paleoenvironments and Facies Relations of the Lower Cambrian Rome Formation along Haw Ridge on the U.S. Department of Energy Reservation, Oak Ridge Area in Roane and Anderson Counties, Tennessee." I have examined the final copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Geology.

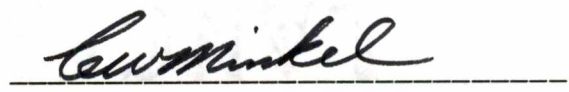

Steven G. Driese, Major Professor

We have read this thesis
and recommend its acceptance :





Accepted for the Council :


Vice Provost
and Dean of The Graduate School

PALEOENVIRONMENTS AND FACIES RELATIONS OF THE LOWER
CAMBRIAN ROME FORMATION ALONG HAW RIDGE ON THE U.S.
DEPARTMENT OF ENERGY RESERVATION, OAK RIDGE AREA IN ROANE
AND ANDERSON COUNTIES, TENNESSEE.

A Thesis
Presented for the
Master of Science
Degree
University of Tennessee, Knoxville

Joseph A. McReynolds
December 1988

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Finally, Thank you, God.

ABSTRACT

The Rome Formation (Lower Cambrian) of East Tennessee is usually considered a terrigenous clastic sequence. Although dominated by siltstone, sandstone, and shale lithologies, the Rome also contains a significant dolostone component. Thus, the Rome in actuality is a mixed siliciclastic and carbonate sequence. This study first constructs a detailed stratigraphy, then, defines lithofacies, interprets their paleoenvironments, and culminates with the presentation of a facies model for the Rome. The study area is located on the U.S. Department of Energy Reservation in Oak Ridge, Tennessee along a twelve kilometer segment of Haw Ridge, which contains Rome Formation exposed along strike within the Copper Creek thrust sheet.

The stratigraphy of the Rome presents a complex problem. As décollement unit to Valley and Ridge thrusting, an already complicated Rome stratigraphy is further confused by structure. Rome structure and stratigraphy are inseparably interrelated. Within the study area, the Rome consists of three structural blocks separated by two tear faults. Two blocks contain reasonably uninterrupted stratigraphic sections, and the other block contains two major imbricate thrusts, duplicating Rome stratigraphy within the block. After restoration, the original undeformed stratigraphy of the Rome has a mosaic pattern and correlates only on a gross scale.

Using the stratigraphy, seven lithofacies are defined in the field area. The first three facies (TB ss/sh, V sh, and B slts/sh/ss) represent pure terrigenous clastic end-members which were deposited in a broad, expansive tidal flat environment that was frequently inundated by storms. The next two are mixed facies (ss/ds and ds/slts), which represent the gradational boundary along which the pure terrigenous clastic facies and pure carbonate facies meet, i.e., "facies" type mixing (Mount, 1984). The final two facies are pure carbonate end members (M ds and Lam ds), which were deposited in a quieter water, protected, back platform environment.

The most basic aspect of the facies model presented is that the Rome inherited a "carbonate platform" type basin built up during the deposition of the underlying Shady Dolomite, and the configuration of this basin forced the siliciclastic sediments of the Rome to take on a mosaic, "carbonate-like" stratigraphy.

Approaching the Rome as a terrigenous clastic sequence has neither been successful in developing a coherent stratigraphy nor in creating a regional depositional model for the Rome. A mixed carbonate and siliciclastic approach explains the "uncorrelatable" stratigraphy of the Rome and also accounts more easily for the rapid shifts in Rome paleoenvironments. Eventually, interpretation as a mixed siliciclastic and carbonate sequence may lead to the development of a comprehensive regional depositional environment model for the Rome in East Tennessee.

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CHAPTER 1

INTRODUCTION

Purpose

The Rome Formation (upper Lower Cambrian) of the Valley and Ridge Province in East Tennessee is usually considered a terrigenous clastic sequence. Within such a clastic paradigm, correlating stratigraphy and interpreting paleoenvironments of the Rome have proven difficult. Thus, at present no regional paleoenvironmental model exists for the Rome Formation. Although dominated by sandstone, siltstone and shale lithologies, the Rome also contains a significant dolostone component; therefore, the Rome is not strictly a terrigenous clastic sequence, but instead, a mixed siliciclastic and carbonate sequence.

The purpose of this study is to re-interpret Rome stratigraphy and paleoenvironments in light of a mixed siliciclastic and carbonate paradigm. Using detailed sedimentologic and stratigraphic data, lithofacies will be defined. Based on these lithofacies, the paleoenvironment of the Rome will be interpreted in the vicinity of Oak Ridge, Tennessee. (Fig. 1.1).

This study is the first of several detailed studies of the Rome that will eventually be combined and used to construct a regional paleoenvironment model. As a pilot study to this larger project, this thesis postulates regional conclusions that will either be confirmed or denied by later Rome studies.

Regional Stratigraphy and Age

In the Valley and Ridge of East Tennessee, the Rome is fault bounded at its base and conformably overlain by the shale and carbonate strata of the Conasauga Group (Fig. 1.2). In the western

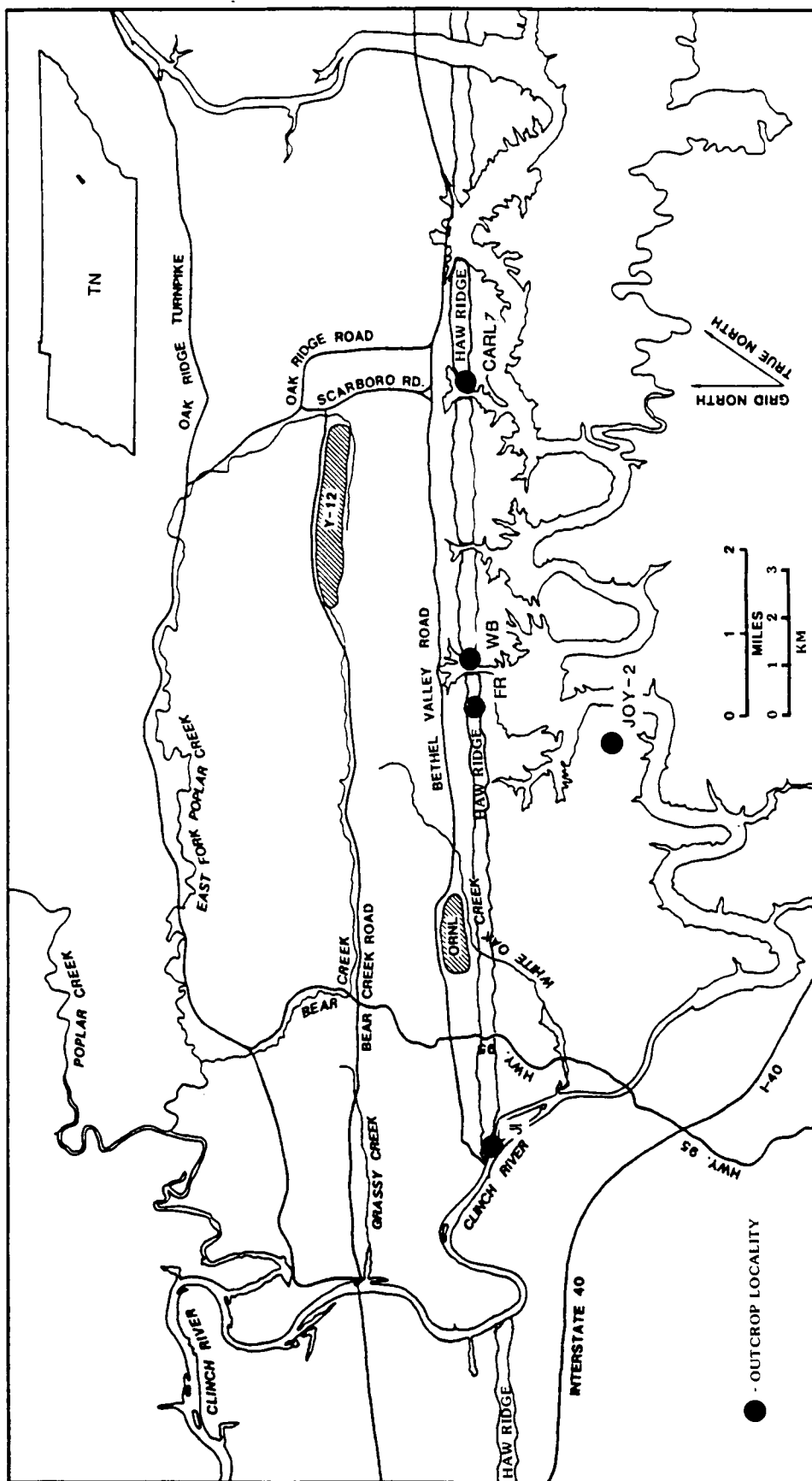
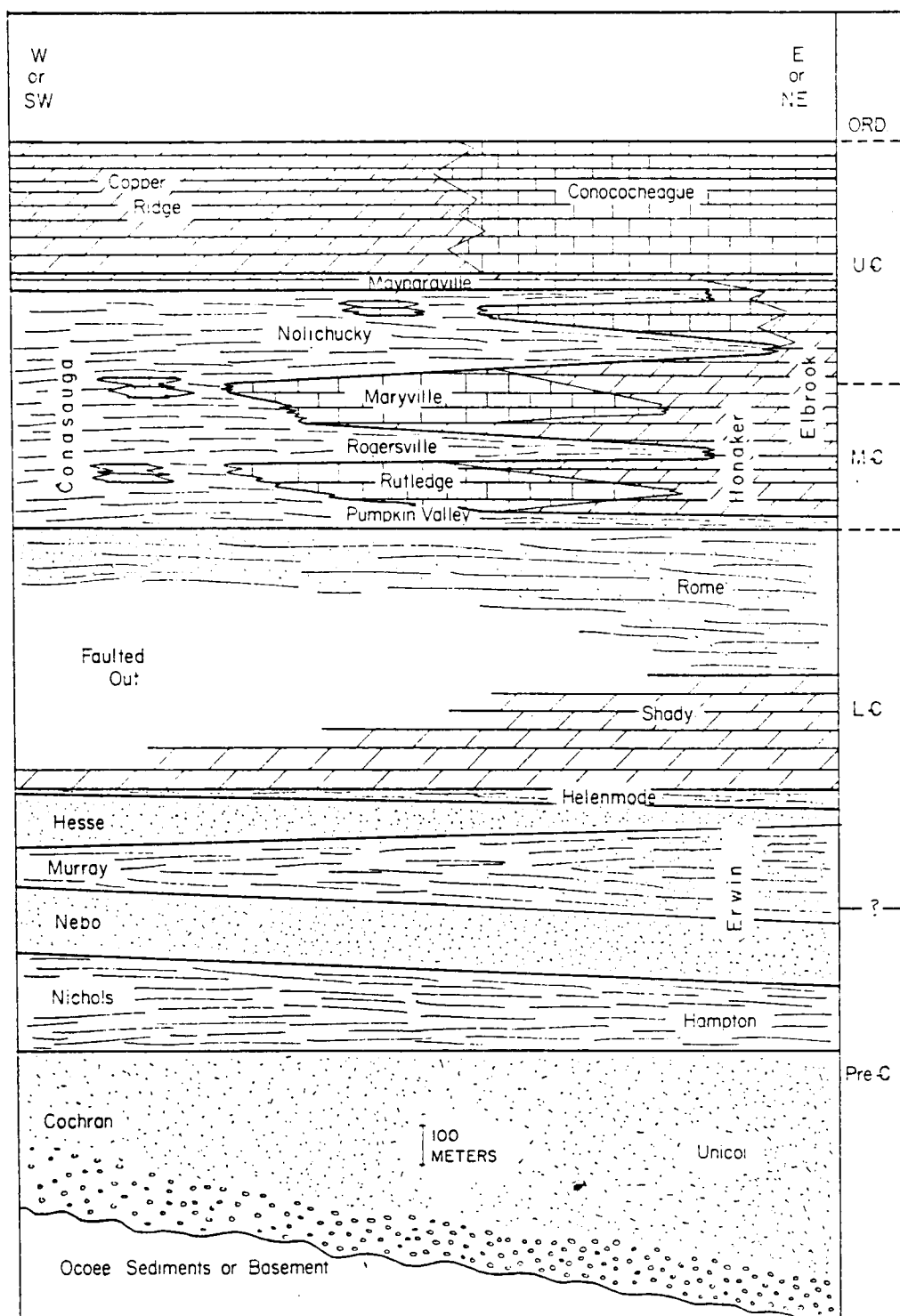


Figure 1.1 Location map of study area. JI, FR, WB, and CARL mark outcrop locations and Joy-2 marks core location.



From Palmer, 1971.

Figure 1.2 Generalized stratigraphy of the lower Paleozoic for the Southern Appalachians.

Blue Ridge, incomplete sections of the Rome conformably overlie the Shady Dolomite. A complete section of the Rome is rare in East Tennessee (King and Ferguson, 1960).

Biostratigraphic evidence in East Tennessee (McLaughlin, 1973), and extrapolation from northeasternmost Tennessee (King and Ferguson, 1960) and southwestern Virginia (Pfeil and Read, 1980) show the Shady - Rome - Conasauga sequence is lithofacies related and partially time equivalent (Fig. 1.3). Weber (1988) also demonstrated this type of lithofacies-dependent relationship between the Rome and Conasauga.

Furthermore, no sharply defined sedimentological boundary exists between the Rome and Conasauga; however, Rodgers and Kent (1948) defined the uppermost thick sandstone of the Rome as marking the boundary between the Rome and the siltstone and shale strata of the Pumpkin Valley Shale, the lowermost formation of the Conasauga Group.

The Rome has been informally subdivided into an upper sandy member and a lower shale member. Haase et al. (1985) interpreted the lower member as tectonically emplaced slices, whereas the upper member was considered coherent stratigraphic section. This thesis will show that this is not good general practice because entire outcrop belts of the Rome are typically composed of repeating imbricate slices bounded by thrust faults.

The age of the Rome ranges from latest Early Cambrian to earliest Middle Cambrian; McLaughlin (1973) stated that,

... to treat the Rome Formation as exclusively Early Cambrian in age requires extending the Middle Cambrian ranges of three orders of trilobites, well established on a worldwide basis. On the other hand, to regard the Rome as entirely Middle Cambrian would amount to an even more unlikely extension of the range of *Olenellus*, and another Rome associate from Virginia to Alabama,

Archaeocyathus, fixed in Early Cambrian time the world over.

Regional Structure

As the décollement of Alleghanian thrusting in the Valley and Ridge Province of Tennessee, the Rome Formation forms the base of numerous southeastward-dipping imbricate thrust sheets. Several major thrust faults in the western portion of the Tennessee Valley bring Rome to the surface (Fig. 1.4). The study area discussed in this thesis is contained in the Copper Creek thrust sheet.

Two important structural factors affecting sedimentological study of the Rome have resulted from this Paleozoic tectonic activity. First, faulting at the base of the Rome has removed the lower stratigraphic contact with the Shady Dolomite and created a problem in determining the true thickness of the Rome. In East Tennessee, a complete section of the Rome is reported only for the Jenkins Hollow section, located along the Doe River between Hampton and Elizabethton, Tennessee (King and Ferguson, 1960) and the Shook's Gap section, located just southeast of Knoxville (Cattermole, 1955). The partial thickness of the Formation in the study area ranges from about 90 to 125 m (Haase et al., 1985), but estimates up to 550 m have been made where a full Rome section is exposed at Damascus, Virginia (King and Ferguson, 1960).

The second result of tectonic activity has been the internal deformation of the Rome which obscurs original stratigraphic and sedimentological properties by multiply stacking and deforming portions of section almost beyond recognition.

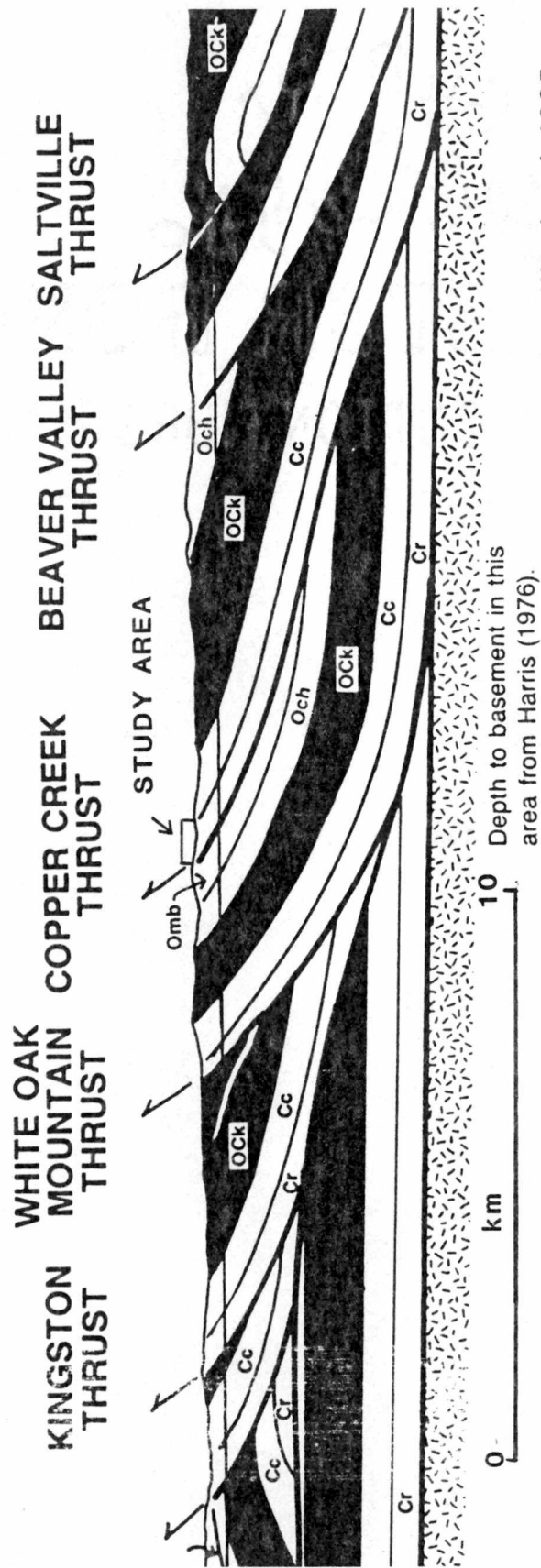


Figure 1.4 Typical structural cross-section in the western Valley and Ridge of East Tennessee. The area of this study is along the Copper Creek Thrust.

Geomorphology

The Rome Formation crops out along southwest-to-northeast trending ridges which have a distinct steep slope and "cockscorn" morphology making the Formation easy to find. Furthermore, the morphology of the ridge provides clues to the amount and style of deformation that has occurred in the Rome (Dreier, pers. comm., 1988). For instance, a single well-formed ridge occurs where the Rome is a single, unduplicated, and relatively undeformed section; whereas, a broad dissected ridge with several peaks indicates a duplicated Rome stratigraphy that contains several imbricate slices (Plate 1). Local sandstone/shale/carbonate ratio of the Formation must also have an important affect on ridge morphology.

Previous Work

Originally named the Knox Sandstone by Safford (1869), the rocks of the Rome have since been assigned many names (Table 1.1). After Rodgers and Kent (1948) separated the Pumpkin Valley Shale from the Rome and assigned it to the Conasauga Group, Rome nomenclature has remained unaltered. For further discussion of the Rome nomenclatural evolution, see Samman (1975), Resser (1938), and Woodward (1929).

Numerous regional geologic mapping studies of East Tennessee have discussed the Rome Formation within the framework of regional stratigraphy. Safford (1869), Hayes (1891), Keith (1928), Butts (1940), Rodgers (1953), King and Ferguson (1960), and Hardeman (1966) are examples of regional studies that have discussed only the general stratigraphy of the Rome.

Regional stratigraphic and/or structural studies such as Harris and Milici (1977), Harris (1964), and Milici (1973) have dealt with the Rome in only a slightly more detailed manner than the above-

Table 1.1. Rome Formation Nomenclature

Rome Formation Synonyms and Year of Introduction	
Knox Sandstone _____	1869
Rome Formation _____	1890
Montevallo Shale _____	1890
Watauga Shale _____	1893
Apison Shale _____	1894
Russell Shale _____	1894
Graysonton Formation _____	1894
Beaver Limestone _____	1895
Buena Vista Shale _____	1905
Choccolocco Shale _____	1905
Waynesboro Formation _____	1906

from Resser, 1938

mentioned regional studies. They described the general characteristics of the Rome well, but contain few details on sedimentology and paleoenvironments.

Few workers have concentrated solely on the Rome, but early works that did: Resser (1938), Fox (1943), and Harvey and Maher (1948), were mainly descriptive in cataloguing the paleontology and sedimentary structures of the Rome and also contain several measured sections. Spigai (1963) was the first to attempt paleoenvironmental interpretation within the Rome. The scope of Spigai's (1963) study was confined to East Tennessee. He concluded that more detailed studies of the Rome were needed before reliable paleoenvironmental interpretations could be made.

Samman (1975) was the latest study to attempt paleoenvironmental analysis of the Rome in East Tennessee. This is by far the most complete work to date compiled on the Rome. Although it contains a great deal of information, it should not be considered the final statement on Rome stratigraphy and sedimentology. The scope of the study also entailed all of East Tennessee. Similar to Spigai (1963), the study suffered from the lack of a detailed stratigraphy as well as lack of detailed sedimentological data. It also ignores the tectonic structure within the Rome, and this, in turn, produced erroneous stratigraphy. The large scope of the study shows once more that the Rome must be studied in smaller geographical parcels if the stratigraphy and sedimentology are to be resolved.

Webb (1969; 1980), investigated the Rome Formation in the Rome trough throughout Kentucky and in parts of East Tennessee. The Rome trough contains many units in addition to the Rome Formation and is mainly known from subsurface data. For the purposes of this thesis, the important point of the study is its regional basin reconstruction.

King and Ferguson (1960) established regional Rome and Shady relations in northeasternmost Tennessee and Southwest Virginia but not in detail. Further north in southwestern Virginia, Pfeil and Read (1980) and Reinhardt (1977) have studied the Rome Formation and underlying Shady Dolomite. Although both of these studies concentrate on the Shady, their study areas allow regional stratigraphic relations of the Lower Cambrian Shady and Rome to be established.

The most recent studies of the Rome within the study area are by Sledz (1980), who studied the clay mineralogy of the unit and by Haase et al. (1985), who described a core (JOY-2) drilled through the Copper Creek thrust sheet which contained Rome correlative with outcrops along Haw Ridge (Fig. 1.1). Siribhadki (1976) also did mineralogical work near the study area and concluded that the Rome contained metabentonite beds. None of the above cited works included paleoenvironmental interpretations.

This thesis represents a more detailed analysis of the Rome that takes the "smaller parcels" approach concluded as necessary by Spigai (1963) to produce a paleoenvironmental model for the Rome Formation in East Tennessee.

Site and Methods of Study

The study area is on the U.S. Department of Energy Reservation in Oak Ridge (Fig. 1.1). It extends along Haw Ridge from Jones Island on the Clinch River, in the southwest corner of the reservation (JI), to Pumphouse Road behind the Scarboro Facility, in the northeast corner of the reservation (CARL).

This 15 kilometer segment of Haw Ridge contains Rome Formation exposed along strike within the Copper Creek thrust sheet, a single, major thrust sheet. This eliminates any need for major

palinspastic restoration of outcrop sections and the problems inherent to the procedure.

Within the field area, the study concentrated on four major outcrops (Fig. 1.1). The first is located behind the Scarboro facility (formerly, the Comparative Animal Research Laboratory, CARL) and is designated as the CARL outcrop. The next outcrop is located to southwest where Walker Branch cuts through Haw Ridge. It is designated the WB outcrop in this study. The third outcrop is found along the Fuel Recycling Road just southwest of WB and is designated the FR outcrop. The fourth outcrop is located near Jones Island along the Clinch River in the southwest end of the study area and is designated as the JI outcrop. In addition to the four outcrops, the JOY-2 core was utilized. The core was drilled just southeast of the FR outcrop and penetrates the entire Copper Creek thrust sheet from the Knox Group down through the Rome and into the Copper Creek fault (Haase et al., 1985).

The study began with these four outcrops and core. The outcrops were measured by means of a Jacob staff. The core had already been measured by Haase et al. (1985). All were described in detail, concentrating on lithologic changes and primary sedimentary structures. The measurement precision varies from outcrop to outcrop. Section thicknesses are generally accurate to about 5 to 10 m depending on the degree of deformation at a particular outcrop.

Next, detailed mapping of Haw Ridge was undertaken and smaller outcrops were located. For each outcrop, lithology, sedimentology, and stratigraphy (if the outcrop was large enough) were investigated. The mapping was done by myself and Peter Lemiszki, a fellow Ph. D. candidate, who collected structural data. For this reason, structural information was not collected for this study except those used to orient paleocurrent measurements.

When field mapping was completed and all sections measured, paleocurrent measurements were taken. No cross-bedding was

observed in the study area, and ripple crests were the only paleocurrent indicator measurable at each outcrop. Using a brunton compass, the trend of the crests were measured for each set of ripples together with the strike and dip of master bedding for the restoration to original horizontal position. No attempt was made to correct for possible lateral rotations. The majority of the measurements were acquired at JI and CARL. After all the data were restored to original position, they were then plotted on Rose diagrams to display trends.

The CARL, JI, and JOY-2 sections were sampled for hand specimens and thin-sections. FR outcrop was not sampled due to its highly weathered nature, and the WB outcrop was not sampled because it was discovered late in the study and is very inaccessible. Sampling strategy for the two outcrops, CARL and JI, was two-fold: to sample as many different types of lithologies as observed at each site, and to sample similar lithologies found at both outcrops for comparison in thin-section to see if they were truly similar lithologies.

The Joy-2 core had previously been sampled and thin-sectioned by ORNL staff. These samples were used in the present study for inspection of the core. All major lithologies were already represented in these thin-sections; therefore, there was no need to sample further. At the outcrop, a sampling bias was introduced because of the poor exposure and difficulty in removing the finer-grained shale-dominated samples. The Joy-2 core did not have this bias and offset much of the difficulty the bias created by allowing direct observation of these finer-grained lithologies.

The thin-sections and hand samples were used to supplement and check field descriptions. Also, the observation of each major lithology on a more detailed scale was important toward environmental interpretation. Each sample was described in detail, with emphasis on carbonate content, detrital mineral composition (by means of visual estimation), degree of bioturbation, and diagenetic

features. The samples were also classified using the relatively new scheme of Mount (1985) for mixed carbonate and siliciclastic rocks in hopes that trends might appear. None were observed.

After all of the data had been collected, the stratigraphy was correlated, lithofacies were defined and interpreted, and finally a facies model was constructed for the study area. The method and rationale behind each of these steps will be explained in the respective chapters in which they are discussed.

