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The Mississippi Mineral Resources Inteitute
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PETROLOGY AND GENESIS OF CLINOPTILOLITE IN THE TALLAHATTA FORMATION OF LAUDERDALE AND CLARKE COUNTIES, MISSISSIPPI

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Final Report for
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83-5F)
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INTRODUCTION

The purpose of MMRI Project 84-9F combined with the results obtained through a previous field investigation supported by MMRI project 83-5F was to research the mining potential of sedimentary zeolites contained in strata of the Tallahatta Formation that is exposed in the vicinity of Meridian, Mississippi. The zeolite mineral found in this area which is used in a variety of industrial applications is clinoptilolite. Principle applications of clinoptilolite to mention only a few include its use as an agricultural food supplement in sewerage and waste water treatment, as a radio active waste containment, as a heavy metal extractant, as a paint extender, and as a whitener.

Sedimentary zeolites, by definition, are microcrystalline hydrated alumina silicates of alkali and alkaline earth cations. They are the product of diagenetic alterations or authigenic deposition in both open or closed marine and alkaline or ground-water sedimentary systems. Structurally zeolites are tectosilicates constructed of three dimensional totally polymerized alumina and silica tetrahedra. Such structural arrangement gives rise to numerous types of interstructural channel and cage configurations of varying sizes. Cations incorporated within these configurations through mainly hydroryl bonding are most commonly sodium, potassium, magnesium, calcium, and rarely strontium and barium. Clinoptilolite, one of the more common sedimentary zeolites, is a monoclinic silica-rich variety with potassium, sodium, and rarely calcium as dominant interchannnel corporate cations.

Clinoptilolite occurring in Gulf Coastal Plain strata of southeastern U.S. was first found in Lower Eocene strata of Alabama (Reynolds, 1966) and Middle Eocene strata of Mississippi (Wermond and Moiola, 1966). Later investigation in Alabama revealed clinoptilolite to be most abundant in the Middle Eocene Tallahatta Formation but also occurring in lesser quantities in the Lower Eocene Nanafalie Formation and the Paleocene Porters Creek Formation (Reynolds, 1970).

Clinoptilolite has also been found in the middle phase of the Porters Formation of Mississippi (Raybon, 1982) and in the lower mud facies of the Porters Creek Formation of Tennessee (Sims, 1972). It was not until 1981 that clinoptilolite was discovered in strata of the Tallahatta Formation that is exposed in the vicinity of Meridian Mississippi (Reynolds, 1983).

Preliminary investigation of the Tallahatta Formation in the vicinity of Meridian, Mississippi supported by MMRI Project 83-5F involved lithologic description and measurement, sampling, and mineral determination of surface exposures of Tallahatta strata. This preliminary investigation provided substantial data by which an initial facies analysis was made, and it also revealed varying concentrations of clinoptilolite throughout the Tallahatta Formation.

The preliminary and field investigation showed that typically, within the study area (Figure 1), the Tallahatta Formation consists of three lithologic or sedimentation units (Figure 2). At the base, immediately above an unconformity between the Meridian and the Tallahatta Formations is, on the average, 15 feet (4.6 m) of transitional bioturbated glauconitic wackes and muds usually capped by two to eight feet of zeolitic clay (unit A). Lenticular to wavy bedding is most notable in both the mud and wacke strata of this unit and the surface between the lower unit and the upward succeeding unit is disconformable. The overlying unit (unit B) is what typically has been described as the Basic Shale even though it is not a shale but rather, for the most part, a massive soft to hard opal-Ct claystone (Lundegard and Samuals, 1982). This unit is, on the average, 45 feet (14 m) thick and contains thin lenses of zeolitic clay, however the massive claystone is often interrupted by upwards to 10 feet (3m) beds of mud and zeolitic clay. The uppermost unit (unit C) begins with either a mud facies or a glauconitic bioturbate opaline cemented wacke, and the average thickness of the entire upper unit is 44 feet (13 m). This unit consists also

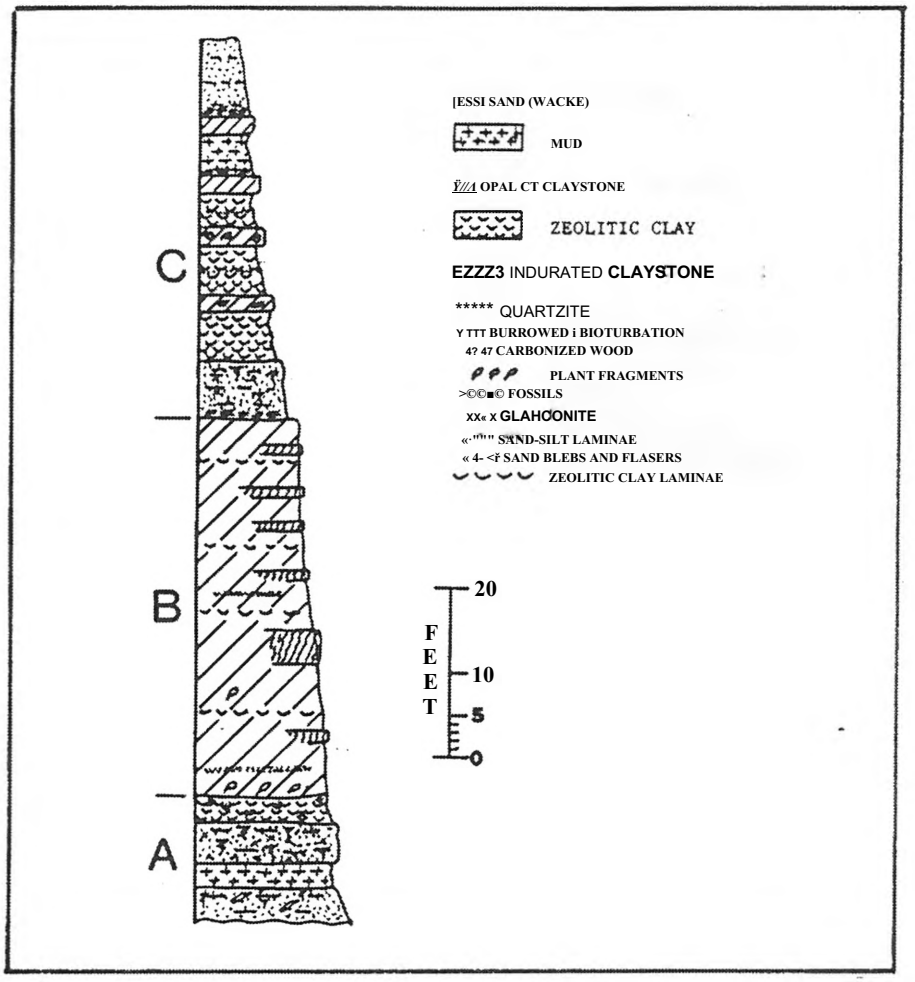


Figure 2a: Average lithologic composition of the Tallahatta Formation in the vicinity of Meridian, Mississippi.

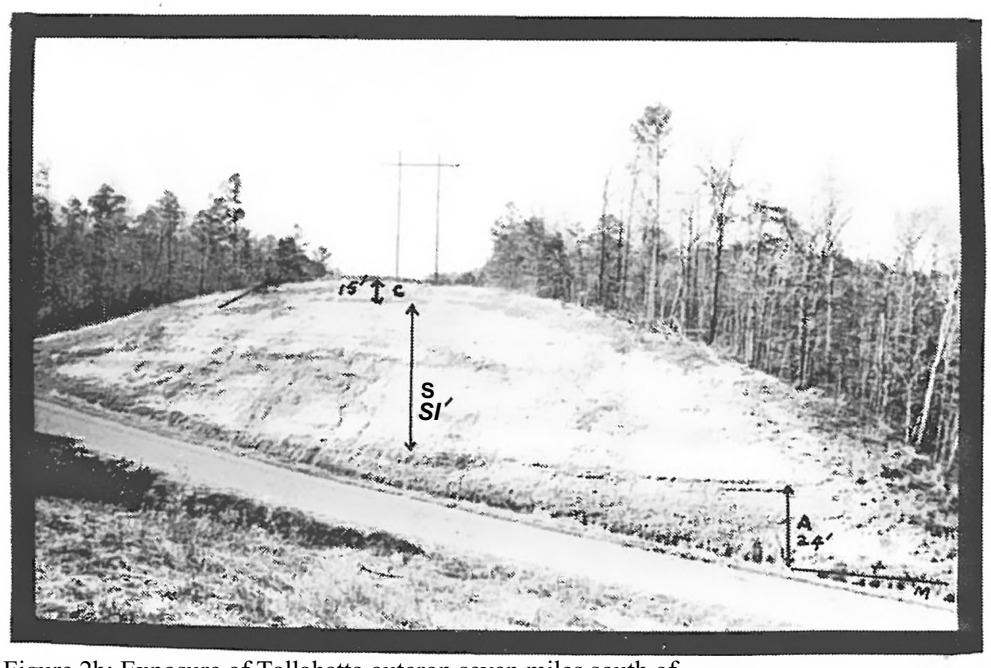


Figure 2b: Exposure of Tallahatta outcrop seven miles south of Meridian on Valley Road. Units A, B and part of C are exposed overlying the Meridian Sand (M-lower right corner).

of alternating thin to massive, hard to soft opal-Ct claystone and zeolitic clay beds plus muds and wackes. Furthermore, it is usually capped by a thin often bioturbated arenaceous sand or sandstone.

The three lithologic units of the Tallahatta Formation, as described above, may vary in thickness and even arrangement but are fairly constant in content and can be traced throughout the study area (Roquemore, 1984).

One of the principal tasks designated as MMRI Project 84-9F is the description and mineral content analysis of eight cores taken with total penetration of Tallahatta strata at selected locations along the Tallahatta outcrop in Lauderdale and Clarke Counties, Mississippi. Drill site location (Figure 1) was based on outcrop exposure information. Data obtained from core analysis was coupled with exposure data in the effort to reconstruct the lithofacies of various depositional environments and subenvironments. Ultimately, when combined with mineral analysis, this would enable the derivation of a genetic model for clinoptilolite depositioned.

Core description and measurement (Appendix A) added information on lithologies and lithologic sequence within the Tallahatta Formation compatible with data obtained from outcrop exposure. Study of the cores provided the extra . stratigraphic control for lithofacies reconstruction. At each drill site approximately 150 feet of core was taken in 10 feet lengths starting in the Winona Sand, totally penetrating the Tallahatta and ending in the top of the Meridian Sand. Each 10 feet length was measured and described as it was pulled (Figure 3), then boxed and shipped to the University of Mississippi for further analysis. Elevation control for each measured section was maintained during field work by levelling from elevation monuments to the base of each exposed section to be measured and described . The position of each exposure section was also plotted on 7 1/2 minute quadrangles which allowed the qualification of subsequent adjustment of each basal elevation ”brought” from various bench

Figure 3a: Describing core during coring operation at MCH 6.

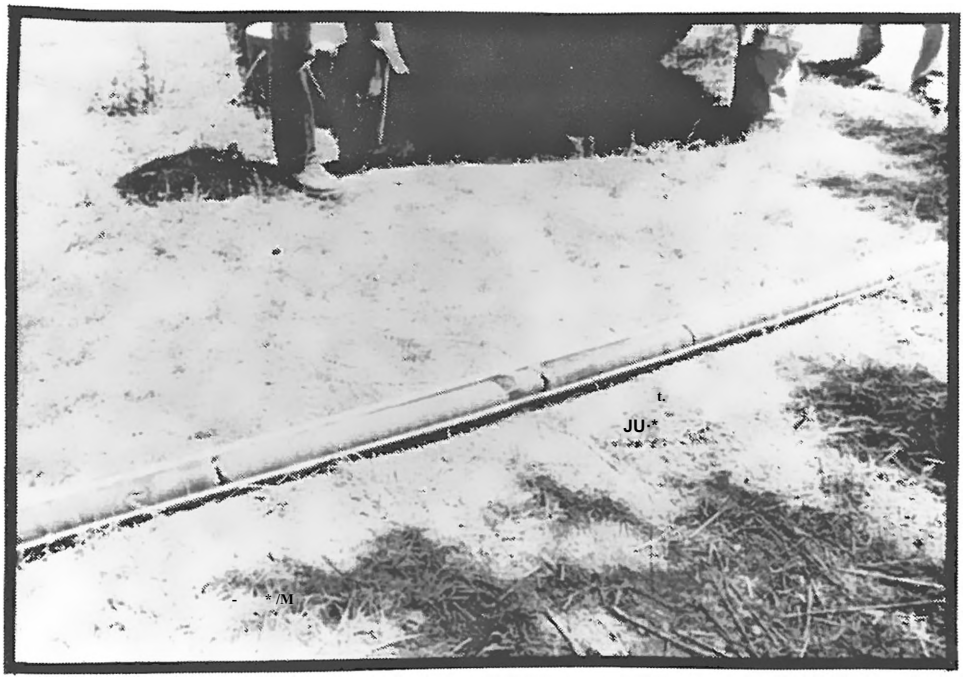


Figure 3b: Ten feet of fresh core ready to be measured and described at core site MCH 6.

marks. This also allowed short sections (Figure 4) which represented scattered integral portions of a singular section to be brought together as a composite section. Each drill site was positioned by triangulation using a compass and the field vehicle tripometer. Drill site elevations were determined by using a pocket altimeter along with 71/2 minute, quadrangles for refinement and adjustment.

STRUCTURE

An initial stratigraphic section was constructed by "hanging" core and exposure logs from a common datum of 500 feet above mean sea level along two cross-section traverses. One cross-section, AA, [1] is essentially along strike, and the other, BB, is down dip (Figure 5). The tectonic elements in the study area turned out to be mainly a series of normal down-to-the-South faults (Figure 6) the movement of which involved the entire Tallahatta section with throws of 15 to 60 feet. The faulting events are not thought to be syndepositional but rather thought to have occured post Tallahatta, deposition. Only one fold feature, the Lost Gap Monocline, was ascertained (figures 4 and 6) as dips measured east to west along 120 from Meridian went from 0° to 15° and finally increased to 34° (Figure 4). More fold features probably exist in the study area but were not evident. Two of the faults can be seen visually in the field. One, between sections 51A and 49 is quite obvious as these sections are only 200 feet apart and the Meridian Sand in section 51A is juxtaposed to unit B claystone in section 49, which is a throw of about 45 feet. The second fault can be seen as a fault-line through unit B at the Basic City type section; a cut along the Illinois Central Gulf railroad one-half mile north of Basic City.

STRATIGRAPHY

Two palinspastic cross sections were constructed from the initial structural cross sections for the purpose of facies reconstruction (Figures 7 and 8).

These cross sections essentially summarize the stratigraphy of the study area. Even though the Meridian Sand was not considered a part of the operational unit of this study it has a few notable lithofacie characteristics pertinent to this study. The Meridian Sand is no longer the lower member of the Tallahatta but now is a separate formal unit (Dockery, 1981). It is quite evident that there is a distinct period of nondeposition of marine sediments between the arenaceous sands of the Meridian and the transitional muds and wackes of what is now the Lower Tallahatta. Throughout the study area the Meridian Sand for the most part is a clean medium-to fine-grained quartz arenite ranging from 100 feet (30 m) to 3 feet (0.9 m) in thickness. Weathered Meridian is either white or orange whereas fresh material is usually gray or brown where it contains organic material and is locally lignitic. The upper part of the Meridian is marked by a zone of intense burrowing with the unique cork-screw (Gyrolithes) and boxwork (ophiomorpha) burrows that are more resistant to erosion than the enclosing sand, and weather in relief.

Channel samples of the Meridian Sand were taken from exposures and cores for the purpose of grain-size distribution analysis. Probability plots indicate a polymodal grain-size distribution with an average phi mean of 1.75 and a strong predominance of the saltation population over a traction population (Appendix B). Most of the probability plots indicate a foreshore to nearshore intertidal beach as a general environment for the deposition of the Meridian Sand. However some plots along with cross-stratification data indicate very localized environments such as esturine, delta-plain fluvial and backshore subarea i beach (Visher, 1969; Roquemore, 1984 and Toulmin, 1966).

The lithologies of the Tallahatta Formation can be segregated into three lithofacies groups, and as previously discussed designated as units basically because each group is a distinct sedimentation unit. Unit A, the lowermost unit, consists of transitional wackes and muds and at least one distinct

zeolitic clay bed. Unit B, the middle unit, consists of massive to thin bedded opal-Ct claystone. Occasionally, this unit will contain beds of zeolitized mud and zeolitic clay. Furthermore, the more massive claystone beds will often contain laminae (1/2" to 3") of zeolitic-opaline clay. The uppermost unit, unit C, consists of wackes, occasionally arenites, muds, silts and often thick beds of zeolitic clay.

Unit A (Figures 7 and 8) is thickest due South of Meridian (Section E45, Valley Road) but thins immediately to the West (E51, Basic City Type Section) then thickens to 35 (11 m) feet further west, and (MCH5, MCH7, C55) north-west, and thins again to the extreme north-west (MCH1). East of the Valley Road Section unit A thins to an average 10 feet (3m). Downdip this unit thins to a thickness of less than 10 feet (3m). Extensive bioturbation is a very characteristic aspect of this unit often halmarked by burrow mottling (Figure 9). Both vertical and horizontal, simple to complex burrows are plentiful in the wackes and muds of this unit especially if these beds are at the top (Figure 9). The common trace fossils include Ophiomorpha, Thalassinoides sp. and Teeichichnus sp. of the Cruziana association (Chamberline, 1978). Zeolitic clay beds in this unit are also heavily burrowed with individual burrows often preserved as opaline casts (Figure 9). Also notable within these beds are small segregated concentrations of sand usually circular or flaser-like in appearance (Figure 9). The wackes and muds are always glanconitic and micaceous. Channel samples were also taken in the lower unit A Sands for grain-size distribution analysis. Probability plots based on these analyses using dry sieve data indicate a mixture of depositional conditions, mainly deposition from suspension which is most common along barred coasts (Visher, 1969). Unit A is for the most part nonfossiliferous however occasionally a shell layer can be observed in the agillaceous sand near the top of the unit. Most common in this unit are plant fragments including large pieces of carbonized wood plus lenticular and wavy

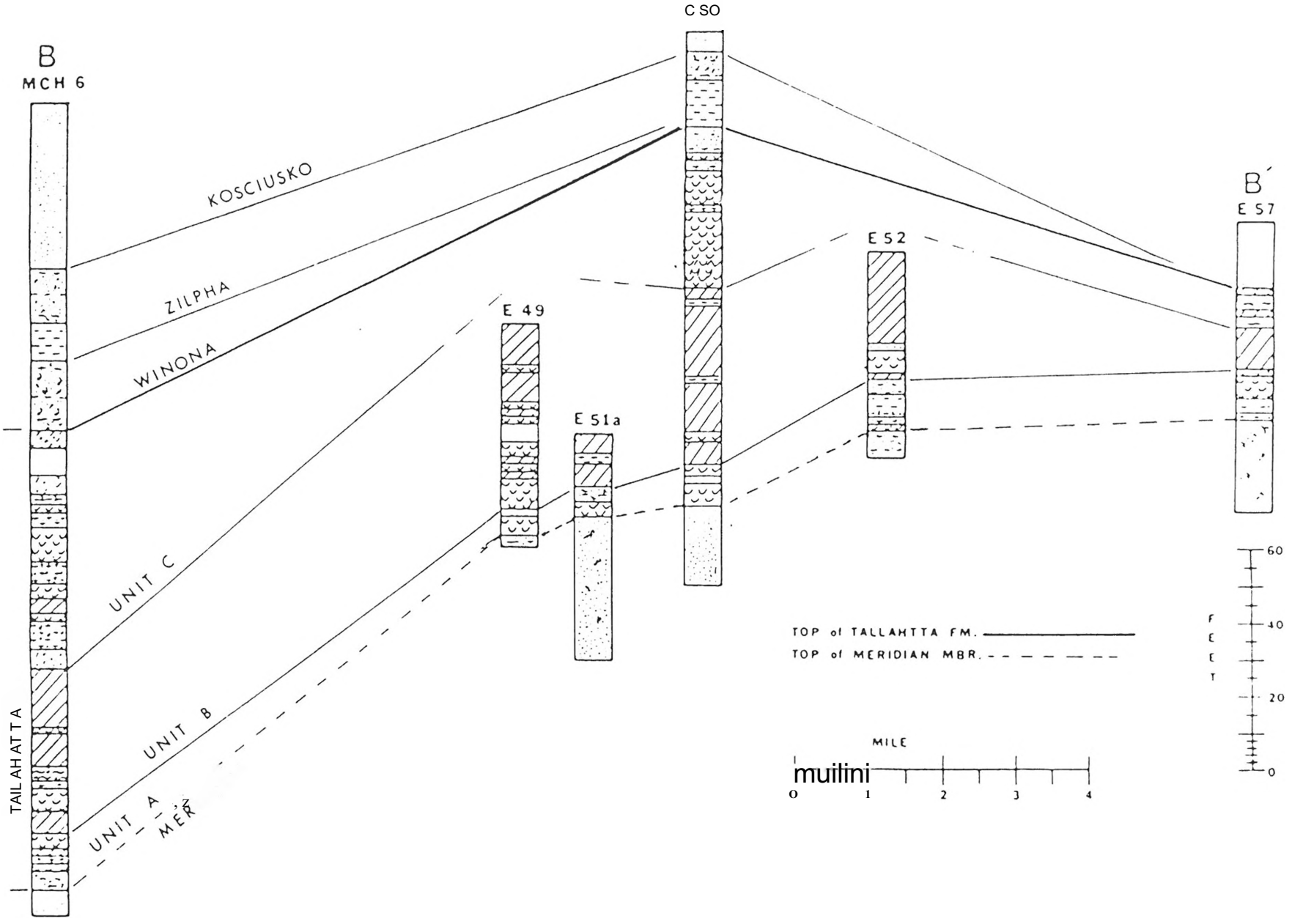
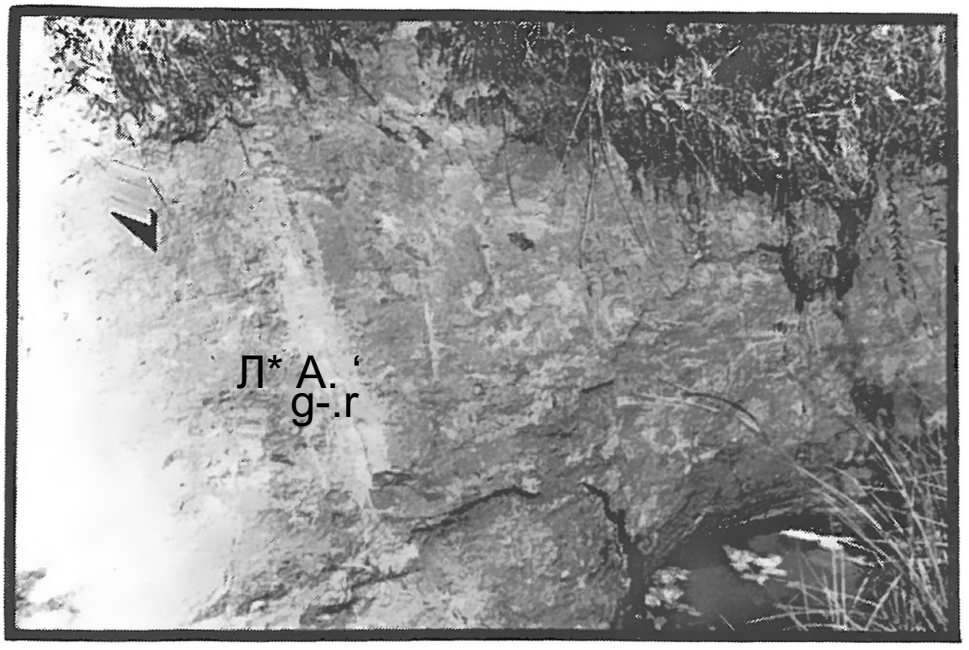


Figure 8: Stratigraphic section BB' down dip of the Tallahatta Formation showing facies units A, B and C plus the underlying upper Meridian Sand and the overlying Winona and Zilpha Formations. Refer to Figure 7 for litholoev kev .

Figure 9 : Unit A exposed in Valley Road section, section 45. Left: Wacke with opaline burrow casts and burrows of Ophiomorpha and Thalassinoid

Lower: Burrow mottling in unit C mud.



bedding (Figure 10).