CHAPTER 2

STRATIGRAPHY AND STRUCTURE

Although this thesis is primarily concerned with Rome stratigraphy, it must also deal with Rome structure because the two are inseparable. When the CARL, FR, and JI sections were first studied it was apparent that they could not be easily correlated. Similar lithologies occur at all outcrops, but the sequence at each is different. Furthermore, these sections have very different thicknesses: 57 m of Rome at CARL, 220 m at FR, and 95+ m at JI (Fig. 2.1, 2.2, and 2.3, respectively). Because of these complications, detailed geologic mapping was undertaken in order to ascertain if, and where, faults or other tectonic structures exist which would explain some of the stratigraphic complexities. During this stage of research, the fourth outcrop (WB) was discovered (Fig. 2.4). At WB, repetition of section indicating imbrication within the Rome was first observed. The faults are marked by abrupt changes in lithology involving maroon shale overlying gray dolostone and by a slight discordance of bedding between the two lithologies. Additionally, these faults clearly correspond to topographic expression of Haw Ridge above WB, confirming the hypothesis of Rome structure controlling ridge geomorphology. Through the integration of detailed mapping, measured section thicknesses, and the hypothesis that Rome structure (specifically, presence or absence of imbricate slices) controls Haw Ridge geomorphology, a basic structural framework for the study area was developed in which the area is subdivided into three structural blocks bounded by two tear faults (Plate 1).

Within structural Block I (Plate 1), CARL (Fig. 2.1) is the only major outcrop. No imbricates are noted in the measured section, and the presence of a single well-defined ridge crest also suggests no duplication. Mapping the ridge to the southwest, between CARL and the first tear fault (point A, Plate 1) just northeast of WB, confirms a structurally uninterrupted sequence up to the fault at point A (Plate

Table 2.1. Symbols for Stratigraphic Columns

	COLOR	LITHOLOGY	SEDIMENTARY STRUCTURES
G	- GRAY	 DOLOSTONE	 HUMMOCKY CROSS-STRATIFIED
DG	- DARK GRAY	 SANDY DOLOSTONE	 WAVY LAMINATED
G/G	- GREENISH GRAY	 DOLOMITIC SANDSTONE	 PLANAR LAMINATED
G/R & G	- GREEN TO RED AND GRAY ALTERNATING	 SANDSTONE	 FISSILE
M/R	- MAROON TO RED	 SILTY SANDSTONE	 MASSIVE
M/R & R/G	- MAROON TO RED AND RED TO GREEN ALTERNATING	 SANDY SILTSTONE	 NO DATA
		 SILTSTONE	 BIOTURBATED
R	- RED	 SILTY SHALE	 DESICCATION CRACKS
R/G	- RED TO GREEN	 SHALE	 CURRENT RIPPLE MARKS
R & G	- MOTTLED RED AND GREEN ALTERNATING	 GLAUCONITIC	 SALT "HOPPER" CASTS
R/GY	- RED TO GRAY	 PHOSPHATIC	 THIN-BEDDED
R/T	- RED TO TAN	 FELDSPATHIC	 MEDIUM-BEDDED
T	- TAN	 FAULT	 THICK-BEDDED
V	- VARIEGATED	 COVERED	 DISCONTINUOUSLY BEDDED

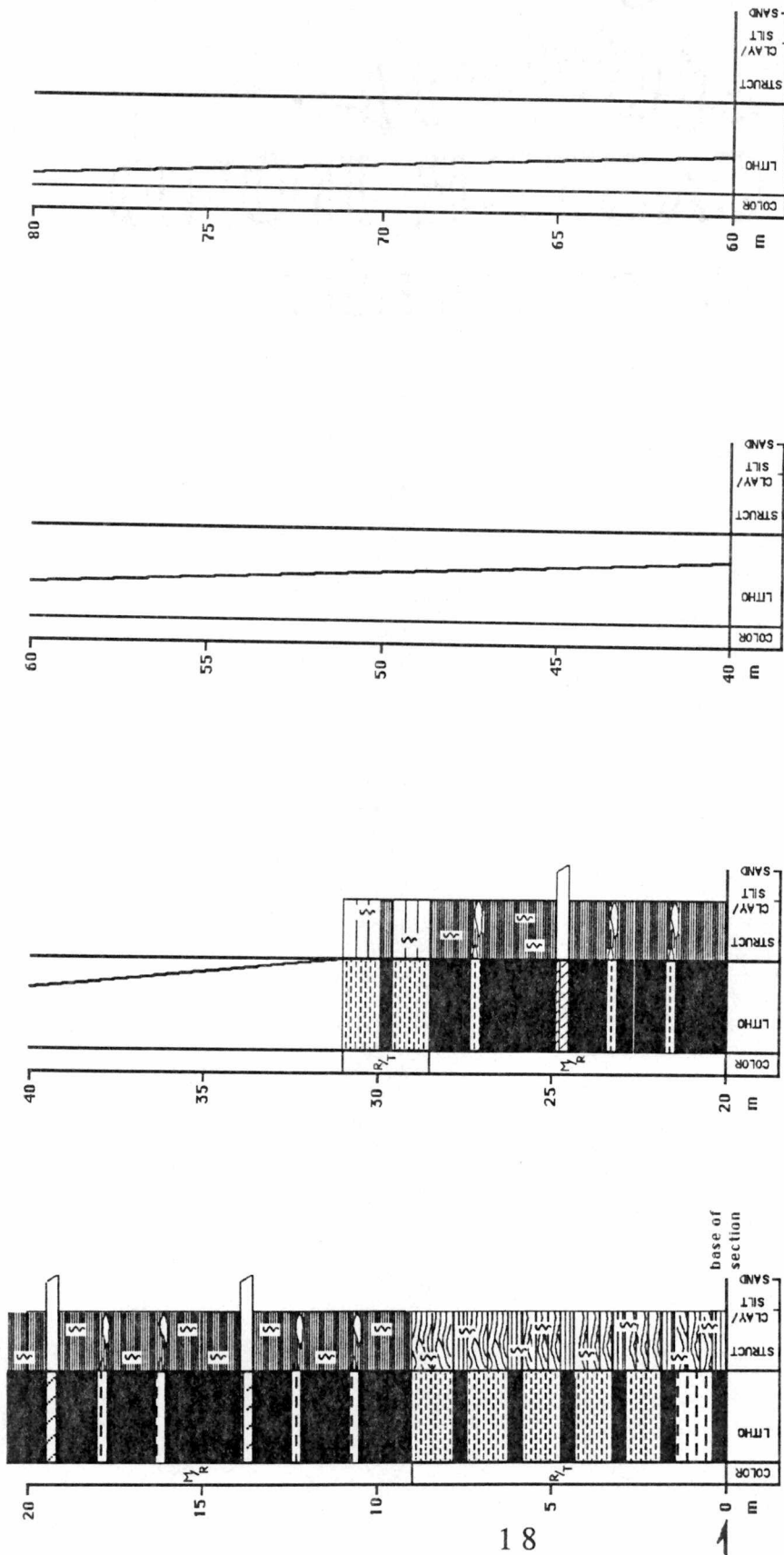


Figure 2.2 FR section stratigraphic column.
See Table 2.1 for key to symbols.

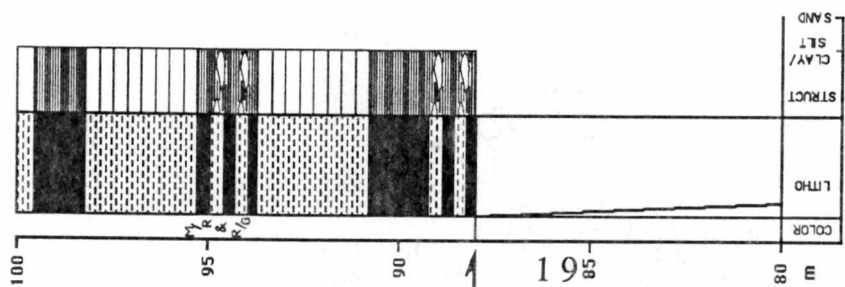
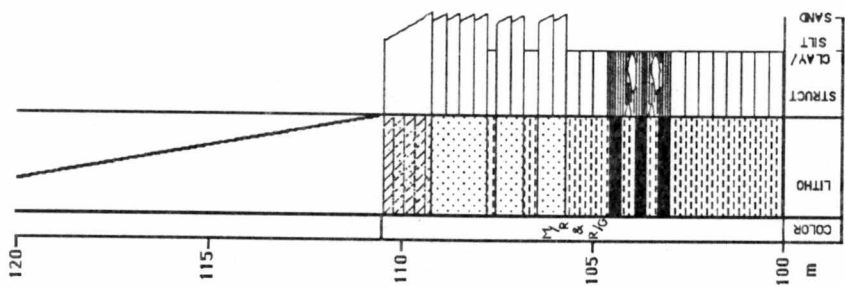
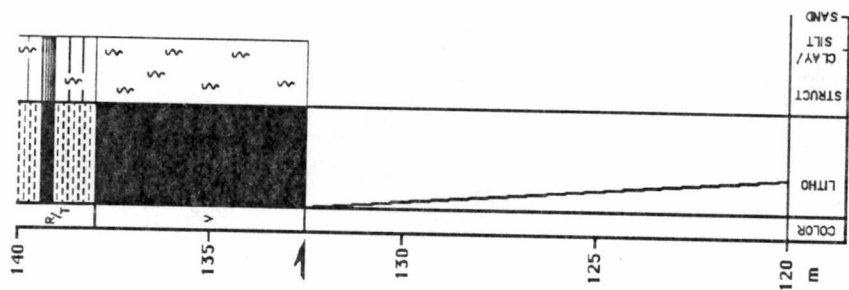
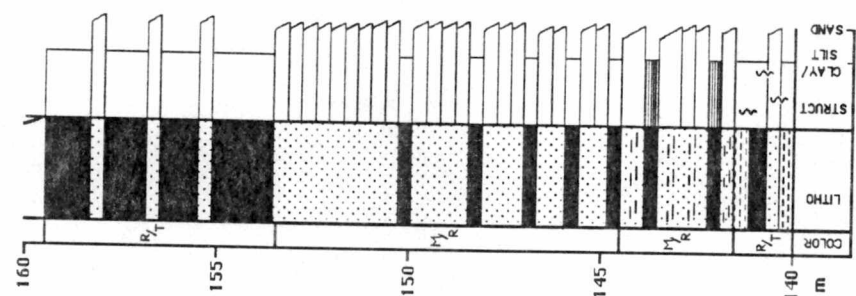


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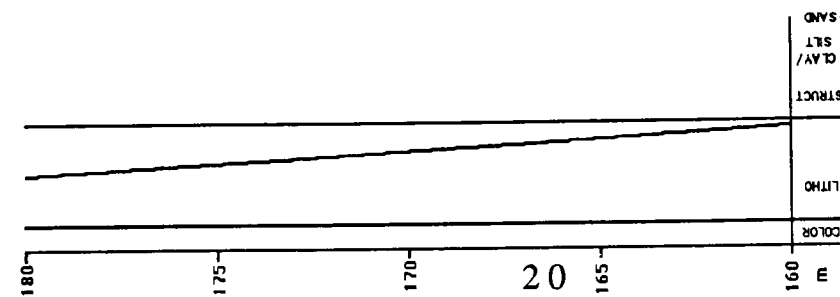
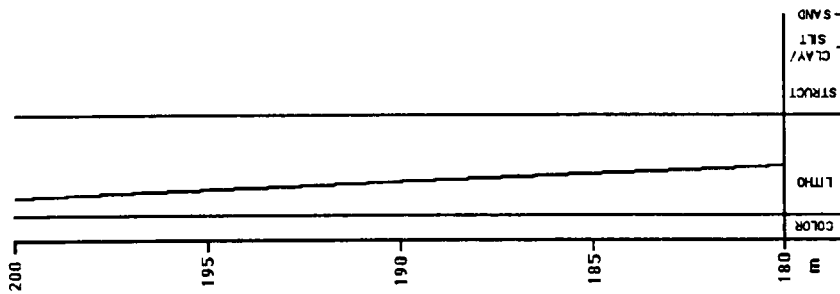
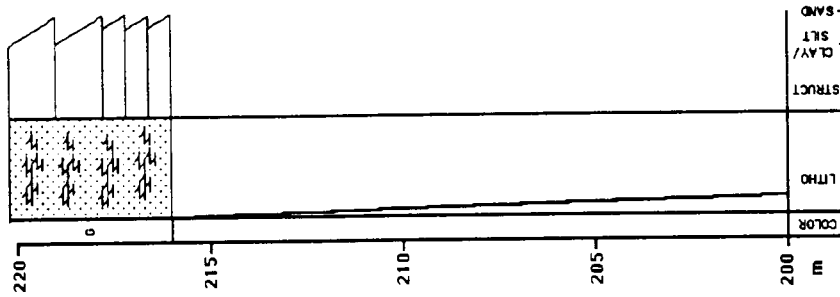
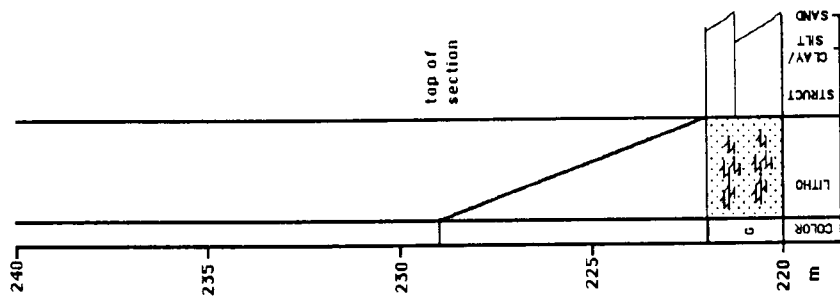


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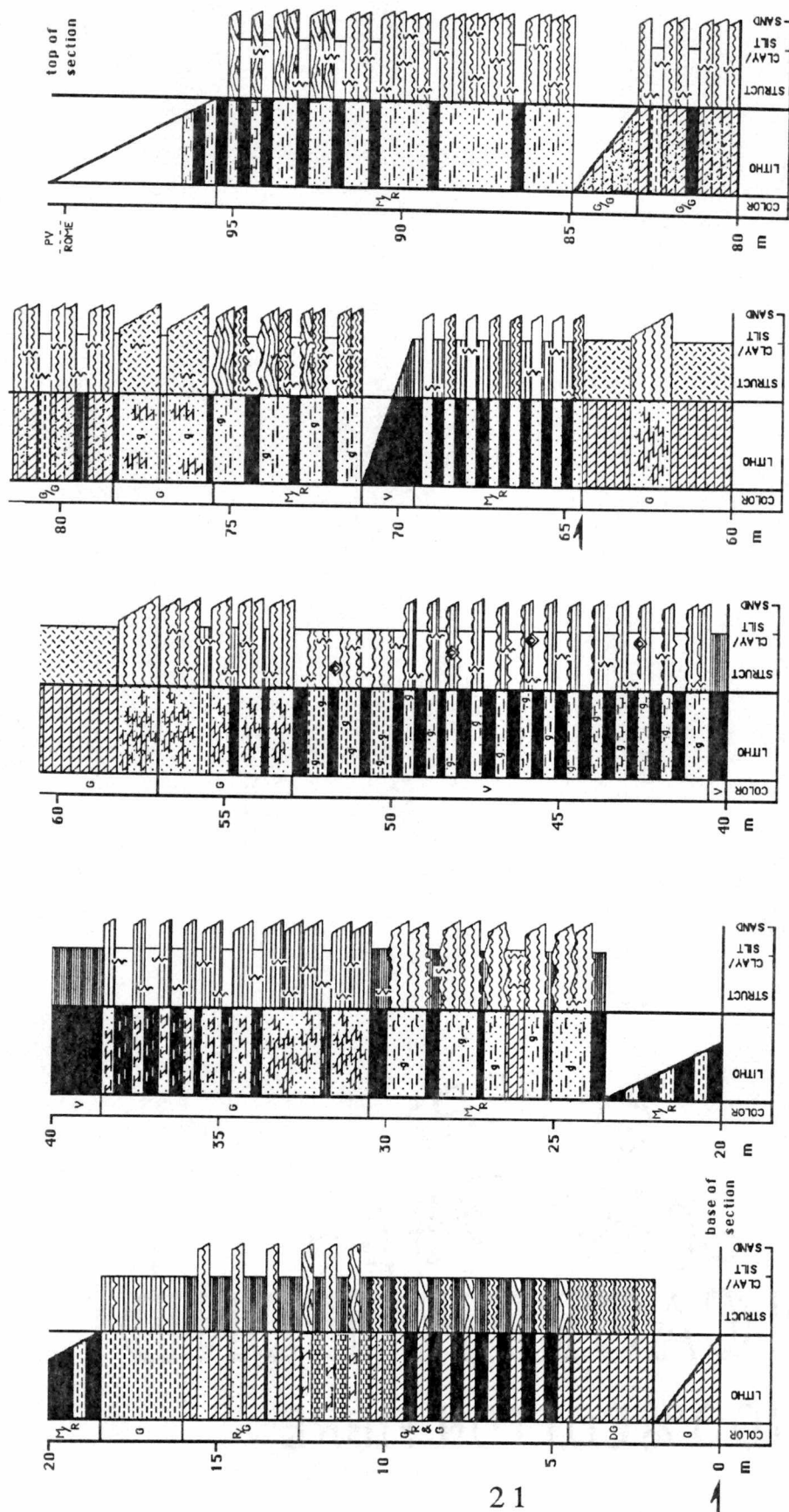


Figure 2.3 JI section stratigraphic column.
See Table 2.1 for key to symbols.

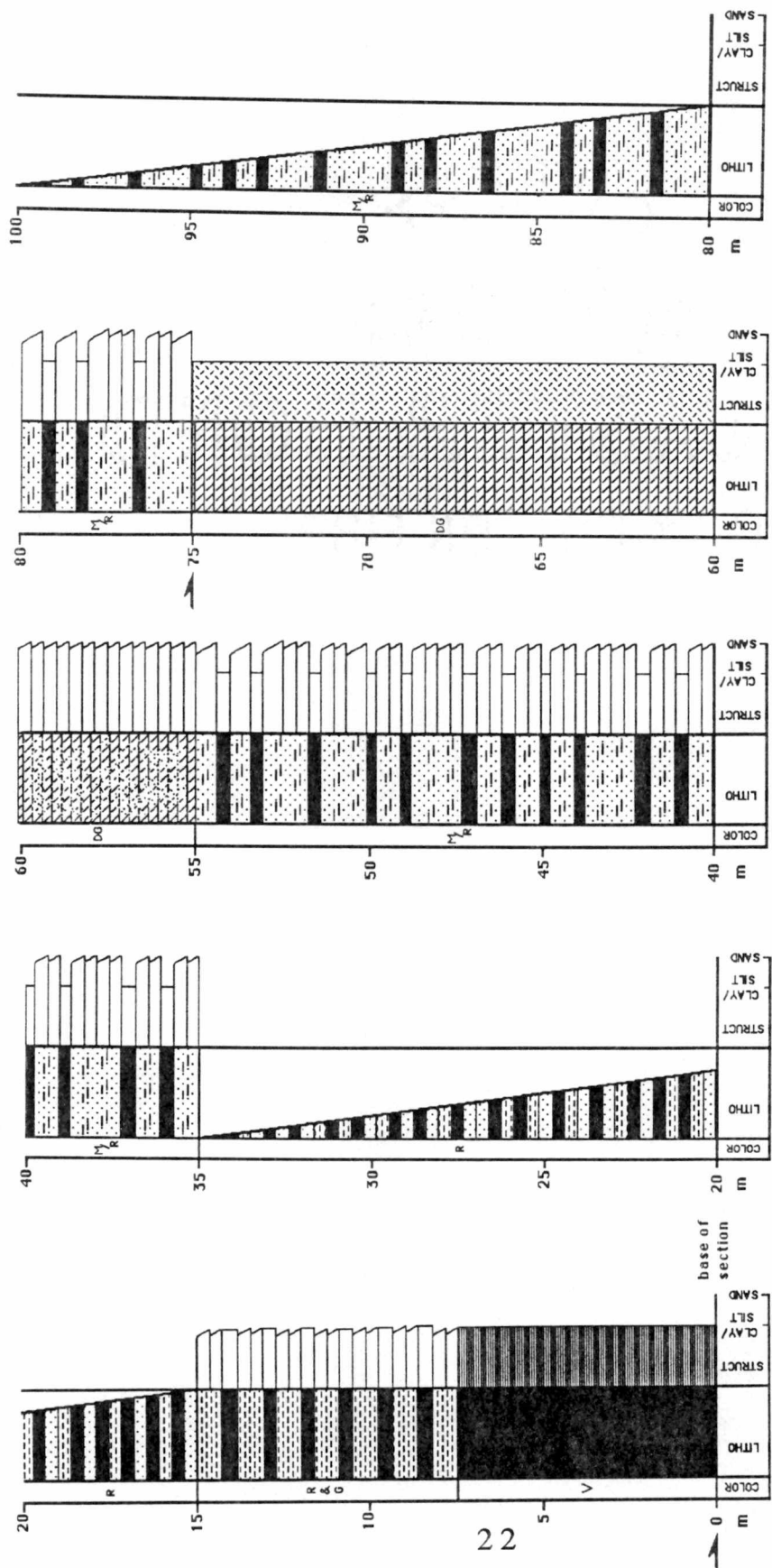


Figure 2.4 WB section stratigraphic column.
See Table 2.1 for key to symbols.

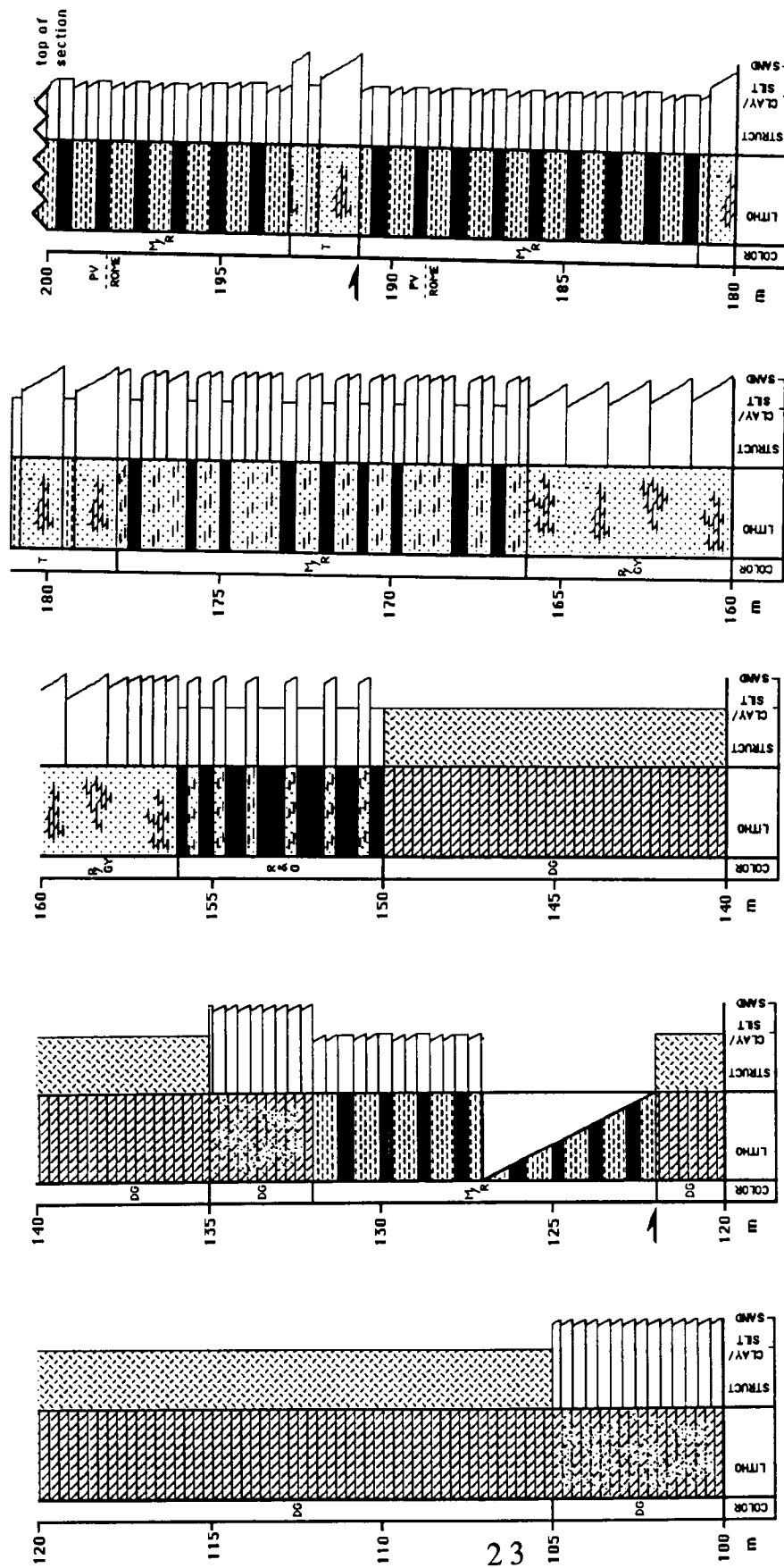


Figure 2.4 (cont.)

1). The first tear fault (point A, Plate 1) is indicated by the abrupt first appearance of massive dolostone on the southeastern side of the ridge, which can be traced down to the edge of the water at WB. Also, the geomorphological change from a single ridge to a broad ridge with three crests occurs at this point on the ridge.

Within structural Block II (Plate 1), Rome section duplication is indicated by the repetition of a sequence which consists of: red siltstone and shale » red sandstone » gray dolomitic sandstone » massive gray dolostone. At WB (Fig 2.4), the sequence is repeated three times. The section repetition suggests the presence of two imbricate faults plus the main thrust, and the topography and stratigraphic sequences noted in ravines in Haw Ridge just to the southwest, support this interpretation. At the FR outcrop (Fig. 2.2), two imbricate slices also appear to comprise the measured section. The apparent thickness of the Rome in Block II is further exaggerated by a broad anticline noted at WB, which probably extends throughout the entire block.

Just southwest of FR, the first or lowermost imbricate dies out into severe folding before it reaches Bearden Creek (point B, Plate 1). The single remaining imbricate and the main thrust can be traced southwestward to the end of Block II which is marked by the other tear fault (point C, Plate 1) that may offset Haw Ridge behind the ORNL facility. Southwest of Bearden Creek, outcrop exposure becomes scarce, and tracing the faults becomes more questionable. Here, ridge geomorphology was relied upon heavily.

Within structural Block III (Plate 1), exposure continues to decrease southwestward to the JI section. JI makes structural interpretation more difficult because it has an orientation slightly oblique to strike and displays near-vertical dips on the southeastern slope of the ridge, while having nearly flat-lying beds on top of the ridge. In this block, Haw Ridge is, again, manifested as a ridge with a single, well-formed crest which suggests that a fairly uninterrupted sequence of Rome would be found in this structural block. The JI

section (Fig. 2.3) is in general agreement with this interpretation with two possible exceptions. First, at 53 m in the section (Fig. 2.3), a complexly folded interval occurs, but is actually a faulted fold in which most of the fault movement was parallel to strike. If this interpretation is correct, then only a small amount of section is lost and no imbrication or duplication of section has taken place. The second possible location for imbrication is at the 65 m level of the section (Fig. 2.3) where red siltstone abruptly overlies gray dolostone observed. The contact between the two lithologies can be traced up the ridge face in an orientation (similar to WB) slightly oblique to bedding, and is at the same stratigraphic level of the imbrication found at WB, but the best fit, simplest solution to correlating JI to the other sections is to interpret the contact as a zone of deformation along which neither significant movement nor duplication has occurred. The scant field data available between JI and the second tear fault (point C, Plate 1) also suggest a single Rome sequence is most likely in Block III. It should be noted that the unusual structure of JI and scarce outcrops throughout the rest of the block combine to make this the least reliably interpreted structural block.

Once the structural problems were resolved well enough for the purpose of correlating Rome stratigraphy, two key beds occurring throughout most of the study area were used to correlate the four sections (Fig. 2.5). The first marker bed is a massive dolomitic sandstone located near the top of the Formation that can be traced across the entire field area, except at JI, and allows Block I and II to be correlated by connecting the CARL, WB, and FR sections. The second marker is a thick, massive dolostone that occurs in the middle of the Rome and is found throughout the study area, except at CARL. Using this distinctive dolostone unit, the Block III can be correlated to Blocks I and II, and the imbricate faults of the Block II can also be located. The deformed stratigraphy (Fig. 2.5) contains the actual stratigraphic data with as little interpretation as possible.

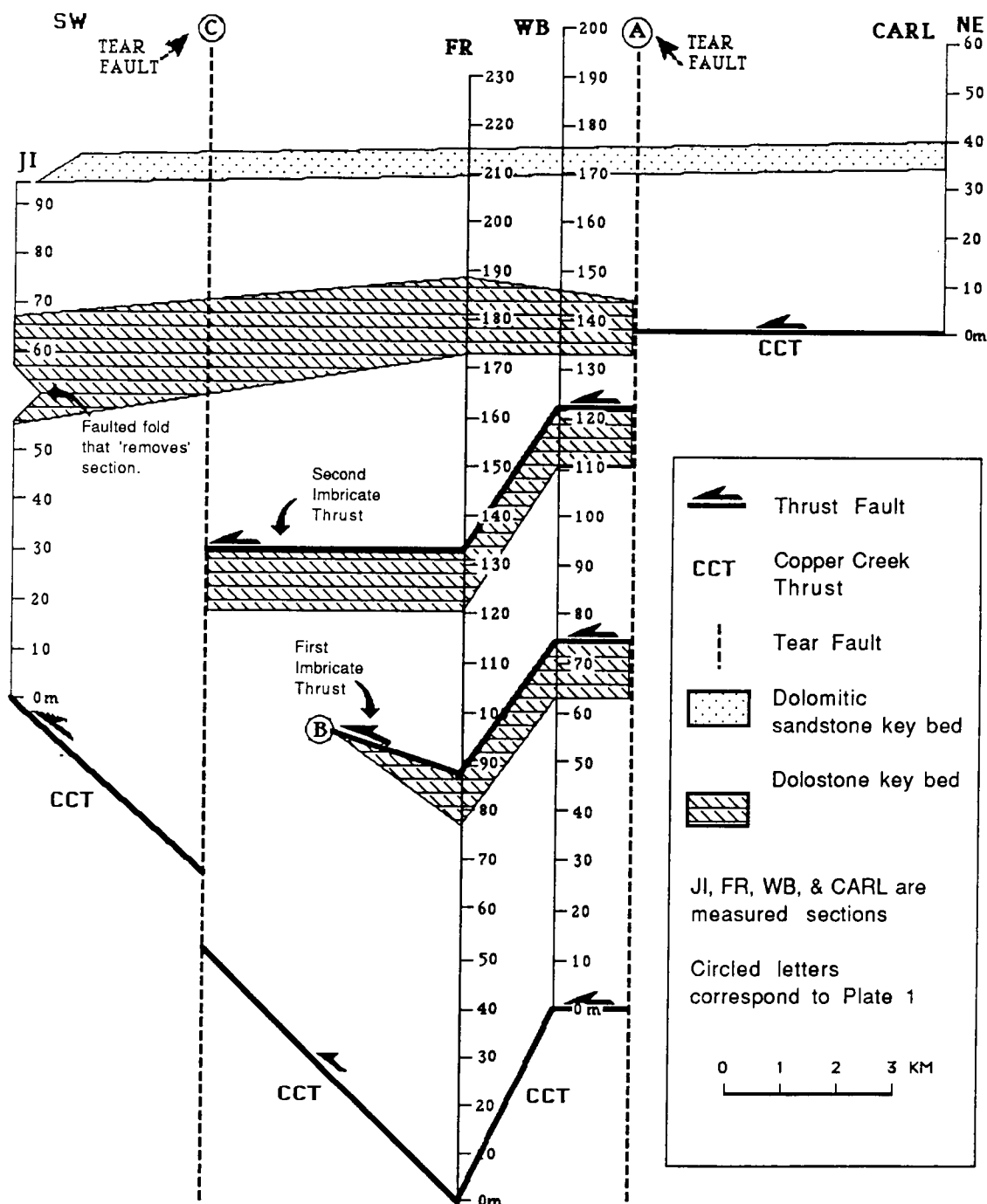


Figure 2.5 Stratigraphic cross-section of the study area with structure. Stratigraphic data shown with as little interpretation as possible.

Next, the Rome was palinspastically restored in Block II to construct the closest possible original, undeformed section. Assuming the faults are imbricate slices in the block (Plate 1, Fig. 2.5), the imbricated section was restored to "original position" by using bed thickness balancing techniques in which bed thicknesses from measured sections were used. A hinterland to foreland thrust sequence was assumed, and no attempt was made to conserve area in these restorations. The other two blocks within the study area were free from this type of structural complication. Finally, with the structure removed from the deformed stratigraphy (Fig. 2.5), a restored, undeformed Rome stratigraphy in the study area was produced (Fig. 2.6, Plate 2).

It should be noted that the JOY-2 core was not used extensively for correlation because it was too difficult to locate faults in the core, due to the fact that severe deformation can occur in places other than sites of imbrication (Fig. 2.7). Also, the faults may not be observed because Joy-2 is too far southeast to have been involved in imbrication.

Few previous workers have taken imbrication of the Rome into consideration when estimating the true stratigraphic thickness of the unit. The Rome is thinner in the study area than previous works would suggest. This overestimation has probably occurred throughout the Appalachian Basin region.

The main conclusion from the stratigraphy is that the Rome correlates only on a gross scale and displays a patchy, mosaic pattern.

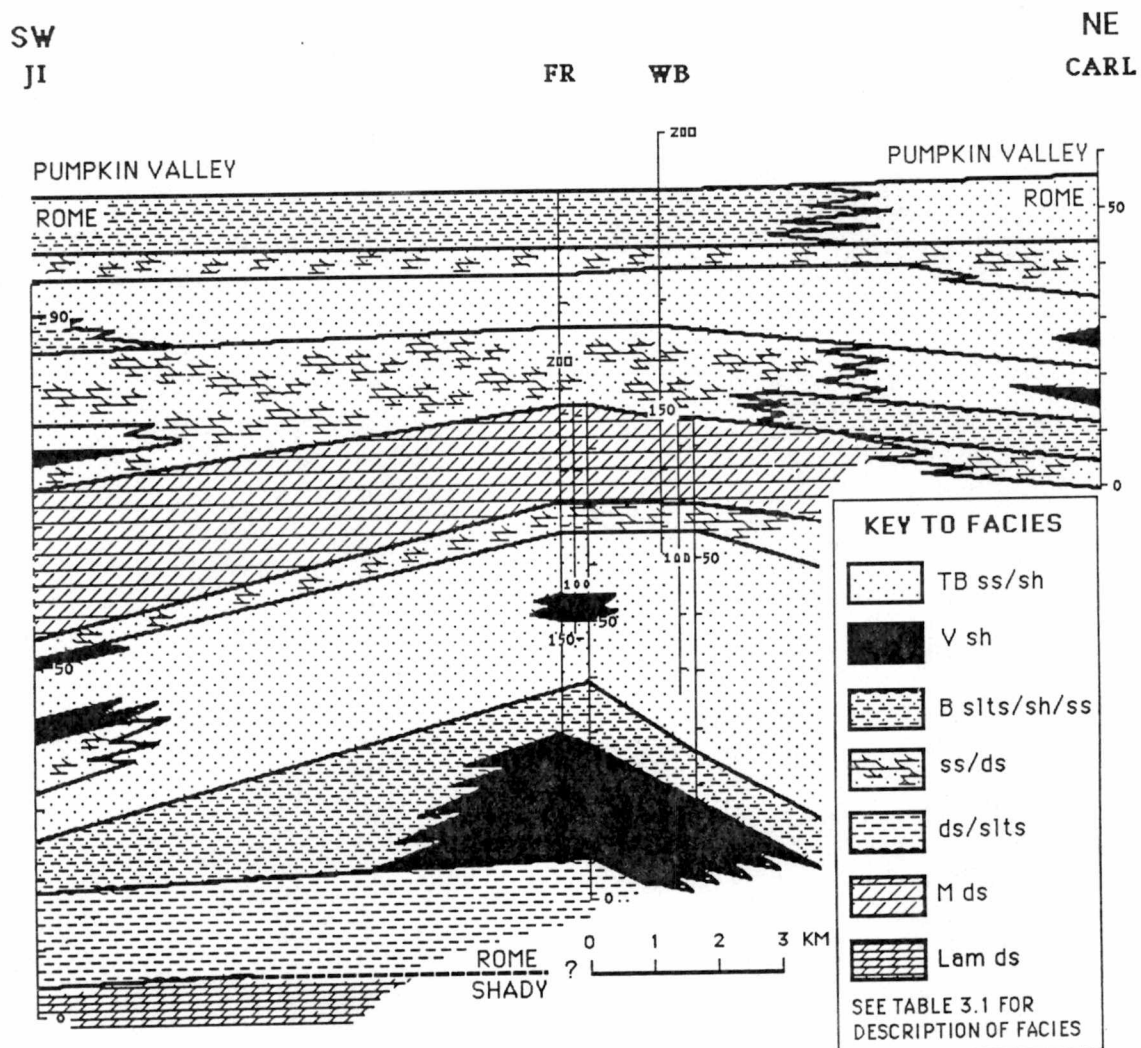


Figure 2.6 Interpreted, restored stratigraphy of the study area.
Thickness scales in meters.

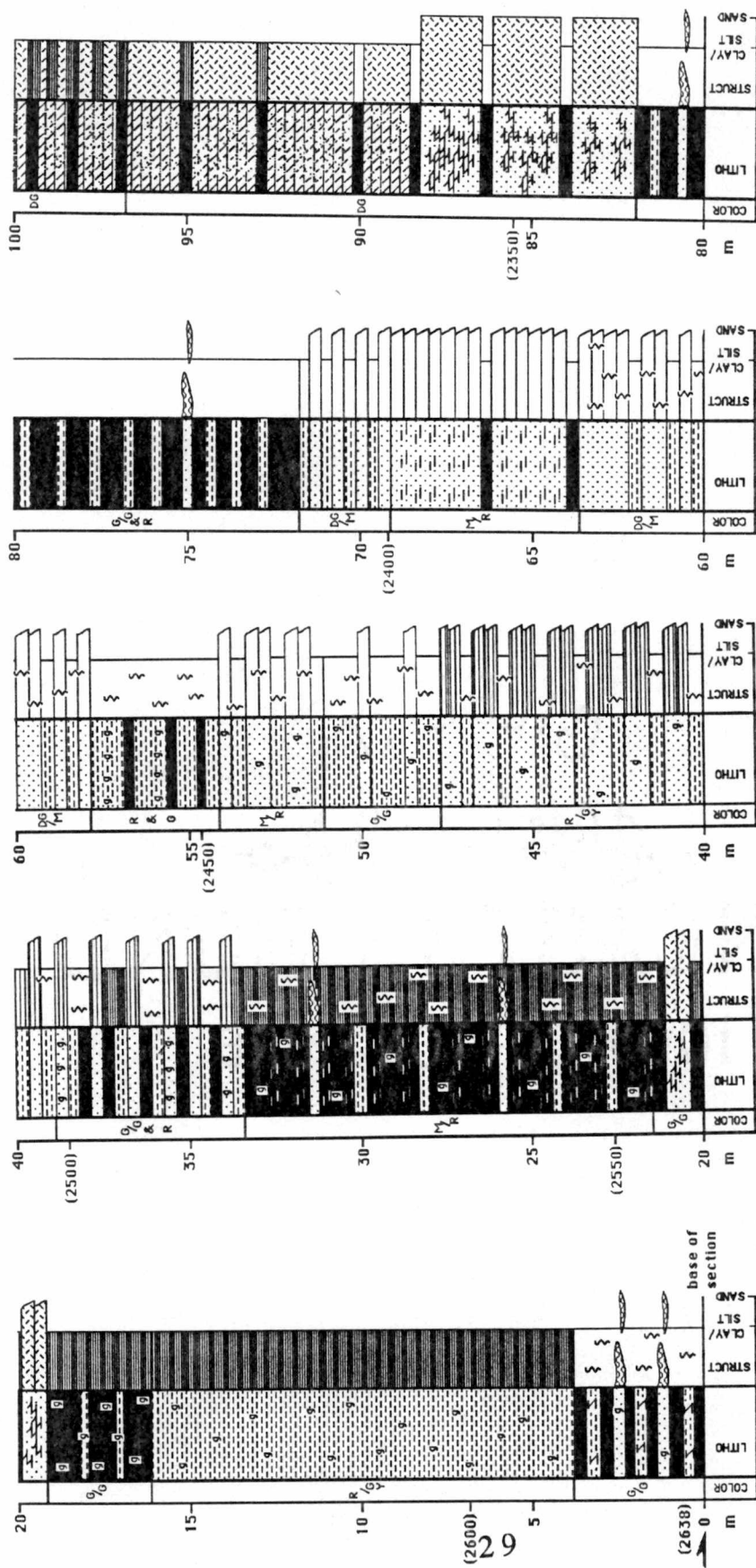


Figure 2.7 Joy-2 core stratigraphic column.
See Table 2.1 for key to symbols. Number in () denotes downhole core footage.

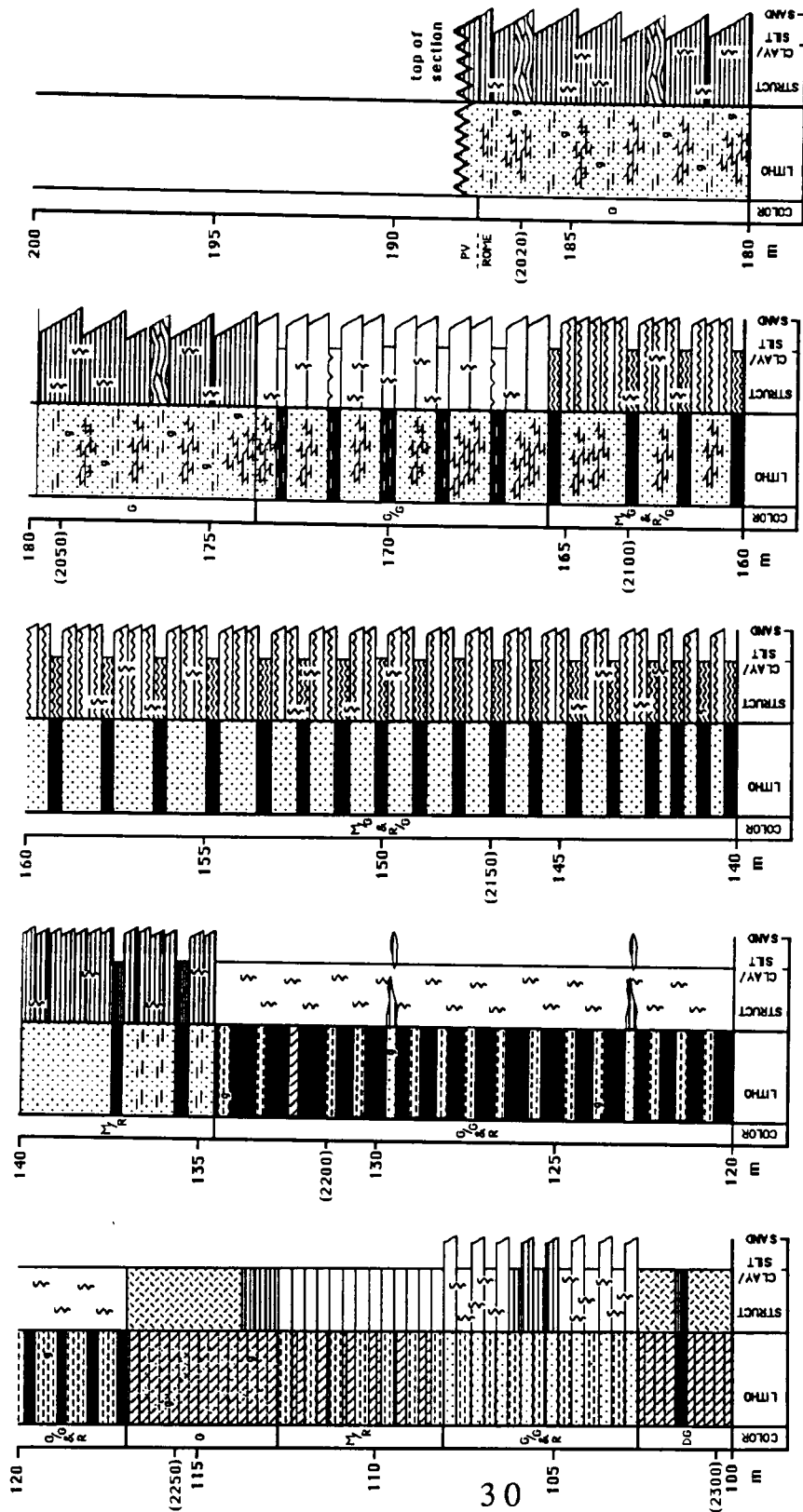


Figure 2.7 (cont.)

CHAPTER 3

LITHOFACIES

This study is the first to use facies-analysis to interpret paleoenvironments in the Rome Formation. It is further unique in its treatment of the Rome as a mixed siliciclastic and carbonate sequence. Seven lithofacies were recognized in the field area (Table 3.1): the first three lithofacies discussed are pure terrigenous clastic end-members; the next two are mixed lithofacies, and the final two are pure carbonate end-members. These lithofacies were defined at the hand sample- to outcrop-scale for easy recognition in the field, and thin-section data, presented in Appendix C, were used mainly to confirm field observations. Lithologic composition, grain size, and sedimentary structures were the major criteria used to define lithofacies.

Lithofacies Description and Interpretation

Dominantly Thin-bedded, Hummocky Cross-stratified Sandstone Interbedded With Shale (TB ss/sh)-

Occurrence:

TB ss/sh, a terrigenous clastic end-member facies, is the most common facies in the Rome (Fig. 3.1) and could be considered the "typical" Rome seen in outcrop. Sharp contacts exist between shale and sandstone lithologies within the facies and are also observed with *Vsh* facies. Contacts with *B slts/sh/ss* and *ss/ds* facies are gradational.

Table 3.1. Summary of facies in the Rome Formation

FACIES NAME	FACIES DESCRIPTION	PROCESS INTERPR./ PALEOENV.	FACIES ASSOCIATION
TB ss/sh (Thin-bedded sandstone and shale)	Maroon, thin to medium-bedded fine-grained sandstone interbedded with shale. Micro-hummocky cross-stratification, ripple marks, wavy laminations, horizontal burrows and mudcracks are common.	Occurs across entire tidal flat in an alternating intertidal to subtidal open marine environment dominated by intense storm and normal tidal processes.	Most abundant facies occurs throughout the Rome and in association with B silts/sh/ss and Vsh.
V sh (Variegated shale)	Variegated, dominantly maroon, fissile shale with infrequent discontinuous thin-bedded siltstone.	Occurs on the tidal flat as a low-energy, quiet water, restricted to anoxic marine environment; coarser lenses represent storm beds.	A minor facies abundant in lower portions of the Rome. Ubiquitously associated with TB ss/sh and B silts/sh/ss facies.
B silts/sh/ss (Bioturbated siltstone, shale, and sandstone)	Red to maroon, bioturbated shaly siltstone interbedded with shale and thin discontinuous fine-grained sandstone beds.	Occurs on the tidal flat as open marine, intertidal to shallow subtidal, storm dominated environment in patches where benthic organisms thrived.	Abundant facies normally occurs in the lower portions of the Rome in association with Vsh and B silts/sh/ss facies.
ss/ds (dolomitic sandstone to sandy dolostone)	Grey, thin to thick-bedded and massive, recrystallized, gradational dolomitic sandstone to sandy dolostone. Percentage of dolomite ranges from near zero to almost 100 %.	Facies mixing environment as siliciclastics on the tidal flat merge with carbonate platform facies in back platform areas; probably intertidal. May contain penecontemporaneous dolomite.	A common facies abundant in the middle portions of the Rome and occurs as transition between TB ss/sh or B silts/sh/ss and Mds facies.
ds/silts (interlaminated dolostone and siltstone)	Grey to red, interlaminated dolostone and micro-hummocky cross-stratified siltstone.	In Situ mixing in intertidal to supratidal tidal-flat depositional environment. Probably contains penecontemporaneous dolomite.	A rare facies that usually occurs near the base of the Rome in association with underlying Lam ds facies.
M ds (Massive dolostone)	Grey, massive recrystallized dolostone; bedding usually not distinguishable.	Deposited as a carbonate mud in back platform areas far behind the shelf edge reefs.	common facies that commonly occurs in middle portions of the Rome and associated with ss/ds facies.
Lam ds (Laminated dolostone)	Grey, finely laminated dolostone with chaotic bioturbated intervals.	Underlies entire basin; intertidal to supratidal tidal-flat environment. Probably contains penecontemporaneous dolomite.	Very Rare facies that occurs at the base of the Rome (only at JI). Associated with overlying ds/silts.

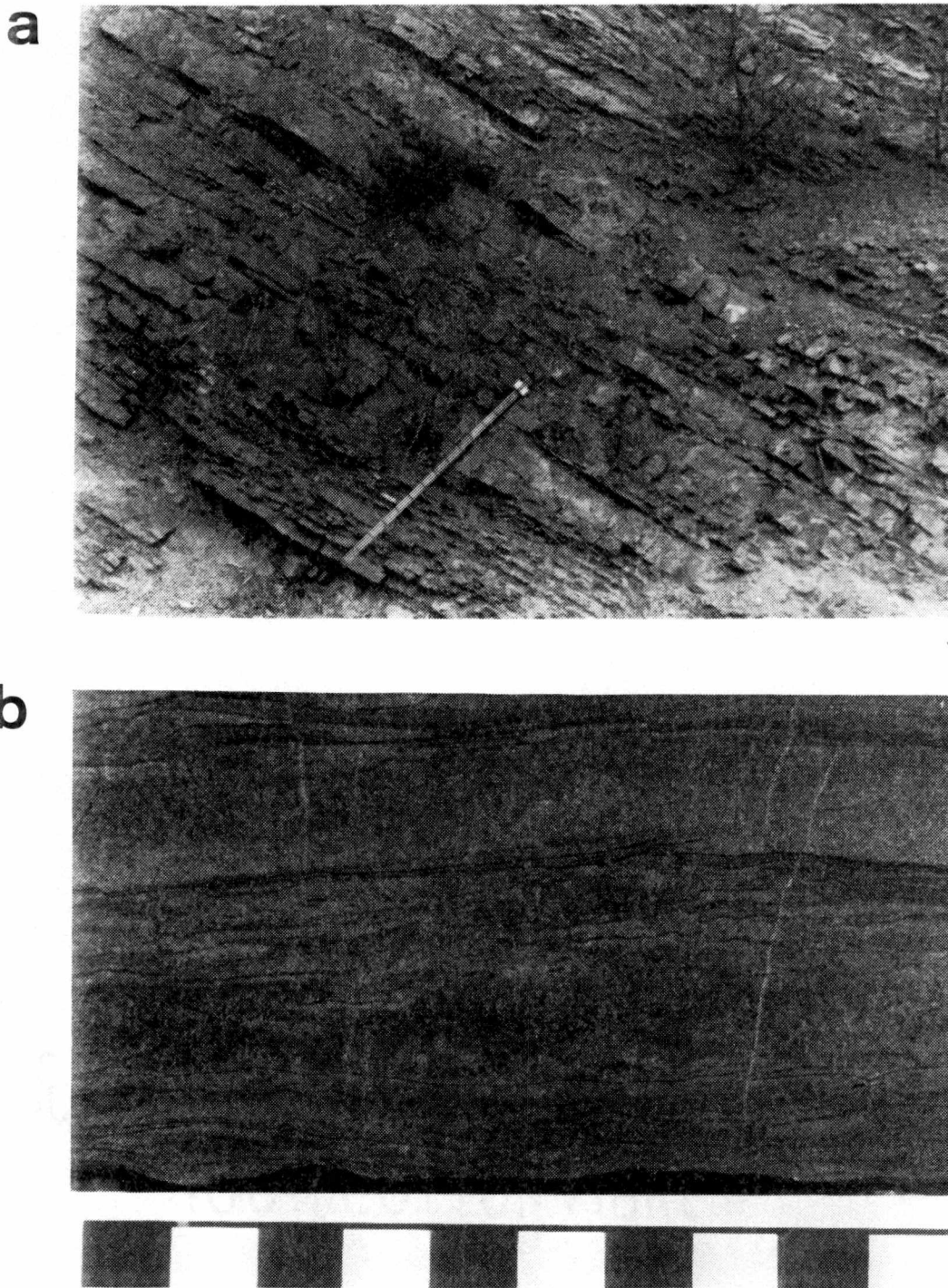


Figure 3.1 Characterization of TB ss/sh facies. (a) 28 to 32 m interval at CARL section. Note hummocky nature of beds. 1.5 m Jacob staff with 10 cm divisions for scale. (b) JM-JI-91.3 hand specimen from JI section shows mhcs. Bar scale in cm. (c) JM-C-20.7 thin-section shows lithology dominated by quartz and feldspar. Note quartz overgrowths. 1.5 mm field of view, lengthwise; cross-nichols.