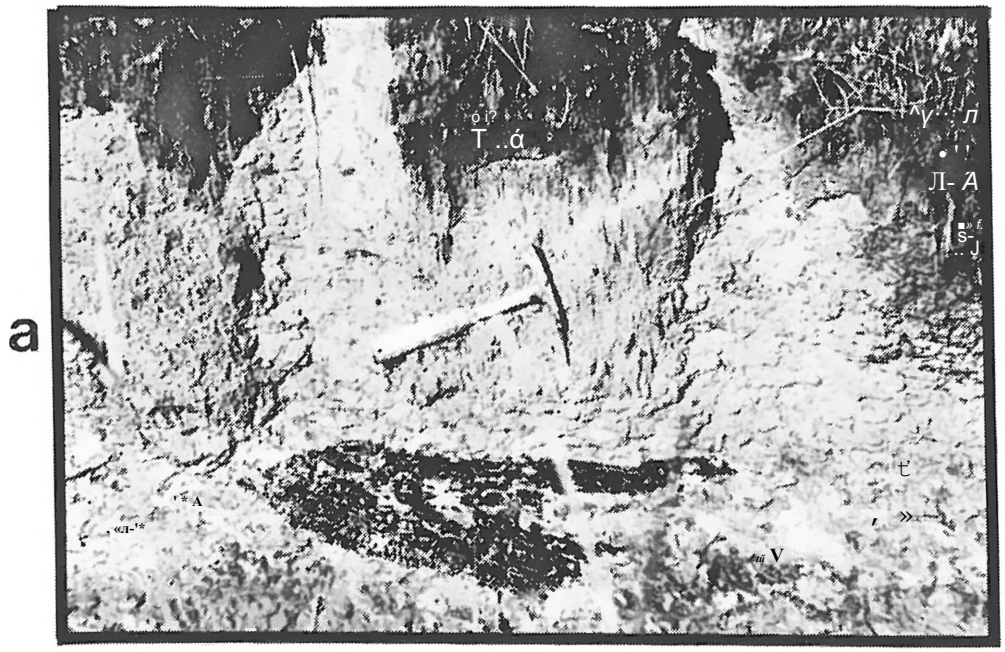
The principle lithology of unit B is a siliceous claystone composed of microcrystalline opal-Ct (Carver, 1980). The opaline strata appear to be massive but upon close examination they are in part laminar. Some of the strata however are thin bedded and have the appearance of a brick pile. Furthermore, some of the beds of unit B are soft and could be referred to as an opaline clay while others are highly indurated and form ledges. A few of the indurated ledges are highly fossiliferous with a dominance of the bivalves Nucula, Nucul ana, and Venericardia. Also notable in this unit, especially in core sections, are numerous thin layers (I^M to 6^M) of extremely brittle, sharp opaline chert.

Occasionally, wacke, mud and zeolitic clay strata are found in unit B. If any of these strata were found lithified the cement was either opal-Ct or clinoptilolite or both.

Throughout the study area unit B varies little in thickness ranging from 30 feet (9m) to 45 feet (14m). It is at its thinnest in the Valley Road Section (E45) where it is 30 feet but immediately thickens to the East and the West.

The clays and claystones of unit B are olive-green to gray-green when fresh, but will bleach to a buff-gray or white when exposed. These clays and claystones have a distinct conchoidal to subconchoidal fracture, however the beds of pure opal-Ct are laminar the opaline material is extremely brittle and sharp. Surface exposures of this unit are quite distinctive, often forming steep cliff faces, vertical walls and pronounced ledges in road and stream cuts.

Primary structures found in unit B claystone include mainly small-scale cross-lamination, hummocky cross-lamination and stratification, lenticular and wavy bedding. Flaser bedding is often found in the wackes and muds along with small-scale cross-stratification. Lebensspuren are common throughout the unit, mainly in the wackes, and consists of unidentifiable horizontal tubes, and the ichnofossil Chondrites sp. (Chamberline, 1978) was identified in several cores.



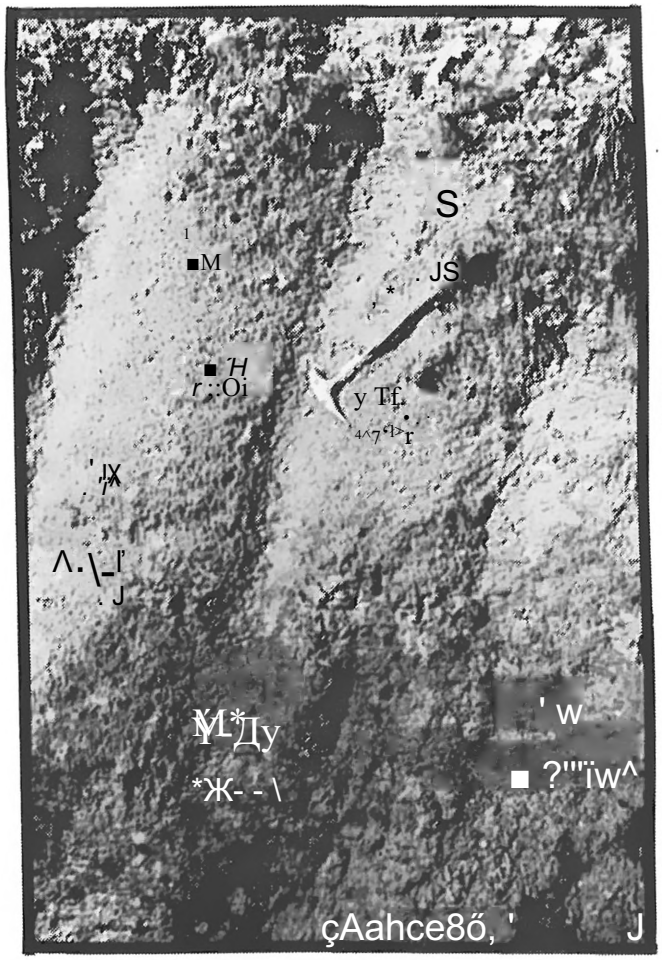


Figure 10: Unit A exposures along Savoy Road Section 50:

a) Carbonized wood in wacke
b) Wavy bedding
c) Storm surge bedding

A secondary structure, quite unique and most diagnostic in the more massive siliceous claystones, the zeolitic clays and some of the muds of unit B is that produced by sheet dewatering (Collinson and Thompson, 1982) (Figure 11).

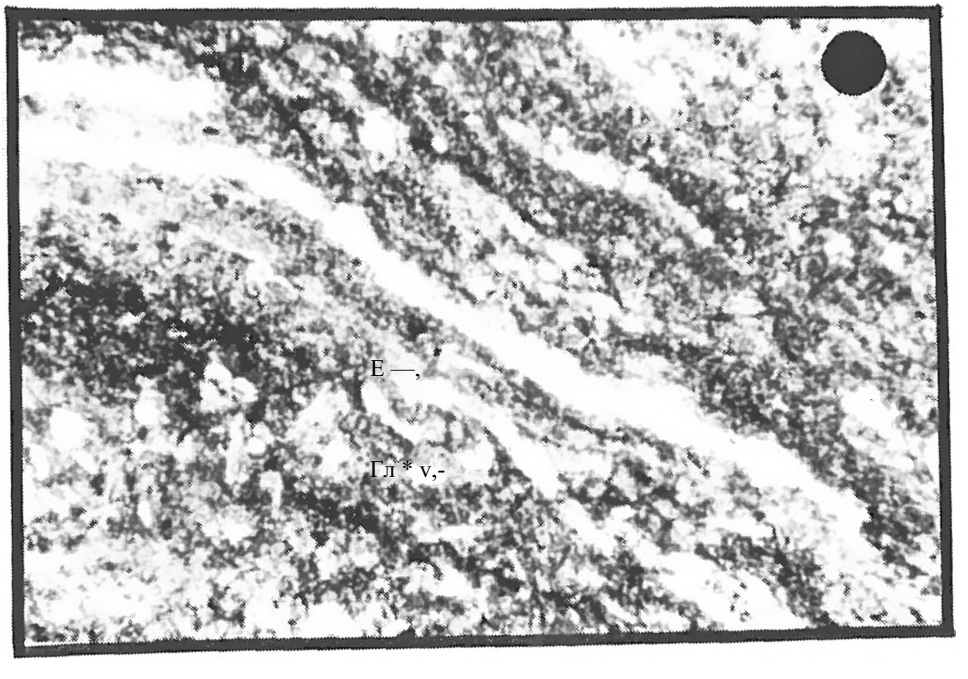
The upper unit, unit C, is similar in lithology to unit A. However, it is thicker than unit A being at its 20 feet (6m) thinnest in the northwest sector of the study area (MCHI) and thickest, 80 feet (24m), in the south west portion. This unit is not exactly a mirror image of unit A even though it contains similar type muds, wackes and zeolitic clays. There are some clay beds in unit C that are not zeolitic but are rather opaline smectites. On the other hand the zeolitic clay beds are thicker and more abundant in this unit than in unit A. Also, in unit C are occasional aberrant opaline claystone beds. Beds of silt are also found in unit C but not in unit A. Like unit A the wackes and muds of unit C are bioturbated and contain plant debris, have hummocky stratification, and display lenticular and wavy bedding. These features, especially bioturbation, are not observable in outcrop exposures but are most diagnostic in the cored sections (Figure 12). One unique but not a common feature seen in the wackes of unit C is that of storms surge bedding; highly contorted and disrupted bedding (Figure 10). Storm surge sands in the road cuts of 120 (Section C55) underly a massive 12 foot bed of zeolitic clay.

The fine to coarse-grained, glauconitic, densely fossiliferous, calcareous and ferrugenous sand of the Winona Formation overlie unit C of the Tallahatta Formation. Exception to this is where Winona, Zilpha and to some extent Tallahatta unit C strata have been removed and replace by nascent Neshoba delta plain fluvial and delta front sands. These sands are generally coarse to medium-grained, quartzose and stained red. The Neshoba Channel Sands can best be seen in the 120 road cuts near the Chunky interchange, the valley road exposures (E45) and in core MCH 8.

The contact between the Winona Formation and the Tallahatta unit C is

a

b



c

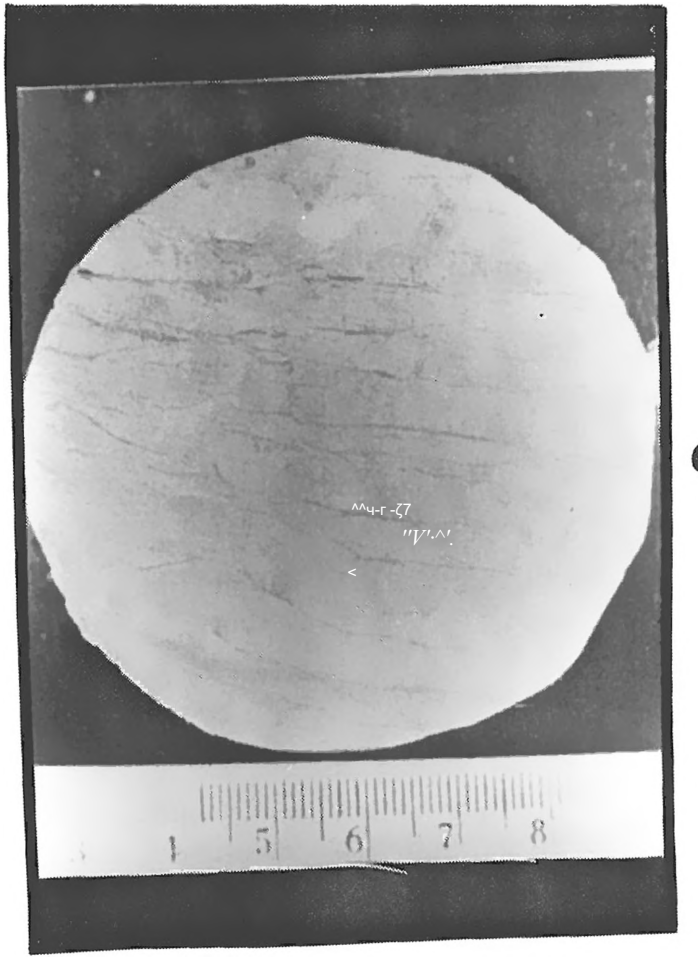


Figure 11: Sheet dewatering features:

a) Petrographic thin section under plane polarized light of unit C clay. Dot scale is 25m«.

b) Same as a except from unit B claystone. Dot scale is 25m;4.

c) Cross section of core from unit B claystone.

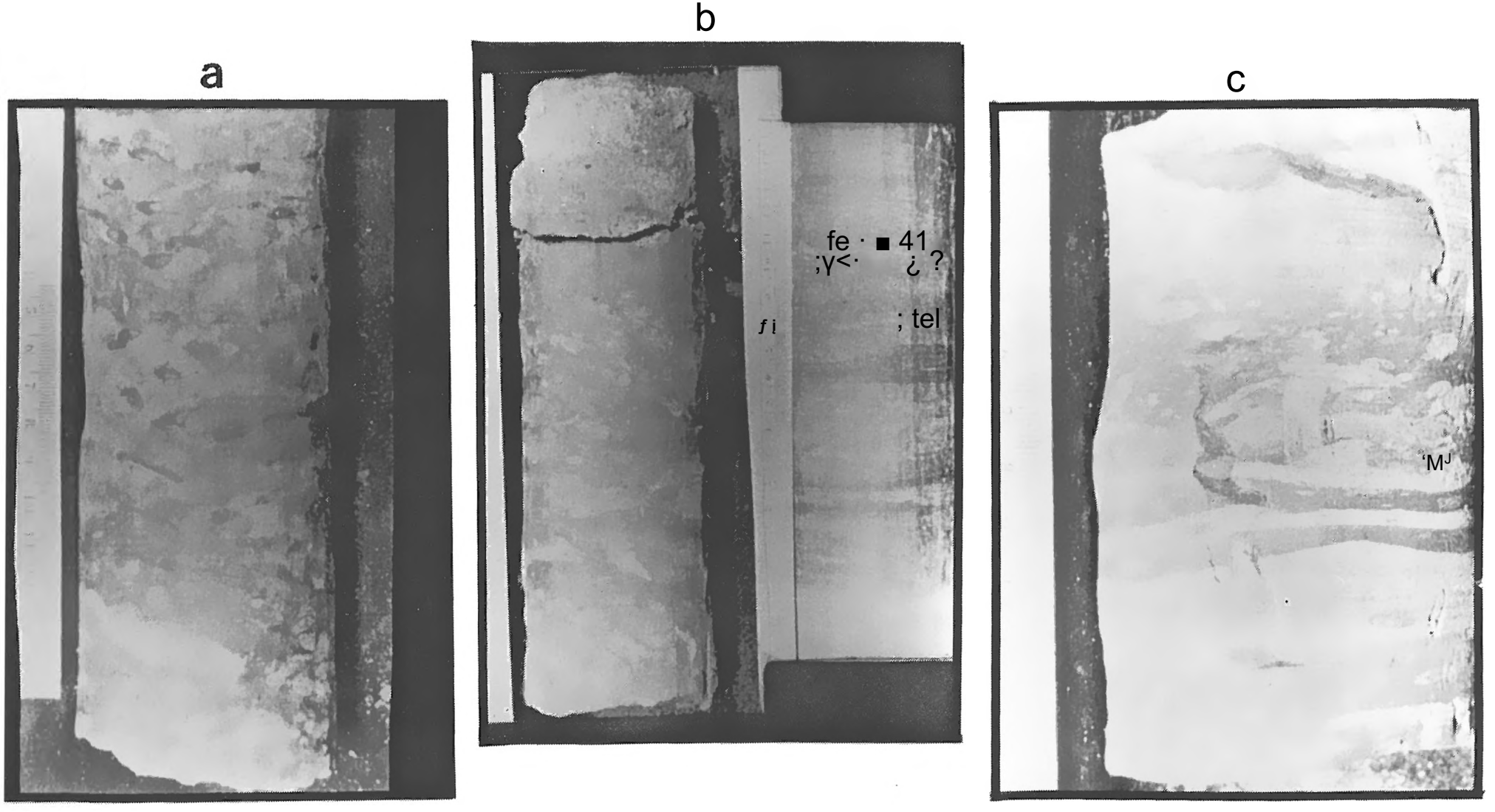


Figure 12: Examples of bioturbation seen in cores from units B and C.

everywhere conformable everywhere and is marked by a gradual change from clay or mud into glauconitic fossiliferous sand.

The Winona Formation in the study area is conformably overlain by the dark brown to black carbonaceous clays and silts of the Zilpha Formation which is a persistent unit throughout the study area. Often however, the Zilpha clays are lateral to the upper portion of the Winona Sand. These clays are massive, have a a conchoidal to blocky fracture, contain mica and glauconite streaks, and down-dip are fossiliferous (MCH 7). These bentonitic clays of the Zilpha Formation which also contain minor amounts of clinoptilolite are in turn disconformably overlain by the delta front and delta plain sands of the Kosciusko Formation.

Mineralogy

Previous field investigation involved in part the sampling of all Tallahatta clay beds exposed in the study area for determination of mineral content. Mud strata and selected wackes and opaline claystone beds and selected Zilpha clays were also sampled and analysed. Samples were then analysed by x-ray diffraction and scanning electron microscopy (SEM) for mineral content, mineral quality, and an estimate of mineral quantity.

The bulk composition of exposed Tallahatta clay, mud, wacke and claystone strata was found to consist of, in varying proportion, the zeolite mineral clinoptilolite, smectite (predominantly montmorillonite), coarse-to fine-grained muscovite, some illite, opal-Ct, and coarse-to fine-grained quartz (Figures 13, 14, and 15).

Material sampled from the cores also analysed in the same manner had a bulk composition identical to that of exposure material (Appendix B). Minor amounts of potassium feldspar and gypsum were also identified in some of the core samples.

X-ray identification of clinoptilolite was based on the presence of the

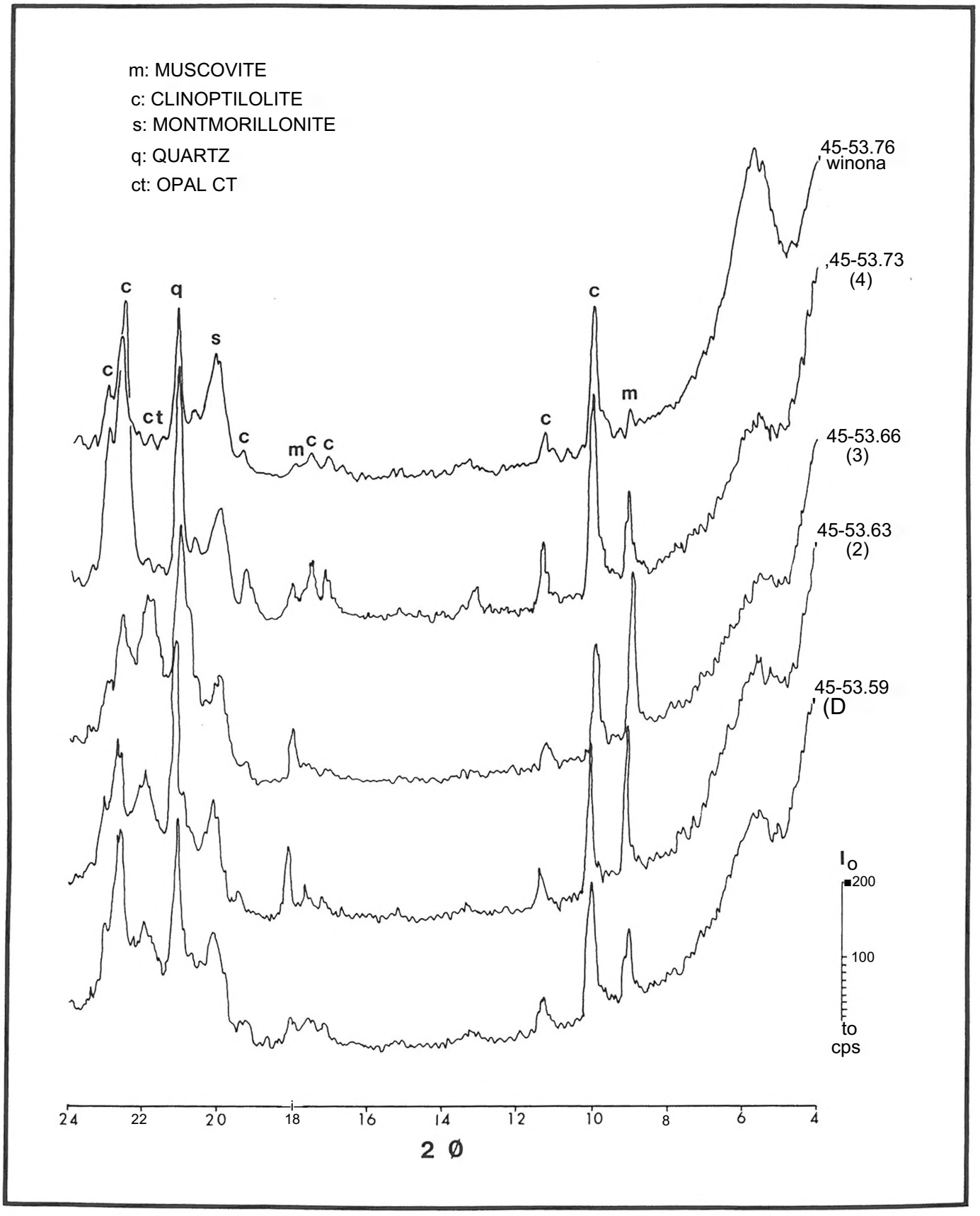


Figure 13: X-ray diffraction patterns of material sampled from clay beds exposed in section 45 (Valley Road).

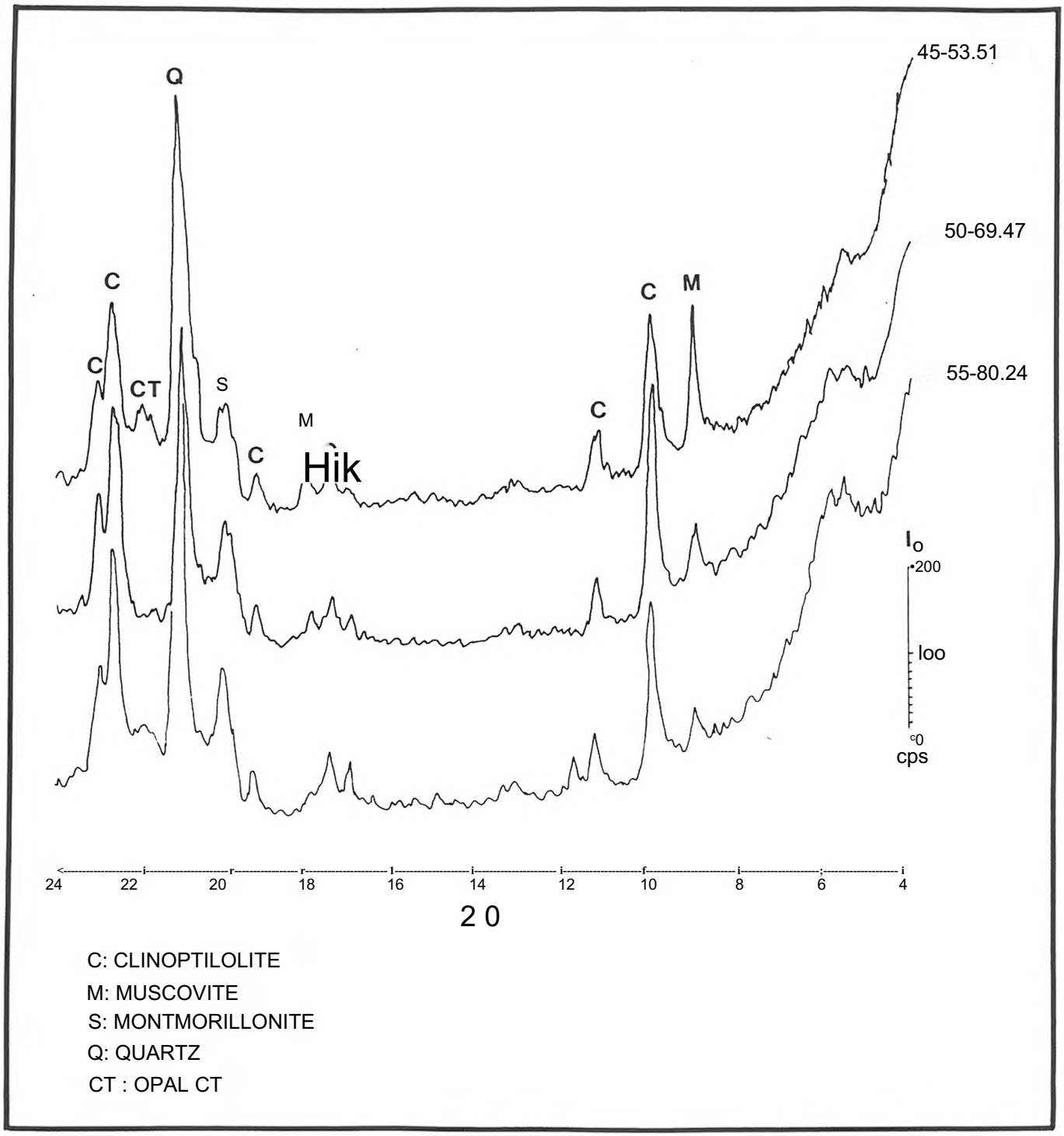


Figure 14: X-ray diffraction patterns of material sampled from Zilpha clay exposed in sections 45 (Valley Road), 50 (Savoy Road), and 55 (120).