C

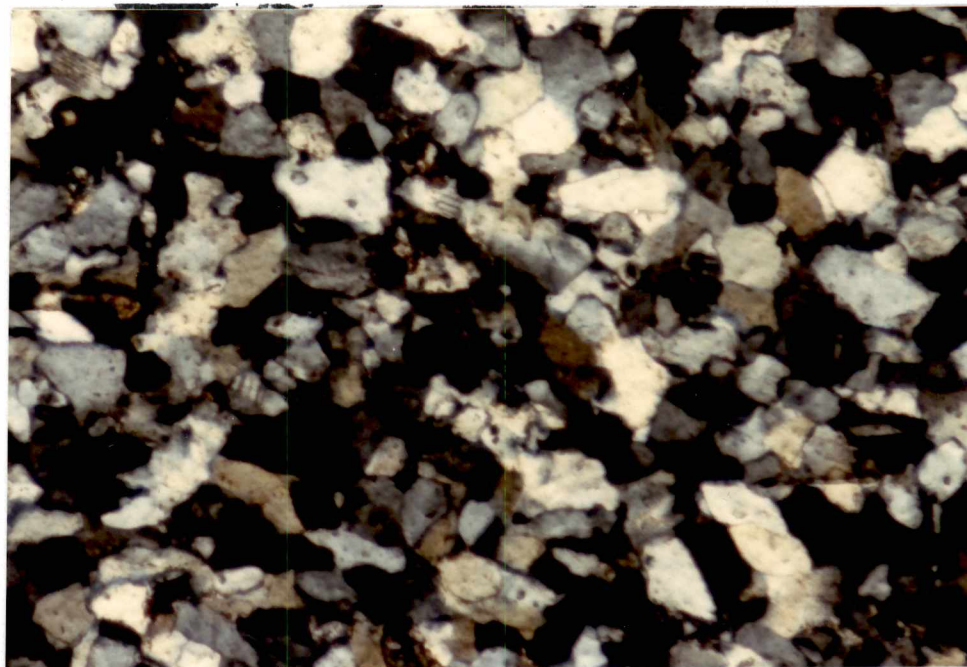


Figure 3.1 (cont.)

Description:

The *TB ss/sh* facies consists of dominantly maroon and red (fresh) to tan (weathered), thinly to medium-bedded, silty, very fine-grained sandstone interbedded with mottled maroon to green-gray blocky shale. The ratio of sandstone to shale is variable, but sandstones are usually more common. The well-indurated, micro-hummocky and hummocky cross-stratified sandstone beds range from 1-20 cm thick and internally draping, planar to wavy thin laminations are common. The shale beds are typically between 1-2 cm and, though overall blocky and burrowed, do become fissile in the thinnest beds. Along bedding planes at boundaries between sandstone and shale beds, abundant ripple structures and desiccation polygons are observed whereas rain drop impact marks and salt "hopper" casts are noted in less abundance. Also along bedding planes, horizontal burrows and crawling traces, *Planolites* and *Cruziana*, are abundant and trilobite resting traces, *Rusophycus*, are rare. Scattered phosphate nodules and glauconite are observed. Strata are strongly folded in places, and minor, traceable faults occur within the facies.

Interpretation:

This facies obviously represents quite variable and changing environmental conditions. Scattered, shallow mudcracks and small salt "hopper" casts observed on bed tops indicate an intertidal tidal flat environment (Handford, 1981; Reading, 1986), while horizontal burrows on bed bottoms, micro-hummocky and hummocky cross stratification, and planar laminations suggest a subtidal, environment also existed (Harms et al., 1975; 1982; Reading, 1986). Additionally, the abundance of micro-hummocky and hummocky cross stratification indicates the facies was affected by storm current processes (Harms et al., 1975; 1982; Dott and Bourgeois, 1982; Duke, 1985). The abundance of very fine-grained to fine-grained sand, (the coarsest sediment in the Rome), shows clastic input was near its peak during deposition of the *TB ss/sh* facies, but the occurrence of

phosphate nodules confirms that periods of slow sedimentation also existed during the deposition of this facies.(Gulbrandsen, 1969; Fuller, 1979) The abundant occurrence of *Cruziana*, *Planolites*, and *Rusophycus* traces suggest the presence of a nutrient-rich environment in which benthic organisms thrived (mostly trilobites, judging from the traces observed) (Frey, 1975). A broad, open tidal flat setting could have provided such an environment (Frey, 1975). The *TB ss/sh* facies is interpreted as an alternating intertidal to subtidal, tidal flat environment, and the dynamics of the tidal flat were dominated by storm processes as well as normal tidal processes. The observation of salt casts in an intertidal environment indicates a seasonally wet and probably subtropical climate existed (Reading, 1986).

Variegated Fissile Shale Facies (Vsh)-

Occurrence:

This volumetrically minor siliciclastic facies typically occurs within the *TB ss/sh* and *B sh/slts/ss* facies (Fig. 3.2). JOY-2 core stratigraphy suggests that this facies is more common than is exposed in outcrop, and that it constitutes much of the covered intervals. Contacts above and below *Vsh* are commonly sharp. This facies tends to be most abundant in the lower portions of the Rome.

Description:

A dominantly red, variegated (red/ green/ yellow/ black) fissile shale interbedded with tan to red, discontinuously thin-bedded siltstone; "dirty" sandy dolostone and glauconite beds are common throughout. Generally highly deformed to the point of developing cleavage.

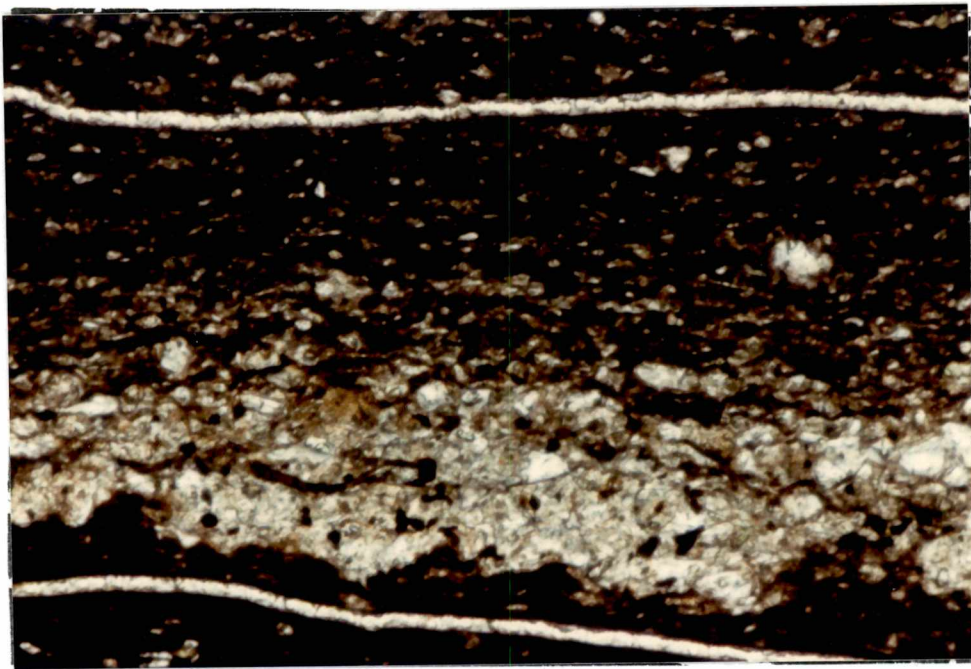
a**b**

Figure 3.2 Characterization of V sh facies. (a) 25 to 28 m interval at CARL section. Shows typical outcrop of V sh. 1.5 m Jacob staff with 10 cm divisions for scale. (b) ORNL-J2-2209 Joy-2 thin-section shows lithology dominated by opaque fine-grained phyllosilicate and organics with the occasional quartz siltstone laminations. 1.5 mm field of view, lengthwise; plain light.

Interpretation:

Potter et al. (1980) stated that most shales are marine in origin based on their association with deltaic and turbidite deposition into marine basins. No evidence is found to suggest the contrary here. This facies was interpreted as being deposited in a low-energy, quiet-water setting which is required for deposition of suspended mud- and silt-sized sediments, and the lack of biota and bioturbation further suggest a restricted and at times, anoxic environment (Potter et al., 1980; Byers, 1974; 1977). The occasional lenses of sand (quartz, dolostone, and glauconite) are interpreted as storm wash, an example of "punctuated" mixing (Mount, 1984). The *Vsh* facies is interpreted to have been deposited in the deeper, more restricted and protected areas of a broad, subtidal, tidal flat environment. Siribhadki (1976) interpreted some shale beds in the Rome as metabentonites, but none occurred persistently enough throughout the field area at the same stratigraphic horizon as to be interpreted as bentonites.

Bioturbated Shaly Siltstone with Sandstone Interbeds Facies (B sh/slts/ss)-

Occurrence:

This common siliciclastic facies is closely associated with *Vsh* and *TB ss/sh* facies and generally has gradational contacts with adjacent facies (Fig. 3.3). The lithology is very similar to that of *TB ss/sh* with the addition of bioturbation. It occurs most commonly in the lower portions of the Rome section.

Description:

Facies *B sh/slts/ss* consists of intensely bioturbated, maroon to green shale, interbedded with maroon fine-grained sandstone and

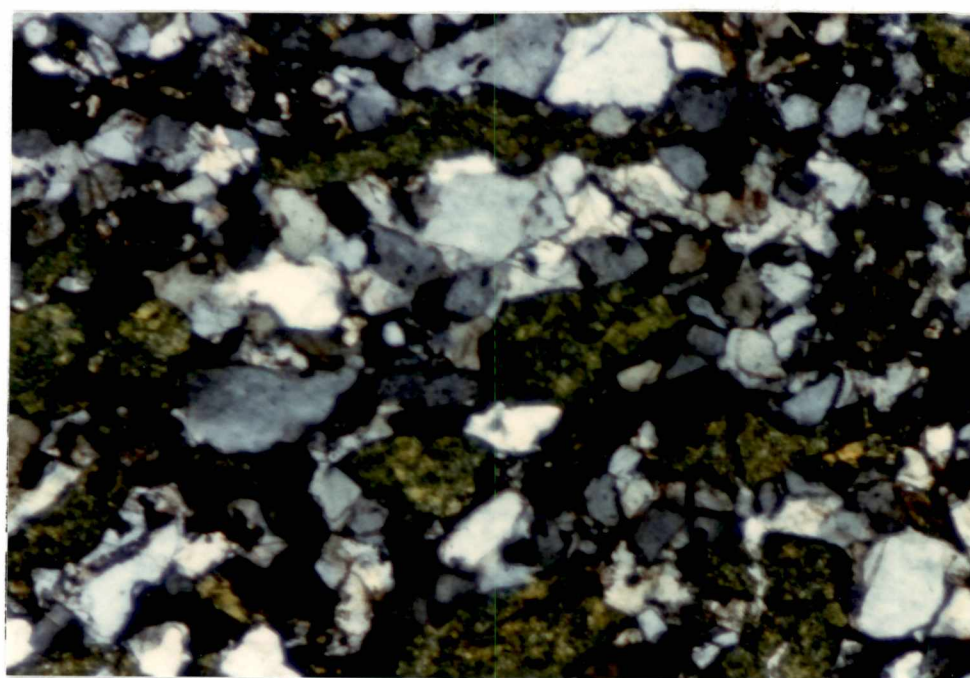
a**b**

Figure 3.3 Characterization of B slts/sh/ss facies. (a) 4 to 13 m interval at CARL section. Note ubiquitous interbedded nature. 1.5 m Jacob staff with 10 cm divisions for scale. (b) JM-C-9.5 thin-section shows quartz sandstone with abundant glauconite. 1.5 mm field of view, lengthwise, cross-nichols. (c) JM-JI-71.5 hand specimen from JI section shows the common mottled, bioturbated bedding. Bar scale in cm.

C



Figure 3.3 (cont.)

siltstone. The shale is blocky, mottled green and red, and contains lenses of glauconite. The red to tan siltstone and sandstone beds are vuggy, discontinuous, ranging from 1-20 cm thick, and become more continuous and abundant upward. Some siltstone and sandstone beds are carbonate rich, and many are glauconitic. Micro-hummocky cross stratification is rare. Wavy, black laminations (organic?), and burrows (horizontal and vertical) were both common throughout the facies. Complex folding, jointing, and faulting complicate the facies.

Interpretation:

The homogenizing effect of bioturbation leaves little evidence of original flow conditions. The evidence of abundant biogenic reworking indicated by ubiquitous and disorganized mottling (Frey, 1975) is ambiguous for environmental interpretations. The facies is so intensely bioturbated, ichnofossils could not be identified. Yet, because vertical stratification has been destroyed, bioturbation is interpreted as vertical burrowing, and the facies is assigned to the *Skolithos* ichnofacies which implies an intertidal to shallow subtidal environment (Frey, 1975). No sedimentary structures indicating subaerial exposure are found in this facies, and the entire unit is mottled by burrowing. These characteristics suggest a subtidal environment. The presence of ubiquitous burrowing suggests an abundance of life which supports the interpretation of a open marine environment with well-circulated and oxygenated water (as opposed to the restricted Vsh facies) (Potter et al., 1980). Furthermore, the lithologic similarity to *TB ss/sh* and rare preservation of micro-hummocky cross-stratification suggests the *B slts/sh/sh* facies had the same depositional environment as the *TB ss/sh* facies, namely a intertidal to subtidal, tidal flat environment frequently interrupted by storms. The facies occurred in more open, well-circulated, subtidal areas on the flat.

Mixed Dolomitic Sandstone To Sandy Dolostone Facies (ss/ds)-

Occurrence:

This facies represents the spectrum of mixed siliciclastic and carbonate lithologies found in the Rome (Fig. 3.4). It is common, occurring in a continuous range of lithologies that vary in sandstone-to-dolostone ratio. The facies typically occurs as a transitional unit between *TB ss/sh* and *M ds* facies or between *B slts/sh/ss* and *M ds* facies, but the *ss/ds* facies also occurs within *TB ss/sh*, *B slts/sh/ss*, and *M ds* facies.

Description:

This facies consists of a gray (fresh) to tan (weathered), thin-bedded to massive (10-100 cm), recrystallized, glauconitic, vuggy, dolomitic, fine-grained sandstone to sandy dolostone. Dolomite content is variable throughout the unit and ranges from 10 to 90 percent. The thinly- to medium-bedded sandstone is typically interbedded with thin gray silty shale. Bedding has been obscured by bioturbation, recrystallization, and tectonism. The facies is mottled throughout, but finely planar-laminated where internal structure is preserved. Horizontal burrows are present but are not abundant, and no body fossils are observed. Minor, traceable faults occur within the facies.

Interpretation:

This facies represents an ideal case of "facies" mixing (Mount, 1984), which is a consequence of Walther's Law; *ss/ds* represents facies mixing gradational between the *M ds* facies (carbonate platform deposits), and the *TB ss/sh* facies (a siliciclastic tidal flat deposit). Common occurrences of *ss/ds* between the *TB ss/sh* and *M ds* facies with gradational contacts support this hypothesis. Faint laminations, sometimes present but usually not preserved due to recrystallization, could indicate mixing occurred in an intertidal,



Figure 3.4 Characterization of ss/ds facies. (a) exposure in ravine between WB and FR sections near top of the Rome. Note general massive appearance interrupted by thin, planar laminations. Jacob staff with 10 cm intervals for scale. (b) JM-C-42.5 hand specimen from CARL section shows massive nature. Bar scale in cm. (c) JM-JI-34.5 thin-section shows mottled, bioturbated, mixing of dolomite (tan) and quartz and feldspar (grays and whites). 1.5 mm field of view, lengthwise; cross-nichols.

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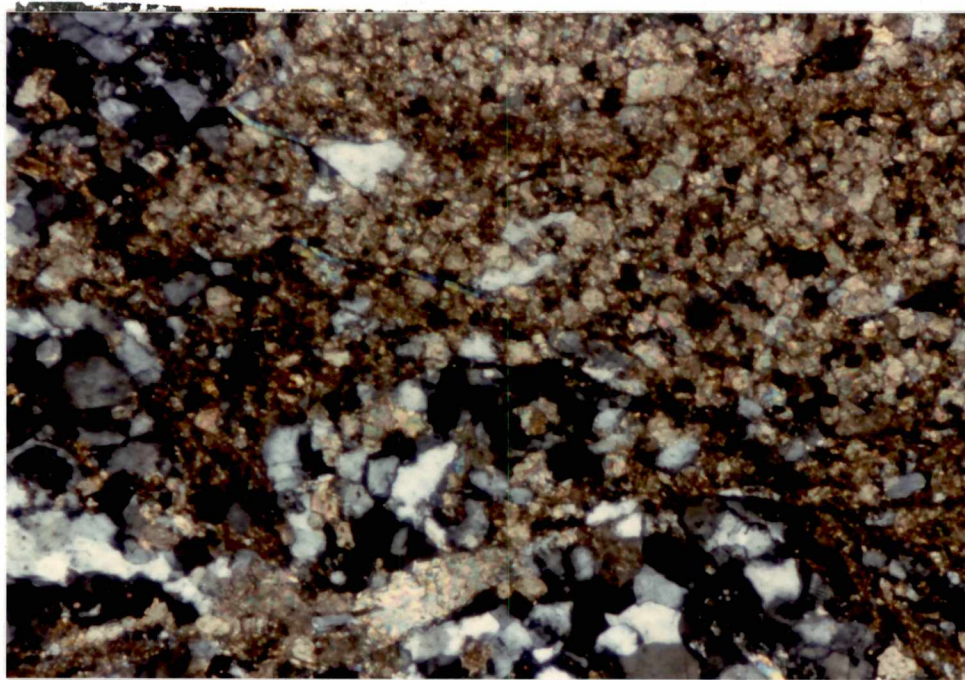


Figure 3.4 (cont.)

sabkha setting such as occurs in Shark's Bay (Logan, 1974), and along the Trucial Coast (Shinn, 1983). It would be reasonable to interpret the dolomite of this facies as forming penecontemporaneously in these sabkha type environments (Shinn, 1983; Logan, 1974), but because the dolomite is mostly ferroan and has been totally recrystallized, a penecontemporaneous interpretation is questionable (Boles, 1978). Ferroan dolomite can be produced by any reducing, iron-rich fluid altering carbonate material. This typically occurs in late diagenetic, deep burial environments, but could also have occurred in the environment of deposition considering the rich organics and abundant iron observed in other Rome lithologies. Also the dolomite could be altered carbonate material that replaced original penecontemporaneous dolomite. Tentatively, the facies is interpreted as deposited in a supratidal, tidal flat environment.

Laminated Dolomitic Mudstone Interbedded with Siltstone Facies (ds/slts)-

Occurrence:

This facies represents another type of mixed siliciclastic and carbonate lithology (Fig. 3.5). Its occurrence is very rare and generally is gradational between *B slts/sh/ss* facies and *M ds* or *Lam ds*. Contacts are also gradational. Its occurrence at section JI is particularly important because it occurs beneath the lower shale and siltstone deposits that commonly mark the lowermost stratigraphic interval in the Rome.

Description:

This facies is comprised of highly weathered, red to gray, faintly wavy laminated, vuggy dolomitic mudstone interbedded with alternating red and green-gray shale and siltstone. Dolomitic mudstone beds, the slightly dominant lithology, are generally 2 cm thick, but range up to 40 cm, and the shale interbeds are thinner,

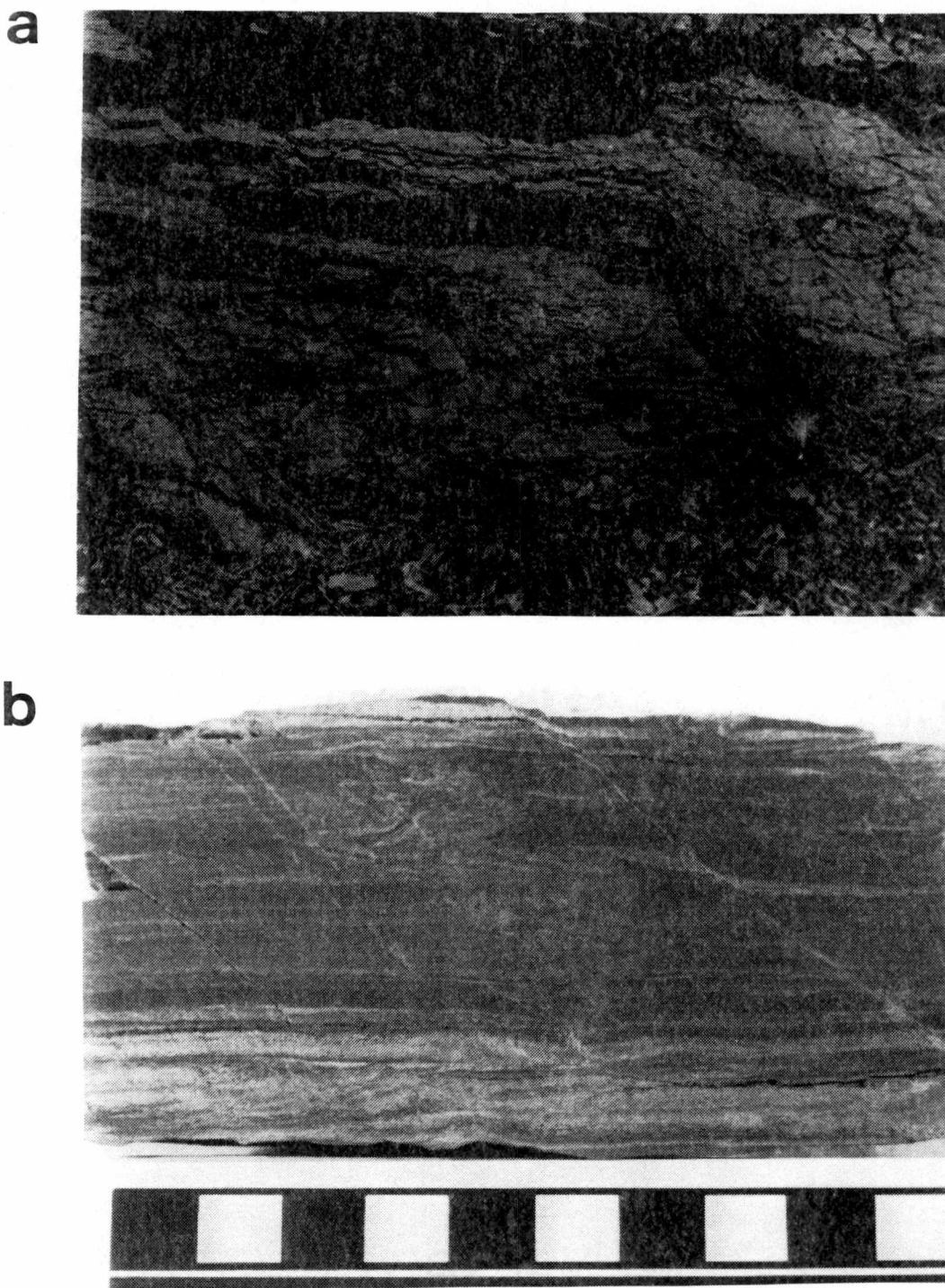


Figure 3.5 Characterization of ds/slts facies. (a) 12 to 16 m interval at JI section. Note laminated nature. Hammer for scale.(b) JM-JI-16.0 hand specimen from JI section shows a rare burrow disturbing laminations. Bar scale in cm. (c) JM-JI-16.0 thin-section shows a thicker dolostone laminae capped by a clastic dominated lamination. 1.5 mm field of view, lengthwise; cross-nichols.

C

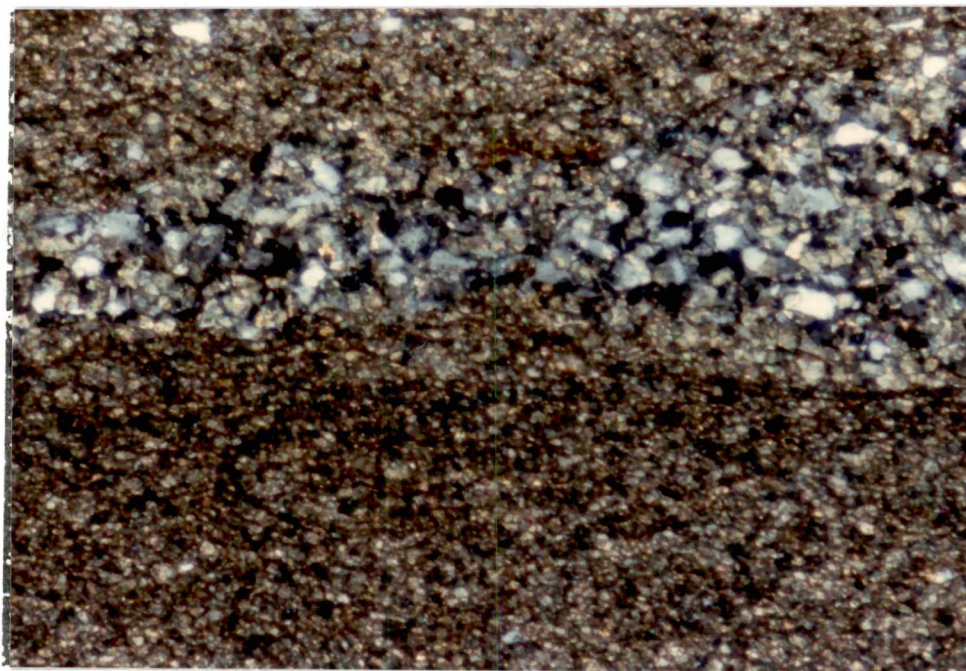


Figure 3.5 (cont.)

ranging from 2 to 4 cm thick. Micro-hummocky cross-stratification and planar laminations are ubiquitous throughout, and ripple marks are less abundant. Faint desiccation cracks and fenestrae are observed, and no fossils are present. Commonly, the dolomitic mudstone becomes sandier up-section as the entire interval becomes coarser. Beds of this facies are highly fractured, folded, and jointed. Microfaults are noted throughout the facies and interbedded shale is jointed to produce an incipient cleavage.

Interpretation:

This facies represents another type of sediment mixing, an example of "in situ" mixing (Mount, 1984), in which thin algally trapped and bound carbonate mud laminations are covered by thin siltstone laminations derived from the siliciclastic tidal flat environment (Hardie, 1977; Logan, 1974). The thin interbedded nature of the dolomitic mudstone and siltstone lithologies along with the identification of fenestrae support this interpretation. The faint desiccation cracks, again, indicate that the mixing occurred in an intertidal sabkha environment similar to Shark's Bay (Logan, 1974) and the Trucial Coast (Shinn, 1983). Just as in ss/ds facies, interpreting the dolomite in the ds/slts facies as penecontemporaneously deposited would be reasonable, but because the dolomite in this facies is mostly ferroan and finely recrystallized, the dolomite may be due to late diagenetic burial environment.