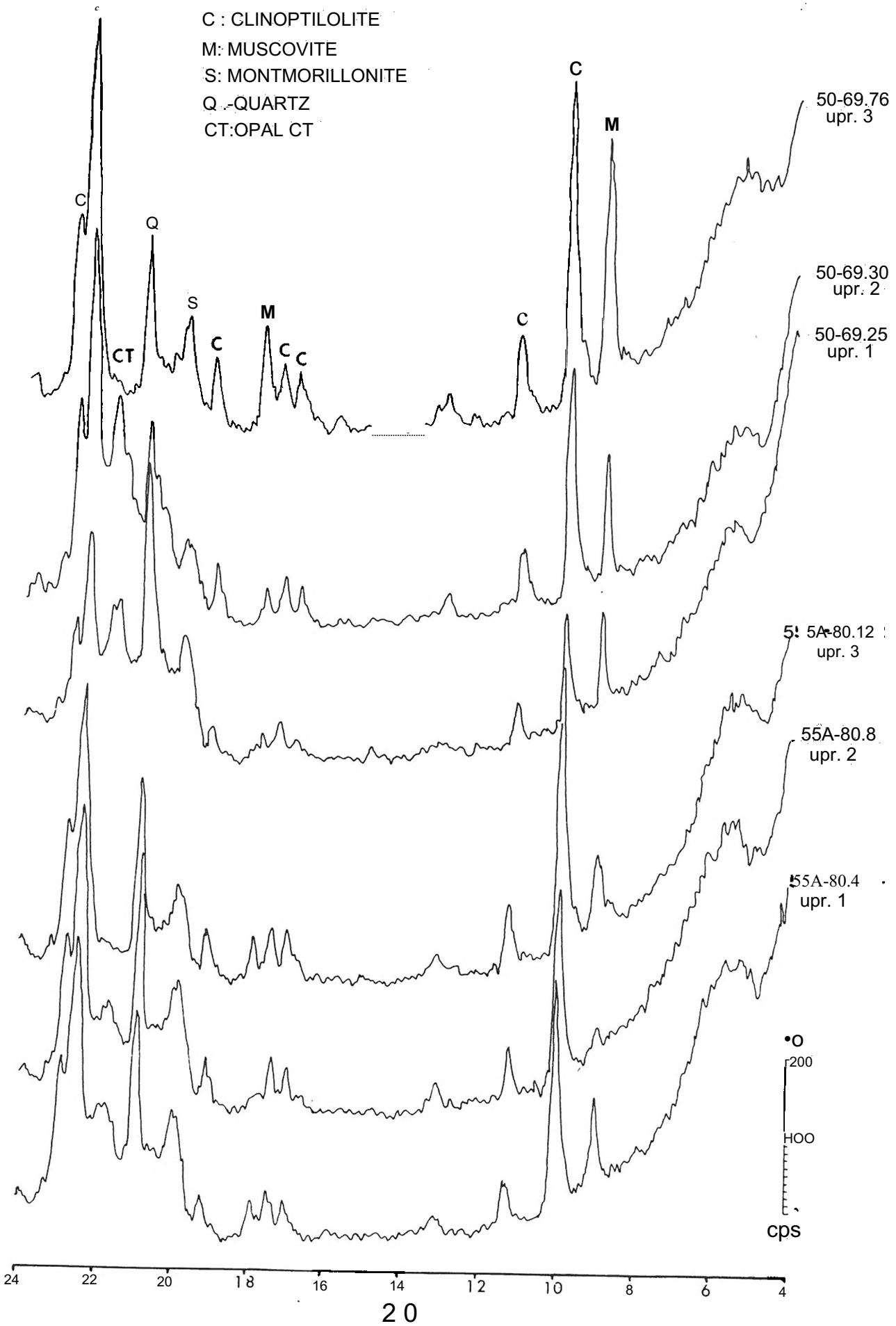


Figure 15: X-ray diffraction patterns of material sampled from selected clay beds i n sections 50 (Savoy Road) and 55 (120).

020, 004, and 042 reflections at 8.92 A°# 3.96 A° and 3.89 A° respectively. Diffraction patterns of smectite minerals are placed into two categories: 1) basal 001 reflections from 12.4 A° to 16 A°, and 2) hk reflections principally from 4.5 A° to 4.62 A°, 2.43 A° to 2.6 A^0, 1.69 A° to 1.72 A°, and 1.49 A° to 1.54 A°· Basal 001 reflections are often unpredictable to use in Smectite mineral identification due to the varying influence of interlayer water, cations in exchange positions, and interlayer organic complexes. Often the 001 reflections are not evident when smectite is present because of layer disruption and disorientation due to large organic molecules being ”stuffed” into the interlayer positions. On the other hand, hk reflections indicate smectite form and therefore, species. Montmorillonite was found to be the dominant smectite identified by diffraction traces of hk reflections at 4.5 A° and 1.5 A^0. There was also indication of minor amounts of montronite and mixed layered illite-montmorillonite.

Jones and Signit (1971) have classified opaline silica into three structural groups designated as opal-A, opal-Ct, and opal-C. In an x-ray diffraction study of mixtures of opaline silica phases Tada and Iijima (1983) characterized and identified these structural groups using the (101) x-ray diffraction reflection. Diffraction patterns of siliceous clays from the Tallahatta Formation often had reflections from 4.06 A° to 4.1 A indicating opal-Ct which is consistent with Tada and Iijima*s results.

Muscovite was identified by its 002 and 004 reflections while quartz was identified by its 110 reflection.

Relative abundance of each of the dominant minerals per described exposure and cored section is shown as relative concentration in Zeta graphs coupled with lithology logs for each section - (Appendix C). Zeta graphs were constructed by assuming the sum of the selected x-ray diffraction peak intensities of the dominant minerals present in each sample would equal unity. Ratios of peak

height were derived for each mineral in a sample and a standard, and were summed for each sampled section. The mean and standard deviation were computed for each ratio sum. The peak ratios were then standardize using a Zeta transform which resulted in new values where each ratio of peak intensity has a zero mean is expressed in units of standard deviation from than mean. This affectively allows a comparison of the relative mineral concentrations within a sample and between samples.

By examining the Zeta charts (bulk mineralogy) for each exposure and core logged section in Appendix C one can see some variance of clinoptilolite content within each section but less variance from section to section. The dominant occurrence of clinoptilolite in each section is in the upper clay bed of unit A and the one to three prominent clay beds of unit C. The variability of clinoptilolite content is shown more graphically in (Figure 16) which was constructed by determining the probability of occurrence of average relative mineral concentration between individual minerals within a stratigraphic unit (Figure 17) and plotting these values against stratigraphic position. This procedure subsequently enabled the construction of stratigraphic cross sections which are identical to Figures 7 and 8 except only the clinoptilolite-rich clay beds are correlated (Figures 18 and 19).

Clinoptilolite was detected in 88 percent of the samples examined by x-ray diffraction. Half of the samples taken from unit A have relative concentrations of clinoptilolite that are above average. Furthermore, clinoptilolite appears to be more concentrated in the muds and wackes than in the clays. Clinoptilolite occurs in 43 percent of the samples taken from unit B despite the fact that unit B composition is predominantly opal-Ct. In unit B above average relative concentration of clinoptilolite is found to correspond to above average relative concentration opal-Ct 26 percent of the time. This is probably due to the occurrence of extremely fine laminae of clinoptilolite clay alternating with

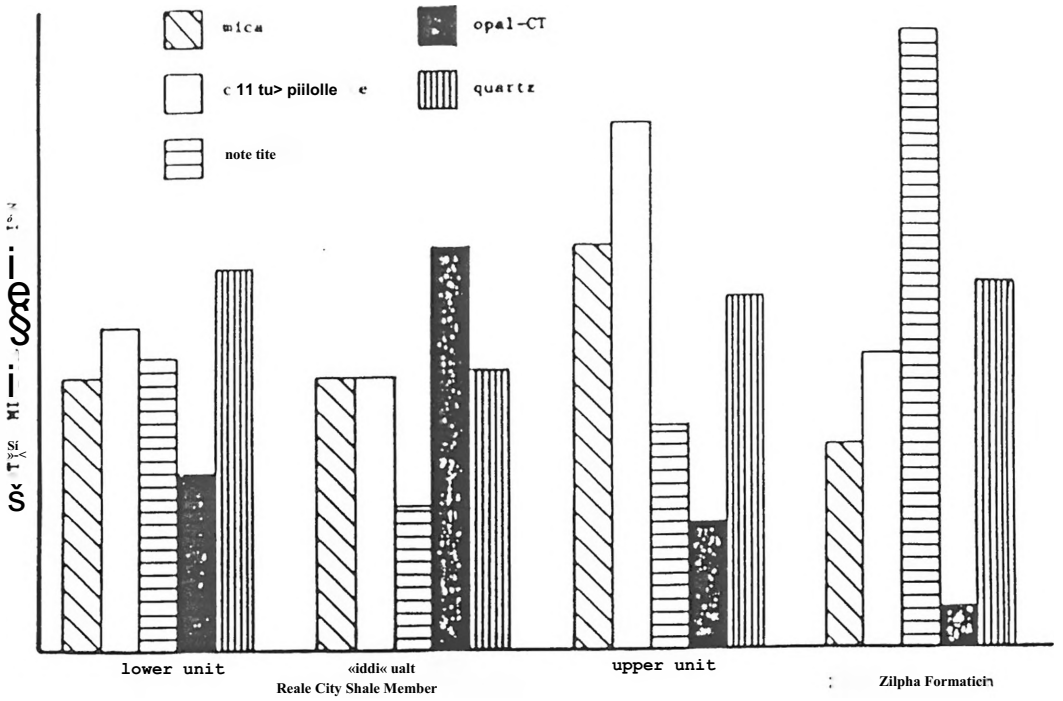


Figure 16: Relative mineral concentration of clays in units A, B and C of the Tallahatta Formation and the Zilpha Formation.

	MICA	CLINOPTILOLITE	SMECTITE	OPAL-CT	QUARTZ
MICA		50	67	24	46
SMECTITE CLINOPTILOLITE			47	24	39
OPAL-CT				28	29
QUARTZ					18
					j

Figure 17: Association probability of above average relative mineral concentration as determined by x-ray diffraction pattern analysis.

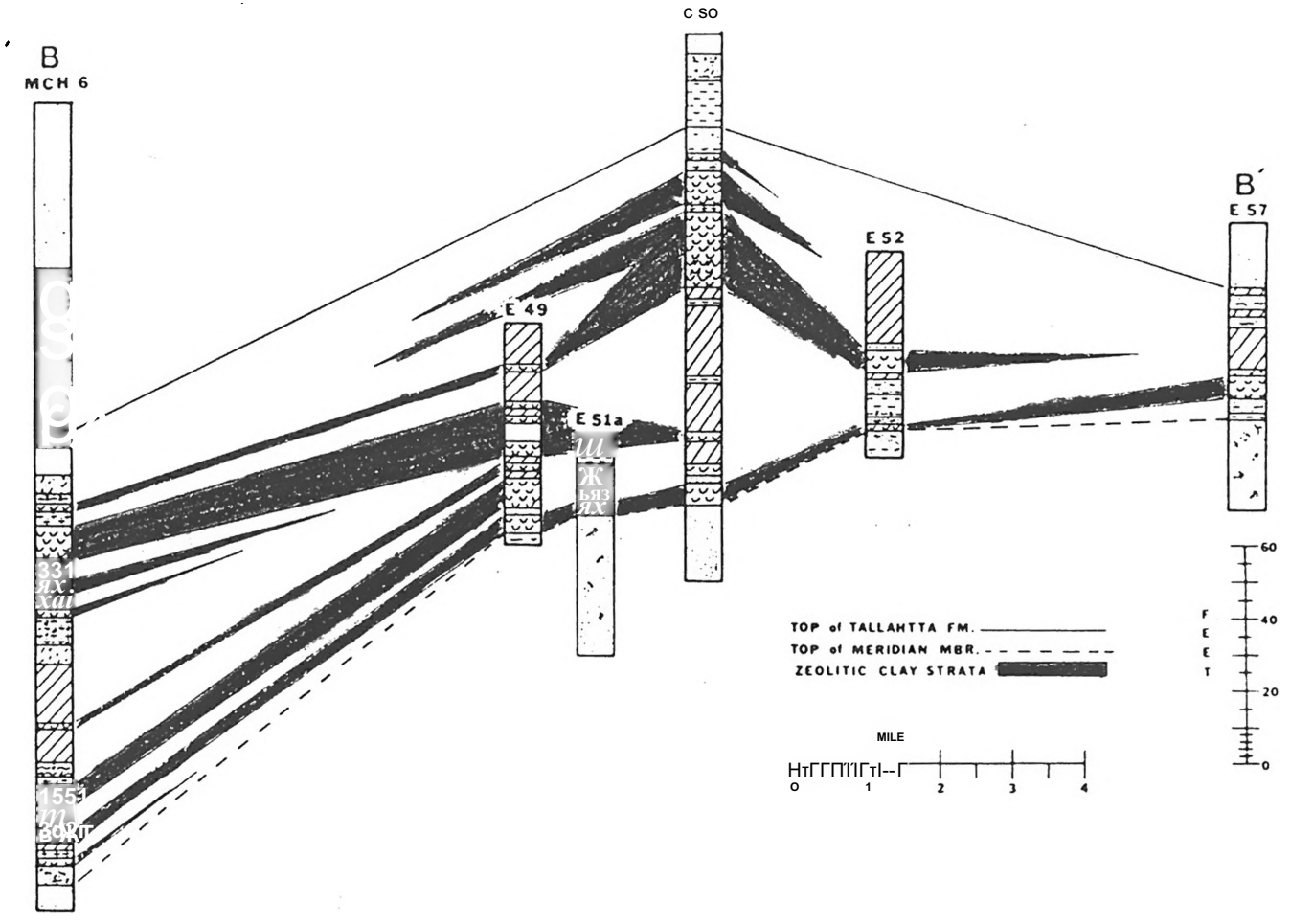


Figure 19: Concentration of clinoptilolite-rich clay strata down dip: cross section BB' (see figure 7 for lithology key).

some regularity throughout unit B with thicker laminae and beds of opal-Ct. For a more complete and refined discussion of clinoptilolite occurrence refer to Roquemore, 1984.

SEM analysis of selected sample material known to contain an above average relative concentration of clinoptilolite revealed this mineral to be cryptocrystalline with well formed monoclinic crystals (Figures 20 and 21) enclosed in what appears to be a pyroclastic matrix (Figure 20a).

Upon closer examination it can be seen that the matrix is composed of authigenic montmorillonite (Figures 20b and 21a). Most often the submicroscopie crystals of clinoptilolite are nestled in clusters within vugs or pores which punctuate the matrix (Figure 21a and c). Clinoptilolite crystals and crystal clusters appear to grow either from the vug or pore wall or they seem to originate from the central portion of the vug or pore. These occurences offer three alternative explanations concerning clinoptilolite formation: 1) clinoptilolite forms from a material that made up the vug itself such as a siliceous microfossil or volcanic glass, 2) the initial material was dissolved creating the pore space and clinoptilolite grew from a material introduced later, 3) or clinoptilolite precipitated from connate pore fluid.

The form of clinoptilolite crystals in the Mississippi materials is more like a potassium feldspar rather than henlandite (Reynolds, 1983). Often one can observe twinning of clinoptilolite crystals of either the carlsbed or manebach type. Furthermore, it appears that soon after a crystal has formed it begins to deteriorate (Figure 21a, c and d). It has recently been suggested that clinoptilolite deposits in humid areas such as the Coastal Plain of Southeastern United States are comprised of crystals formed in fluid filled pores which may or may not be relict bubble structures. Crystal growth proceeds to a point when there is a change in pore fluid chemistry at which time the fluids attack the crystals producting crystal degradation (Reynolds, 1983).

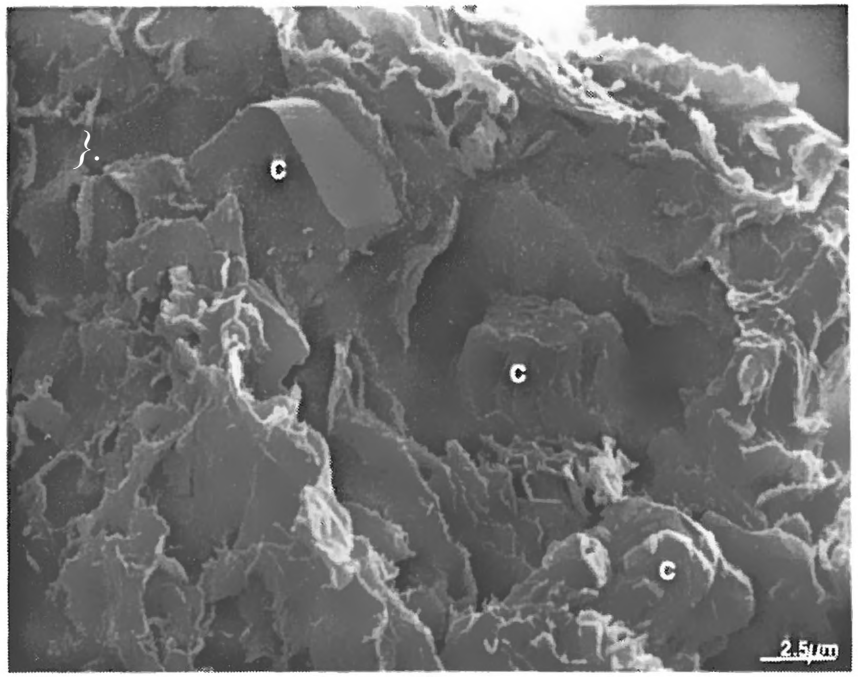
Figure 20

a. Section 55A (Interstate 20)
Sample 80.10
320x Magnification
Low Magnification SEM surface sean of material from the upper zeolitic clay bed. Surface appears to have a relic pyroclastic texture.

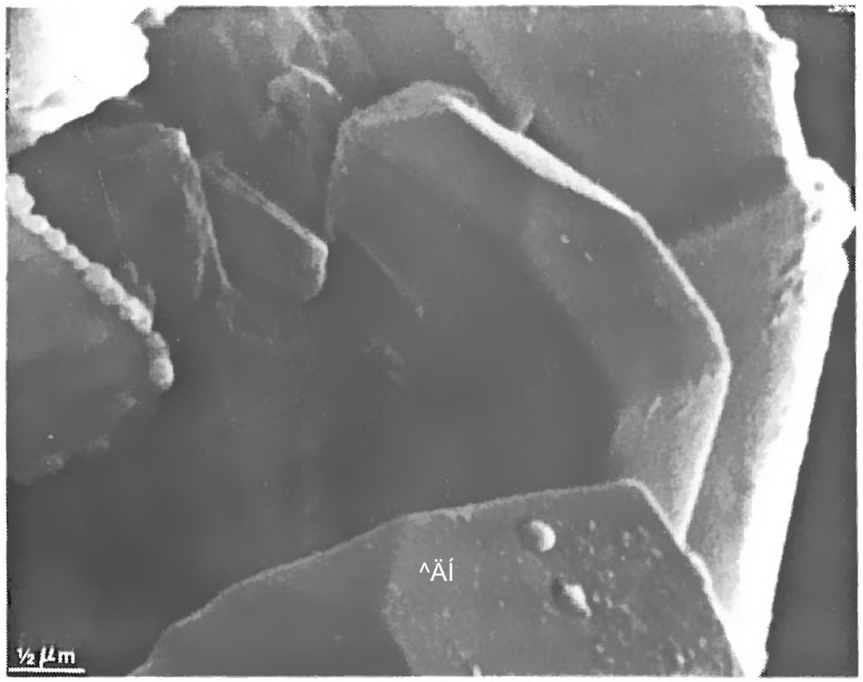
b. Section 55A (Interstate 20)
Sample 80.10
7780x Magnification
High magnification SEM surface scan of authigenic montmorillonite.

c. Section 45 (Valley Road)
Sample 53.33
5238x Magnification
SEM identification of a well formed clinoptilolite crystal with no indication of crystal deterioration.

d. Section 55A (Interstate 20)
Sample 80.10
21400x Magnification
SEM identification of a clinoptilolite crystal showing well formed 010, 110, 101, and 100 faces.

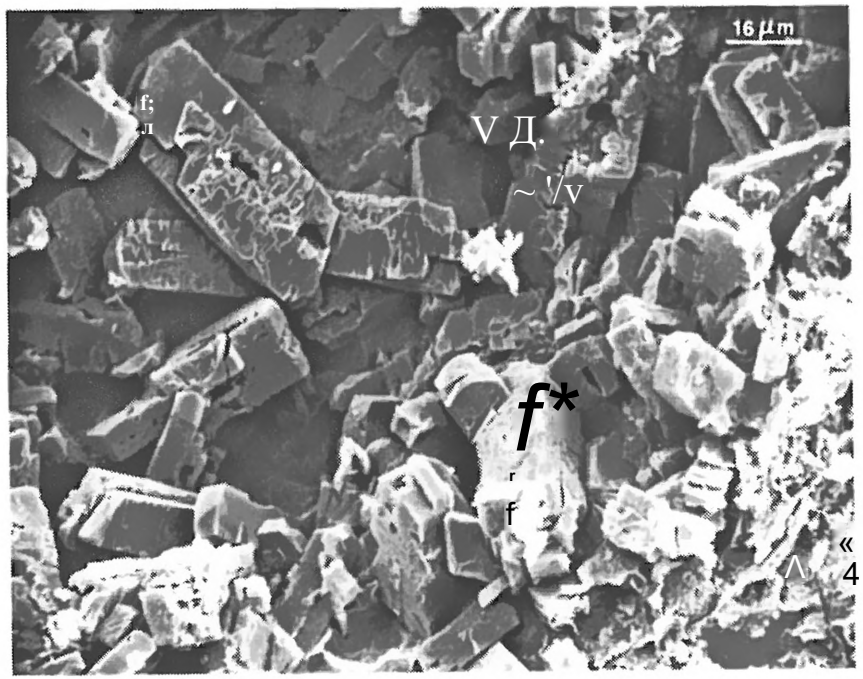


a

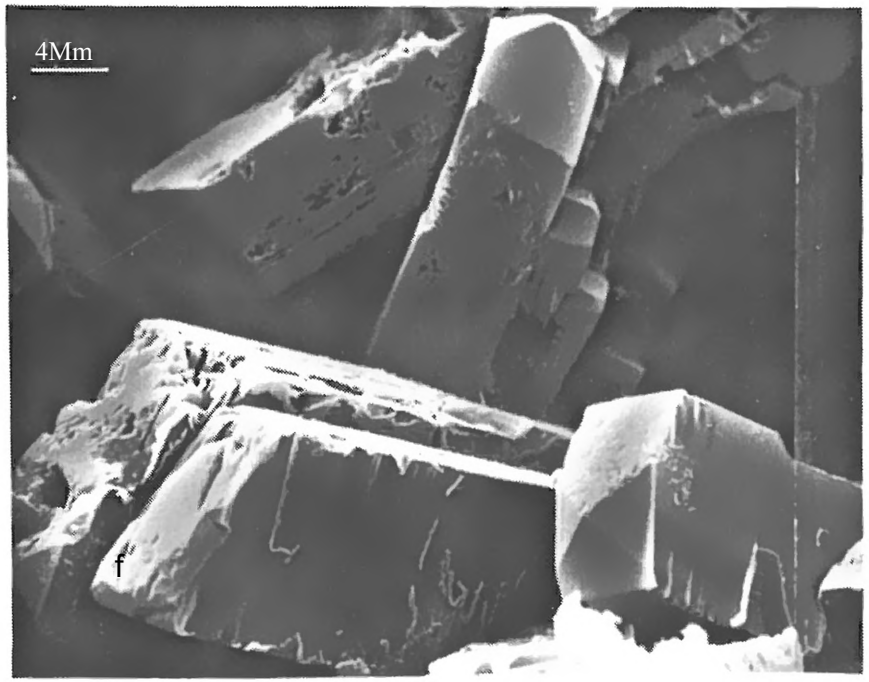


b

2



c



d

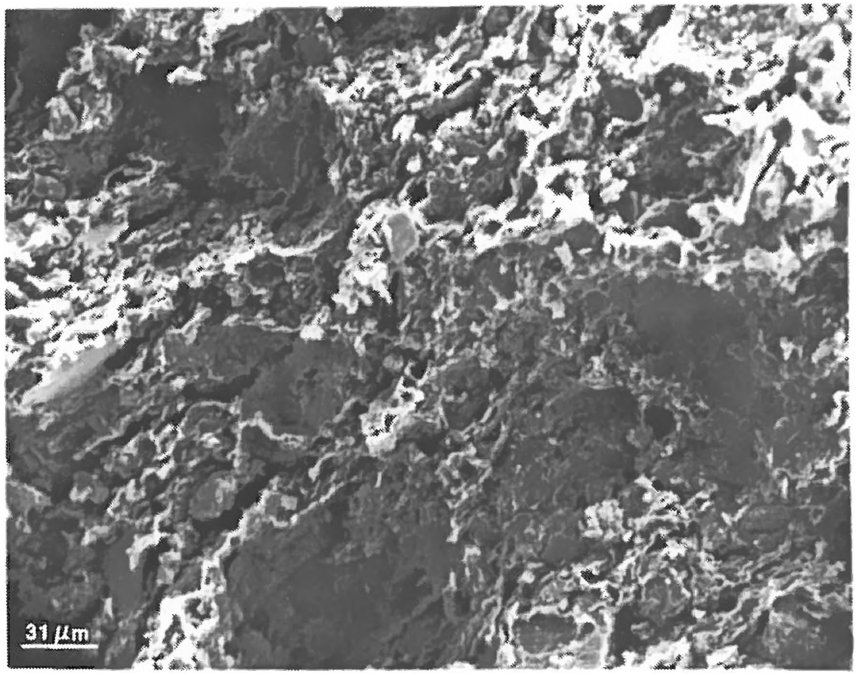
Figure 21

a. Section 55A (Interstate 20)
Sample 80.10
4000x Magnification
SEM micrograph showing different states of clinoptilolite crystal deterioration. The three crystals of interest, marked with c, are encased in authigenic montmorillonite.
The Crystal at the upper left shows little alteration, the central crystal shows the effects of severe leaching, and the crystal in the lower right has undergone almost total deterioration .

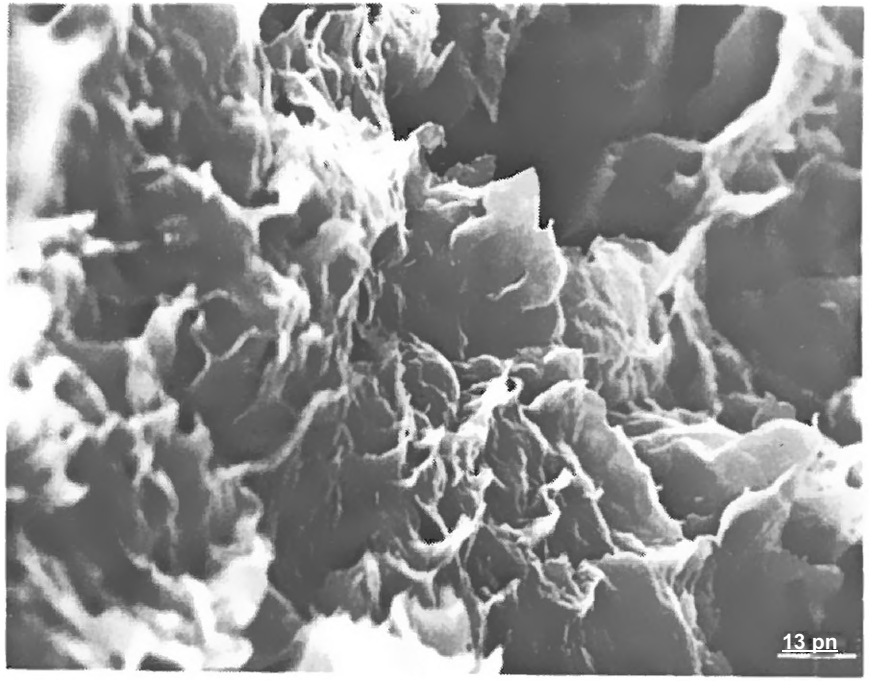
b. Section 50 (Savoy Road)
Sample 69.76
22470x Magnification
SEM micrograph of well formed clinoptilolite crystals. Note at left side of photo the beads of incipient montmorillonite along a crystal face boundary.

c. Section 52 (Arnndel)
Sample 76.1
644x Magnification
SEM micrograph showing a cluster of clinoptilolite crystals in various stages of deterioration.

d. Section 52 (Arnndel)
Sample 76.1
2600x Magnification
SEM micrograph of c above at increased magnification to show incipient montmorillonite in the form of "tooth-paste" and "sheet" structure along cleavage planes.

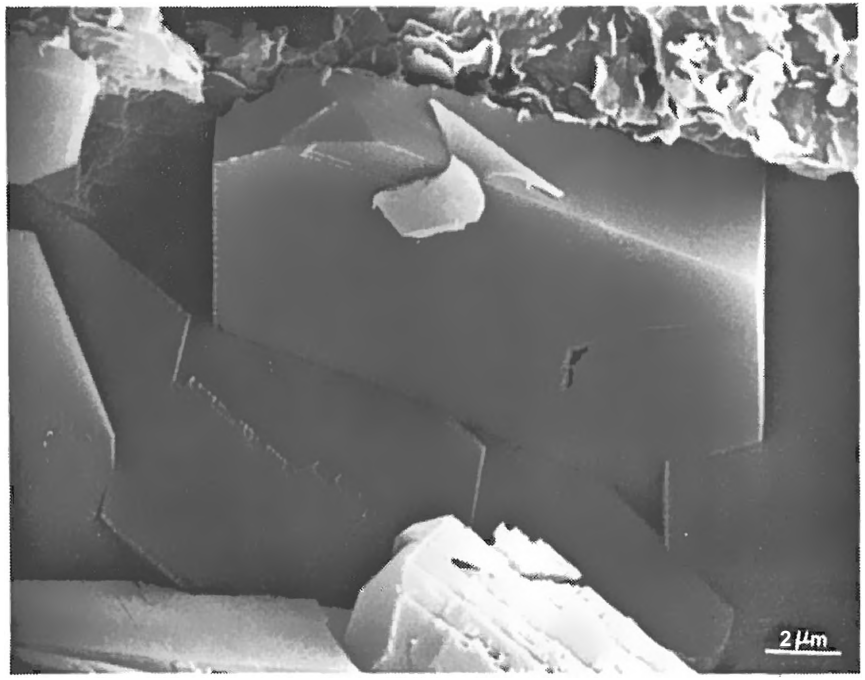


a



b

1



c

d

11 i. ís n o t k n o w n p r e s e n 11 y w h e t h e r o r n o t t h e T a 11 a h ¿à 1.1 a c Mississippi i sì produced from the alteration o-f a volcanic precursor. The montmorillonite observed occurring with the clinoptilolite is possibly an initial authigenic product from the alteration of volcanic ash. If this is the case, clinoptilolite then is a later formed product growing in pore spaces provided by relic bubble structures. On the other hand, close examination of clinoptilolite crystals in various stages of deterioration reveals incipient montmorillonite in the forms of "beads" (Figure 21a) or as "toothpaste" lines (Figure 21a and c) and "sheets" (Figure 21d) along either crystal face boundaries or cleavage plane junctures.

M IN E B A L 0 C C U R R E N C E

X-ray and SEN investigations were significant in determining the existence of clinoptilolite besides crystal morphology and to some extent mineral quantity in material sampled from wackes, muds and clays of the Tallahatta Formation. These analytical methods however did not lend much insight into the modes of mineral occurrence or mineral genesis. Therefore, for this phase of investigation it was decided that in addition to x-ray and SEIM analysis there should be a return to the "basics"; petrography.

Petrographic characterization of clinoptilolite was based upon optical e x am i nat i on o f t h i n-sect i ons pr ep a r ed using out c r op e x pos ure and cor e samples b o t h the T ¿A 1 1 a h a 11 a a n d Z i 1 p h a F o r m a t ions. T o c o m p 1 e m e r 11 t h e t thirty samples were disaggregated, separating the coarse fraction (62 urn) for optical examination in immersion oils with refractive indices of 1.54. Samples were selected for thin-section examination based on mineral content as revealed by examination of x-ray data. The samples were selected to represent different-combinations of zeolite concentration and mineral association, and minerals were identified using standard optical methods.

Detailed petrographic description of each thin-sec tion and grain mount was

beyond the scope and purpose of this study. Rather, a summary of the general characteristics of both thin-sections and grain mounts is presented here, with thi p e t r o g r a p h i (I c h a r a c t e r o f c lino p t i 1 o 1 i1 e r e c e i v i n g a mor e d e

The detrital component of the thin-sections studied consisted mostly of angular silt-sized quartz grains, crudely oriented laths of white mica, and more rarely alkali feldspar. The ground mass consisted of smectite and opal-CT (verified by x-ray diffraction). Texturally the samples are muds, silts and clays, as material coarser than 62 microns was not common. Bright green glauconite grains occurred in all thin-sections and most grain mounts. Usually these grains were elipsoidal to spherical in shape and of uniform size. Rare subhedral glauconite grains were also observed. Occasionally the elipsoidal and spherical glauconite grains are with cracks filled with a matrix material, probably opal-Ct. Glauconite was also found to replace organic remains such as the central canals of sponge spicules. Pyrite was found in most all the thin—sections and grain mounts, and was usually associated with organic material and often occurred as single cubes or framboidal masses. Completely pyritized microfossils of diatoms, sponge spicules were observed. Opaque to semi—opaque organic material was common in the smectite-rich samples. Microfossils are abundant in all samples and consist mostly of diatoms, sponge spicules and more rarely r ad i o 1 ar i ans. Calcareous microfossils, mostly chambered f orami ni f erans and some calcareous algae were observed in a few samples. The most common accessory h e av y mine ra1 s ob served i n c1 u ded r ound ed z i rcon, horn blende and s t au2 o1 ite, a n d r a r e 1 y p hi o s p h a t e g r a i n s.

In both thin-sections and grain mounts clinoptilolite exhibits prismatic and tabular crystals having a monoclinic outline (Figure 22c). These crystals range in size from barely discernible under highest magnification to well -formed crystals up to a maximum of 40 microns. Average crystal size was about 15 to 20 micrometers. Observed clinoptilolite has a refractive index of approximately 1.48

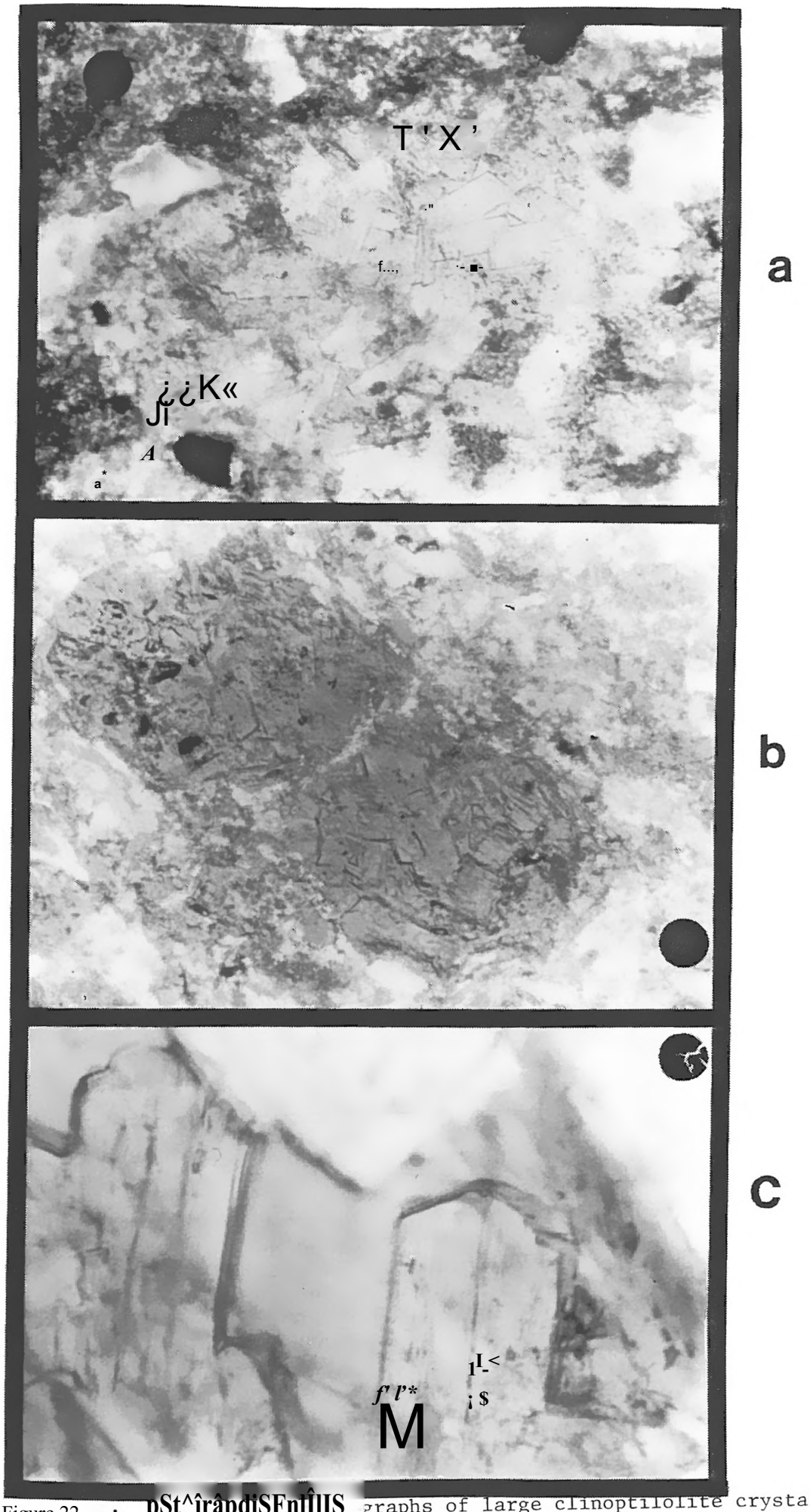


Figure 22 : pSt^îrâpdiSFnlîlIS graphs of large clinoptilolite crystals filling large pore spaces. Dot scale for a and b is 50m and for c is 25m/-..

which is in agreement with the index given by Boles (1972) and Mumpton (1960). Under pl sin light clinoptilolite is colorless to light violet and has a strong negative relief. Under crossed polarizers clinoptilolite shows dark to pale grey -firs t - orde r i n t e r f e r enee co .1. or. This t e n d e n c y f o r ci a r k i n t e r -fer the small size makes optical determination difficult in thin-sectior though a well-formed biaxial figure can be obtained with difficulty from some crystals. Clinoptilolite crystals were usually euhedral, commonly twinned and inclusion free. Corrosion of individual crystals is apparent, in some samples, though it it not common.

Clinoptilolite observed in thin section and grain mounts from the operational units in southeast Mississippi has several different petrographic modes of occurrence, which are classified into the following groups.

(1) . Clinoptilolite occurs as matrix—cement of silt to sand sized particles, an occurrence which could only be observed in thin—section (Figure 23). The clinoptilolite in this category appears to grow within the pore spaces between angular particles of quartz, occasionally mica, and rarely feldspars. Other particles making up approx i matei y 5 to 10 percent of the coarse fraction include abundant sponge spicules and diatoms and more rarely radiolarians. Glauconite grai ns and opaque organic particles were also present in the coarse fraction. Where other matrix material was associated with clinoptilolite, opal—CT was more common than was smectite. One should note in Figure 23 the sharp angularity and embayment of quartz particles. These particles more often than not exhibit straight extinction. Both of the above aspects suggest the quartz to be volcanic. Also, in Figure 23 note the wavy or undulóse structure of the clinoptilolite matrix which appears as a pyroclastic fabric similar to authigenic montmor illonite.

(2) . Clinoptilolite occurs as a mineralization product within dewatering veins and sheets (Figure 11) where it either fills the veins or sheets or only

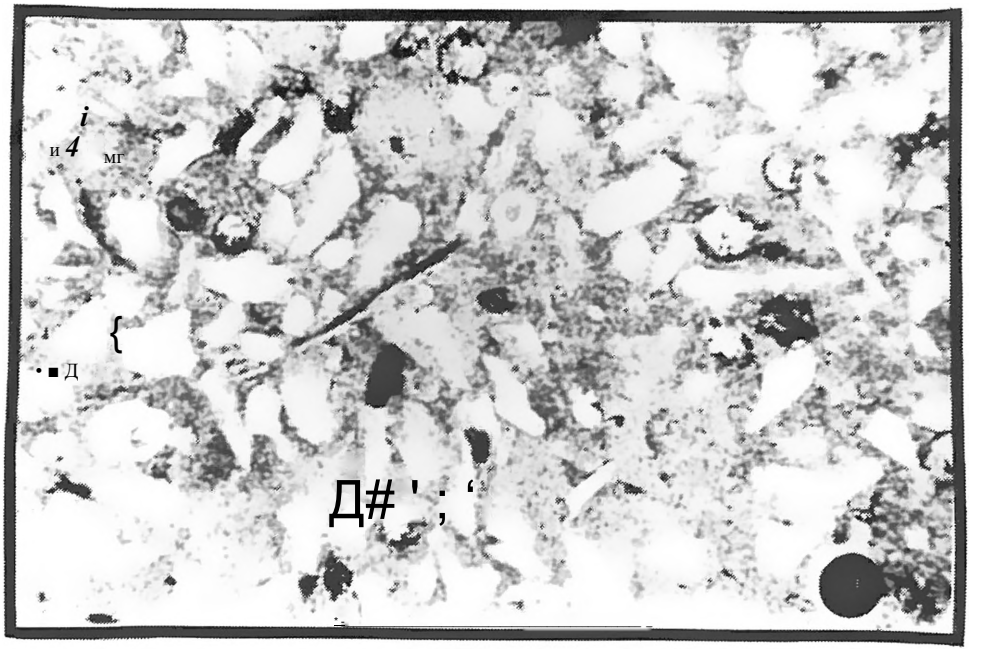


Figure 23: Petrographic micrographs showing pyroclastic fabric and clinoptilolite infilling of microfossils (upper) and clinoptilolite as a cement (lower). Dot scale is equivalent to IOOιηχ.

lines the perimeter (Figure 24c). It appears; that clinoptilolite growth proceeds from the vein or sheet wall inward which suggest preci pi tati on from fluids moving n o t o n l y t h r o u g h b u t in t o t. h e v e i n s and s h e e t s.

(3) . Clinoptilolite occurs as a replacement material in voids of microfossil! and shell fragments. These voids are formed by the dissolution of diatoms, spongi spicules, forami niferans and radiolarians are often filled by blocky crystals of clinoptilolite whereas others seemly have converted to opal-CT (Figure 23). Replacement involves dissolution and reprecipitation which destroys most of the textural aspects of the microfossils even though the relative size and shape remain the same. Grain mounts offer a better means of observing the replacement. type of clinoptilolite growth which seems to be toward the center of such voids Pyrite is neari y always found associated with clinoptilolite within these voids.

(4) . Clinoptilolite occurs as a direct transformation product of siliceous microfossils. This mode of zeolite occurrence involving siliceous microfossils was very apparent with optical examination of grain mounts. Clinoptilolite o c c u r r" e n c e i n t h i s m a n n er s u g g e s t s t. h e a p p ¿A r e n t d i r e c:: t t r microfossils to the zeolite without involving dissolution since the external structural integrity of the microfossil is retained (Figure 25c). This also may suggest material packed into the microfossil test after death and subsequently converted to clinoptilolite.

(5) ., The prominent occurrence of clinoptilolite is in large pore spaces (Figure 24a and b) where crystal clusters are seen growing from the walls or the central p or ti ons of the pore spac es. Thi s oceurr enee li ke that i n dewater i ng viens and sheets suggests clinoptilolite precipitated from fluids either that have moved through a buffering matrix into the pore spaces or were already occupying the pore spaces and responded to a physical stimulus such as temperature change and/or compaction pressure.

(6) . Clinoptilolite occurs as an encrusting material on detrital grains.

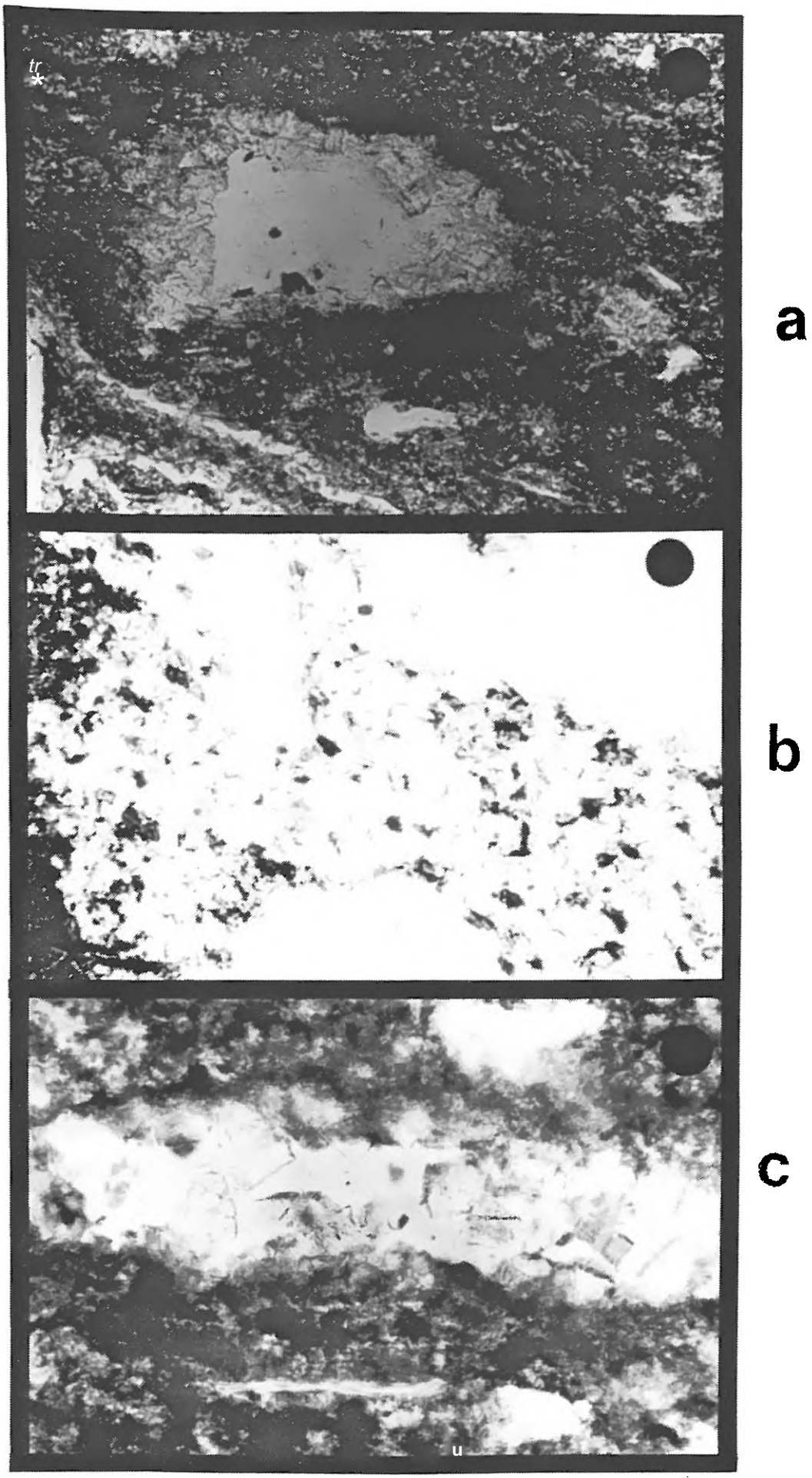


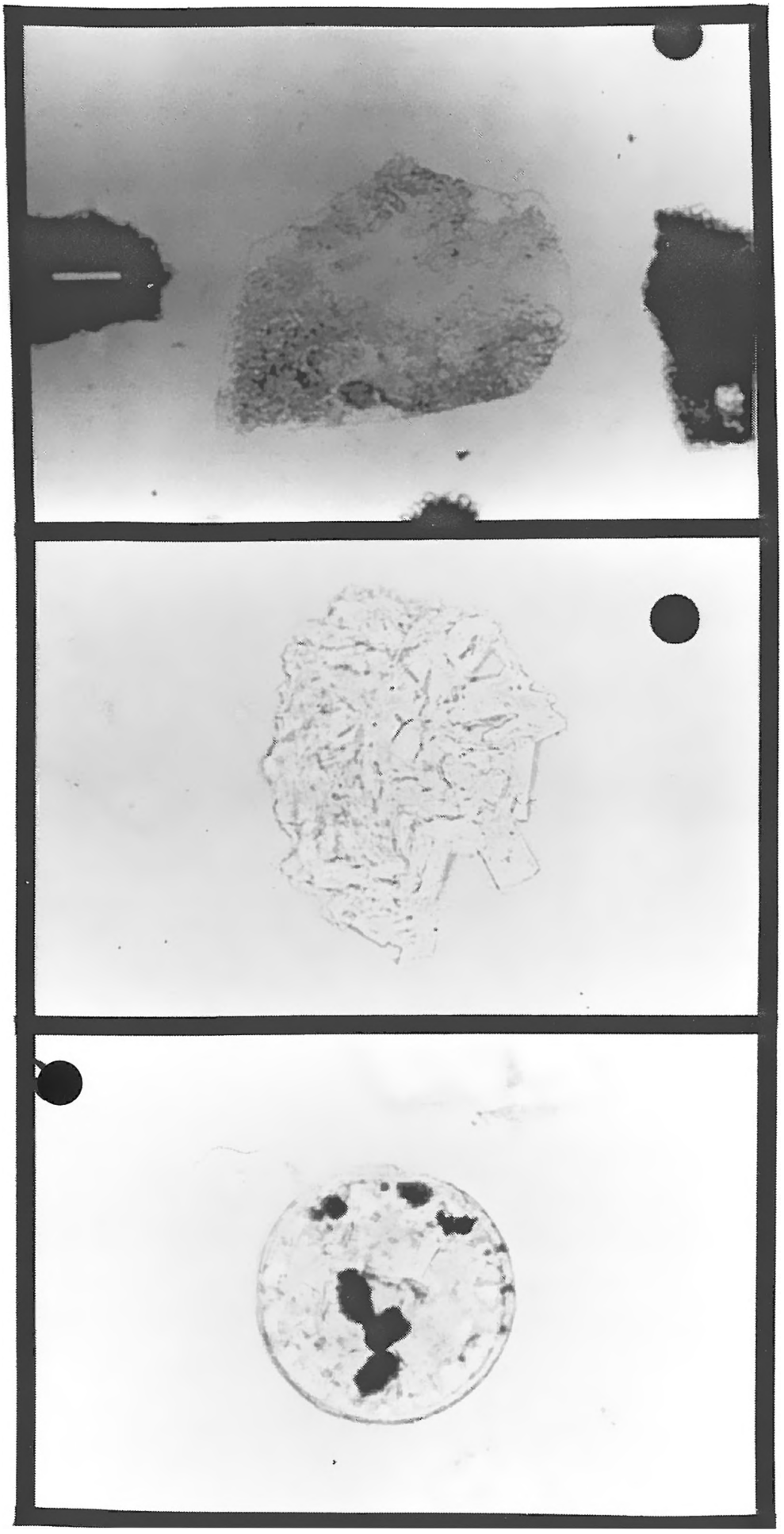
Figure 24: Petrographic micrographs showing clinoptilolite infilling large vugs (a and b) and dewatering veins (c).