Massive Dolostone Facies (M ds)-

Occurrence:

This facies represents one of the pure end-member carbonate deposits from the spectrum of facies defined in the study area (Fig. 3.6). Unfortunately, very few original depositional structures have been preserved due to extensive tectonic deformation and

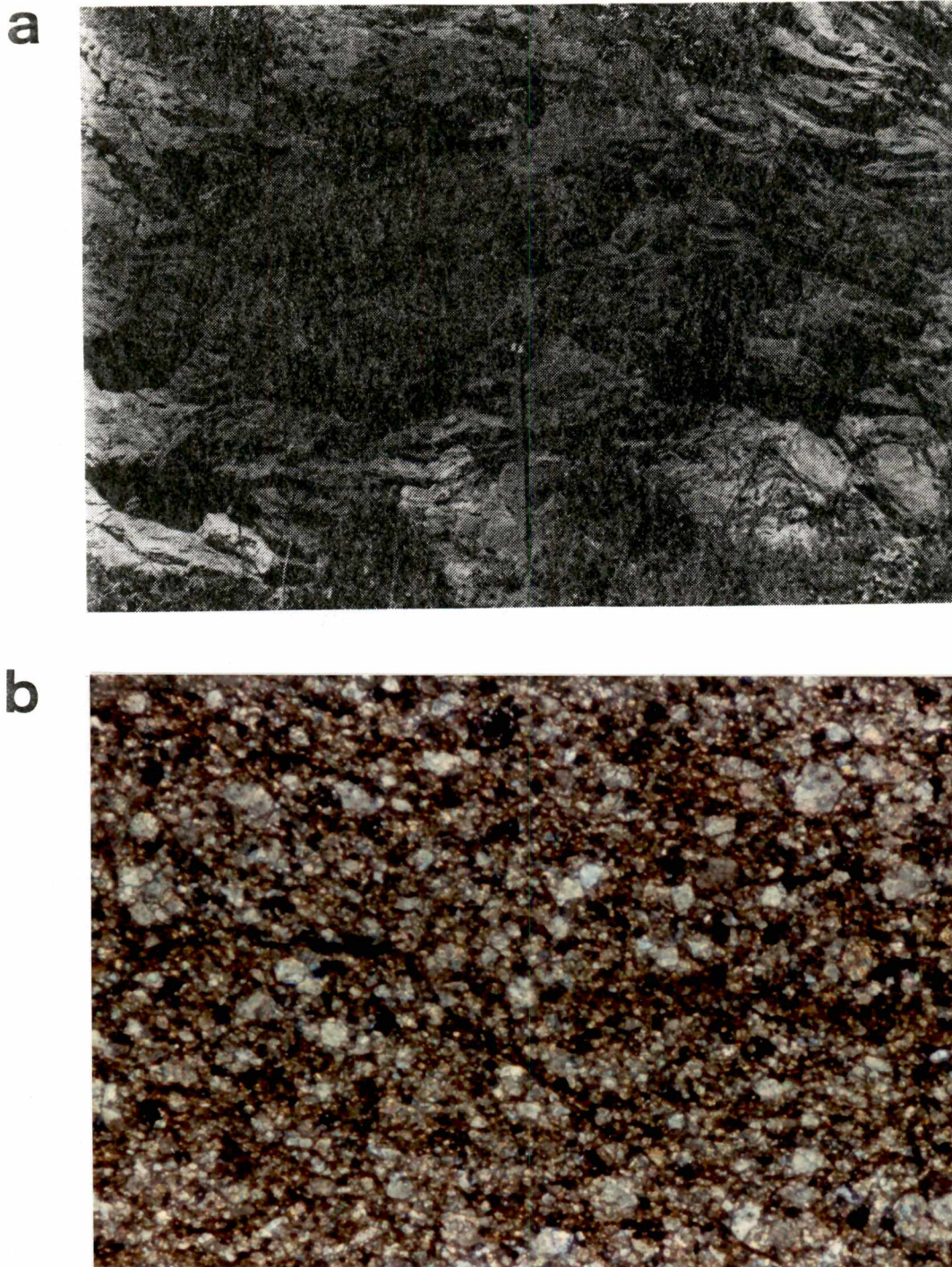


Figure 3.6 Characterization of M ds facies. (a) 30 to 39 m interval at JI section. Note vague hint of bedding is all that remains of original stratification. 1.5 m Jacob staff with 10 cm divisions for scale. (b) JM-JI-80.7 thin-section is totally recrystallized. 0.55 mm field of view, lengthwise; cross-nichols. (c) JM-JI-34.5 hand specimen shows contorted bedding. Bar scale in cm.

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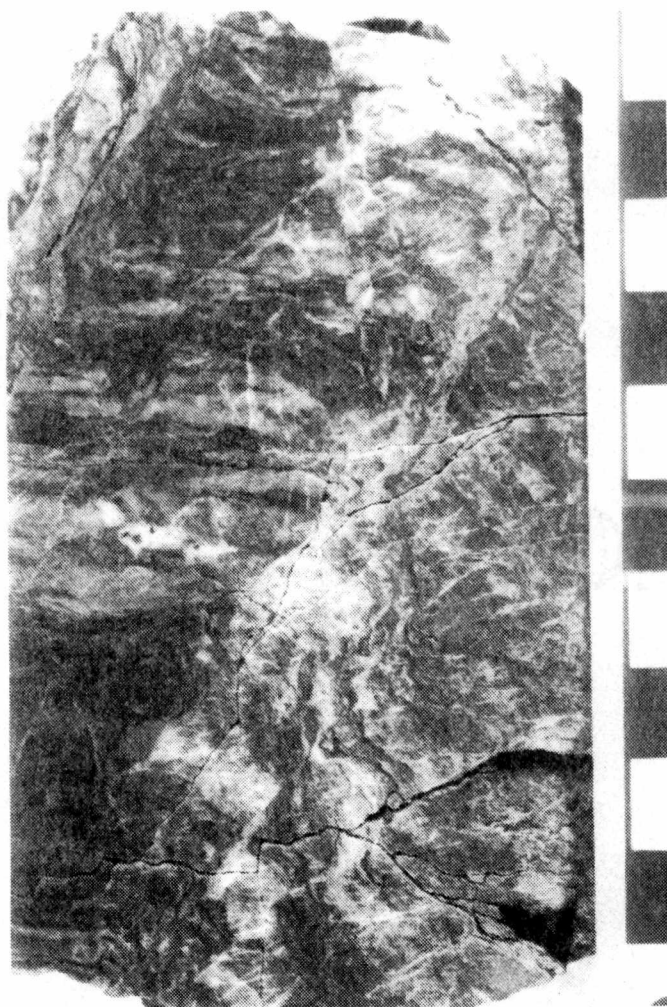


Figure 3.6 (cont.)

recrystallization. The facies is typically associated with the *ss/ds* facies with which it has a gradational contact.

Description:

This facies is composed of gray (fresh) to tan (weathered), thickly-bedded to massive, recrystallized sandy dolomitic mudstone. The amount of terrigenous sand, although minor, is visually estimated to range up to 10 percent of the total rock volume. Bedding, indistinguishable in many places, is generally destroyed by both bioturbation and tectonism; however, wavy laminations are observed where bedding is preserved.

Interpretation:

Interpretation of this facies is difficult due to almost complete recrystallization and severe tectonic deformation, and the observation of the dolomite as ferroan with a coarse-grained fabric suggests the possibility of a late diagenetic, deep burial origin for the dolomite, but does not preclude a supratidal, intertidal tidal flat interpretation.(Boles, 1978). Although this facies represents the pure carbonate end-member of the facies model, it does contain a small percentage of terrigenous sand. The original sediments are believed to have been carbonate mud (Bathhurst,1975), and the lack of stratification is attributed to intense bioturbation as well as diagenetic and tectonic recrystallization (Bathhurst, 1975). The facies is interpreted as a lagoonal back-platform deposit which was adjacent shelfward of the tidal flat. It was probably deposited during a lull in siliciclastic input from the source area. Large salt "hopper" casts found by the author in the same lithology near Sweetwater, Tennessee suggest a subtidal to intertidal environment (Reading, 1986). A subtropical to tropical climate is interpreted for the facies because of its carbonate nature (Wilson, 1975), and agrees with the paleogeographic reconstruction of the Lower Cambrian which places the Appalachian Basin just below the equator in the Southern hemisphere (Scotese et al., 1979).

Laminated Dolomitic Mudstone (LAM ds)-

Occurrence:

This facies is also a carbonate end-member facies (Fig. 3.7) and is differentiated from the *M ds* facies in the unique occurrence at the base of the JI section and the well-preserved sedimentary structures of the facies. The facies occurs only with the *ds/slts* facies with which it has a gradational contact.

Description:

This facies consists of dark gray, medium-bedded, sandy dolomitic mudstone with beds between 1-3 cm thick. Fine, wavy and vuggy laminations representing cryptalgal structures are intercalated with thin, chaotic intervals attributed to bioturbation and soft sediment deformation; no fossils are observed. Strata are gently folded and jointed throughout.

Interpretation:

The cryptalgal structures within the facies indicate an intertidal to supratidal tidal-flat environment of deposition (Hardie, 1977; Logan, 1974). It may well have occurred in a sabkha type environment in which penecontemporaneous dolomite formed; however, evidence is inconclusive because of the large amounts of coarser ferroan dolomite now present (Boles, 1978) and the fact that evaporites (or their pseudomorphs) are not observed (Reading, 1986). Due to the occurrence at the base of JI below what has previously been interpreted the lowermost terrigenous shale and siltstone deposits of the Rome (Samman, 1975; Haase et al., 1985), as well as the striking similarity of the facies to the Ivanhoe and Austinville members of the Shady Dolomite of Southwestern Virginia described by Pfeil and Read (1982), the *Lam ds* facies is tentatively

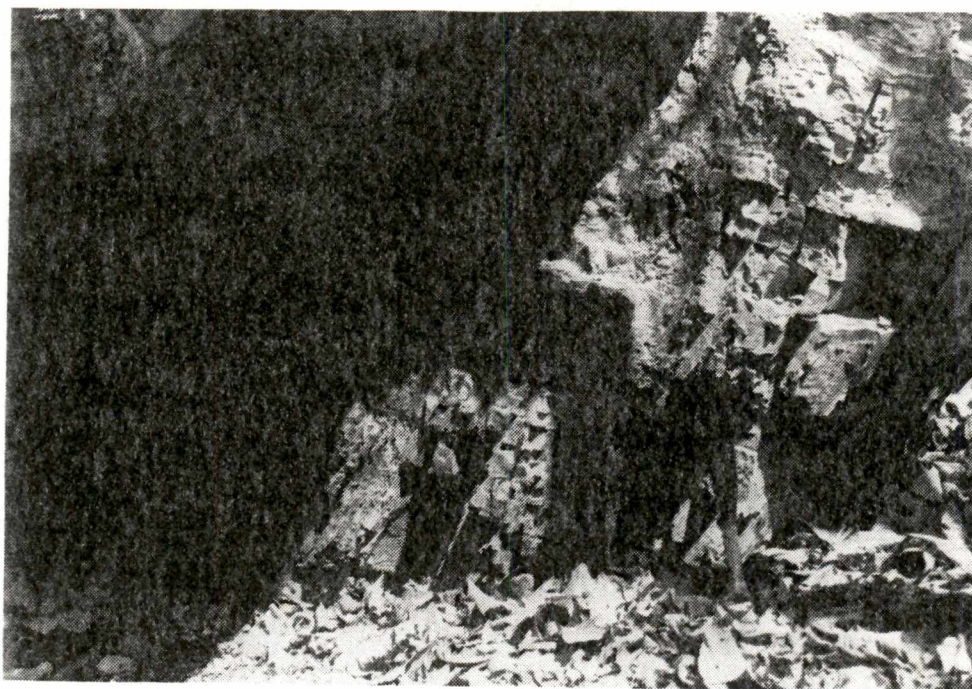
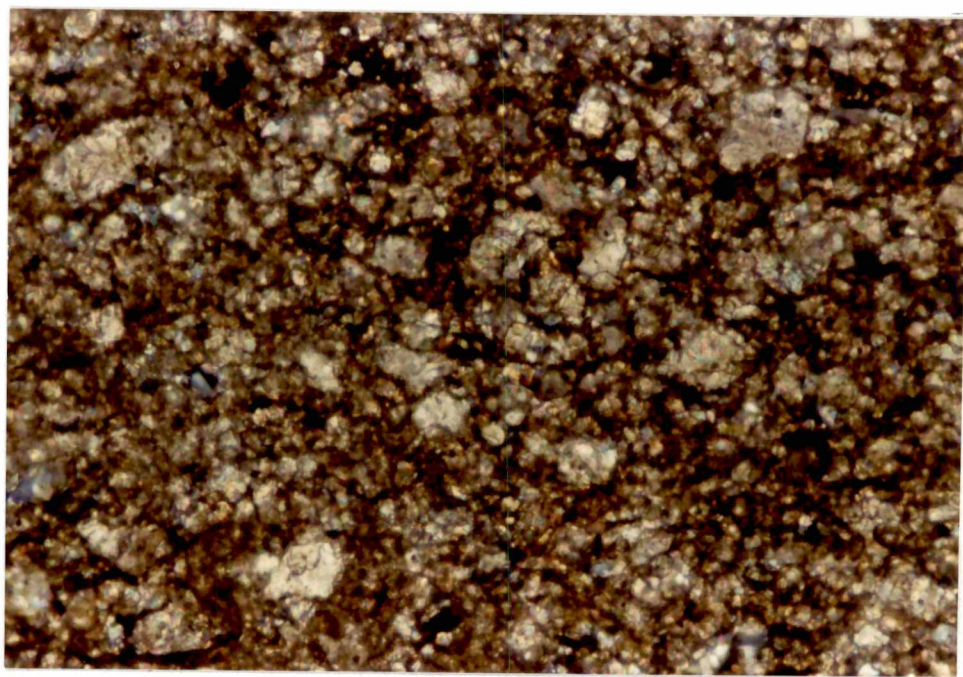
a**b**

Figure 3.7 Characterization of Lam ds facies. (a) 0 to 2 m interval at JI section. Note laminated nature. Hammer for scale. (b) JM-JI-2.5 thin-section shows fine-grained nature of dolostone. 0.55 mm field of view, lengthwise; cross-nichols. (c) JM-JI-2.5 hand specimen from JI section shows bioturbated interval disturbing laminae. Bar scale in cm.

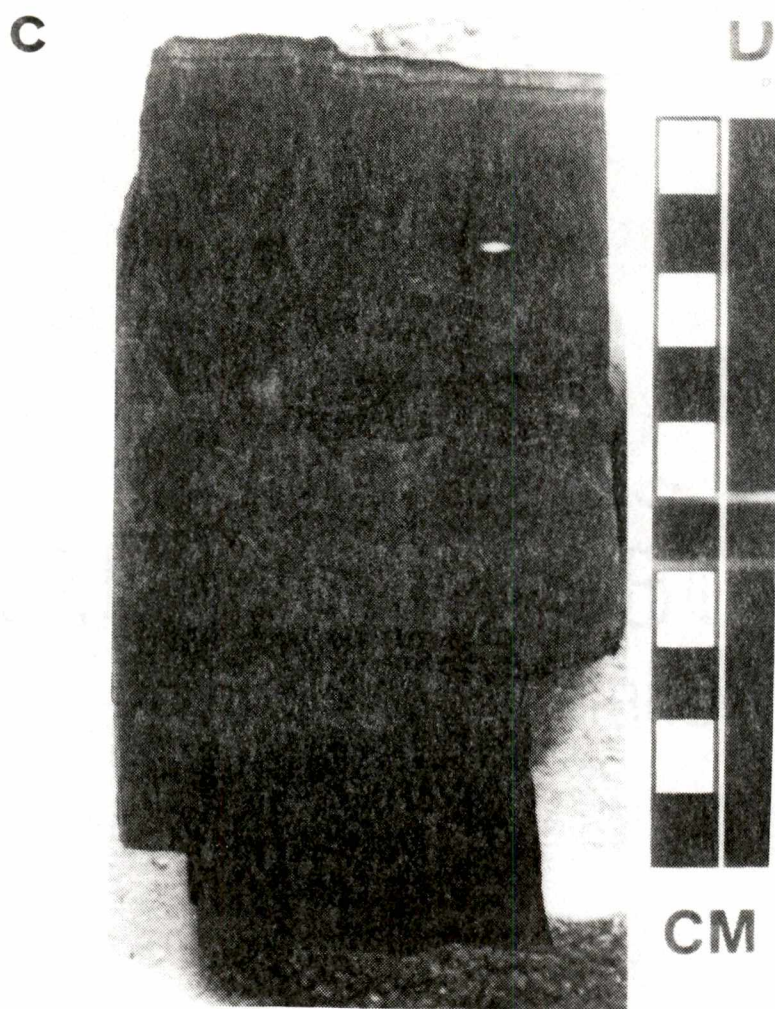


Figure 3.7 (cont.)

interpreted as a carbonate tongue of the uppermost part of the Shady Dolomite.

Sedimentary Structures and Hydrodynamics

Sedimentary structures are observed most commonly in the *TB ss/sh* facies, and the structures in the facies appear to imply contradictory interpretations. Internal bedding structures, hummocky cross-stratification and micro-hummocky cross-stratification (Fig. 3.8), indicate high flow velocities that occur most often during storms at depth (10-20 m ?) (Harms et al., 1975), whereas bedding top structures: desiccation polygons, salt "hopper" casts, and rain drop impact marks (Fig. 3.9), indicate a lack of flow and subaerial exposure (Potter and Pettijohn, 1963; Hardie, 1977). By applying the idea of storm and flood layers (Field et al., 1988) to the Rome, the apparent contradiction of sedimentary structures can be explained.

Field et al. (1988) stated that,

Large wind-driven storm waves offshore and heavy rainfall inland are both commonly associated with the passing of low pressure centers, but the two phenomena produce markedly different sedimentary signatures in continental shelf deposits.

First the bottom storm layer deposited 10 cm of lower angle, sub-parallel, cross-stratified sand overlain by 5 cm of ripple cross-laminated sand that is topped by surface ripples and is interpreted to be a result of intense storm processes on the shelf (Field et al., 1988). Second, the top flood layer deposited 3 cm of mud to cap the sequence, and is interpreted to be the result of inland flooding which transported suspended sediment to the shelf that settled out following the storm (Field et al., 1988). Preservation of this sequence

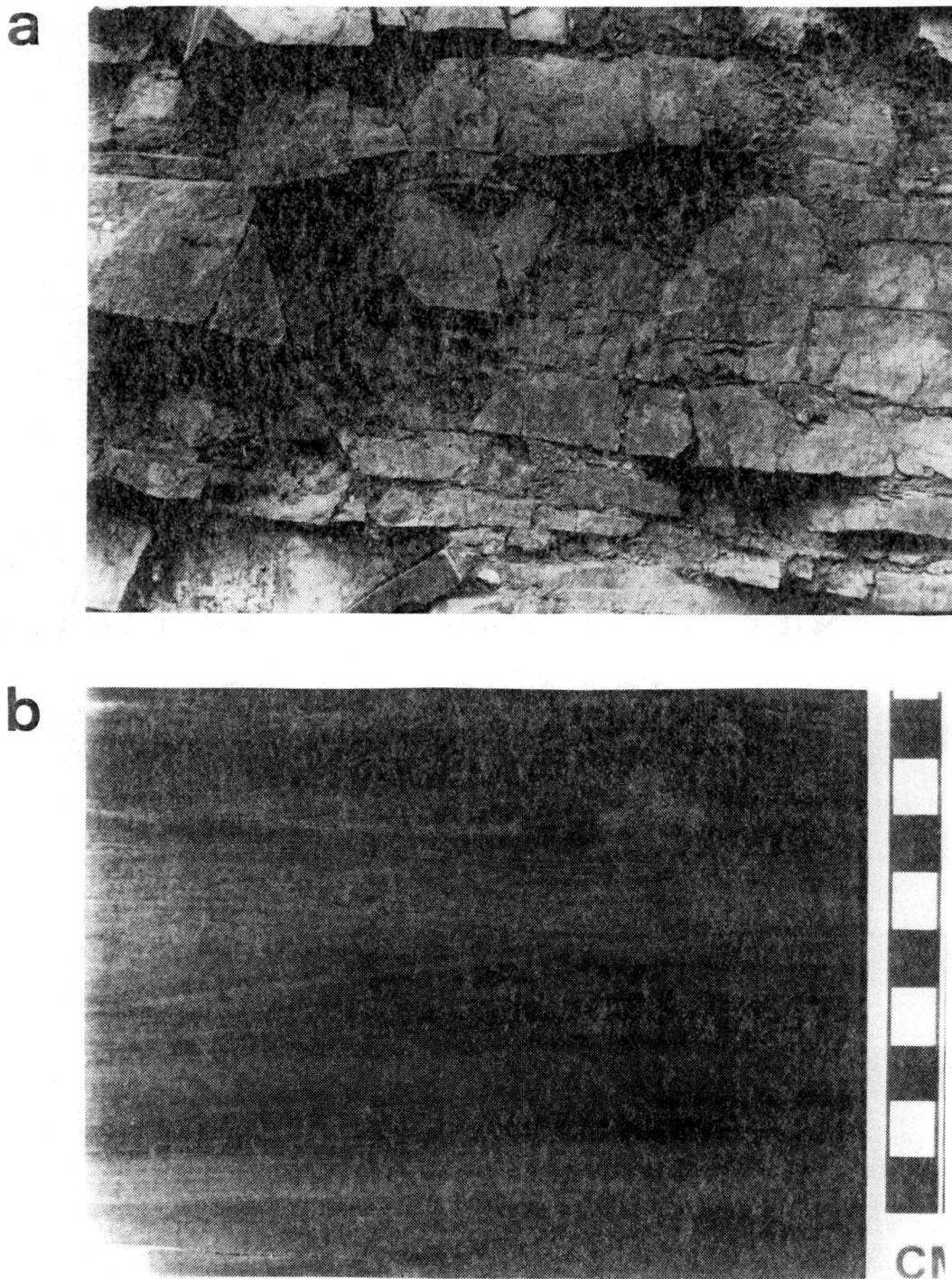
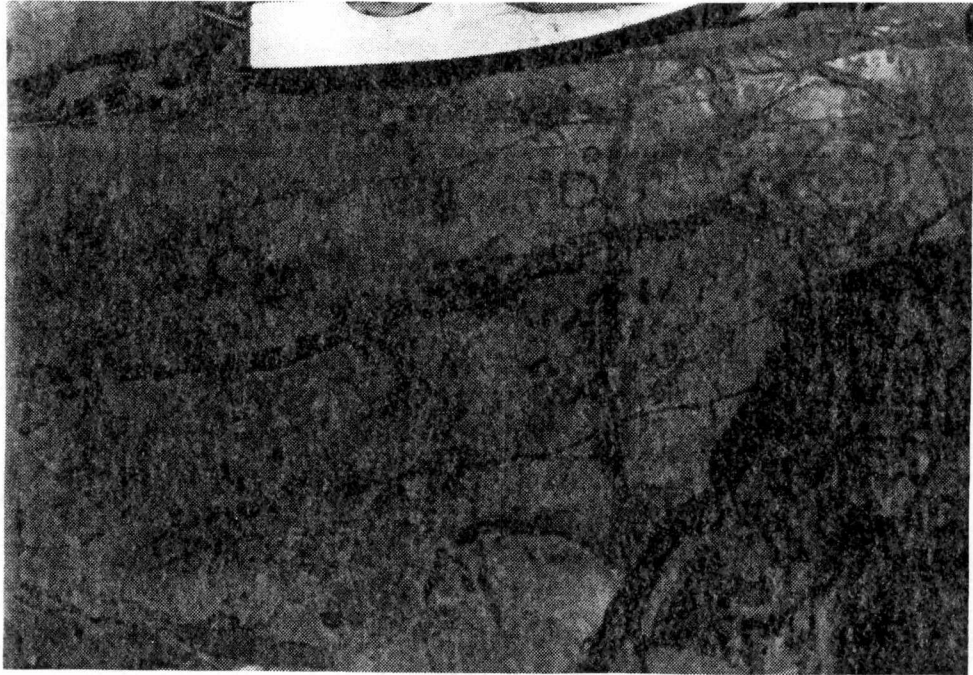


Figure 3.8 Characterization of hummocky cross-stratification. (a) 32 m interval at CARL section shows undulatory or hummocky bed forms. Hammer head at base for scale. (b) JM-JI-75.3 hand specimen shows low-angle cross-laminations interpreted as mhcs. Bar scale in cm.

a



b

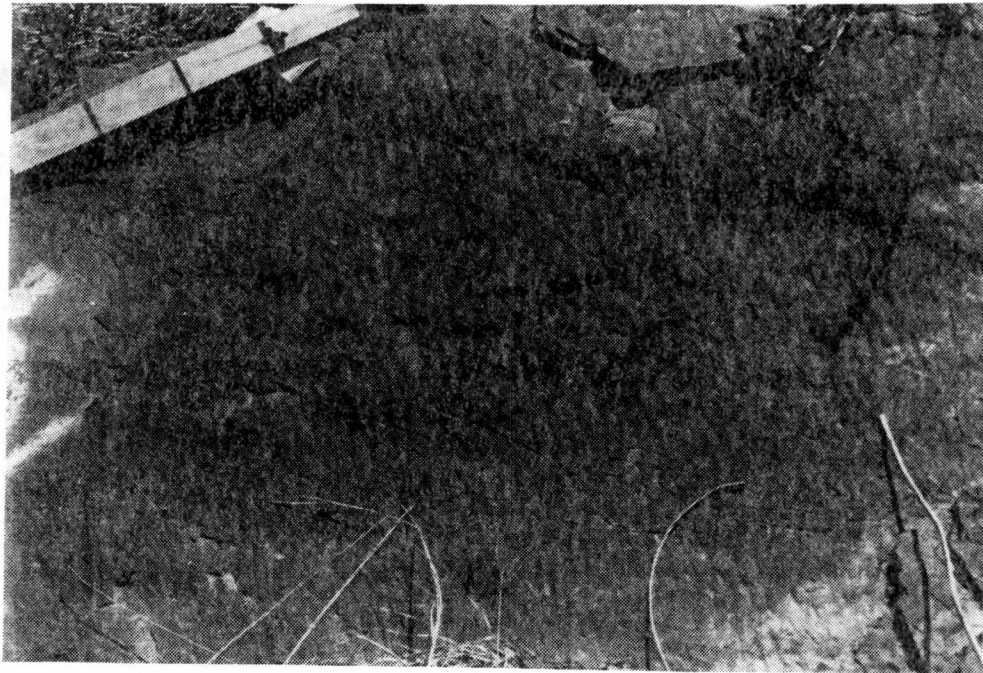


Figure 3.9 Characterization of bedding top structures. (a) Slab from 50 m interval at JI section shows dessication cracks, tool marks, and possibly rain drop imprints. Hammer head at top for scale. (b) Slab from 36 m interval at JI section shows wave ripple marks. Jacob staff with 10 cm intervals for scale.

is believed possible if biologic activity is low, storm events are frequent, and sedimentation rates are high (Field et al., 1988).

Although the present Pacific Coast shelf of Field et al.'s study, a steeply sloping, open marine environment, is a vastly different setting from the broad tidal flat environment interpreted for the Rome, applying the storm layer/ flood layer idea to the Rome is reasonable because no matter what the configuration of the shelf is, large low pressure systems should still produce sediment reworking on the shelf and flooding inland. For the *TB ss/sh* facies, the hummocky cross-stratified sandstone beds are interpreted as storm layers and the shale beds as the flood layers which means hummocky cross-stratification and micro-hummocky cross-stratification were produced in a tidal flat dominated by storm processes whereas the shale interbeds along with bedding top structures: desiccation polygons, salt "hopper" casts, and rain drop impact marks, were produced on a tidal flat dominated by normal tidal processes. The abundant ripple marks and planar laminations were probably produced by both normal tidal and storm processes.

Thus, the deposition of *TB ss/sh* facies was controlled by two alternating hydraulic regimes. One occurred as normal tidal processes prevailed in which a low velocity flow regime and quiet water, conditions allowed the flood suspended material to settle out as mud layers and tidal fluctuations of some unspecified periodicity to subaerially expose the tidal flat to create desiccation polygons, salt "hopper" casts, and rain drop impact marks. The other regime occurred during storm events on the tidal flat at which time a high velocity flow regime produced hummocky cross-stratification and micro-hummocky cross-stratification.