This final category is most obvious observed in grain mounts rather than thin section. Here, clinoptilolite crystals encrust, quartz, mica and possibly feldspai grains, and there appears to be no dissolution, alteration or transformation involved between the clinoptilolite and the detrital mineral grain (Figure 25a ant b). This association indicates clinoptilolite probably grew into pore spaces surrounding the detrital material from the grain surfaces thus becoming the grain to grain cement of the lithified wackes and muds (Figure 26).

Th i n-sect i on and grain mount, examination revealed no conclusive textural evidence to suggest a precursor pyroclastic material ever being present in the Lower Claiborne sediments of southeast. Mississippi. According to Ross (1928) and Ross and Smith (1961) pyroclastic sediments have characteristic structures produced by the fragmentation of globular bubbles which produce curved plates, cusp and lunate shaped, and Y and U shaped shard particles. In addition, a definite mineral association is often present including: idiomorphic zircon, euhedral brown biotite, euhedral quartz with embayed structure, subhedral sanidine with irregular embayed fractures, hornblende and pyroxene.

Authigenic feldspar was identified in some samples, usually first revealed by analysis of x-ray patterns.. A cursory examination of fine sand from various positions in the Basic City showed a surprising abundance of sponge spicules and diat o m f r u st u 1 es associat e d w i t h z e o 1 ite. 01 h e r , p e r hi a p s u n u s u a 1 , n o t e d i n d i s a g g r e g a t e d Z i. 1 p h a a n ei s o me T a 11 a h a 11 a s ¿i m p 1. e s aggregates of sponge spicules surrounded by matrix of light brown (clay mineral) material are commonly observed. These aggregates also contain bright green glauconite part, ici es, quartz grains and opaque organic materials. Disaggregation of samples containing a high opal-CT content also revealed this same aggregate feature. Close inspection of individual "grains" in grain mounts indicated they were composed of skeletal fragments of diatoms and or radi olari ans in a pale brown cement.

Figure 25 : Photomicrograph of grain mounts showing.



a

Clinoptilolite encrusting a mica grain. Dot scale is equivalent to 50m¿<.

b

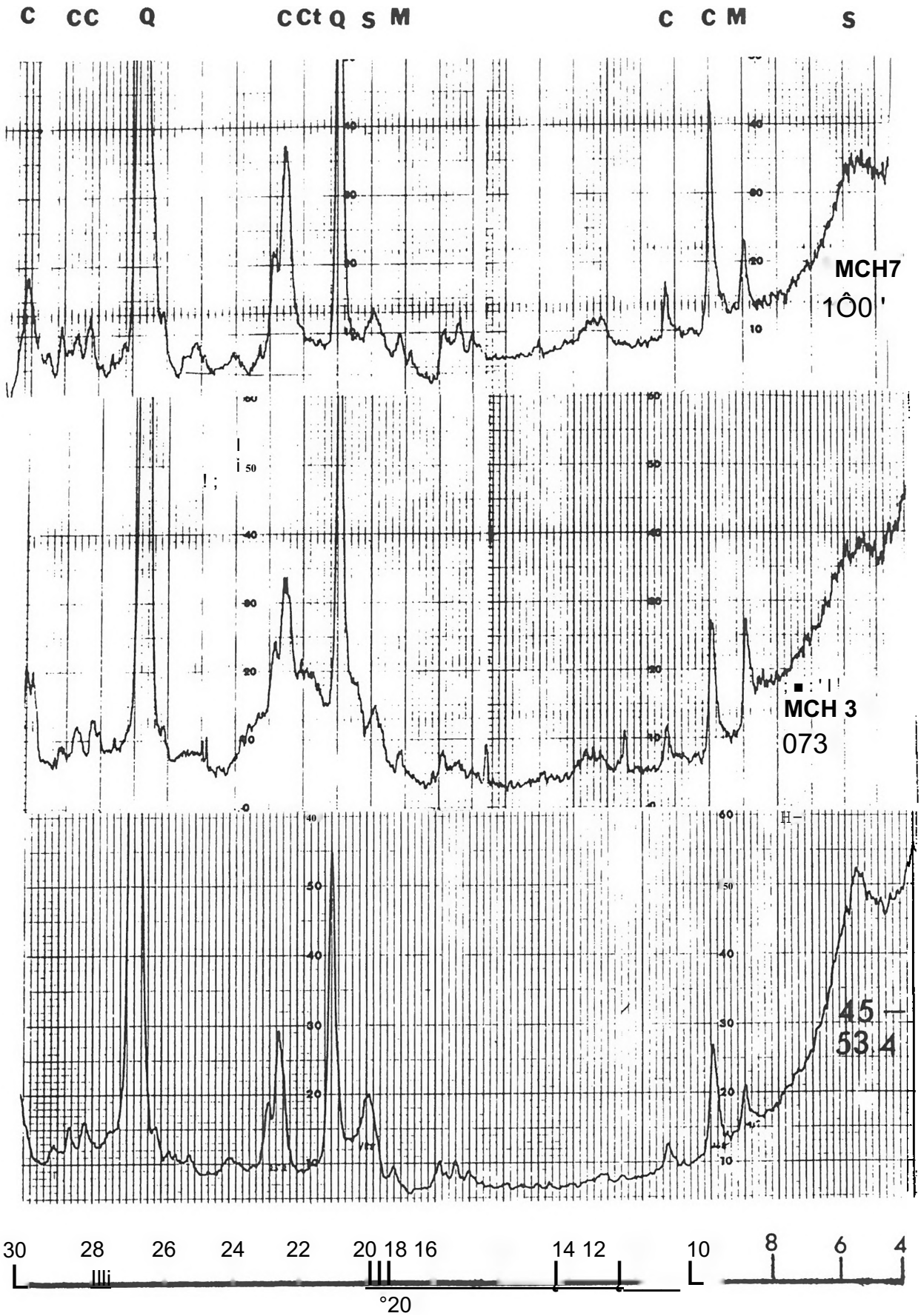
Clinoptilolite encrusting a quartz grain. Dot scale is equivalent to 50m/x.

c

Clinoptilolite completely enclosed within a radiolaria test. Dot scale is equivalent to 25тп>и.

Figure 26 : X-ray diffraction patterns of selected sand strata which contain clinoptilolite as a matrix cement.

CLINOPTILOLITE AS A CEMENT



D X. E? У. У s § λ Q D

EE v e n t h o u g h t h e ¿A n c:: i e n t M i ss i s s i p p i e m t) a y m e n t. w ¿A S g e t. h e c: h a r a c t. e r i s t i c ss c J f s e dime n t. a t i. o n p t- o c. e s s-s e ss and r e •found along the mesotidal coast of a shelf sea with incorporate depositional environments as tidal flats, barred coastal areas, open beaches and nascent deltas. During Wilcox and early Claiborne time the western and northwestern portions of the embayment were lined with large coalescing delta complexes (Duplantis 1975). On the other hand, along the eastern and southeastern portion smaller Wilcox deltas easily gave way to wave dominated coasts which seaward boardered a broad shallow marine shelf.

The lithologic units of the Tall ahata Formation in the area of Meridian, Mississippi reflect, a marine transgr essi on-r egressi on cycle, beginning in the upper Meridian Sand and continuing into the Koscinsko Formation. Mainland beach, barrier beach, delta front and tidal flat sands of the Meridian Formation give way to transi ti onal wackes and muds of an early Tallahattaa marine transgression from the southwest and extending beyond Meridian, Mississippi. The transgressive processes abated during the middle tallahatta with the deposition, under low energy conditions, of siliceous clays over a broad tidal flat shelf. During this time however were numerous short periods of coastal progradation and retrogration r e p r e s e n t e d by sediment dis t r i b u t i on c h ara c t e ri st i c o f n u m e r o u s s local li zed transgressions and regressions.

The lithofacie associations observed in the upper tallahatta suggest this time to be a period of marine regression. This was a time when coastal nearshore and foreshore plus nascent delta environments moved seaward to the southwest over the previous broad tidal flat shelf. The thickness of unit ft strata indicates the regressive phase to have occupied more time than the transgressi ve phase. However, there is little evidence in unit ft strata that suggests rapid tr ansgr essi on. The difference must lie in the aspect that more t err i geneous

m a t erial was s u p p 1 i e ei t. ot h e d e p o s i t i on a 1a r e a ísd u r i. n gt h ere g r e d u r i r ɪ g t h e t r a n s g r e s s i v ep h a s e-

C 1. .ị D. 9 P. t í L Q1 í. t æ E C! Ł Φ É t .Ł Q Π

Obviously the tal .1 ahat, t a sedimentsrepresent a period of extensive silica deposi ton. The initial deposition of silica would have been in the form of opal-C (Carver 1980) which presently is undergoing transformation to quartz through the opal-Ct phase. Deposition of material eventually altered to clinoptilolite was apparently concomitant in time to the deposition of silica. Sites of clinoptilolite precursor deposition appear to have been segregated subenvironments on the shelf and along the coastal regions. Such segregated sites include a variety of entrapment depocenters, mainly nearshore runnels, lagoonal troughs, anc back barrier inter t.idal zones.

Cryptocrystalline clinoptilolite crystals disseminated in argillaceous sediments consequent with the occurrence of clinoptilolite as much larger euhedral crystals in-filling varaus microfossil voids, sponge spicules and anomalous vugs and pores suggest clinoptilolite to be an authigenic mineral formed through preci pi tation from interstitial solutions. Furthermore, clinoptilolite growth in dewatering veins and sheets and as a cement, matrix suggest, post-burial migration of pore solutions prior to clinoptilolite formation. Growth of clinoptilolite within diatom and other siliceous fossils could be evidence for direct, in situ transformation with no apparent dissolution and reprecipitation phase (Curtis and Cornel 1 , 1972; Fan and Zemmels, 1972; Burger and van Rad, 1972; Lancelot, 1979; Houghton, et. al. 1979; and Riech, 1979).

There is only scanty petrographic evidence that volcanic ash was a major source of si lica in the Tallahatta and Zilpha sediments. This may be due the fact that in nearshore environments strong currents and high production of biogenic material may have rework, redi str i bute and dilute pyroclastic material so that it is less easily recognizable in these types of deposits (Hathaway et al, 1970).

Boles and Wise (1978, p» 239), discuss the occurrence of clinoptilolite in deep-sea sediments and suggest, that if clinoptilolite is formed only from glass then the majority of clinoptilolite occurrences should be associated with ash beds, and concluded that the majority of deep-sea clinoptilolite is not associate! with volcanic glass. Furthermore, Kastner and Stonecipher (1978) report that onix twenty to twenty-five percent of the deep-sea clinoptilolite occur in sediments that are prdominantly volcanic.

The presence of abundant siliceous microfossils in various stages of dissolution somewhat supports the hypothesis that they contributed to the vast, amount of silica deposited during Tallahatta time. Hein et al. (1978), in a study of sediments from the Berincj Sea, derived a similar hypothesis for ¿A biogenic contribution to the formation of clinoptilolite in those sediments. .pa
The absence of petrographic evidence of pyroclastic material in Tallahatta sediments does not however preclude the existence of such. Perhaps a cause—and-effect relationship between volcanic activity and biogenic deposition is possible. Reynolds (1970) has pointed out that the clinoptilolite-rich strata in the fall ahatta Formation of Alabama may have had a volcanic precursor, but also suggested that volcanic ash could not have been the precursor of the opal-CT.

In this study it was found that clinoptilolite is more likely* to be associated with detritial sediments than with large amounts of opal.....CT. This relationship suggests that clinoptilolite formation is more favorable in sediments with some terrigenous input while? opal-CT formation is favored when there is a minimum of terrigenous input. Kastner et al., (1977) has shown that the rates of dissolution of opal-A (biogenic) and recrystallization of opal-CT is inhibited by the presence of clay minerals. Houghton et al. (1979), reports that high c a r bona t e con t e n t p r o h i b its c 1 i n o p t i 1 o 1 i t e g r o w t h a n d e v e n p r dissolution. Nathan and Flexer (1977) have noted the negative correlation between opal-CT and clinoptilolite and suggest, that clinoptilolite formation is favored by

h i. g h e r t h a n n orma J. c o n c e n t ratons o f m a. g n e s i u m.

Tradì ti onal 1 y Zeolite -formation is considered as an alteration process of volcanic, glass; a concept well documented for most categories; of zeolite occurrence in a variety of sedimentary environments (Hay, 1978). In this study however field and laboratory investigation failed to produce strong evidence of a volcanic ash precursor for clinoptilolite formation. This does not suggest, however, that the volcanic precusor was not there. Alternatively, results of petrographic study show that a biogenic contribution of silica was possible as clinoptilolite has been observed in void spaces provided by dissolution of siliceous as well as calcareous microf ossi is. Therefore, it seems plausible to suggest that clinoptilolite in Tal ihatta sediments may owe its origin, at least in part, to silica derived from the dissolution of siliceous organisms. Stratigraphic positioning and mineralogic relationships by the simplest of interpretation indicate clinoptilolite formation is more favorable when a clastic component has diluted biogenic sediments, whereas opal-CT formation is more likely in sediment havei ng a greater proportion of biogenic silica.

The major source of silica is thought to be the same for both clinoptilolite and opal-CT formation, and deposi tonal environment is thought to have played a significant role in influencing the formation of either mi neral. The absence of opal—CT in the zeolitic beds of both unit A and unit C is thought, to have resulted from a number of factors. First, in the lower and upper beds of the Tallahatta a g r e a ter- c o n t ent o f c o a r s e - g r · a i n e d m a t e r i a l prod u c e s h i g h e r p porosity and permeability which could have enhanced the formation of clinoptilolite by allowing easier migration of reactive ions in silica-rich fluids. The upper and lower units are also highly bioturbated, which suggests organic activity may have been an effective agent for clinoptilolite formation. Finally, pyri tized organic material such as plant remains and diatom frustules indicate reducing post-depositional conditions.

The one discrepancy concerning clinoptilolite formation from siliceous biogenic materi al is the lack of an apparent aluminum source. In the case where clinoptilolite forms from a volcanic precursor this source is readily apparent. However, diatom frustules and other siliceous microrganisms are reported to contain only a minor amount of aluminum (0.5 ppm). Hein, et al. (1978) support a biogenic source of silica for clinoptilolite formation, but suggest that the reacting system in which clinoptilolite forms must derive its necessary aluminum through the dissolution of amorphous clays.

Their work suggest that diatom debris, already covered with clay-like minerals, might serve as nucleius for authigenic mineral formation such as clinoptilolite. Smectite has been reported to be present in living diatoms the frustules of which are reported to contain up to 1.5 percent aluminum (Van Bennekum and Vander Gaast , 1976). This may suggest diatom debris, already covered with clay-like material, might serve as a nucleus for authigenic mineralization such as clinoptilolite formation.

When considering all of the evidence it seems highly unlikely that dissolution of siliceous microorganisms would provide an adequate amount of necessary ion constituents to form clinoptilolite. Evidence is strong however for the preci pi tation of clinoptilolite from interstitial fluids. From where do these fluids incorporate, to a state of saturation, the necessary ions? Detrital clay h a s been one s u g g e s t ion. U n f o r t u n a t e 1 y mos t o f t he s m e c: t i t e o c c u clinoptilolite is also authigenic. Clay and zeolite can form from the same precursor material which is evident in the recent Mt. St. Helens ash falls (Revier 1982) ..

Mol for mol clinoptilolite is composed of the same ions found in ryolitic ash however, montmorillonite requires only half the silica and some magnesium (Reynolds, 1970). Therefore, montmorillonite could be produced by the deterioration of the first formed clinoptilolite which originated by precipitation

+ r om pare waters enriched by the dissolution o(v o 1 c an i c a s h .

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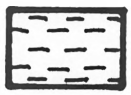
APPENDIX A

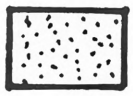
CORE LOGS

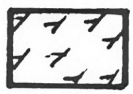
CORE LOG KEY

LITHOLOGY

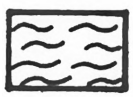

CLAY


SAND (WACKE)


SAND (ARENITE)

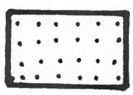

OPALINE CLAY

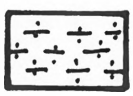

CLAYSTONE OPAL CT


SILT & SILTSTONE


CHERT


MUD


SANDSTONE


MUDSTONE

ALPHA NUMERIC

A1 MICACEOUS
A1a SLIGHTLY MICACEOUS
A2 GLAUCONITIC
A2a SLIGHTLY GLAUCONITIC
A3 PYRITE
A4 OPAblNE
A5 OPALINE CEMENT
A6 CHERTY
A7 GYPSUM
A8 FERRUGENOUS
A9 ARGILLACEOUS
A10 CALCAREOUS

B FOSSILIFEROUS
BI BIOTURBATED
B2 PLANT REMAINS

CI MASSIVE BEDDING
C2 LAMINAR BEDDING
C3 TRANSITIONAL
C4 DENSE

DI BLOCKY
D2 CHONCOIDAL
D2a SEMI-CHONIOIDAL
D3 FRONDESCENT OR VEIN STRUCTURE
D4 MOTTLED
D5 CROSS LAMINATION
D6 FISSIL

E SECONDARY SULFATES

F LIGNITIC

G1 COURSE TEXTURE
G2 MEDIUM TEXTURE
G3 FINE TEXTURE
G4 PLASTIC
G5 WAVY
G6 SILT LAMINAE OR STREAKS
G7 SAND LAMINAE
G8 CLAY LAMINAE
G9 BRITTLE
G10 SHARP
G11 CLAY BLEBS
G12 QUARTZ PEBBLES
G13 CLAY PEBBLES
G14 SILT BLEBS
G15 SILTY
G16 OPALINE BLEBS

H1 SAND FLASERS
H2 LENTICULAR BEDDING
H3 WAVY BEDDING
H4 SAND BLEBS
H5 SANDY

SECTION NO: [illegible] CORE 1 EXPOSURE ___ SERIES: ___

STATE: Mississippi COUNTY: Lauderdale

SEC. 34 T. 7N R. 14E

TOTAL DEPTH: 195 ft. CORE INTV. ___ MISSC. INTV.: 54.7 ft. RECOVERY: [illegible]

DEPTH	SAMPLE	LOG	LITHOLOGY	COLOR	ACCESSORY INFORMATION
FT./M					Missed out 9 feet
10					Missed, prob. Winona Sand
	001 → 002 →		CLAY	Ochre	Massive; blocky; s. t. [illegible] al. micaceous; plant [illegible]
20 6.1					Missed, prob. sand below
			SAND(wacke)	Ochre	Quartz, crs. to med.; glauc.; clay & qtz. pebbles
30 9.1					Missed, prob. above sand
			SAND(wacke)	Ochre	As above
	003*		CLAY	Ochre	Massv-lamin; crs. texture; ferro.
40	004*		CLAY	Gr.-Green	Massv.; crs. texture; Bd. Flasers; glauc.; mica; blocky
12.2	005*		CLAYSTONE	Gr.-Green	Opaline; fn. texture; mica
			SANDSTONE	Buff	Opal cement; fn. qtz. wacke
					Missed, prob. a sand
50	006 →		CLAY	Gr.-Green	Massv.; crs. texture; blocky; [illegible] appears vitroclastic
15.2	007 →		CLAY	Gr.-Green	Massv.; opaline; sandy; crs. t[illegible] lignite str.; glauc.; cherty
	008*		CLAY	Gr.-Green	Fn. texture; massv.; silt str.
60			CLAYSTONE	" "	Massv.; hard; opal; brittle
18.3	009 →		CLAY	Gr.-Green	Massv.; opal; crs. texture; sandy;
	010 →		CLAYSTONE	Gr.-Green	Massv.; opal; fn. texture; soft-hd; vein st.; cherty
			SILT	Buff	
70	011 →		CLAYSTONE	Gr.-Green	Massv.; hard-sft.; chonoid.; glauc sand strc.; cherty; opal; crs. texture
21.3	012 →				
			CHERT	Grey	[illegible]; plastic; plant fos.
			MUD	Gray	
80	013 →		CLAYSTONE	Gr.-Green	[illegible] texture; fos.; [illegible]
24.4			CHERT	Grey	
	014* 015*		CLAYSTONE	Gr.-Green	[illegible] texture [illegible]; b[illegible]
90			CLAY	Gr.-Green	
27.4	016* 017 → 018*		CLAYSTONE	Gr.-Green	Massv.; fn. texture; sand filled burrows; fos.; soft; mica; chert
	019** 020**		CLAY	Gr.-Green	Massv.; crs. texture; fos.; mica; sandy; blocky
100 30.5	021**		CLAYSTONE	Gr.-Green	Massv.; crs. texture; chert; bioturb
			CHERT	Gr.-Green	
			CLAYSTONE	Gr.-Green	Lamin.-massv.; fn. texture; soft; mica; vein struc.; glauc.
110 33.5			SANDSTONE	Olive	Quartz wacke; med.grd; glauc.; opal blebs; opal matrix
			SAND(wacke)	Olive	Quartz, med.-crs. grd.; glauc.; fecal pellets; qtz. pebbles in lower foot
120 36.6	022** 023**		MUD	Gr.-Green	Mica; burrowed; glauc.; sand blebs
			CLAY	Gr.-Green	Massv.; fn. texture; plastic
			MUD	Gr.-Green	As above
			SAND(arenite	White	Quartz, fn.grd.; lignite
					Missed, above sand (Meridian)
130 39.6			CLAY	Chocolate	Lamin.; fn. texture; plastic; carbonaceous
140 42.7					
150 45.7			MUD	Grs.-Green	
160 48.8					
170 51.8					
180					Missed, possible sand
54.9				Gr.-Green	(Hatchetigbee)
					Missed
190 57.9				Gr.-Green	(Hatchetigbee)

SECTION NO: MCK 2 CORE I EXPOSURE ___ SAMPLE SERIES: _____ PAGE ___ OF ___

STATE: KIRTLAND ___ COUNTY: LAUDERDALE QUAD: CHURCH HV ___ ELEV.: 472'

SEC. 10 T. 6N R. 14E GRID COORD.: [illegible]

TOTAL DEPTH: 199 ft. CORE INTV.: 190 ft. MISSG.INTV.: 51.5 ft. RECOVERY: 87%

DEPTH	SAMPLE	LOG	LITHOLOGY	COLOR	ACCESSORY INFORMATION
72/M					Dilled out 9 feet
10					3 f..t [illegible]
3			SAND(wacke)	Red	Quartz, fn.grd.; A1, E (Lisbon)
20			CLAY	Orange	[illegible]
6.1			SAND(wacke)	Ochre	Quartz, med.grd., A2, E
			MUD	Chocolate	[illegible]
	028				
	029				
30			CLAY	Chocolate	G5, [illegible]
9.1	030				
	031				
40			[illegible]	[illegible]	[illegible]
12.2					
50					
15.2			MUD	Dk. Green	[illegible]
					[illegible]
			MUD	Dk. Green	As [illegible]
			CLAY	Dk. Green	G5, [illegible]
60			MUD	Dk. Green	C1, [illegible]
18.3	032				
	033				
	034		CLAY	Dk. Green	[illegible]
	035				
70					
21.3	036				
			MUD	Olive	[illegible] A1, A2
	037		CLAY	Dk. Green	[illegible] G5, A1a, B, D1
			SAND(wacke)	Olive	Quartz, med.grd.; C1, A2, A1, D1
80			SANDSTONE	Lt. Olive	[illegible]
24.4			CLAY	Dk. Green	[illegible]
			SAND(wacke)	Lt. Olive	Quartz, [illegible] grd.; A1, [illegible]
	038		CLAY	Dk. Green	C3, C4
			MUD	Dk. Green	C1, C6, [illegible] A2
	039		CLAY	Olive to green	C1, C5, A1a, C2, [illegible]
90	040				
27.4			MUD	Olive	C1, A1, [illegible]
	041		CLAY	Olive-green	[illegible] B, C5, A1a, D1, B
	042				
100	043				
30.5	044				
	045		CLAYSTONE	Dk. Green	[illegible] A1a, A2, B3, C17, [illegible]
	046		CLAY	Olive-green	[illegible] A1, [illegible] C7, [illegible]
110					
33.5			MUD	Olive	[illegible] A1, A2, [illegible]
			CLAY(opaline)	Olive-green	C1, C5, [illegible]
120					
36.6	047		CLAYSTONE	Olive-green	[illegible] B, A1,
130					
39.6			SHALE	GR. GREEN	
			CLAY(coal)	Gl. green	A6, C15, [illegible]
	048		CLAY	Gl. green	C1, C5, [illegible]
			MUDSTONE	Gl. green	C1, C1, [illegible]
140			SANDSTONE	Olive	Quartz, [illegible] wacke; A2, B, A4
42.7					
150			CLAYSTONE	Gray-green	[illegible] to [illegible] C7, C1, B1, A7
45.7					
160			SANDSTONE	Olive	Quartz, [illegible] A2, B, A4
48.8			MUDSTONE	Gray-green	C1, C1, B1, C5, A1a, A2, B, A5, C16
	049		CLAYSTONE	Gl. green	C1, C5, C6, H1, A1, B
					Missed
170			Mudstone	Gr. green	As Above
51.8	050		CLAYSTONE	Gl. green	As Above
			MUD	[illegible] green	C1, C1, C5, [illegible] F
180					[illegible]ed
54.9					
			SAND(arenit)	Brown	[illegible] F (Meridian)