The origin of hummocky cross-stratification has long been controversial and is poorly understood (e.g. Marsaglia and Klein, 1983; Duke, 1985; Nøttvedt and Kreisa, 1987). Originally, oscillatory flow conditions were believed to produce hummocky cross-stratification (Harms et al., 1975), but recently, combined flow

conditions (combined oscillatory and unidirectional flow) have been postulated as capable of producing hummocky cross-stratification. A combined flow interpretation is probably more realistic because it reflects the hydraulic condition observed in modern intense storms (Allen, 1985; Nottvedt and Kreisa, 1987). Recent experimental studies on combined and oscillatory flows (Southard et al., 1988; Myrow and Southard, 1988; Arnott and Southard, 1988) show both types of flow are capable of producing hummocky cross-stratification. Reflecting the present state of research, hummocky cross-stratification in *TB ss/sh* facies is believed to have been created in a high velocity, combined flow regime. This interpretation in the Rome requires that either greater water depths were produced by storms piling up water on the tidal flat during deposition, or hummocky cross-stratification as a combined flow product can be produced in much shallower water than has previously been believed. Results of the flume tests suggest that in a combined flow regime, water depth may not be a critical control on formation of hummocky cross-stratification. Thus, it is reasonable to interpret hummocky cross-stratification forming in a shallow tidal flat environment. Finally, Rome storm events in the facies had to be frequent enough, and the rate of deposition high enough to allow these storm sequences to be preserved in the stratigraphy.

Structures observed in the other facies give more internally consistent interpretations than does the *TB ss/sh* facies. The *B slts/sh/ss* facies, dominated by ubiquitous bioturbation is interpreted to have been deposited in the same hydraulic conditions as *TB ss/sh* with the exception that bioturbation during normal, non-storm periods reworked the sediments so completely as to destroy other original sedimentary structures. The *V sh* facies lacked sedimentary structures on the whole suggesting a low flow regime and quiet water conditions for the tidal flat. The mixed facies and carbonate end-member facies are dominated by cryptalgal structures and bioturbation which are both suggestive of normal tidal processes with frequent subaerial exposure. Rome sedimentary structures

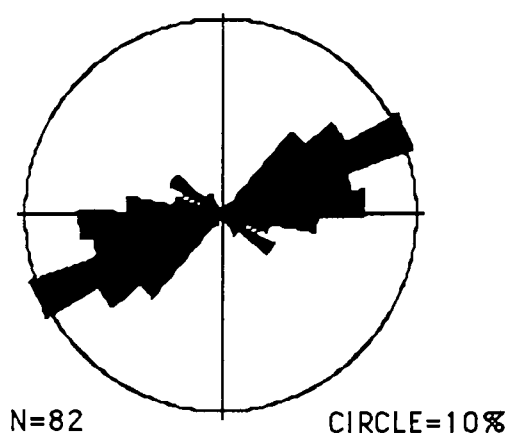
considered as a whole indicate that both storm and normal tidal processes were major factors in creating the hydraulic conditions that prevailed during the deposition of the unit.

Paleocurrents

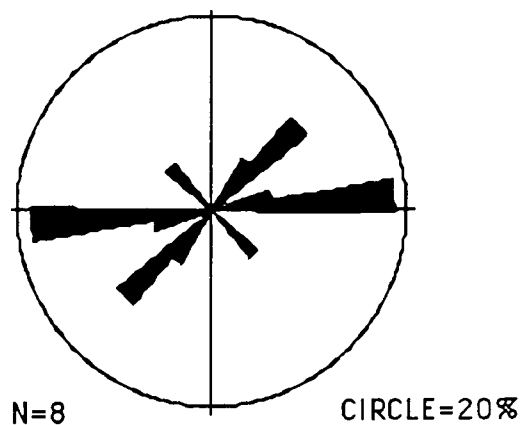
Paleocurrent interpretation, like interpretation of hydraulic conditions, is confined to the *TB ss/sh* facies because within this facies, symmetrical and asymmetrical wave ripple marks, the only current direction indicators in the field area, are observed, and symmetric ripples are by far the most abundant of the two with asymmetrical ripples observed only rarely. Unfortunately, measuring symmetrical ripples produces ambiguous results in that the structures only narrow the possible paleocurrent directions to two, opposite directions (Potter and Pettijohn, 1963).

From three outcrops (CARL, JI, and WH) in which the trends of ripple crests were taken, 133 data points (see Appendix B) were gathered. The FR section was not used because it is so badly weathered, and WB section was not used because of its inaccessibility. Initially, the data were plotted as Rose diagrams for individual intervals within an outcrop section to see if systematic vertical change had occurred through Rome time. For all three outcrops no changes were noted, as most intervals contained orientations similar to the outcrop data plotted as a whole. Rose diagrams of all outcrops individually as well as combined (Fig. 3.10) show wave ripple crests were consistently oriented in a northeast to southwest trend (mean trend azimuth approximately 50 degrees). Asymmetrical ripples generally dip to the southeast, indicating current flow in that direction, but so few were observed that this author places no confidence in their implications.

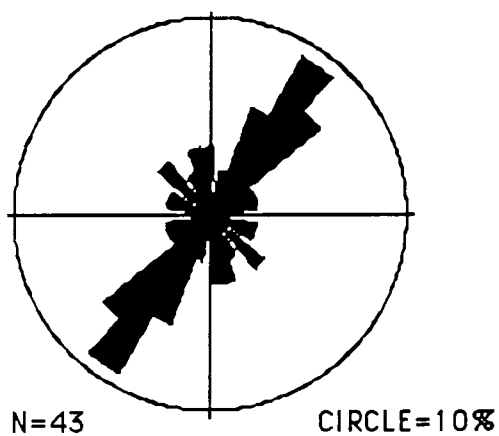
The paleocurrent data fit well into both hydraulic regimes interpreted for the *TB ss/sh* facies. The ripples could have formed



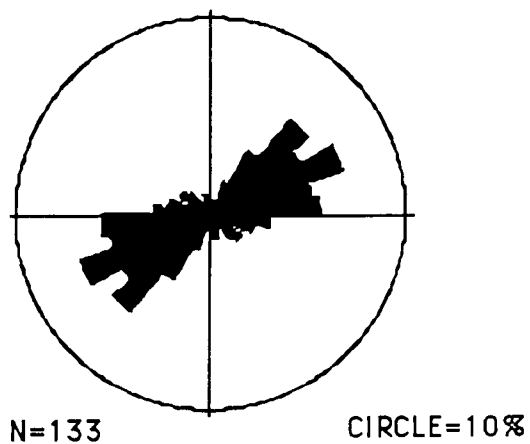
CARL
SECTION



WH
SECTION



JI
SECTION



ALL SECTIONS
COMBINED

Figure 3.10 Paleocurrent data for CARL, WH, and JI section and for all data combined.

either during normal tidal processes by ebb and flood tidal currents, or in weakened oscillatory flow at the end of an intense storm event indicating a normal-to-shoreline flow direction. Water waves are produced by wind-driven currents which commonly blow roughly normal to shoreline, and in turn, these water waves produce the oscillatory flow conditions in which the wave ripples form. Thus, a normal-to-shoreline flow direction is indicated (Harms et al., 1975 and Potter and Pettijohn, 1963). In either scenario, ripple crests parallel the trends of wave crests which typically approach the shore orientated parallel to shore (Potter and Pettijohn, 1963). Thus, the northeast-to-southwest trend of the ripple crests suggests a northeast-southwest trending paleoshoreline, which is in general agreement with the interpretations for the Paleozoic rocks of the Appalachian Basin (Colton, 1970).

Facies Model

Developing a Rome facies model from a mixed siliciclastic and carbonate perspective instead of using strictly terrigenous clastics concepts requires two fundamental changes in the underlying framework with which the paleoenvironments of the Rome are interpreted. First, instead of using a typical siliciclastic shelf setting (Fig. 3.11a) which contains a beachface gently sloping basinward to the shelf's edge, a carbonate-platform basin configuration is interpreted to have been inherited from the underlying Shady Dolomite, a carbonate platform sequence (Fig. 3.11b). Secondly, instead of forcing the Rome to conform to a more linear shoreline-parallel stratigraphy, a patchy or mosaic stratigraphy is interpreted in which the basin-controlled dynamics inherited from the Shady forced the terrigenous deposits of the Rome into "carbonate-like" mosaic patterns.

The specifics of the model (Fig. 3.12) begin with the initial basin configuration which consists of a broad, expansive tidal flat

(a)



Typical terrigenous clastic type passive margin

(Swift et al., 1972)

(b)



Typical carbonate platform type passive margin

(Wilson, 1975)

Figure 3.11 Diagrammatic representation of two types of general basin shapes.

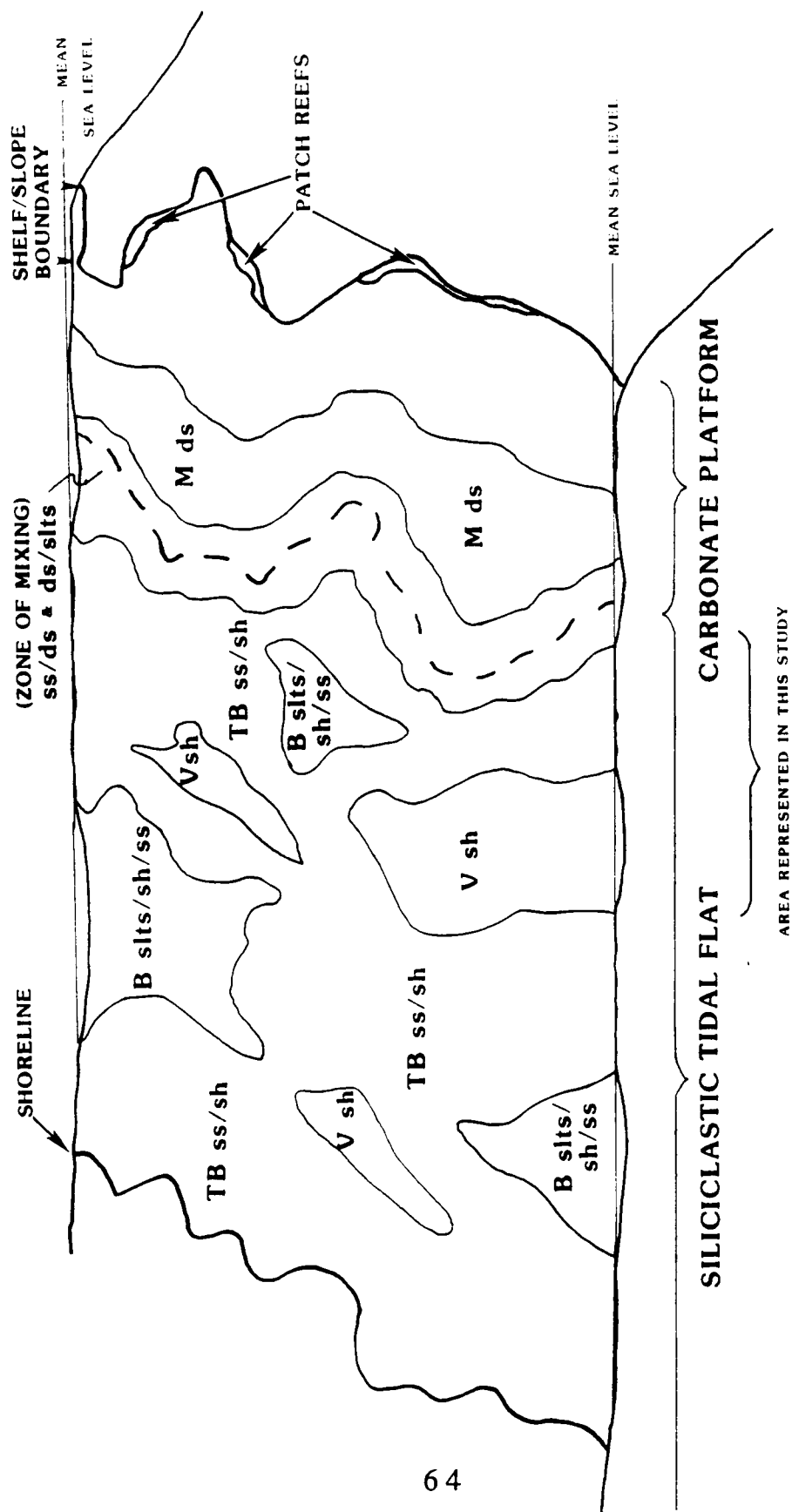


Figure 3.12 Rome mixed siliciclastic and carbonate depositional model. See Table 3.1 for description of facies.

between continental shoreline and a carbonate platform at the edge of the shelf. The three siliciclastic facies, *TB ss/sh*, *V sh*, and *B slts/sh/ss* were deposited on the broad tidal flat, which was frequently inundated by storms. The *TB ss/sh* facies occurred basin wide, possibly in broad, shallow tidal channels and reflected both fairweather and storm processes that controlled tidal flat deposition. The *V sh* facies occurred in the subtidal, more restricted and protected "ponds" on the tidal flat. The *B slts/sh/ss* facies occurred in patches over the entire basin as the biota reworked the sediment, probably in a subtidal environment. The occasional carbonate bed within these facies represent "storm" type mixing (Mount, 1984) in which storm events occasionally moved carbonate mud from the backside of the adjacent platform onto the tidal flat. Preservation of these storm sequences suggest high depositional rates and storm frequencies (Arnott and Southard, 1988).

The *ss/ds* and *ds/slts* facies represent the mixed sediments classified as "facies" type mixing (Mount, 1984). They formed at the boundary of the tidal flat and platform areas in an intertidal environment and were transitional between the tidal flat clastic facies and the platform carbonate facies (Fig. 3.12).

The pure carbonate facies, *M ds*, occurred on the backside of the carbonate platform as a bioturbated carbonate mud which was deposited in quiet water, on a protected, landward side of the platform behind patchy reefs that existed much further southeastward at the edge of the shelf (Fig. 3.12).

Lam ds facies is not represented in the diagram because it is interpreted as the upper part of the Shady Dolomite and is believed to represent the state of the basin before the influx of Rome clastics. It was deposited in intertidal to supratidal environments.

As sediment influx increased in the area, the clastic tidal flat facies eventually engulfed the carbonate platform. Hydraulic conditions for the tidal flat alternated from normal tidal processes to

intense storms that produced a combined flow regime in which alternating storm and flood layers were deposited (Field et al., 1988). The stacking of storm beds and fairweather deposits through time controlled by the original "carbonate-platform" type basin produced the mosaic stratigraphy found in the study area (Fig. 2.6 and Plate 2). Paleocurrents indicate a northeast-to-southwest trending shoreline in which storms generally approached from the southeast or northwest.

Though the match is not exact, the Great Barrier Reef Province of northeastern Australia is an reasonable modern analog to Rome paleoenvironments. This vast area (270,000 square km) is a mixed siliciclastic and carbonate environment which contains a dominantly terrigenous clastic coast and inner shelf, whereas the outershelf is dominated by a carbonate reef environment (Belperio and Searle, 1988). The mixing of these two environments does not occur as a gradation from one to the other on the intervening shelf area, but instead is mixed in patchy environments created by the movement of along-shelf currents (Flood and Orome, 1988). Transgression with the increasing influx of terrigenous clastics is slowly drowning the shelf and burying the barrier reefs. While the match is not exact: the small delta environments along shore and the patchwork reef area have not been found in the Rome in this study nor are abundant tidal flat indicators found in the Great Barrier area, it is striking how similar Belperio and Searles' (1988) general model for the Great Barrier Reef region and the Rome facies model are considering the fact that they were arrived at independently.

The Rome mixed siliciclastic and carbonate paleoenvironment model has several strengths. It accounts for the mosaic stratigraphy and carbonate content of the Formation. The model fits well into the present lower Paleozoic regional framework because it maintains the same basic basin shape that has been better documented above and below the Rome in the Valley and Ridge stratigraphy. Furthermore,

the intertonguing nature of the Shady/Rome/Conasauga interval also fits what the model would predict.

CHAPTER 4

DEPOSITIONAL HISTORY OF THE ROME FORMATION

The final objective of this thesis is to place the study area and the proposed Rome mixed siliciclastic and carbonate model into a regional paleoenvironmental framework by describing the deposition of the Formation through time (Fig. 4.1). While this study is the first of several studies that hope to produce a detailed picture of the paleoenvironments of the Rome, enough information does presently exist to form a first-order approximation of geologic setting during deposition of the Rome.

Regional discussions of the geologic setting of the southern Appalachian lower Paleozoic sequence, for example, Colton (1970), proceed from Precambrian rifting and Early Cambrian passive margin clastic sedimentation, to stable Middle Cambrian to Early Ordovician carbonate deposition which culminated in the development of the Middle Ordovician carbonate bank. In the discussion, the Rome is only mentioned in passing because it has presented an apparent paradox: How is it that a clastic sequence like the Rome exists sandwiched between two carbonate units (Shady and Conasauga) on a tectonically stable continental margin experiencing regional transgression?

Two incorrect underlying assumptions have created this paradox. The first is that the Rome is entirely a terrigenous clastic unit. The Rome is actually a mixed siliciclastic and carbonate unit. Generally, it has been held that siliciclastic and carbonate sediments do not mix, and that carbonate deposits cannot form in the presence of siliciclastics (Mount, 1984). Research in the last ten years has shown that this generality is not strictly true (Doyle and Roberts, 1988; Mount, 1984). Mount (1984) claimed that research in modern environments like the Bahamas has created this misunderstanding. Examples of modern mixed siliciclastic and carbonate environments

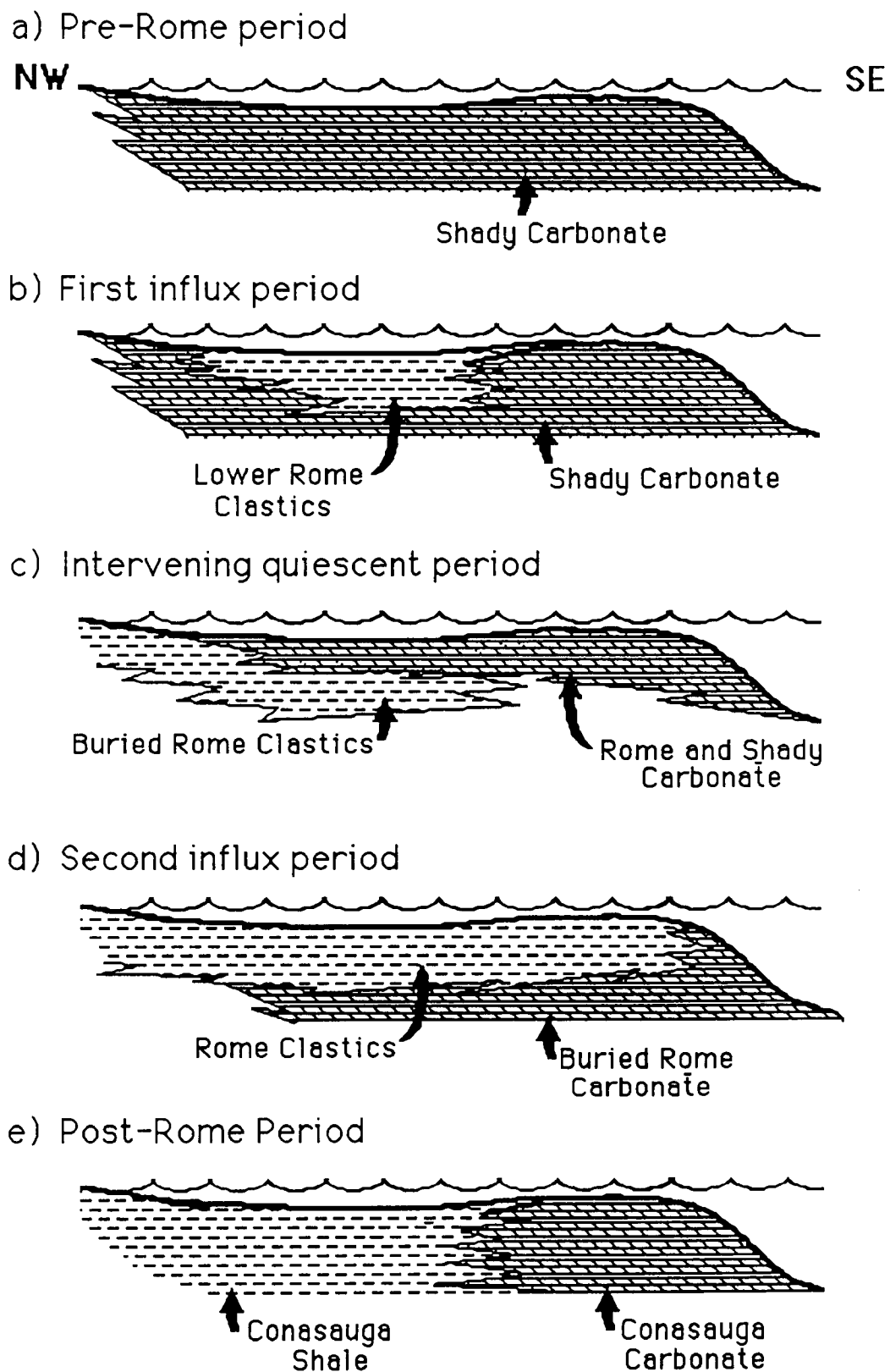


Figure 4.1 Deposition of the Rome through time.

are the Great Barrier Reef in northern Australia, the Spanish eastern coast, Puerto Rico in the Caribbean, Java Sea in Southeast Asia, and the Trucial Coast in the Persian Gulf (Roberts and Doyle, 1988). Ancient examples have also been cited by Walker et al. (1983) in Ordovician sequences of East Tennessee, Gawthorpe (1987) from the Carboniferous Bowland Basin in northern England, Tucker (1982) from the Late Precambrian Biri Formation of southern Norway, Price (1977) in the Mesozoic continental margin deposits of Greece, and Nelson (1978) from the Cenozoic sequence of New England. Mixed siliciclastic and carbonate are not only possible, but are documented in both modern and ancient environments.

The second assumption is that from Early Cambrian through Early Ordovician time, a **stable** continental margin existed in the Appalachian Basin; however, Palmer and James (1980) suggested that a regionally significant late Early Cambrian orogenic event occurred which they named the Hawke Bay event. Their interpretation is based on evidence: (1) involving the timing of the regressive Hawke Bay Sandstone at the top of the Lower Cambrian section in the autochthonous sequences in western Newfoundland (that is, it is a clastic unit occurring within a generally carbonate succession), and (2) on the relationships between allochthonous Lower and Middle Cambrian conglomerates of the Forteau Formation and the earlier mentioned autochthonous sequences in western Newfoundland, which indicate these conglomerates are tectonic in origin. Because it is not a major tectonic event, the Hawke Bay was probably another case of a small, suspect terranes accreting to North America, such as Hatcher (1987) postulates for later smaller Appalachian tectonic events.

This tectonic event would have provided an excellent source area for Rome sediments. Also, as a northerly source, it would explain the overall southeastward fining trend noted in the Rome. By the time the Formation is traced to Rome, Georgia (the type section), the Formation is almost exclusively shale (Rodgers, 1953). Further, it

explains the lack of coarser, cross-bedded, deltaic deposits in the Rome in East Tennessee as would be expected with the source area so far removed from the depositional basin. Although Newfoundland is nearly 1000 km from East Tennessee, paleogeographic reconstruction (Scotese et al., 1979) suggests that trade winds would have been blowing from northeast to southwest which might have allowed such lengthy transport of sediments to have occurred more rapidly during deposition of the Rome.

Rome regional geology is easily fit within the larger regional geologic picture of the Lower Paleozoic of the southern Appalachian Basin. With the close of Chilhowee deposition, the continental margin was stabilized and siliciclastic influx was at a low as a slow, overall transgression of the margin began. Within this terrigenous clastic-free, tropical setting (the continental margin has been reconstructed to equatorial regions by Scotese et al., 1979), the Shady Dolomite succession began to build up on the shelf edge and develop as seas continued to slowly transgress. During the deposition of the Shady, carbonates formed a shelf platform and produced the general shape of the basin for lower Paleozoic deposits. A lower, broad tidal-flat shoreline developed landward of the carbonate platform at the edge of the shelf (Fig. 4.1a).

At the close of Shady deposition, the Hawke Bay event occurred to the northeast and disturbed what had been a previously stable margin. The sediments shed from the resultant orogeny were deposited in the Proto-Atlantic Ocean, and along-shelf currents created by northeast to southwest prevailing winds, transported these sediments southward into what is now East Tennessee.

The beginning of Rome deposition was marked by the initial finer-grained clastic influx onto the tidal flat. The first sedimentary sequences were deposited in a somewhat restricted, but gradually becoming a more open, broad tidal flat. This lowermost Rome formed an intertonguing relationship with the upper Shady Dolomite which was forming in platform-edge and slope environments (Fig. 4.1b).

After the initial influx of lower Rome sediments, a quiescent period followed in which carbonate production resumed across much of the shelf and resulted in the deposition of the thin carbonate units observed in the middle of the Rome (Fig. 4.1c).

The second influx of siliciclastics resulted from an episode of renewed tectonism of even greater magnitude than the first because coarser sediments were delivered to the tidal flat and the carbonate platform was entirely engulfed and buried by siliciclastics. Even the slope environments are speculated to have been covered by siliciclastics. (Fig. 4.1d).

During all of Rome deposition, the slow rise of sea level proceeded (undoubtedly in small pulses and not as a single, slow, smooth event), but Rome depositional rates were high enough to keep pace with the sea level rise to produce a near static tidal-flat shoreline setting. With the location of the Rome in East Tennessee near the "carbonate platform" type shelf edge, not only would randomly shifting environments have created constant and abrupt changes in Rome depositional environment, but minor sea level fluctuations would also have aided in producing the unexpected shifts back and forth from subtidal to intertidal environments.

Finally, as the Hawke Bay event came to a close, sediment influx diminished, and Rome deposition came to a close. With loss of the major sediment source from the northeast, local sediment production became dominant again. The low relief, highly-weathered local source area was probably supplying mostly clays to the basin as is observed in lithologically similar modern source areas (Potter et al., 1980).

During Conasauga deposition, abundant local sediment and possibly the last sediments derived from the Hawke Bay event were deposited as a fine-grained clastic sequence on the shrinking tidal flat that intertongued with the revived carbonate platform (Fig. 4.1e).

From this scenario, it is obvious the Rome and Conasauga depositional histories are considered to be interconnected. This author feels the stratigraphic boundary between the Rome and Conasauga marked by the last thick sandstone (Rodgers and Kent, 1948) is arbitrary, but by coincidence would appear to estimate the close of the Hawke Bay event as well.