SECTION NO: MCM 3 CORE X EXPOSURE ____ SAMPLE SERIES: ____ PAGE ____ OF ____

STATE: MISSISSIPPI COUNTY: LAUDERDALE QUAD: MERIDIAN SW ELEV.: 550'

SEC. 33 T. 4N R. 16E GRID COORD.: NW OF SW OF NW

TOTAL DEPTH: 150' CORE INTV.: 141' MISSG. INTV.: 37.5 RECOVERY: 73%

DEPTH	SAMPLE	LOG	LITHOLOGY	COLOR	ACCESSORY INFORMATION
0					3 — 9 feet
10					
20					Missed
6.1					
30					
9.1	051, 052, 053		CLAY	Chocolate	∞, P, S, A1, A2
40			SAND(wacke)	Green	Quartz, I, P, A1
12.2					
50	054, 055, 056		CLAY	Olive-green	A1, A2, C, S, Z, B, B2
15			MUD	Olive-green	A1, A2, K, F, F, F, Z, F, Missed, F, ∞
60			SILTSTONE	Olive-green	A1, G1,
18.3	057, 058		CLAYSTONE	Olive-gm	G7, K, F2, H1, H15, H1, K
			CLAY	Olive-gm	A1, A2, H4, G7, G8, M, G8
	059, 060		CLAY	Olive-gm	D2, F, K, A1,
70			MUDSTONE	Olive-gm	F, F, Z, Z*, P, K, ∞, F
21.3			CLAYSTONE	Olive	7, ∞*
80					
24.4	061		CLAY(opal)	Olive-gm	G1-G2, G3, G15, Z, ∞, K
			CLAYSTONE	Gray-gm	G1, G3, G17, G3,
	062		CLAY(opal)	Gray-gm	G2, ∞, G15, G6, A1a, G5
90					
27.4	063, 064		CLAYSTONE	Olive-gm.	G1, G3, G17, B2, A1, A2
	065		CLAY(opal)	Olive-gm.	G1-G2, G3, H4, H4
			CLAYSTONE	Olive-gm.	G1, G3, G17, G5, A2, B2, A1
			SILTSTONE	Gray-gm.	G2, G1, A1, A2, B2, B1
100	066		CLAY	Olive-gm.	G2, G1, G15, G7, F, E, K
30.5	067, 068		MUDSTONE	Olive-gm.	∞, F, A1, P, S, P, K
110			CLAY	Olive-gm.	H4, F3, H4, H
33.5	069		MUDSTONE	Olive-gm.	G1, A1, A2, B2
			CLAYSTONE	Olive-gm.	G1, G3, A1, A2, B3, G15
			SHALE	Green	G2, B, B4
120	070		CLAY	Olive-gm.	H1, H1, H15
36.6	071		CLAY(opal)	Olive-gm.	G1, G1, G15, B2, B3, ∞, K
	072		CLAY	Olive-gm.	G1, G1, A1, B2, H15, B3
			CLAYSTONE	Olive-gm.	A2, A2a
	073		MUD	Olive-gm.	G1, G1, P, K, Z
130			SAND(wacke)	Olive-gm.	Quartz, cro-med.grd.; A2, A1, B2, G3, B2
39.6					Missed
140					
42.7			I I I		Quartz, fn. (Meridian) I, P, 4, P, ∞*, F
					Missed
150					
45.7					

STATE: MISSISSIPPI COUNTY: CLARKE QUAD: GUTTMAN NE ELEV.: 500'

SEC. 34 T. 4N R. 17E GRID COORD.: [illegible]

TOTAL DEPTH: 139 ft. CORE INTV.: 139 ft. MISSG.INTV.: 48 ft. RECOVERY: 65%

DEPTH	SAMPLE	LOG	LITHOLOGY	COLOR	LOCKHART INFORMATION
0					Drilled out 9 feet
10					Missed; probably [illegible]
20			SAND(wacke)	Orange	Quartz, fn.gnd.
6.1					Missed; probably sand above
	074		CLAY	Dk.Brown	C1, [illegible]
	075				
30			CLAY	Orange	C1, [illegible]
9.1			CLAY	Brown	C1, [illegible]
			MUD	Olive-grn	C1, A2, B3
	076		MUDSTONE	Olive-grn	C1-C2, [illegible], A1, [illegible]
	077				
40	078				
12.2	079				
			CLAYSTONE	Olive-grn	C1, B3, G17, B8, A6, B5
			CLAY	Olive-grn	C1, G3, A1, A2, G15
			CLAYSTONE	Olive-grn	C1, G1, B5, B, A1, G17
50	080		CLAY	Olive-grn	C2, G1, G15, B, G7, B2, G5
15	081				
	082		CLAYSTONE	Olive-grn	C2, G9, B5, B5, B1
	083		MUD	Olive-grn	C2, G1, G6, A1, A2, B2
			MUDSTONE	Olive	Quartz sandy, fn.gnd.; A1, A2, A3
60	084		CLAY(opal)	Olive-grn	C1, G3, G15, B4, A4
18.3	085		CLAY(opal)	Olive-grn	C1-C2, G3, G15, B2, G7, G6, A2a, G18, B2a, B3, A1, B, A4
	086				
	087				
	088				
70	089				
21.3					Missed; probably sand below
80			SAND(wacke)	Olive-grn	Quartz,grn.gnd.; A2, A1, G12
24.4			CLAYSTONE	Olive-grn	C1, G3, G15, A1, A2, G18
	090		CLAY(opal)	Olive-grn	C1, G1, G6, G4, A1, A2a, B
			CLAYSTONE	Olive-grn	C1, G3, G17, A6, B2, G9, G15
90			MUD	Olive-grn	C1, G3, A2a, A4
27.4	091		CLAY(opal)	Olive-grn	C1, [illegible] A1, [illegible]
	092				
	093		CLAYSTONE	Olive-grn	C1, B3, B17, B6, B5, B2
	094		MUD	Olive-grn	C1, A1
100			CLAYSTONE	Olive-grn	As above
30.5	095		CLAYSTONE	Olive-grn	As above
			CLAYSTONE	Olive-grn	As above
			CLAY	Olive-grn	As above
			CLAYSTONE	Olive-grn	C1, G1, A1, [illegible], B
	096		MUD	Olive-grn	C1, B3, B2, B5
			CLAYSTONE	Olive	C1, B3, B2, B7, A3, B6, B, B5
110			CLAYSTONE	Olive-grn	B1, B2, C3
33.5	097		CLAY	Olive-grn	C1, G1, B4, A1, [illegible]
	098		MUD	Olive-grn	C2, G1, A2, A1, [illegible]
			SAND(wacke)	Olive	Quartz,med-fn.gnd; A1, A2, F, B1, G12, C3
120			Missed		
36.6			Missed		Put [illegible] catcher and washed to 1[illegible]
130			SAND(wacke)	Buff	Quartz,fn.gnd; A1, F
39.6			Missed		Sand wash-out
140					
42.7					

STATE: Kansas COUNTY: Lansing QUAD: Gardner SE ELEV.: 307'

SEC. 17 T. 9S R. 24E GRID COORD.: NW OF NW OF NW

TOTAL DEPTH: 162 ft. CORE INTV.: 160 ft. MISSG.INTV.: 55 ft. RECOVERY: 75%

DEPTH (feet / m)	SAMPLE	LOG	LITHOLOGY	COLOR	ACCESSORY INFORMATION
0					→ ω — 9 feet
10 / 3			Mixed		Coarse quartz sand
20 / 6.1					
	099		SAND(wacke)	Orange	Quartz,fn-med.grd.; A2, A6
			CLAY	Brown	C1, G1, A2a, C5
30 / 9.1	100		SAND(wacke)	Orange	Quartz,fn-med.grd; A2, A6
	101		CLAY	Brown	C1, G2, B4, A2, C5
	102		CLAY	Brown	C1, H3(very), C5
			SAND(wacke)	Orange	A2, Quartz,med.grd.
40 / 12.2			SAND(wacke)	White	A2, F, A7, Quartz, crs.grd.
			Mixed		
50 / 15			SAND(wacke)	Ochre	Quartz,med.grd; A2, A1, G12
			Mixed		Loose sand similar to above sand
60 / 18.3			SAND(wacke)	Ochre	As above
			CLAY	Ochre	C1, G1, B4, B3, A2, C4
			SAND(wacke)	Ochre	Quartz, fn.grd; A1, A2
	103		CLAY	Olive-grn	C1, G1, B1, A2, A1
	104		SANDSTONE	Olive	A1, Quartz,fine-dry,massive
70 / 21.3			SHLE	Olive-grn	G2, G1, B1, A2, A1
	105		CLAY	Olive-grn	G2, G1, G15, A1, ⊏, ⊗ →), B2
	106		CLAY	Olive-grn	A6 and as above
80 / 24.4			CLAYSTONE	Olive-grn	G17, G9, A6, A2, A1
	107		CLAY	Olive-grn	H1, H2, A2, A1, B, H6, B3
			CLAYSTONE	Olive-grn	C1, G3, G17, A6, B1
	108		CLAY(coal)	Olive-grn	C2, A2a, A1, G15, B1
	109		SILT	Green	C2, B4, A2, A1, G6, A4
90 / 27.4			SHLE	Olive-grn	C3, B, B5, A1, A2, B2, B1
			CLAYSTONE	Gray-grn	G17, G9, A2
100 / 30.5			SILT	Gray-grn	Bleaches whi→ ∞, *
110 / 33.5			CLAYSTONE	Olive-grn	C1, G1, G17, A6, B1, A2, B3, B2, B2
120 / 36.6					
			CLAY(coal)	Olive-grn	H1, G1, H1, B3, A1a, A2,
130 / 39.6			CLAYSTONE	Green	C1, G3, G17, G9, A6
			SAND(wacke)	Olive-grn	Quartz,fn.grd; A2, A1, G18, B3, B1, A A5
			SHLE	Olive-grn	C1, G1, A2, A1, B3, B1
140 / 42.7			CLAYSTONE	Green	C1, G3, G17, ∞ ⊗, →, G15
			SILT	Gray-grn	H2, H1, A1
			CLAYSTONE	Olive-grn	G2, G1, A2, B, G15, A6
			SANDSTONE	Gray-grn	Quartz,med.grd; wacke, A2, B3, B
			SAND(wacke)	Olive-grn	Quartz,med.grd; A2, A1, B, B1
			SAND(arenite)	Olive	Quartz,med.grd; A2(very), A1
150 / 45.7			Mixed		Above sand
			SAND(wacke)	Olive-grn	Quartz,med.grd; A2, A1, A7, B3, B1, A4, C5
160 / 48.8	110		CLAY	Olive-grn	C1, G1, B3, A1, A2, G12,B3
			SAND(wacke)	Olive	Quartz,med.grd; A2, A1, H12
			Mixed		
			SAND(arenite)	Buff	Quartz, fn-med.grd; A1, F, A2a
170 / 51.8					

SECTION ∞ [illegible] CORE X EXPOSURE ____ SAMPLE SERIES: ____ PAGE ____ OF ____

STATE: MISSISSIPPI COUNTY: CLARKE QUAD: QUITMAN NE ELEV.: 525'

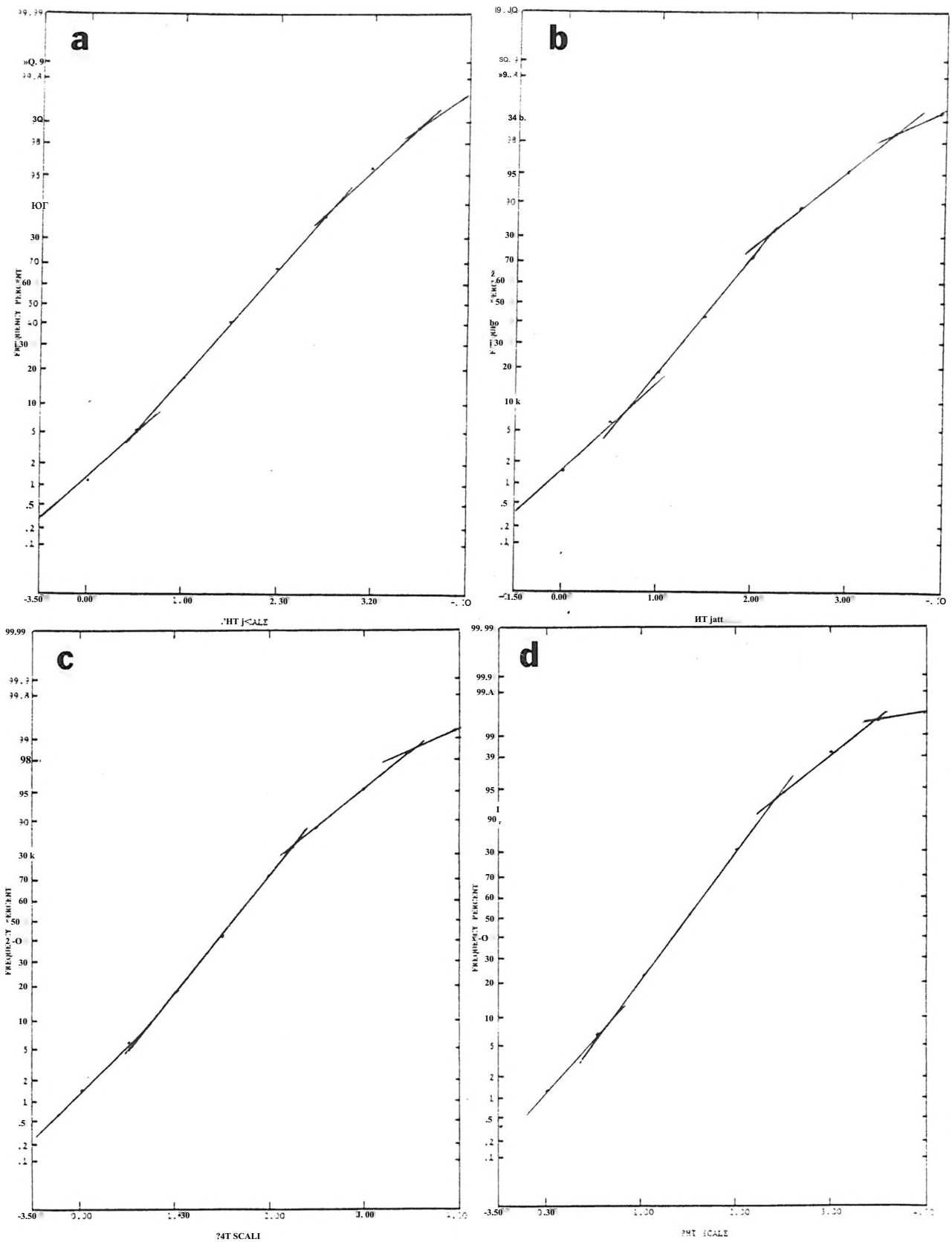
SEC. 24 T. 4N R. 16E GRID COORD.: NE [illegible]

TOTAL DEPTH: 170 ft. CORE INTV.: 110 ft. MISSC. INTV.: 5 ft. RECOVERY: 95%

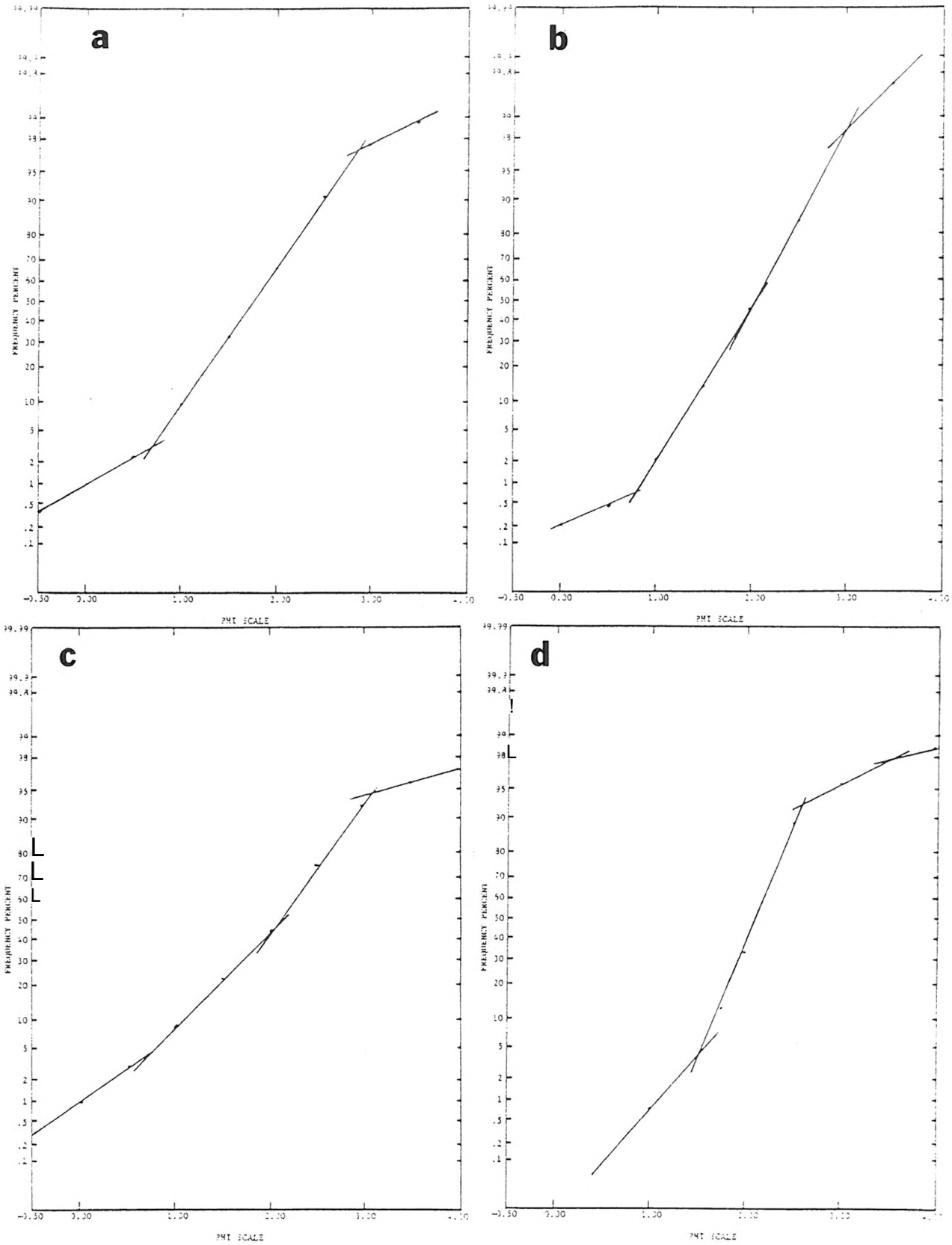
DEPTH	SAMPLE	LOG	LITHOLOGY	COLOR	ACCESSORY INFORMATION
20 ft. H 60					Drilled out 44 feet to set core barrel. Drilled through 36 feet sand; orange md.grd. quartz arenite
18			Missed		
			SAND(wacke)	Green	Quartz,md-fn.grd; A1, A2, G19
			MUD	Olive-grn	[illegible], A1, G1
70	162°°		CLAY	Olive-grn	[illegible], G1, [illegible]5, A1, B1, H1
21			MUD	Yellow to orange-red	C1
	163°°		CLAY(opal)	Olive-grn	C2, G1, A1, A2, G15
80			SILTSTONE	Lt.Green	C1-C2, G1, A1, B, B1
24.5	164°° 165° 166° 167°		CLAY(opal)	Olive-grn	C2, [illegible] 5, [illegible], A1, A2a, B2
90			MUD	Grey-grn	C2, [illegible]
27.5			SANDSTONE	Grey-grn	Quartz [illegible] A1,A2
			MUD	Grey-grn	As above
			CLAYSTONE	Grey-grn	C1, G1, G17, G10, A6, B2, A1, H4
100	168°°		CLAY(opal)	Olive-grn	C2, G1, B, B2, A1, A2a
30.5			CLAYSTONE	Grey-grn	As above
	169 170°		CLAY(opal)	Olive-grn	As above
110	171°		CLAYSTONE	Grey-grn	C2, G3, [illegible] 0, [illegible]7, G8
33.5	172°° 173°° 174°°		CLAYSTONE	Olive-grn	C2, [illegible] 5, G18, G8(sampled), A1, [illegible], B1, B2
36.5			SANDSTONE	Lt.Grey	Quartz wacke,fn-[illegible], A2, G15
			CLAYSTONE	Grey-grn	C2, G3, G18, A6, [illegible], B2
			MUD	Olive-grn	C1, C1, H5, A1, [illegible], B2
130	175°° 176°° 177°°		CLAY(opal)	Olive-grn	C2, G1, G15, [illegible], [illegible], [illegible]
39.5			CLAYSTONE	Dk.grey	C2, G1, G15, G17, [illegible], B
			CLAY(opal)	Olive-grn	C2, G2, A1, A2, B
140			CLAYSTONE	Dk.Grey	As Above
43			SANDSTONE	Lt.Grey	Quartz wacke,crs.grd; A5
			CLAYSTONE	Olive-grn	C2, [illegible] 1, A2, H1
			CLAYSTONE	Olive-grn	C2, [illegible] 5, A1, A2, [illegible], B, [illegible]
150			MUD	Grey-grn	G1, [illegible] 1, A2, G12
46			SAND(wacke)	Lt.Brown	Quartz,fn-[illegible]; A1, F, [illegible]
160 49			SAND(areni-	[illegible]	Quartz,fn-med.grd; A1, F
170 52					