From the regional picture just presented, the Rome Formation in the study area is interpreted to span the entire time of Rome deposition. By chance, it appears that Alleghanian thrusting has not removed all of the lower Rome in the study area, and the *Lam ds* facies at JI is Shady Dolomite. The study area fits into the regional picture approximately near the middle of the expansive tidal flat closer to the carbonate platform and records the progradation of tidal flat facies across the back part of the platform in which intense storm and normal tidal processes alternately controlled deposition. No evidence of continental shoreline facies, nor of shelf-to-slope facies was observed in the field area, but might be expected to be present in outcrops northwest and southeast, respectively, of the study area.

CHAPTER 5

CONCLUSIONS

Conclusions resulting from this study:

1. Stratigraphy and structural deformation (especially imbricate duplication of stratigraphic section) within the Rome are inseparably interrelated.
2. The Rome consists of three structural blocks in the study area in which Block I and III contain reasonably uninterrupted stratigraphic sections, and Block II contains two major imbrications, duplicating Rome stratigraphy within the block (Plate 1).
3. Few previous workers have taken such imbrication of the Rome into consideration when calculating its true stratigraphic thickness. The Rome is thinner in the study area than previous works would suggest. This overestimation probably occurs across the Appalachian Basin.
4. Rome stratigraphy, after structural deformation is accounted for, is still complex. Only on a gross scale do the four measured sections of this study correlate. Furthermore, excluding the two key marker beds used for correlating, the four sections show significantly different stratigraphic sequences. The Rome does not have a "layer-cake" stratigraphy, but instead forms a mosaic pattern (Plate 2).

5. Due to its occurrence at the base of the JI section below what has previously been interpreted as the lowermost terrigenous shales and siltstones of the Rome and its striking similarity to the Ivanhoe and Austinville members of the Shady Dolomite of southwestern Virginia described by Pfeil and Read (1982), the *Lam ds* facies is tentatively interpreted as a tongue of the uppermost part of the Shady Dolomite making JI a complete section of Rome.
6. The Rome Formation has traditionally been considered a terrigenous clastic sequence. Although dominated by siltstone, sandstone, and shale lithologies, the Rome also contains a significant dolostone component. The Rome is a mixed siliciclastic and carbonate sequence.
7. The Rome mixed carbonate and siliciclastic model (Fig. 3.12) depicts a paleoenvironment in which terrigenous sediments were deposited on a broad, expansive tidal flat adjacent to a shelf-edge carbonate platform. Normal tidal and storm process alternately controlled deposition.
8. The Rome model (Fig. 3.12) accounts for the mosaic stratigraphy and carbonate content of the Rome Formation and fits well into the present lower Paleozoic regional framework by maintaining the same regional "carbonate-platform" shape that has been documented above and below the Rome and predicting the intertonguing nature of the Shady/Rome/Conasauga interval.
9. The model also postulates the Rome documents the formation of hummocky cross-stratification on a shallow tidal flat, contrary to the deep shelf environment usually interpreted to form the structure.

10. Though the match is not exact, the Great Barrier Reef Province of northeastern Australia is an reasonable modern analog to the Rome mixed carbonate and siliciclastic model.
11. The Hawke Bay event noted in Newfoundland by Palmer and James (1980) is postulated as the source of Rome siliciclastic sediments.
12. The Rome and Conasauga depositional histories are considered to be interconnected. The stratigraphic boundary between the Rome and Conasauga marked by the last thick sandstone (Rodgers and Kent, 1948) is arbitrary, but by coincidence would appear to estimate the close of the Hawke Bay Event .

Future studies of the Rome will either confirm or deny the general validity of this model across the depositional basin; however, it should be emphasized that most of the conclusions of regional significance are tentative due to this thesis serving as the pilot study for a larger project on the Rome.

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APPENDICES

APPENDIX A.

UNIT DESCRIPTION THICKNESS	CUMULATIVE THICKNESS	CARL SECTION
3.8	3.8	Grey to green weathering to tan dolomitic siltstone interbedded with Maroon and green deeply weathered to tan sandy siltstone . The thin, wavy laminated recrystallized dolo-mudstones are dominant lithologies with planer bedding that varies 1-10 cm . Sandy siltstone is bioturbated and more massive (beds usu. 30 cm thick) also with thin wavy black laminations (organic rich?). 30 cm rust colored siltstone caps the unit. SAMPLES: JM-C- 0.5, JM-C-3.0
9.2	13.0	Highly deformed maroon to green shale interbedded with maroon fine-grained sandstone and siltstone. The dominant unit, shale, is blocky, mottled green and red, and contains lenses of glauconite. The red to tan siltstone and sandstone beds are vuggy, discontinuous and range from 1-20 cm, and become more continuous and abundant upward. Some beds were carbonate rich, and many were glauconitic. Wavy, black laminations (organic?), and burrows were both common throughout the section. complex folding, jointing, and faulting complicate the interval. SAMPLES: JM-C-8.0, JM-C-9.5, JM-C-10.3, JM-C-11.5.

UNIT DESCRIPTION THICKNESS	CUMULATIVE THICKNESS	CARL SECTION
1.0	14.0	Coarse grained thickly bedded dark red to black weathering to light tan glauconitic carbonaceous sandstone. mhcs common. Beds have undulatory surface and are usu. 15cm thick.
6.0	20.0	Maroon to tan silty sandstone interbedded with red to green mottled shale. The very fine-grained sandstone, the dominant lithology, is glauconitic, dolomitic and well-indurated. Fine to medium-bedded unit thickens upward and ranges 2-20 cm. Burrow tubes, scrape marks, and mudcracks are abundant. Both hcs and mhcs are common, and internal thin planer laminations were were abundant. The shale beds are < 2cm thick and near the bottom are blocky and burrowed, but thin upward and become more fissile. Except for the lowermost meter, deformation is slight. SAMPLES: JM-C-17.9, JM-C-18.5, JM-C-19.9.
0.9	20.9	Red to tan, jointed, thickly-bedded (~30cm), well-indurated, very fine-grained sandstone with a phosphatic rind at its top caps the sequence below. Recrystallization obscures internal bedding. SAMPLES: JM-C-20.7.
3.9	24.8	Highly deformed, tan to red, silty fine-grained sandstone

UNIT DESCRIPTION THICKNESS	CUMULATIVE THICKNESS	CARL SECTION
		interbedded with red to green-grey mottled silty shale. Sandstone lithology is only slightly more abundant. The, well-indurated sandstone beds vary in thickness from 2-10 cm. Mudcracks, ripple marks, and mhcs are more abundant than the underlying unit. The shale are commonly blocky and burrowed. Scattered phosphate nodules and glauconite were observed. The uppermost bed is a 5 cm, clean, friable, tan sandstone.
3.5	28.3	Highly deformed, dominantly maroon fissile shale unit with thin discontinuous interbeds of red, finely laminated, glauconitic, silty, fine-grained sandstone (< 2 cm thick). Shale is green and more fissile in the top and bottom 20 cm of the unit. At the top the sandstone beds become more phosphatic and micaceous.
4.1	32.4	Red weathering to tan very fine-grained, silty sandstone interbedded with thin, fissile shale with beds between 1-3 cm thick. The well-indurated sandstone beds, the dominant lithology, are between 2 and 30 cm thick and thicken upward. hcs and mhcs are common, and tool marks, ripple marks, and mudcracks are present. Thin planer laminations were noted in the thinner sandstone beds

UNIT DESCRIPTION THICKNESS	CUMULATIVE THICKNESS	CARL SECTION
		throughout the base. SAMPLES: JM-C-29.0, JM-C-32.2.
3.6	36.0	Highly deformed interbedded red to tan fine-grained silty sandstone and red, fissile shale. Similar to underlying unit, except shale and sandstone fractions nearly equal here. Thinner sandstone beds are between 1-5 cm thick with thin planer laminations. Ripple marks, tool marks, and mhcs are common, and a trilobite resting trace was observed. The interval is jointed, faulted, and fractured. It may contain a major fault that disconnects the section.
0.5	36.5	Jointed green-grey fissile shale with an occasional very fine-grained sandstone lense. Thin (~1mm) curvilinear, calcite filled joints were observed near it top (prob. structural). SAMPLES: JM-C-36.4.
5.2	41.7	Green-gray weathering to black and brown dolomitic sandstone interbedded with thin layers of of green-grey weathering to red, fissile shale. Occasional beds of dark gray mottled dolo-mudstone were noted. Sandstone is very fine-grained with green shale flakes (rip-up clasts) at its base. The dolomite content is quite variable from bed to bed. Beds are 2-30 cm thick with the thickest

UNIT DESCRIPTION THICKNESS	CUMULATIVE THICKNESS	CARL SECTION
		beds in the middle part. Ripple marks are abundant in the thinner bedded lower portions, and it is thinly- laminated throughout where bioturbation has not destroyed bedding. The shale beds were < 2cm. The unit is faulted and folded in a number of places. SAMPLES: JM-C-36.5, JM-C-38.3, JM-C-38.7, JM-C-39.0.
3.8	45.5	Thickly-bedded to massive, gray weathering to tan, dolomitic, fine-grained sandstone. The well-indurated sandstone beds range from 20-100 cm thick. Thin planer laminations were found only in the middle thinly bedded interval, otherwise bedding was destroyed by bioturbation and recrystallization. Dolomite content is variable throughout the unit. Its outcrop surface is often slickensided. SAMPLES: JM-C-42.5, JM-C-45.2.
7.7	53.7	<u>TOP OF THE ROME FORMATION</u> Dominantly red to tan, silty, very fine-grained sandstone interbedded with mottled orange to green-gray blocky shale. Well-indurated sandstone beds range from 1-20 cm and have abundant ripple structures and mhcs. Internally draping and wavy thin laminations are common. Burrows were common and an occasional trilobite resting trace was found. Phosphate and found but

UNIT DESCRIPTION THICKNESS	CUMULATIVE THICKNESS	CARL SECTION
		no glauconite. The shale beds were usu. between 1-2 cm and, though overall blocky, did become fissile in the thinnest beds. SAMPLES: JM-C-47.0, JM-C-53.0.
23.8	75.5	<u>BASE OF THE PUMPKIN VALLEY FM.</u> Highly deformed interbedded red weathering to tan silty sandstone and green-grey weathering to red shale. Shale is more dominant throughout the unit. The blocky shale beds 1-4 cm thick with fissility increasing up section. The sandstone beds are between 1-4 cm thick as well and have abundant mhcs, amalgamation surfaces, ripple marks, and burrow traces. Trilobite resting traces, salt casts, and load structures were also observed in fewer numbers. Glauconite and phosphate nodules are abundant throughout the interval. Marker beds at 61.3m (30cm) and 72.5m (20cm). (O may divide unit in terms of lower < fissile and upper >).

UNIT DESCRIPTION THICKNESS	CUMULATIVE THICKNESS	W B SECTION
7.5	7.5	Red/green, fissile, thin-bedded shale; highly deformed.
7.5	15.0	Dominantly red/green thin-bedded siltstone interbedded with shale; highly deformed.
20	35	Mostly covered interval; red interbedded sandstone, siltstone, and shale; deformed.
20	55	Typical red, dominantly thin to medium-bedded, silty sandstone interbedded with shale; sandstone beds average about 10 cm thick; highly deformed.
5	60	Grey thin-bedded sandy dolostone.
15	75	Grey massive dolostone; fractured throughout; section disconnecting fault at top.
25	100	Red thin to medium-bedded (upward), silty sandstone interbedded with shale rarely; first 5 m exposed with upper part of unit mostly covered.
5	105	Grey, thin-bedded, sandy dolostone.
17	122	Grey, thick-bedded to massive, fractured, dolostone; covered at top; inferred covered fault at top.

UNIT DESCRIPTION THICKNESS	CUMULATIVE THICKNESS	W B SECTION
10	132	Mostly covered red, thin-bedded siltstone interbedded with shale; probably deformed.
3	135	Grey, thin-bedded sandy dolostone; syncline structure within unit which greatly increases apparent section thickness.
15	150	Dark gray, thick-bedded, to massive, fractured dolostone.
6	156	Red/green shale interbedded with grey silty sandstone.
10	166	Red to dark grey thick bedded, dolomitic sandstone; thin-bedded at base.
12	178	Red, thin-bedded, silty sandstone interbedded with shale.
3	181	Tan weathered, thick-bedded, dolomitic sandstone interbedded with thin-bedded siltstone; (Top of Rome).
10	191	Red weathering to tan. interbedded sandy siltstone and shale; (Pumpkin Valley); section capped by fault.
2	193	Tan, thick-bedded, sandstone; (Top of Rome, again).

UNIT DESCRIPTION THICKNESS	CUMULATIVE THICKNESS	W B SECTION
--	----	More Sandy siltstone interbedded with Shale: (Pumpkin Valley).

UNIT DESCRIPTION THICKNESS	CUMULATIVE THICKNESS	F.R. SECTION
9	9	Dominantly red to tan, thin-bedded thickening upward mhes siltstone interbedded with mottled red/maroon and green, laminated to thin-bedded shale Entire unit bioturbated and tectonically deformed.
19.5	28.5	Dominantly red variegated (red/ green/ yellow/ black) fissile shale interbedded tan to red , discontinuously thin-bedded siltstone; "dirty" sandy dolostone beds are common throughout.
2.5	31	Mottled tan to red, blocky, friable, thin-bedded siltstone; beds average 10 cm in thickness. Red, fissile, discontinuous shale laminations are noted, but not common. Entire unit is highly bioturbated as well as faulted and folded.
57	88	Covered interval; has siltstone float low in unit and turns to a red soil residuum (possibly a carbonate soil). Section disconnecting fault is noted at its top
22.5	110.5	Mottled tan to red, discontinuously thin-bedded siltstone interbedded with red/green fissile shale. siltstone is the dominant lithology, but intervals of pure shale exist. Unit grades into a maroon, thin-bedded sandstone and the interval is

UNIT DESCRIPTION THICKNESS	CUMULATIVE THICKNESS	F.R. SECTION
		capped by a thick (50 cm) dolomitic sandstone bed. From one side of the road to the other, the dip of this bed changes radically.
22	132.5	Covered interval; Red residuum with grey, thick-bedded, recrystallized dolostone float block near its top.
5.5	138	Variegated (red/ green/ yellow) mottled shale; Highly bioturbated and tectonically deformed.
3.5	141.5	Dominantly mottled tan to red shale interbedded with red, burrowed, discontinuously thin-bedded (10 cm) siltstone and sandstone. (Similar lithology to unit 2.5/31).
3	144.5	Dominantly, red, thin to medium bedded, silty, fine-grained sandstone interbedded with a red, fissile shale. A reverse fault with ~3m of displacement is observed.
9	153.5	Dominantly red sandstone interbedded with shale. Unit coarsens upward.
6	159.5	Tan to red shale with interbeds of red sandstone.
56.5	216	Covered interval. shale to sandstone to dolostone ?

UNIT DESCRIPTION THICKNESS	CUMULATIVE THICKNESS	F.R. SECTION
6	222	Grey, medium to thickly-bedded, jointed dolomitic sandstone.
7	229	Covered interval; probably the last sandstone dominated interval at the top of the Rome below the Pumpkin Valley Shale.

UNIT DESCRIPTION THICKNESS	CUMULATIVE THICKNESS	J.I. SECTION
2.0	2.0	Covered just above Copper Creek thrust.
2.5	4.5	Dark grey med. bedded sandy dolo-mudstone with beds between 1-3 cm thick. Unit has fine wavy laminations with chaotic intervals due to bioturbation and no fossils were observed. Gently folded and jointed throughout. SAMPLES: JM-JI-2.5 (a&b).
8.0	12.5	Highly weathered, grey faintly wavy laminated, vuggy ds interbedded with alternating red and green gray shale. dolo-mudstone beds, the slightly dominant lithology, are usually 2 cm thick and the shale interbeds are thinner. mhcs were ubiquitous throughout and ripple marks were rarely observed. ds become sandier up section as the entire interval becomes siltier. Interval highly fractured and folded.
3.5	16.0	Red to gray dolo-mudstone interbedded with weathered red to tan wavy laminated sandstone. sandstone beds range from 2 to 4 cm thick and dolostone between 1 and 40 cm. No fossils noted. Microfaults noted throughout and shale jointed almost to point of having cleavage. SAMPLES: JM-JI-16.0.

UNIT DESCRIPTION THICKNESS	CUMULATIVE THICKNESS	J.I. SECTION
2.5	18.5	Grey weathering to tan, thinly-bedded (1 cm) finely planer laminated siltstone. Faint mudcracks observed. Unit highly jointed.
5.0	23.5	Covered. Float suggests typical red silty sandstone interbedded with shale and dolostone.
7.0	30.5	Maroon med. bedded wavy finely laminated to lenticular silty fine-grained sandstone is interbedded with thin red shale laminations and the occasional dolo-mudstone bed. Glauconite lenses are common throughout. Sandstone beds are between 2 and 10 cm and the ds are usu. 10 cm thick. Ripple marks and mud cracks are abundant. Horizontal burrows were also noted in less abundance. A resting trace was also noted. Unit is genly folded and jointed throughout. SAMPLES: JM-JI-24.5, JM-JI-26.8.
8.0	38.5	Grey weathering to tan, recrystallized, dolomitic sandstone interbedded with thin grey silty shale. The thinly to medium-bedded sandstone is nearly half dolomite and mottled throughout, but finely planer-laminated where internal structure was preserved. Minor traceable faults within unit. Gently folded throughout with

UNIT DESCRIPTION THICKNESS	CUMULATIVE THICKNESS	J.I. SECTION
		increasing deformation as unit becomes shalier upward. SAMPLES: JM-JI-34.5.
2.0	40.5	Variegated tan, red, and green fissile shale with rare sand lenses. Very highly deformed.
12.5	53.0	Maroon thinly bedded, finely laminated, glauconitic silty fine-grained sandstone interbedded with variegated tan, maroon, and green shale. Horizontal burrows and ripple marks are abundant. Mud cracks and salt casts noted in less abundance. Up section the unit fines becomes dolomitic, thicker bedded and more burrowed. Unit has faulted fold with minor displacement at its top. SAMPLES: JM-JI-47.5, JM-JI-50.0, JM-JI-52.5.
4.0	57.0	Mottled grey weathering to tan, thinly to medium bedded, recrystallized, dolomitic, very fine-grained sandstone interbedded with finely laminated to lenticular wispy lenses of siltstone and shale. Sandstone has had internal bedding destroyed by bioturbation and tectonics. Small horizontal burrows common in siltstone and shale. Unit is highly jointed with microfaults common throughout. SAMPLES: JM-JI-54.3.

UNIT DESCRIPTION THICKNESS	CUMULATIVE THICKNESS	J.I. SECTION
7.5	64.5	Grey weathering to tan, thickly-bedded to massive recrystallized dolomitic, very fine-grained sandstone to sandy dolomudstone. Amount of dolomite is quite variable. Highly deformed and bioturbated, bedding indistinguishable in places; wavy laminated where internal structures can be observed. A fault at the top disconnects the section. SAMPLES: JM-JI-57.6, JM-JI-61.7.
5.0	69.5	Interbedded maroon weathering to tan mottled, silty very fine-grained sandstone and red weathering to tan shale. Sandstone beds are thin-bedded (2 to 5 cm thick) and shale are thinner laminations. Wavy laminations are noted in thicker beds. Unit ubiquitously burrowed as well containing internal tectonic deformation. SAMPLES: JM-JI-66.5.
1.5	71.0	Partially covered unit, variegated red, green, and tan fissile shale. Unit highly deformed.
4.5	75.5	Maroon weathering to tan, thinly to medium-bedded, wavy laminated, glauconitic, silty fine-grained sandstone with the occasional shale laminations and thin beds. Horizontal burrows are

UNIT DESCRIPTION THICKNESS	CUMULATIVE THICKNESS	J.I. SECTION
		abundant and mudcracks, mhcs, and rain drop imprints are also present. Minor traceable faults within unit. SAMPLES: JM-JI-71.0, JM-JI-73.3, JM-JI-75.3.
3.0	78.5	Dark gray weathered to tan, thick-bedded to massive, glauconitic and dolomitic vuggy fine-grained sandstone. Bedding ranges from 10 to 50 cm. Horizontal burrows were noted but not abundant. Partially covered intervals suggest a few shale and siltstone beds may also be present.
4.5	83.0	Grey-green weathering to tan, medium to thin-bedded, planer laminated sandy dolo-mudstone interbedded with grey siltstone and shale. The well-indurated and recrystallized dolostone was bioturbated with horizontal burrows. Bedding ranges from 2 to 10 cm. bulbous algal looking protrusion noted on a bedding plane at about 82m in section (between R & S). SAMPLES: JM-JI-78.8, JM-JI-80.7 JM-JI-83.0.
2.0	85.0	Covered interval. Probably gradation from dolomitic sandstone to "purer" sandstone unit.

UNIT DESCRIPTION THICKNESS	CUMULATIVE THICKNESS	J.I. SECTION
10.5	95.5	Maroon, vuggy, silty, very fine-grained sandstone with occasional shale interbeds. Wavy laminations and mhcs were noted. The well-indurated and recrystallized sandstone beds are medium to thin-bedded, between 2 and 20 cm thick. The unit is highly burrowed throughout. SAMPLES: JM-JI-86.4, JM-JI-87.3, JM-JI-91.0.

Top of Rome Formation

UNIT DESCRIPTION THICKNESS	CUMULATIVE THICKNESS	JOY-2 SECTION
3.9	3.9	Green-gray, silty, dolomitic mudstone interbedded with shale and glauconitic sandstone lenses; highly deformed, fractures infilled with calcite; brecciated.
12.2	16.1	Red to grey, finely laminated, glauconitic siltstone; highly fractured infilled with calcite.
3.0	19.1	Dark grey-green, finely laminated, silty shale; very glauconitic; highly deformed.
2.4	21.5	Dark grey-green dolomitic sandstone; highly indurated; interbedded with red/ green shale.
11.9	33.4	Typical maroon, finely lam, glauconitic, silty shale; rare grey sandstone lenses observed; intervals highly bioturbated and tectonically deformed;
5.5	38.9	Green-grey and red interbedded sandstone, siltstone, and shale; glauconite lenses common; intervals of fine laminations and bioturbation alternate.
8.8	47.7	Red and gray laminated, glauconitic, sandstone interbedded with siltstone; burrows common.
3.4	51.1	Mottled olive green and light gray, glauconitic, siltstone interbedded with sandstone. bioturbated.

UNIT DESCRIPTION THICKNESS	CUMULATIVE THICKNESS	JOY-2 SECTION
3.0	54.1	Dominantly mottled red bioturbated, glauconitic sandstone interbedded with red/green siltstone.
3.7	57.8	Red/green shaly siltstone, thin discontinuous glauconite lenses; highly deformed.
5.8	63.6	Dark grey to maroon, glauconitic, silty sandstone; highly bioturbated and tectonically deformed; unit coarsens upward.
5.5	69.1	Typical maroon , glauconitic, finely laminated silty sandstone with occasional shale interbeds; highly indurated; unit coarsens upward and becomes less deformed.
2.7	71.8	Dark red to grey, well indurated, glauconitic, sandstone interbedded equally with dark red /gray, highly deformed siltstone.
10.1	81.9	Green-gray to red interbedded siltstone and shale with occasional sandstone lenses; highly deformed; fault zone.
14.9	96.8	Dominantly dark grey, massive dolomitic sandstone to sandy dolostone interbedded with grey shale; highly deformed.
5.8	102.6	Dark grey, finely laminated, almost massive sandy dolostone;

UNIT DESCRIPTION THICKNESS	CUMULATIVE THICKNESS	JOY-2 SECTION
		dolostone becomes interbedded with red shale at base.
5.5	108.1	Red/green-grey shaly siltstone interbedded with thin sandstone beds. Alternating intervals of mottling (bioturbation) and laminations.
4.6	112.7	Interbedded red muddy siltstone and grey dolo-mudstone. Glauconitic sandstone lenses noted but not commonly; highly deformed. Samples: ORNL-J2-2290.5 *(106.0), ORNL-J2-2283 (108.3), ORNL-J2-2278.5 (109.6), ORNL-J2-2269 (112.5)
4.3	117	Grey, recrystallized, massive sandy dolo-mudstone. Sand and dolomite occur in about equal parts and glauconite is also present. Thin bedded in lower part; highly deformed and bioturbated. Samples: ORNL-J2-2266.5 (113.3), ORNL-J2-2259 (115.6).
17.4	134.4	Red to green-grey, sandy siltstone interbedded with thinly laminated shale; highly bioturbated and deformed; upper contact is gradational. Rarely, Siltstone beds are dolomite rich and glauconite was noted. Samples: ORNL-J2-2252.5 (117.7), ORNL-J2-2240.5 (121.2), ORNL-J2-2233 (123.5),

UNIT DESCRIPTION THICKNESS	CUMULATIVE THICKNESS	JOY-2 SECTION
		ORNL-J2-2226 (125.7), ORNL-J2-2215.5 (129.8), ORNL-J2-2209 (130.8), ORNL-J2-2207 (131.5), ORNL-J2-2203 (132.7).
5.5	139.9	Dark red, finely laminated, silty, fine-grained sandstone with occasional thin, red/green shale laminations; silty sandstone coarsens upward into a well-indurated sandstone. Bioturbation is common throughout the unit. Samples: ORNL-J2-2195.5 (135.0), ORNL-J2-2191 (136.3), ORNL-J2-2187.5 (137.4).
25.6	165.5	Dominantly maroon and grey, thin bedded, dolomitic, fine-grained sandstone interbedded with red/green, wavy-laminated shale; contains intervals of bioturbation. Dolomite content is variable, but tends to increase at the top of the unit. Generally, the unit coarsens upward. Samples: ORNL-J2-2177 (140.6), ORNL-J2-2175 (141.2), ORNL-J2-2172 (142.2), ORNL-J2-2164 (144.4) ORNL-J2-2152 (148.2), ORNL-J2-2140 (151.9), ORNL-J2-2132.5 (154.2), ORNL-J2-2131.5 (154.5), ORNL-J2-2115 (159.5), ORNL-J2-2112.5 (160.3), ORNL-J2-2105 (162.6), ORNL-J2-2103.5 (163.0).
8.2	173.7	Dominantly green-gray, medium bedded, dolomitic fine-grained sandstone interbedded with

UNIT
DESCRIPTION
THICKNESS

CUMULATIVE
THICKNESS

JOY-2 SECTION

		green-gray silty shale. Dolomite content is variable. Mudcracks noted; highly bioturbated and deformed, internal bedding destroyed. Samples: ORNL-J2-2090.5 (167.0), ORNL-J2-2086.5 (168.2), ORNL-J2-2079 (170.5), ORNL-J2-2073.5 (172.2).
14.0.	187.7	Grey , thick bedded, finely laminated, glauconitic, dolomitic, muddy, silty, fine-grained sandstone; bioturbated and mhcs observed. Dolomite content is variable, from a few percent to beds of pure dolostone. Highly indurated; rare graphitic shale intervals. Samples: ORNL-J2-2067.5 (174.0), ORNL-J2-2064.5 (174.9), ORNL-J2-2051 (179.0), ORNL-J2-2044.5 (181.0), ORNL-J2-2041.5 (181.9), ORNL-J2-2037 (183.3), ORNL-J2-2030 (185.5), ORNL-J2-2022.5 (187.7), ORNL-J2-2022 (187.9).

* The number in parenthesis represents the meter interval at which the sample occurs in this measured section.