AFFEND I X B

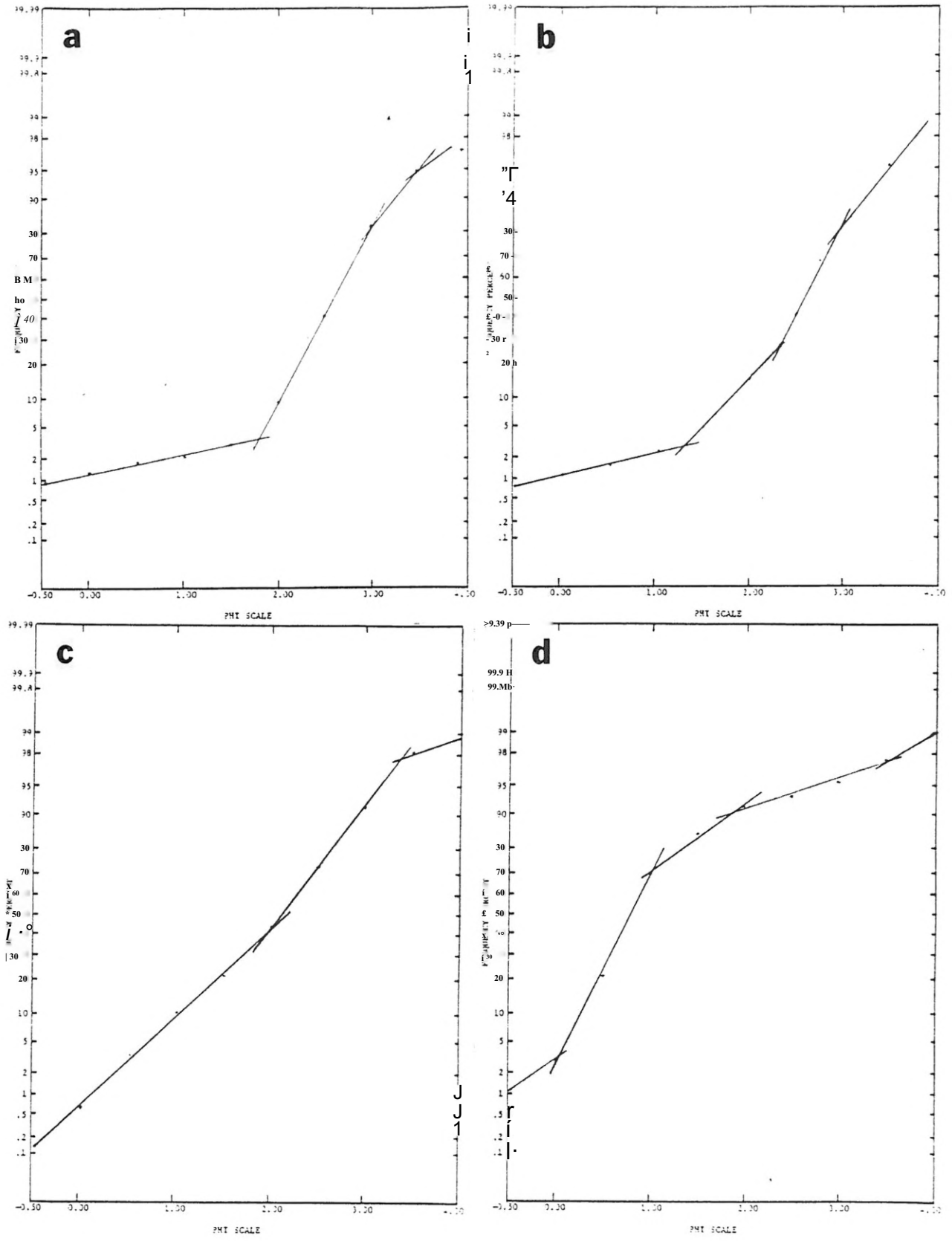
FRODABILITIES ÜF SAND-SIZE POPULATIONS



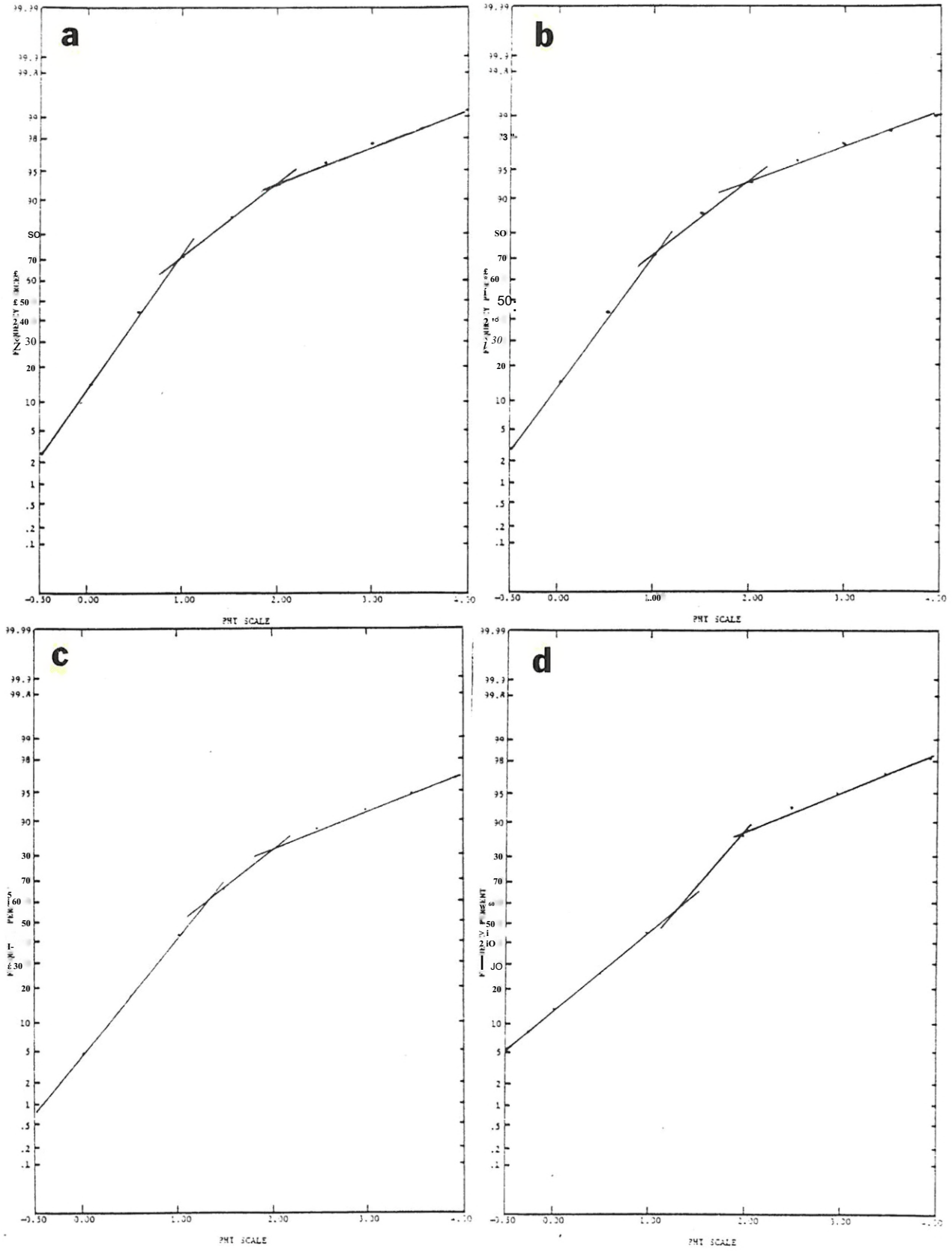
Cumnulative probabilities of sand-size populations
of the Upper Meridian Formation.
Section 57 (Mt. Barton): a, b, c
Section 55 (l 20): d



Curamulative probabilities of sand-size populations
of the Upper Meridian Formation.
Section 45 (Valley Road): a, b
Section 50 (Savoy Road): c, d



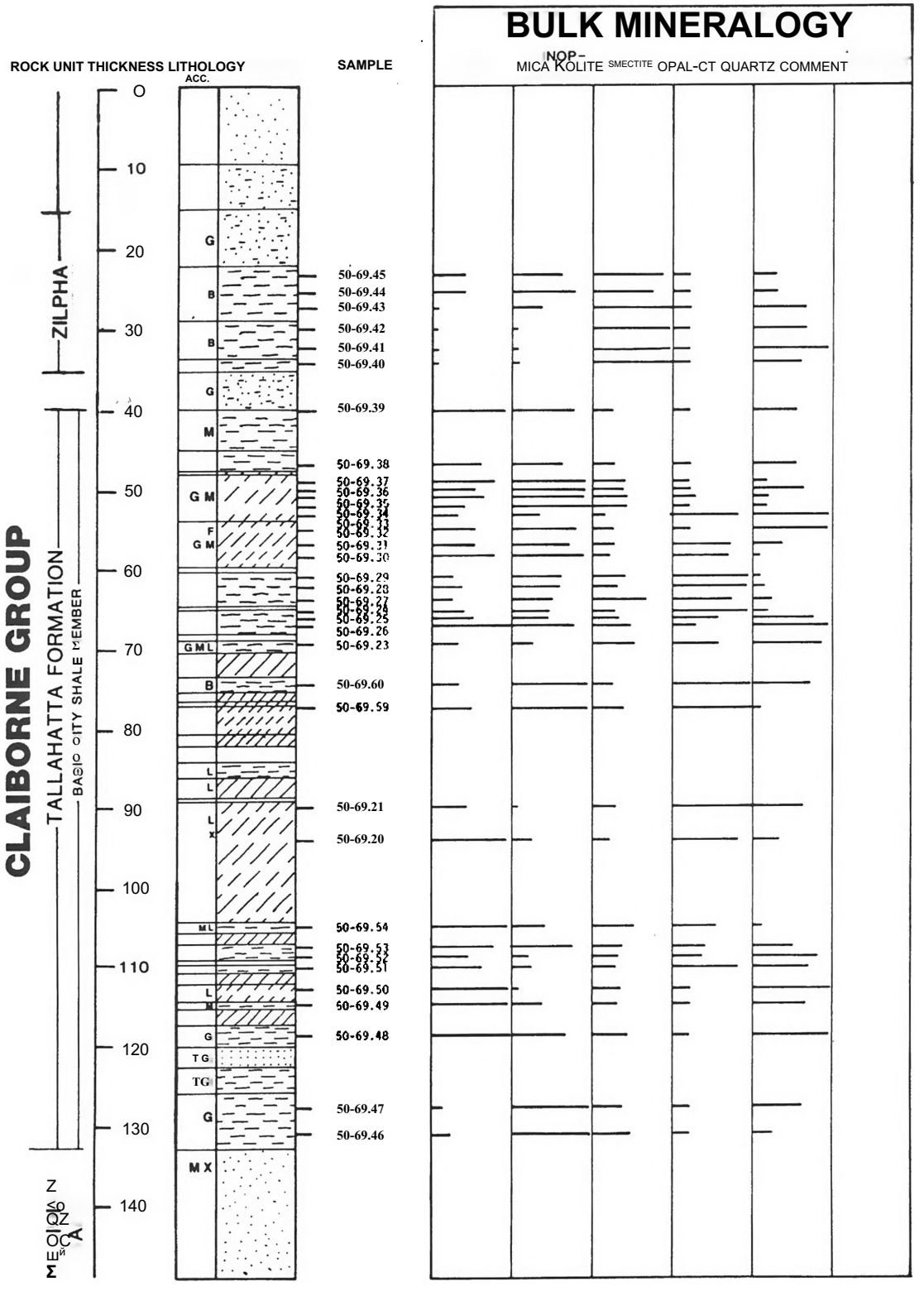
Cummulative probabilities of sand-size populations of the Upper Meridian Formation (section 51» Highway 111 a, b, c) and of the Lower Tallahatta Formation (section 55? 120; d).



Cummulative probabilities of sand-size populations of the Lower Tallahatta Formation (section 49; Basic City: a, b) and of the Winona Formation (section 45; Valley Road: c, d)

APPENDIX C

MINERAL DULK COMPOSITION



EXPLANATION

SANDSTONE

SAND/WACKE

SAND/ARENITE

SILT/STONE

MUD/STONE

CLAYSTONE

CLAYSTONE/CLAY

CLAY

MISSING/COVERED

ACCESSORY

Q GLAUCONITIC
M MICACEOUS
F FOSSILIFEROUS
F FLANT FRAGMENT
B BIOTURBATED
T TRACE FOSSILS
W DEWATERING VEIN
X CROSS LAMINATIONS
L LAMINATED
C CHERTY

COMMENT

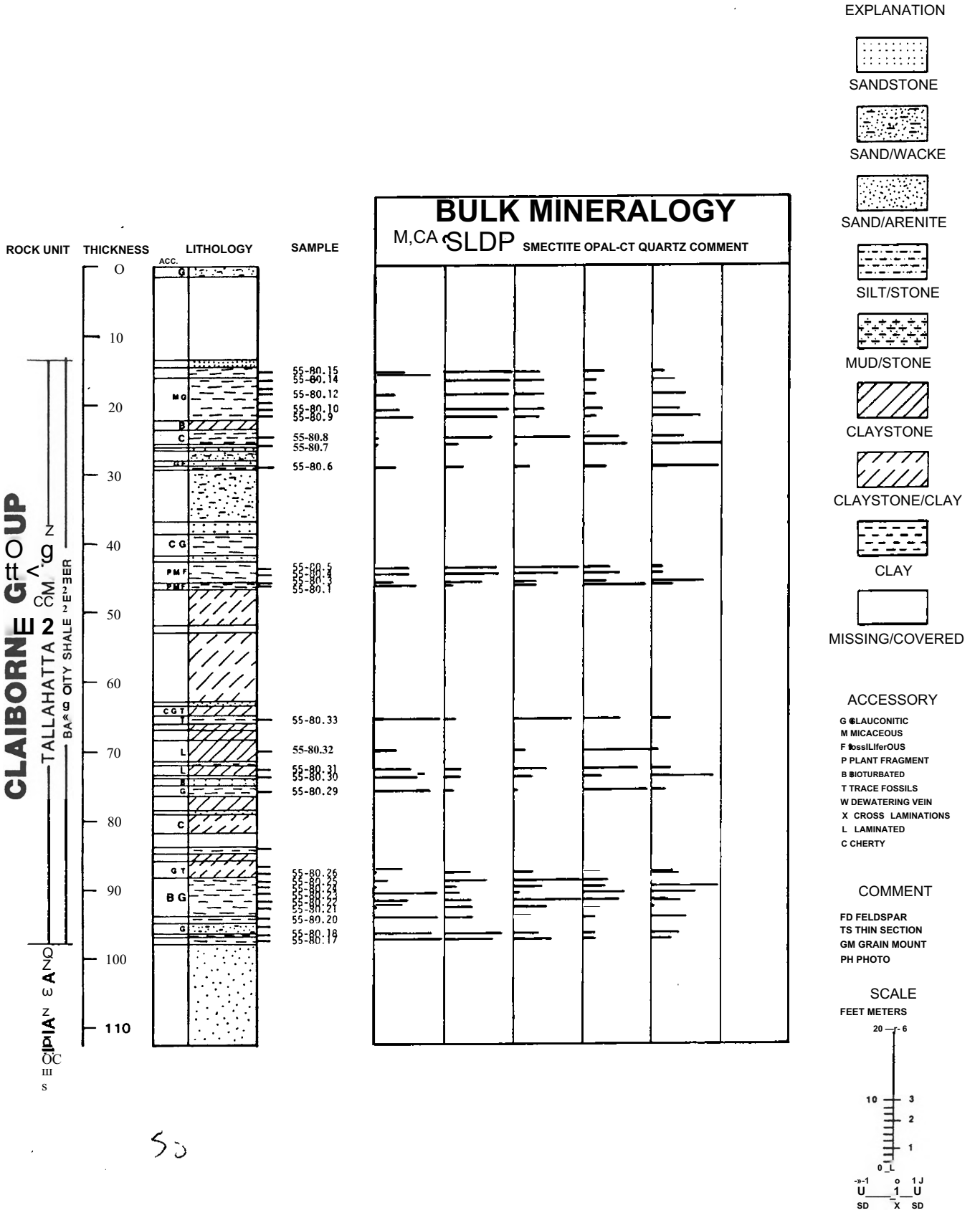
FD FELDSPAR
TS THIN SECTION
GM GRAIN MOUNT
PH PHOTO

SCALE

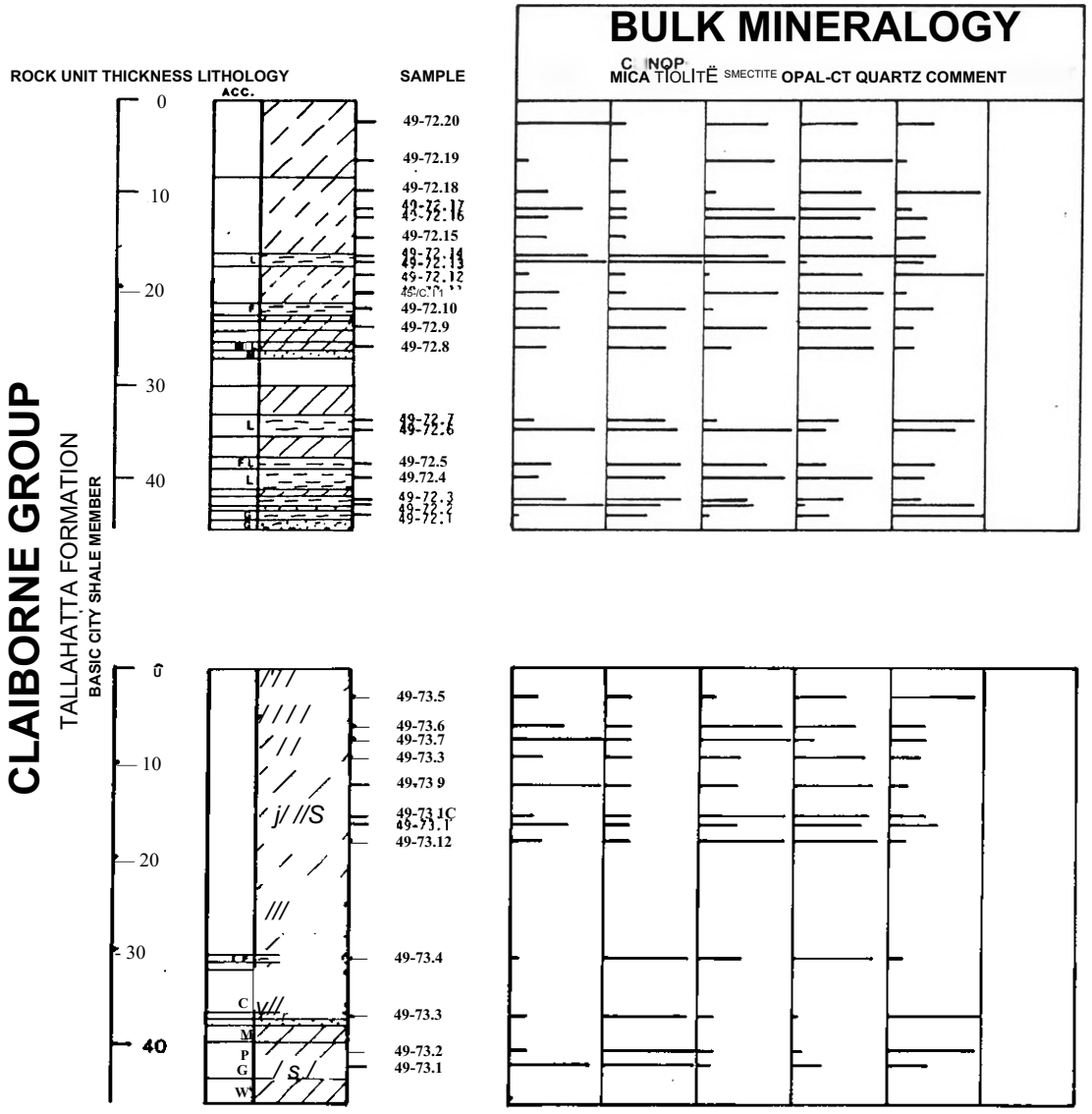
FEET METERS

20 — 6
10 — 3
2
1
0

-3 -1 0 1 3
SD $\bar{X}$ SD


BULK MINERALOGY
M,CA SLDP SMECTITE OPAL-CT QUARTZ COMMENT
ROCK UNIT
THICKNESS
LITHOLOGY
SAMPLE
CLAIBORNE GROUP
TALLAHATTA
BACON CITY SHALE MEMBER
0
10
20
30
40
50
60
70
80
90
100
110
55-80.15
55-80.14
55-80.12
55-80.10
55-80.9
55-80.8
55-80.7
55-80.6
55-80.5
55-80.4
55-80.3
55-80.1
55-80.33
55-80.32
55-80.31
55-80.30
55-80.29
55-80.26
55-80.25
55-80.24
55-80.23
55-80.22
55-80.21
55-80.20
55-80.18
55-80.17
EXPLANATION
SANDSTONE
SAND/WACKE
SAND/ARENITE
SILT/STONE
MUD/STONE
CLAYSTONE
CLAYSTONE/CLAY
CLAY
MISSING/COVERED
ACCESSORY
G GLAUCONITIC
M MICACEOUS
F FOSSILIFEROUS
P PLANT FRAGMENT
B BIOTURBATED
T TRACE FOSSILS
W DEWATERING VEIN
X CROSS LAMINATIONS
L LAMINATED
C CHERTY
COMMENT
FD FELDSPAR
TS THIN SECTION
GM GRAIN MOUNT
PH PHOTO
SCALE
FEET METERS
20 6
10 3
2
1
0
SD X SD

50



EXPLANATION

SANDSTONE

SAND/WACKE

SAND/ARENITE

SILT/STONE

MUD/STONE

CLAYSTONE

CLAYSTONE/CLAY

CLAY

MISSING/COVERED

ACCESSORY

O GLAUCONITIC
M MICACEOUS
F FOSSILIFEROUS
P PLANT FRAGGSENT
B BIOTURSATED
T TRACE FOSSILS
W dewATErInG VEIN
X CROSS LAMINATIONS
L LAMINATED
C CNERTY