APPENDIX B.

Paleocurrent Methods

Measurements were taken in the quadrant form. The data collected were then entered into "EXCELL", a Microsoft spreadsheet application for the Macintosh microcomputer. In "EXCELL", the quadrant data were converted to azimuth data and filed as a text file. Using "EDIT 2.0", a text editor, the data were then manipulated into the format used by "STEREONET", a plotting program for orientation data by R.W. Allmendinger at Cornell University. It should be noted that for the purposes of paleocurrent data, plunge is unimportant, but to use the program each trend reading must also have a corresponding plunge reading; therefore, a zero plunge (any number would work) was entered for each data point. With the data now in "STEREONET" format, the separate sets of ripple crests were restored to horizontal by using the "rotate lines" selection from the operations menu. After all the data were restored to original position, they were then plotted on Rose diagrams to display trends. The "Rose diagram" selections from the Plotting Menu was used for this. Both the original and manipulated data follow.

UNROTATED			ROTATED	STRUCTURE	LOCATION	FACIES
AZIM		PLUNGE	AZIM			
37	,	42		S&D, DIP SE	JONES ISL.	TB ss/sh
35	,	0	36	SYM RIP CR	JONES ISL.	TB ss/sh
38	,	0	218	SYM RIP CR	JONES ISL.	TB ss/sh
40	,	42		S&D, DIP SE	JONES ISL.	TB ss/sh
313	,	0	314	SYM RIP CR	JONES ISL.	TB ss/sh
296	,	0	291	SYM RIP CR	JONES ISL.	TB ss/sh
28	,	75		S&D, DIP SE	JONES ISL.	TB ss/sh
295	,	0	287	ASYM RIP CR, DIP SE	JONES ISL.	TB ss/sh
29	,	0	208	ASYM RIP CR, DIP SE	JONES ISL.	TB ss/sh
15	,	0	25	ASYM RIP CR, DIP SE	JONES ISL.	TB ss/sh
60	,	44		S&D, DIP SE	JONES ISL.	TB ss/sh
19	,	0	28	SYM RIP CR	JONES ISL.	TB ss/sh
20	,	0	29	SYM RIP CR	JONES ISL.	TB ss/sh
30	,	0	37	SYM RIP CR	JONES ISL.	TB ss/sh
45	,	0	49	SYM RIP CR	JONES ISL.	TB ss/sh
350	,	0	357	SYM RIP CR	JONES ISL.	TB ss/sh
48	,	55		S&D, DIP SE	JONES ISL.	TB ss/sh
305	,	0	296	SYM RIP CR	JONES ISL.	TB ss/sh
318	,	0	318	SYM RIP CR	JONES ISL.	TB ss/sh
28	,	39		S&D, DIP SE	JONES ISL.	TB ss/sh
30	,	0	210	SYM RIP CR	JONES ISL.	TB ss/sh
35	,	35		S&D, DIP SE	JONES ISL.	TB ss/sh
35	,	0	35	ASYM RIP CR, SE DIP	JONES ISL.	TB ss/sh
40	,	56		S&D, DIP SE	JONES ISL.	TB ss/sh
327	,	0	339	SYM RIP CR	JONES ISL.	TB ss/sh
55	,	0	229	SYM RIP CR	JONES ISL.	TB ss/sh
330	,	0	343	SYM RIP CR	JONES ISL.	TB ss/sh
62	,	0	233	SYM RIP CR	JONES ISL.	TB ss/sh
46	,	0	223	SYM RIP CR	JONES ISL.	TB ss/sh
310	,	0	310	SYM RIP CR	JONES ISL.	TB ss/sh
348	,	0	4	ASYM RIP CR, SE DIP	JONES ISL.	TB ss/sh
35	,	0	37	SYM RIP CR	JONES ISL.	TB ss/sh
330	,	0	343	SYM RIP CR	JONES ISL.	TB ss/sh
42	,	58		S&D, DIP SE	JONES ISL.	TB ss/sh
75	,	0	241	SYM RIP CR	JONES ISL.	TB ss/sh
49	,	0	226	SYM RIP CR	JONES ISL.	TB ss/sh
35	,	50		S&D, DIP SE	JONES ISL.	TB ss/sh
344	,	0	177	SYM RIP CR	JONES ISL.	TB ss/sh
14	,	0	201	SYM RIP CR	JONES ISL.	TB ss/sh
37	,	0	36	SYM RIP CR	JONES ISL.	TB ss/sh
49	,	52		S&D, DIP SE	JONES ISL.	TB ss/sh
16	,	0	30	SYM RIP CR	JONES ISL.	TB ss/sh
50	,	44		S&D, DIP SE	JONES ISL.	TB ss/sh
338	,	0	344	SYM RIP CR	JONES ISL.	TB ss/sh
53	,	0	232	SYM RIP CR	JONES ISL.	TB ss/sh
50	,	50		S&D, DIP SE	JONES ISL.	TB ss/sh
328	,	0	332	SYM RIP CR	JONES ISL.	TB ss/sh

UNROTATED			ROTATED	STRUCTURE	LOCATION	FACIES
AZIM		PLUNGE	AZIM			
5	,	0	17	SYM RIP CR	JONES ISL.	TB ss/sh
45	,	52		SYM RIP CR	JONES ISL.	TB ss/sh
340	,	0	352	SYM RIP CR	JONES ISL.	TB ss/sh
35	,	58		S&D, DIP SE	JONES ISL.	TB ss/sh
80	,	0	243	SYM RIP CR	JONES ISL.	TB ss/sh
45	,	45		S&D, DIP SE	JONES ISL.	TB ss/sh
9	,	0	18	SYM RIP CR	JONES ISL.	TB ss/sh
42	,	34		S&D, DIP SE	JONES ISL.	TB ss/sh
75	,	0	250	SYM RIP CR	JONES ISL.	TB ss/sh
292	,	0	288	SYM RIP CR	JONES ISL.	TB ss/sh
50	,	30		S&D, DIP SE	JONES ISL.	TB ss/sh
46	,	0	47	SYM RIP CR	JONES ISL.	TB ss/sh
49	,	36		S&D, DIP SE	JONES ISL.	TB ss/sh
42	,	0	43	SYM RIP CR	JONES ISL.	TB ss/sh
80	,	0	255	SYM RIP CR	JONES ISL.	TB ss/sh
75	,	51		S&D, DIP SE ,	WAREHOUSE	TB ss/sh
80	,	0	258	SYM RIP CR	WAREHOUSE	TB ss/sh
84	,	0	261	SYM RIP CR	WAREHOUSE	TB ss/sh
79	,	43		S&D, DIP SE	WAREHOUSE	TB ss/sh
80	,	0	260	SYM RIP CR	WAREHOUSE	TB ss/sh
32	,	0	41	SYM RIP CR	WAREHOUSE	TB ss/sh
73	,	40		S&D, DIP SE	WAREHOUSE	TB ss/sh
25	,	0	33	SYM RIP CR	WAREHOUSE	TB ss/sh
65	,	20		S&D, DIP SE	WAREHOUSE	TB ss/sh
43	,	0	44	SYM RIP CR	WAREHOUSE	TB ss/sh
67	,	20		S&D, DIP SE	WAREHOUSE	TB ss/sh
320	,	0	319	COMB FLOW RIP	WAREHOUSE	TB ss/sh
80	,	22		S&D, DIP SE	WAREHOUSE	TB ss/sh
85	,	0	265	COMB FLOW RIP	WAREHOUSE	TB ss/sh
40	,	35		S&D, DIP SE	CARL	TB ss/sh
52	,	0	230	SYM RIP CR	CARL	TB ss/sh
90	,	0	264	SYM RIP CR	CARL	TB ss/sh
60	,	22		S&D, DIP SE	CARL	TB ss/sh
322	,	0	321	RIP X LAM DIP SW	CARL	TB ss/sh
42	,	39		S&D, DIP SE	CARL	TB ss/sh
320	,	0	322	SYM RIP CR	CARL	TB ss/sh
50	,	42		S&D, DIP SE	CARL	TB ss/sh
65	,	0	241	SYM RIP CR	CARL	TB ss/sh
47	,	0	48	SYM RIP CR	CARL	TB ss/sh
74	,	0	248	SYM RIP CR	CARL	TB ss/sh
41	,	44		S&D, DIP SE	CARL	TB ss/sh
280	,	0	271	SYM RIP CR	CARL	TB ss/sh
289	,	0	282	SYM RIP CR	CARL	TB ss/sh
79	,	0	250	SYM RIP CR	CARL	TB ss/sh
293	,	0	287	SYM RIP CR	CARL	TB ss/sh
72	,	0	244	SYM RIP CR	CARL	TB ss/sh
70	,	36		S&D, DIP SE	CARL	TB ss/sh

UNROTATED			ROTATED	STRUCTURE	LOCATION	FACIES
AZIM		PLUNGE	AZIM			
310	,	0	304	STARV RIP CR	CARL	TB ss/sh
72	,	29		S&D, DIP SE	CARL	TB ss/sh
40	,	0	43	SYM RIP CR	CARL	TB ss/sh
66	,	27		S&D, DIP SE	CARL	TB ss/sh
69	,	0	249	SYM RIP CR	CARL	TB ss/sh
70	,	0	250	SYM RIP CR	CARL	TB ss/sh
311	,	0	308	SYM RIP CR	CARL	TB ss/sh
59	,	44		S&D, DIP SE	CARL	TB ss/sh
31	,	0	38	SYM RIP CR	CARL	TB ss/sh
75	,	0	251	SYM RIP CR	CARL	TB ss/sh
294	,	0	285	STARV RIP CR	CARL	TB ss/sh
65	,	38		S&D, DIP SE	CARL	TB ss/sh
57	,	0	59	SYM RIP CR	CARL	TB ss/sh
272	,	0	267	SYM RIP CR	CARL	TB ss/sh
68	,	0	247	SYM RIP CR	CARL	TB ss/sh
270	,	0	265	SYM RIP CR	CARL	TB ss/sh
282	,	0	276	SYM RIP CR	CARL	TB ss/sh
55	,	31		S&D, DIP SE	CARL	TB ss/sh
78	,	0	255	SYM RIP CR	CARL	TB ss/sh
297	,	0	293	SYM RIP CR	CARL	TB ss/sh
40	,	0	42	SYM RIP CR	CARL	TB ss/sh
56	,	0	236	SYM RIP CR	CARL	TB ss/sh
66	,	37		S&D, DIP SE	CARL	TB ss/sh
310	,	0	305	SYM RIP CR	CARL	TB ss/sh
310	,	0	305	SYM RIP CR	CARL	TB ss/sh
314	,	0	309	SYM RIP CR	CARL	TB ss/sh
90	,	0	266	SYM RIP CR	CARL	TB ss/sh
60	,	36		S&D, DIP SE	CARL	TB ss/sh
85	,	0	261	SYM RIP CR	CARL	TB ss/sh
280	,	0	274	SYM RIP CR	CARL	TB ss/sh
54	,	32		S&D, DIP SE	CARL	TB ss/sh
65	,	0	243	STARV RIP CR	CARL	TB ss/sh
66	,	0	244	STARV RIP CR	CARL	TB ss/sh
60	,	0	239	STARV RIP CR	CARL	TB ss/sh
72	,	0	249	STARV RIP CR	CARL	TB ss/sh
52	,	34		S&D, DIP SE	CARL	TB ss/sh
275	,	0	270	SYM RIP CR	CARL	TB ss/sh
60	,	20		S&D, DIP SE	CARL	TB ss/sh
274	,	0	272	SYM RIP CR	CARL	TB ss/sh
40	,	0	41	SYM RIP CR	CARL	TB ss/sh
53	,	25		S&D, DIP SE	CARL	TB ss/sh
44	,	0	45	SYM RIP CR	CARL	TB ss/sh
64	,	0	243	SYM RIP CR	CARL	TB ss/sh
77	,	0	255	SYM RIP CR	CARL	TB ss/sh
84	,	0	262	SYM RIP CR	CARL	TB ss/sh
68	,	0	247	SYM RIP CR	CARL	TB ss/sh
60	,	25		S&D, DIP SE	CARL	TB ss/sh

UNROTATED			ROTATED	STRUCTURE	LOCATION	FACIES
AZIM		PLUNGE	AZIM			
52	,	0	53	SYM RIP CR	CARL	TB ss/sh
72	,	0	251	SYM RIP CR	CARL	TB ss/sh
42	,	0	44	SYM RIP CR	CARL	TB ss/sh
71	,	0	250	SYM RIP CR	CARL	TB ss/sh
74	,	0	253	SYM RIP CR	CARL	TB ss/sh
270	,	0	268	SYM RIP CR	CARL	TB ss/sh
40	,	27		S&D, DIP SE	CARL	TB ss/sh
64	,	0	242	SYM RIP CR	CARL	TB ss/sh
65	,	0	243	SYM RIP CR	CARL	TB ss/sh
60	,	0	238	SYM RIP CR	CARL	TB ss/sh
40	,	0	40	SYM RIP CR	CARL	TB ss/sh
54	,	0	233	SYM RIP CR	CARL	TB ss/sh
55	,	35		S&D, DIP SE	CARL	TB ss/sh
48	,	0	49	SYM RIP CR	CARL	TB ss/sh
85	,	0	260	SYM RIP CR	CARL	TB ss/sh
90	,	0	265	SYM RIP CR	CARL	TB ss/sh
86	,	0	261	SYM RIP CR	CARL	TB ss/sh
57	,	49		S&D, DIP SE	CARL	TB ss/sh
270	,	0	260	SYM RIP CR	CARL	TB ss/sh
285	,	0	273	SYM RIP CR	CARL	TB ss/sh
90	,	0	260	SYM RIP CR	CARL	TB ss/sh
56	,	0	56	SYM RIP CR	CARL	TB ss/sh
50	,	27		S&D, DIP SE	CARL	TB ss/sh
42	,	0	43	SYM RIP CR	CARL	TB ss/sh
287	,	0	284	SYM RIP CR	CARL	TB ss/sh
80	,	0	257	SYM RIP CR	CARL	TB ss/sh
65	,	0	243	SYM RIP CR	CARL	TB ss/sh
275	,	0	272	SYM RIP CR	CARL	TB ss/sh
65	,	48		S&D, DIP SE	CARL	TB ss/sh
285	,	0	274	SYM RIP CR	CARL	TB ss/sh
77	,	0	253	SYM RIP CR	CARL	TB ss/sh
70	,	0	248	SYM RIP CR	CARL	TB ss/sh
50	,	0	55	SYM RIP CR	CARL	TB ss/sh
60	,	42		S&D, DIP SE	CARL	TB ss/sh
61	,	0	241	SYM RIP CR	CARL	TB ss/sh
53	,	0	55	SYM RIP CR	CARL	TB ss/sh
62	,	0	241	SYM RIP CR	CARL	TB ss/sh
66	,	0	244	SYM RIP CR	CARL	TB ss/sh
76	,	0	252	SYM RIP CR	CARL	TB ss/sh
47	,	0	50	SYM RIP CR	CARL	TB ss/sh
55	,	0	56	SYM RIP CR	CARL	TB ss/sh

APPENDIX C.

Samples are labeled such that the first letters are the authors initials (JM), a dash, a second set of letters denote the outcrop (JI for Jones Island and C for CARL), another a dash, and the ending number indicates meters up from the base of the section at which the sample was collected.

Abbreviations

Mineral composition numbers are visually estimated percentages.

* means component is present

QTZ - quartz

PLG - plagioclase

ORT - orthoclase

FeD - ferroan dolomite

MgD - magnesium dolomite

MUS - muscovite

GLA - glauconite

P/O - fine-grained phyllosilicate and organics

SRF - sedimentary rock fragments

FeO - iron oxide

ZTR - zircon, tourmaline, and rutile

QF - quartz and feldspar overgrowths

PM - fine-grained phyllosilicate matrix

CA - calcite

DO - dolomite

md - medium sand

fn - fine sand

vf - very fine sand

sl - silt

c - clay

w - well

m - moderately

p - poorly

w - well rounded

sr - sub-round

sa - sub-angular

a - angular

STY - stylolites abundant

FRC - fractures abundant

BIO - bioturbated

REX - recrystallized

VITA

Joe McReynolds was born in Tacoma Park, Maryland in 1964, a Baltimore Oriole fan from birth. Soon, he moved to the sticks in Southwest Virginia where he grew up. Later, he, again, moved back to the big town and attended high school in Manassas in northern Virginia graduating in 1982. He, then, attended The College of William and Mary spending four of his funnest years in the 17th Century and graduated in the spring of 1986 with a Bachelors of Science with high honors in Geology. Next, he entered the Master's program at the University of Tennessee, Knoxville in the fall of 1986. 1988 has been the year of big changes. Joe was married in the spring instantaneously becoming a daddy as well and also completed his Master's degree in the fall of 1988. He also saw the light in 1988 in his conversion from IBM to Macintosh with the arrival of his Mac SE early in the year. Too bad the O's year didn't go as well.

SAMPLE NUMBER	MINERALOGIC COMPOSITION													CEMENTS				TEXTURE				MISCELL.			
	QZ	PLG	ORT	Fed	Mgd	Fec	Mgc	MUS	GLA	P/O	SF	Fcd	ZIR	CF	PM	CA	DO	SIZE	SORT.	ROUND.	STY	FRC	BIO	REX	
JM-C-0.5	60	10	5	5				<1		15	<1	5		*	*	*	*	*	*	*	*	*	*		
JM-C-3.0	45	5	5	40				<1	5		<1	1		*	*	*	*	*	*	*	*	*	*		
JM-C-8.0	80	5	3					1		10	1			*	*	*	*	*	*	*	*	*	*		
JM-C-9.5	78	5	<1						15			2		*	*	*	*	*	*	*	*	*	*		
JM-C-10.3	10			89							1			*	*	*	*	*	*	*	*	*	*		
JM-C-11.5	30			60					2		8			*	*	*	*	*	*	*	*	*	*		
JM-C-17.9	65	3	2		25		<1	2		1		1		*	*	*	*	*	*	*	*	*	*		
JM-C-18.5	85	3	2		10							<1		*	*	*	*	*	*	*	*	*	*		
JM-C-19.9	79	3	2		15					1			<1	*	*	*	*	*	*	*	*	*	*		
JM-C-20.7	88	5	5					<1				-2	<1	*	*	*	*	*	*	*	*	*	*		
JM-C-29.0	61	8	7					20	2			2		*	*	*	*	*	*	*	*	*	*		
JM-C-32.2	80	8	7					1				5		*	*	*	*	*	*	*	*	*	*		
JM-C-36.4	85	3	2			3	1			7			>1	*	*	*	*	*	*	*	*	*	*		
JM-C-36.5	80	3	2		7		1			3		5		*	*	*	*	*	*	*	*	*	*		
JM-C-38.3	5	2		45	33	<1		<1				5		*	*	*	*	*	*	*	*	*	*		
JM-C-38.7	83	5	3	5	3	1								*	*	*	*	*	*	*	*	*	*		
JM-C-39.0	87	5	3		1		1			2				*	*	*	*	*	*	*	*	*	*		
JM-C-42.5	40	3	2	25	30							<1		*	*	*	*	*	*	*	*	*	*		
JM-C-45.2	89	3	2						<1	5		1	<1	*	*	*	*	*	*	*	*	*	*		
JM-C-47.0	89	5	5					1		<1				*	*	*	*	*	*	*	*	*	*		
JM-C-53.0	80	5							1	15		1		*	*	*	*	*	*	*	*	*	*		
JM-JI-2.5 a,b	1			99								<1		*	*	*	*	*	*	*	*	*	*		
JM-JI-16.0	5		<1	94								1		*	*	*	*	*	*	*	*	*	*		
JM-JI-24.5	83	5	5		3			1				3	<1	*	*	*	*	*	*	*	*	*	*		
JM-JI-26.8	10			88			2							*	*	*	*	*	*	*	*	*	*		
JM-JI-34.5	50	5	5	35	5			1						*	*	*	*	*	*	*	*	*	*		
JM-JI-47.5	61	3	3		15		15	1				2		*	*	*	*	*	*	*	*	*	*		
JM-JI-50.0	83	7	5					<1		3		2	<1	*	*	*	*	*	*	*	*	*	*		
JM-JI-52.5a,b	10	2	3	35	50									*	*	*	*	*	*	*	*	*	*		
JM-JI-54.3	55	5	3	20	10					7				*	*	*	*	*	*	*	*	*	*		
JM-JI-57.6	54	15	8	13	7		2	<1				1		*	*	*	*	*	*	*	*	*	*		
JM-JI-61.7	15	5	5	5	70			<1						*	*	*	*	*	*	*	*	*	*		
JM-JI-66.5	76	4	3							10		7		*	*	*	*	*	*	*	*	*	*		
JM-JI-71.0	77	4	4	1				1		10		3	<1	*	*	*	*	*	*	*	*	*	*		
JM-JI-73.3	70	8	8					2		2		10	<1	*	*	*	*	*	*	*	*	*	*		
JM-JI-75.3	80	6	5					2				7		*	*	*	*	*	*	*	*	*	*		
JM-JI-78.8	28	5	5	60								2		*	*	*	*	*	*	*	*	*	*		
JM-JI-80.7	13	5	2	73				<1		5		2		*	*	*	*	*	*	*	*	*	*		
JM-JI-86.4	80	7	7					1		2		3		*	*	*	*	*	*	*	*	*	*		
JM-JI-87.3	77	10	8					1		2		3		*	*	*	*	*	*	*	*	*	*		
JM-JI-91.0	60	8	7					<1		5		15		*	*	*	*	*	*	*	*	*	*		

SAMPLE NUMBER	MINERALOGIC COMPOSITION													CEMENTS				TEXTURE				MISCELL.									
	QTZ	PLG	ORT	Fed	Mgd	Fec	Mgc	MUS	GLA	P/O	SPF	FEO	ZIR	QF	PM	CA	DO	md	fn	v	f	sl	c	w	m	p	ROUND.	STY	FTC	BIO	REX
ORNL-J2-2269	72	5	5	<1	5				7			5	<1	*	*	*	*		*	*	*	*	*	*	*	*		*			*
ORNL-J2-2266.5	35	5	4	1	40			1	2	7		5		*	*	*	*		*	*	*	*	*	*	*	*		*			*
ORNL-J2-2259	45	3	4	25	10			2	8			3		*	*	*	*		*	*	*	*	*	*	*	*		*			*
ORNL-J2-2252.5	44	3	5						5	40		3		*	*	*	*		*	*	*	*	*	*	*	*		*			*
ORNL-J2-2240.5	25	8	8					3	5	38		3		*	*	*	*		*	*	*	*	*	*	*	*		*			*
ORNL-J2-2233	40	8	8					1		42		2		*	*	*	*		*	*	*	*	*	*	*	*		*			*
ORNL-J2-2226	51	8	10					3	3	35			<1	*	*	*	*		*	*	*	*	*	*	*	*		*			*
ORNL-J2-2212.5	65	6	7	5	10					5		2		*	*	*	*		*	*	*	*	*	*	*	*		*			*
ORNL-J2-2209	20	13	12					2	<1	45		1		*	*	*	*		*	*	*	*	*	*	*	*		*			*
ORNL-J2-2207	55	15	5					3		15		7	<1	*	*	*	*		*	*	*	*	*	*	*	*		*			*
ORNL-J2-2203	25	15	10					5		10		35		*	*	*	*		*	*	*	*	*	*	*	*		*			*
ORNL-J2-2195.5	53	8	5	5	7	3			<1	5		3		*	*	*	*		*	*	*	*	*	*	*	*		*			*
ORNL-J2-2191	61	5	4							20		10		*	*	*	*		*	*	*	*	*	*	*	*		*			*
ORNL-J2-2187.5	56	6	4	12	15		1	1				5		*	*	*	*		*	*	*	*	*	*	*	*		*			*
ORNL-J2-2177	62	10	8							15		5	<1	*	*	*	*		*	*	*	*	*	*	*	*		*			*
ORNL-J2-2175	65	15	10							10			<1	*	*	*	*		*	*	*	*	*	*	*	*		*			*
ORNL-J2-2172	75	4	5	1						12	<1	3		*	*	*	*		*	*	*	*	*	*	*	*		*			*
ORNL-J2-2164.5	87	5	4		<1	1						3	<1	*	*	*	*		*	*	*	*	*	*	*	*		*			*
ORNL-J2-2152	47	5	4					1	30	3		10		*	*	*	*		*	*	*	*	*	*	*	*		*			*
ORNL-J2-2140	41	5	4					10	10	25		5		*	*	*	*		*	*	*	*	*	*	*	*		*			*
ORNL-J2-2132.5	20	10	8					1	54	<1		7	<1	*	*	*	*		*	*	*	*	*	*	*	*		*			*
ORNL-J2-2131.5	40	7	6					2		30		15	<1	*	*	*	*		*	*	*	*	*	*	*	*		*			*
ORNL-J2-2115	62	6	5	5	5			<1	1	1		15	<1	*	*	*	*		*	*	*	*	*	*	*	*		*			*
ORNL-J2-2112.5	60	8	7						3	15		7		*	*	*	*		*	*	*	*	*	*	*	*		*			*
ORNL-J2-2105	63	8	7	4	3	1			10	3		2	<1	*	*	*	*		*	*	*	*	*	*	*	*		*			*
ORNL-J2-2103.5	33	4	4	5	46			1		5		2		*	*	*	*		*	*	*	*	*	*	*	*		*			*
ORNL-J2-2090.5	32	6	3	10				1	<1	45		3		*	*	*	*		*	*	*	*	*	*	*	*		*			*
ORNL-J2-2086.5	56	10	8	3	12			1		5		5		*	*	*	*		*	*	*	*	*	*	*	*		*			*
ORNL-J2-2079	30	5	5	30	30	1			<1			3	<1	*	*	*	*		*	*	*	*	*	*	*	*		*			*
ORNL-J2-2073.5	20	4	3	45	25							3		*	*	*	*		*	*	*	*	*	*	*	*		*			*
ORNL-J2-2067.5	50	10	10	8	2					8		2		*	*	*	*		*	*	*	*	*	*	*	*		*			*
ORNL-J2-2064.5	57	12	10	3	12	1				2		3		*	*	*	*		*	*	*	*	*	*	*	*		*			*
ORNL-J2-2051	47	10	8	5	25					4		1	<1	*	*	*	*		*	*	*	*	*	*	*	*		*			*
ORNL-J2-2044.5	68	7	7	1				2		10		5	<1	*	*	*	*		*	*	*	*	*	*	*	*		*			*
ORNL-J2-2041.5	53	5	5			1		1		35				*	*	*	*		*	*	*	*	*	*	*	*		*			*
ORNL-J2-2037	55	10	10	5						18		2		*	*	*	*		*	*	*	*	*	*	*	*		*			*
ORNL-J2-2030	5			30	64	1								*	*	*	*		*	*	*	*	*	*	*	*		*			*
ORNL-J2-2022.5	61	5	4				<1		7	20		3	<1	*	*	*	*		*	*	*	*	*	*	*	*		*			*
ORNL-J2-2022	45	8	7						5	30		5		*	*	*	*		*	*	*	*	*	*	*	*		*			*