COMMENT

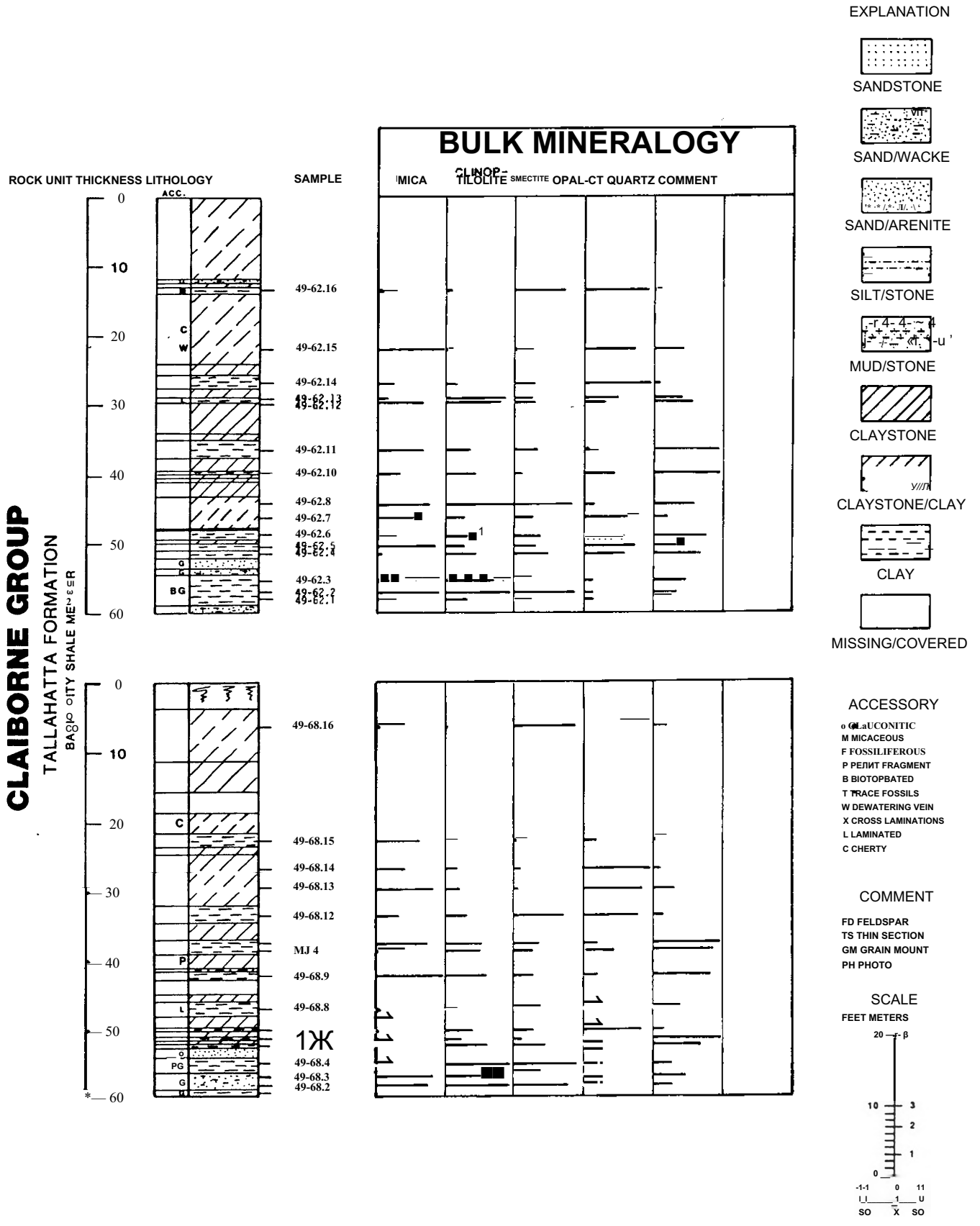
FD FELDSPAR
TS THIN SECTION
GM GRAIN MOUNT
PH PHOTO

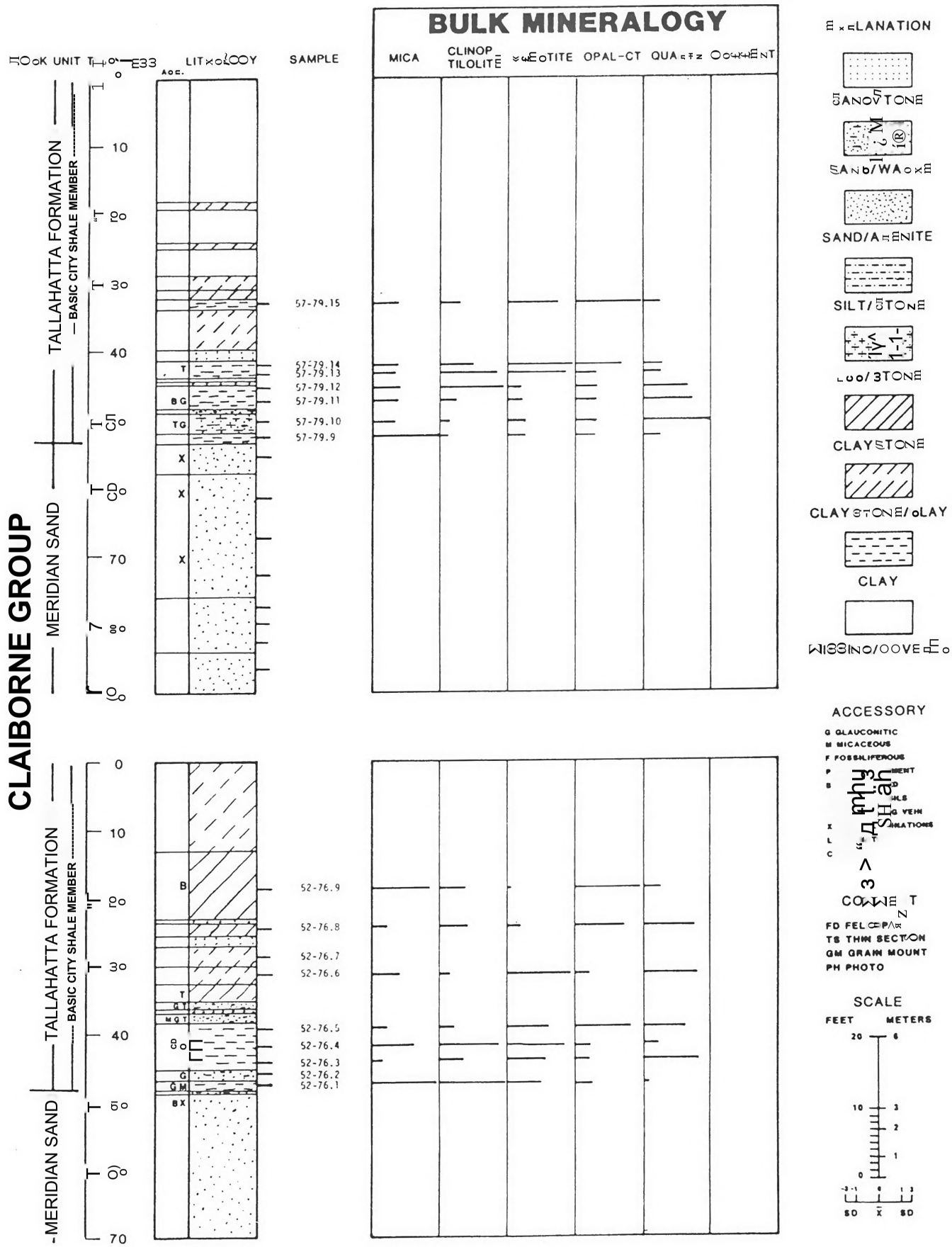
SCALE

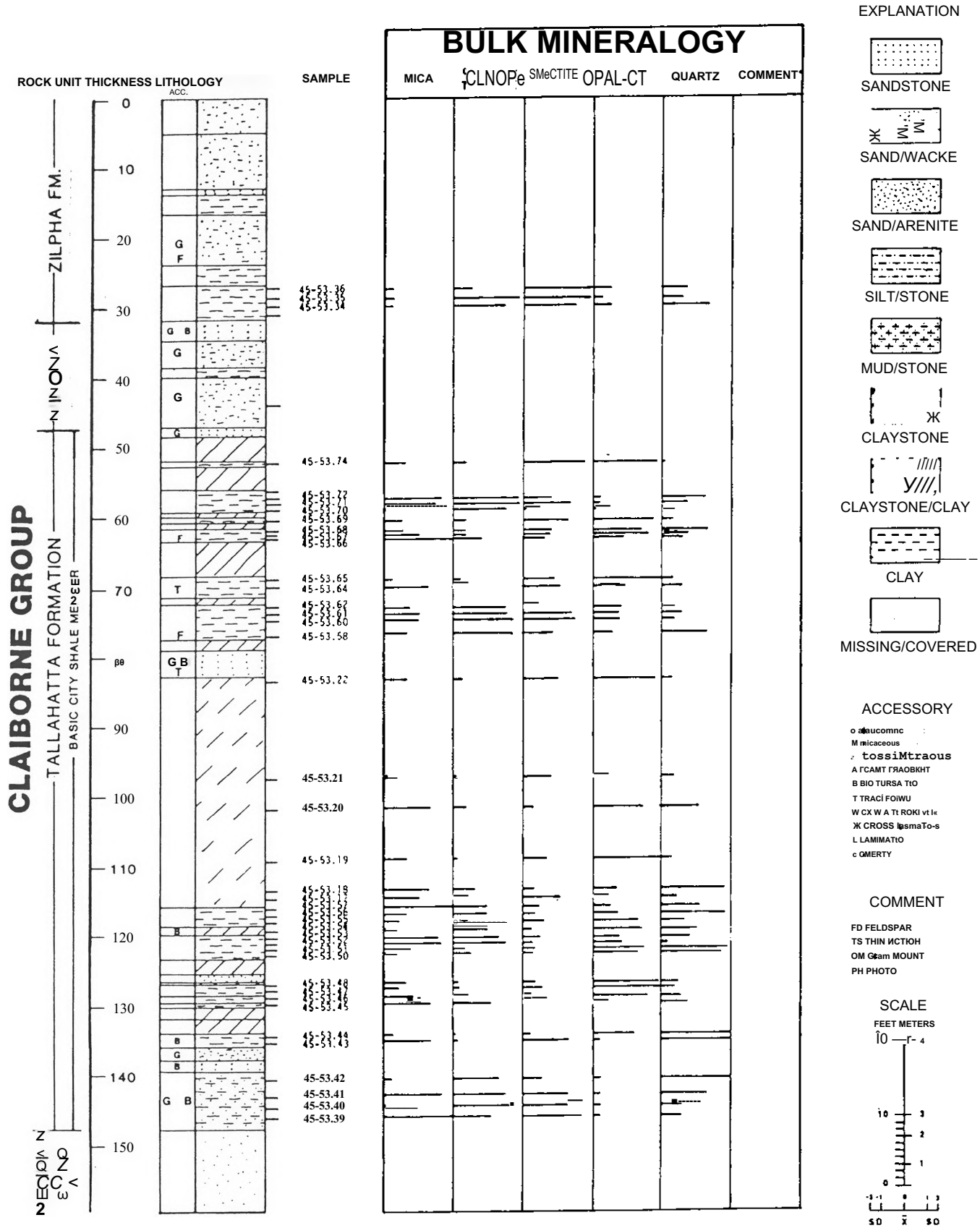
FEET METERS

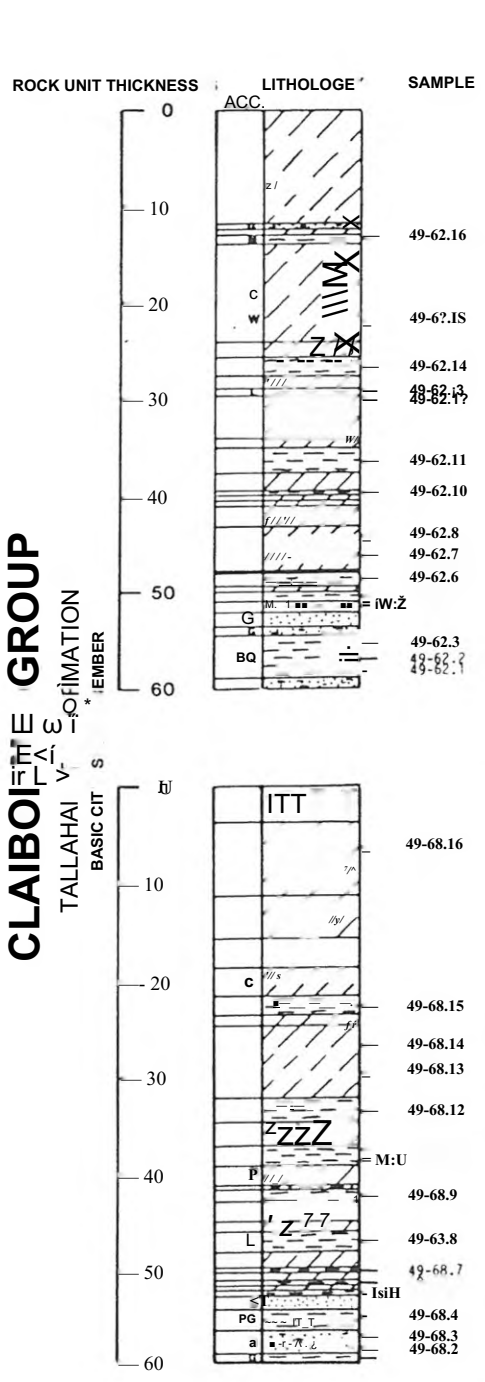
20 β
10 3
2
1
0

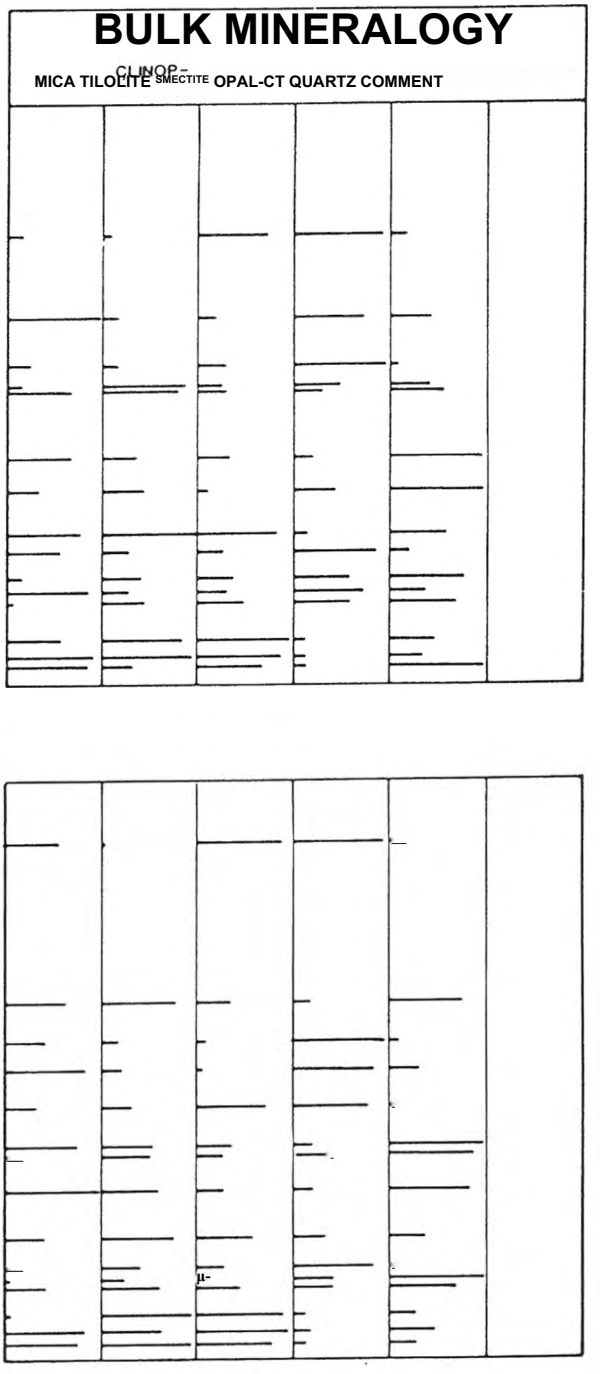
SD X SD


CLAIBORNE GROUP
TALLAHATTA FORMATION
BAGO CITY SHALE MEMBER
ROCK UNIT THICKNESS LITHOLOGY
SAMPLE
BULK MINERALOGY
MICA
CLINOP-TILOLITE
SMECTITE
OPAL-CT
QUARTZ
COMMENT
ACC.
49-62.16
49-62.15
49-62.14
49-62.13
49-62.12
49-62.11
49-62.10
49-62.8
49-62.7
49-62.6
49-62.5
49-62.4
49-62.3
49-62.2
49-62.1
49-68.16
49-68.15
49-68.14
49-68.13
49-68.12
MJ 4
49-68.9
49-68.8
49-68.4
49-68.3
49-68.2
EXPLANATION
SANDSTONE
SAND/WACKE
SAND/ARENITE
SILT/STONE
MUD/STONE
CLAYSTONE
CLAYSTONE/CLAY
CLAY
MISSING/COVERED
ACCESSORY
M MICACEOUS
F FOSSILIFEROUS
P PELIT FRAGMENT
B BIOTOPBATED
T TRACE FOSSILS
W DEWATERING VEIN
X CROSS LAMINATIONS
L LAMINATED
C CHERTY
COMMENT
FD FELDSPAR
TS THIN SECTION
GM GRAIN MOUNT
PH PHOTO
SCALE
FEET METERS


BULK MINERALOGY
MICA
CLINOP TILOLITE
OPAL-CT
SAMPLE
LITHOLOGY
CLAIBORNE GROUP
TALLAHATTA FORMATION
BASIC CITY SHALE MEMBER
MERIDIAN SAND
57-79.15
57-79.14
57-79.13
57-79.12
57-79.11
57-79.10
57-79.9
52-76.9
52-76.8
52-76.7
52-76.6
52-76.5
52-76.4
52-76.3
52-76.2
52-76.1
LAMINATION
SANDSTONE
SILTSTONE
CLAYSTONE
CLAYSTONE/SILTSTONE
CLAY
ACCESSORY
G GLAUCONITIC
M MICACEOUS
F FOSSILIFEROUS
COMMENT
FD FELDSPAR
TS THIN SECTION
GM GRAIN MOUNT
PH PHOTO
SCALE
FEET
METERS


BULK MINERALOGY
ROCK UNIT THICKNESS LITHOLOGY
ACC.
SAMPLE
MICA
CLNOPe
SMeCTITE
OPAL-CT
QUARTZ
COMMENT
CLAIBORNE GROUP
TALLAHATTA FORMATION
BASIC CITY SHALE MEMBER
ZILPHA FM.
EXPLANATION
SANDSTONE
SAND/WACKE
SAND/ARENITE
SILT/STONE
MUD/STONE
CLAYSTONE
CLAYSTONE/CLAY
CLAY
MISSING/COVERED
ACCESSORY
COMMENT
FD FELDSPAR
TS THIN SECTION
OM Grain MOUNT
PH PHOTO
SCALE
FEET METERS





EXPLANATION

SANDSTONE

SAND/WACKE

SANDIARENITE

SILT/STONE

MUD/STONE

CLAYSTONE

CLAYSTONE/CLAY

CLAY

MISSING/COVERED

ACCESSORY

a OLAUcOcTC
M MIcAcEouS
F FOIBKIFWXM
P FVAKT «AOИПП
в в ю TURUA nro
T TAAC« FO«K.e
W [XWAnmFQ YT MI
X CAO·· LAM·« A ПОИ
L LAMMIA TYD
C CMYWTY

COMMENT

FD FELDSPAR
τ · TMIN вестюн
GM QRAM MOUNT
PH PHOTO

SCALE

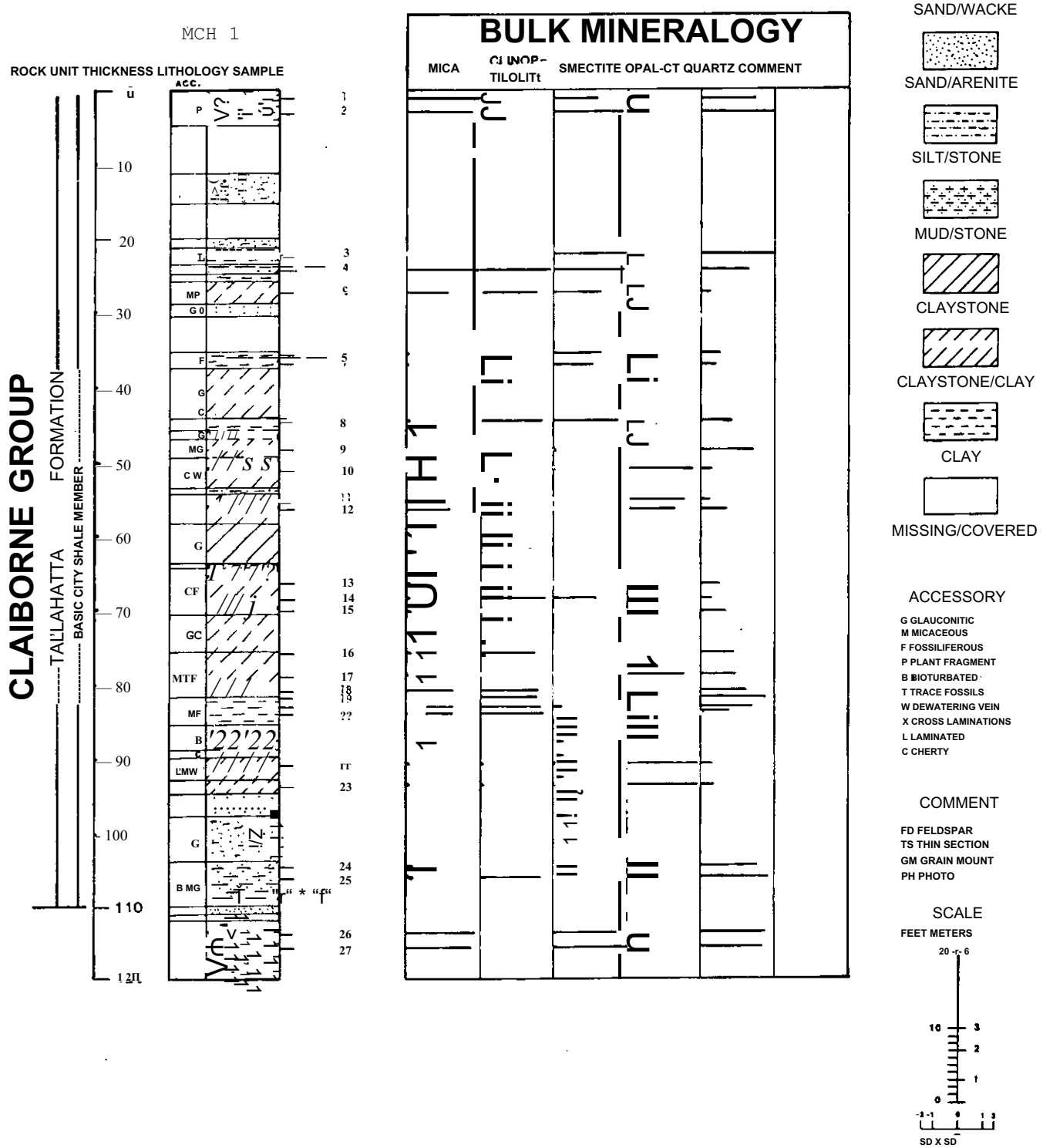
FEET METERS

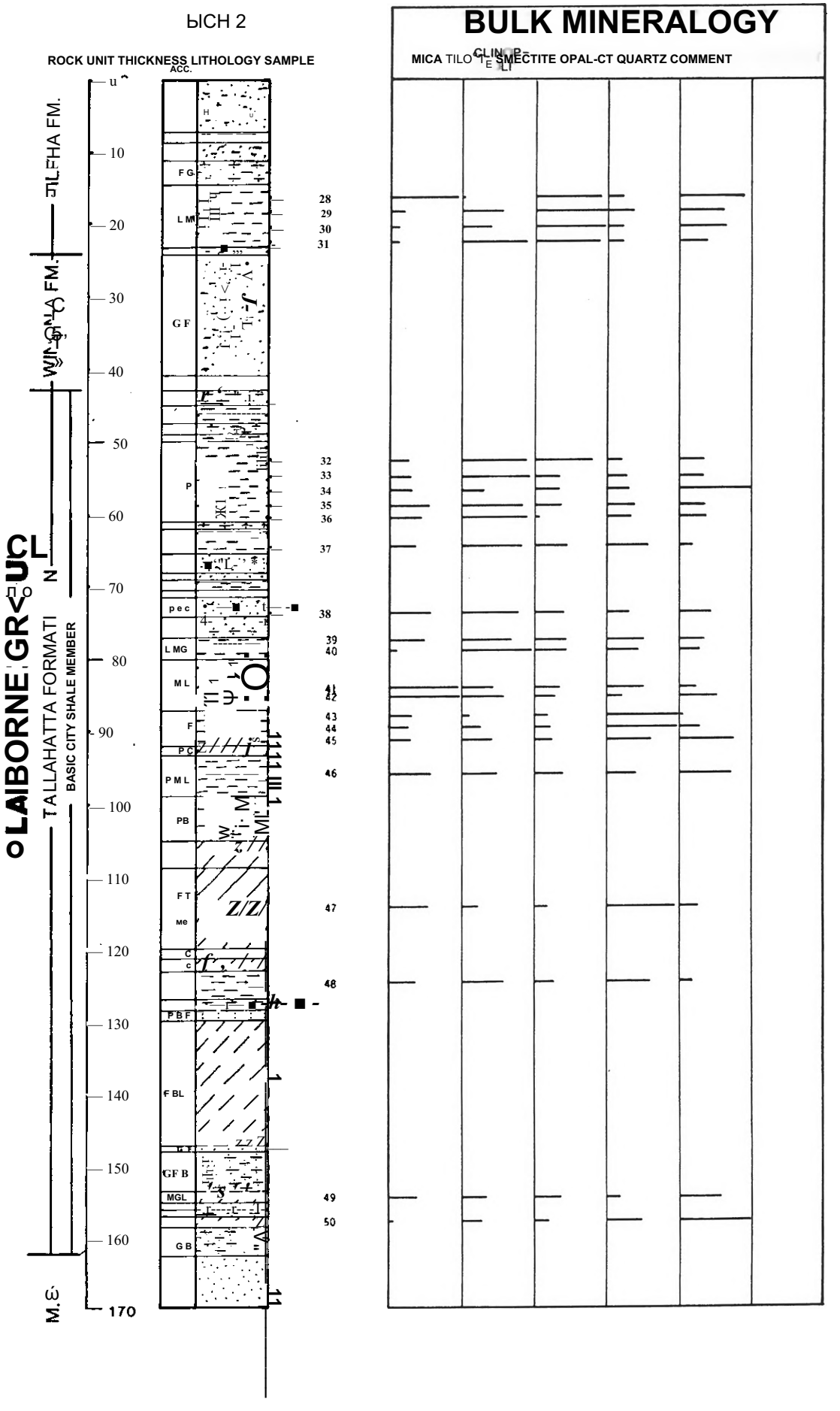
2« —r- ·

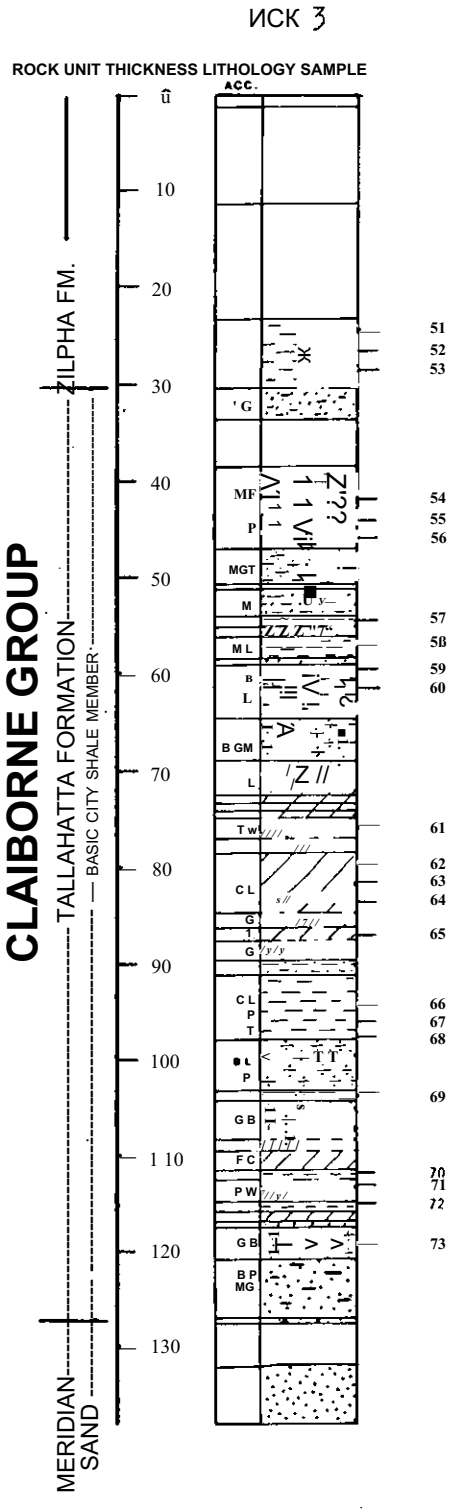
10 3
2
1
0

-3 -1 0 1 3

SD X̄ SD


MCH 1
ROCK UNIT THICKNESS LITHOLOGY SAMPLE
ACC.
CLAIBORNE GROUP
TALLAHATTA FORMATION
BASIC CITY SHALE MEMBER
BULK MINERALOGY
MICA
CLINOP-TILOLITE
SMECTITE OPAL-CT QUARTZ COMMENT
EXPLANATION
SANDSTONE
SAND/WACKE
SAND/ARENITE
SILT/STONE
MUD/STONE
CLAYSTONE
CLAYSTONE/CLAY
CLAY
MISSING/COVERED
ACCESSORY
G GLAUCONITIC
M MICACEOUS
F FOSSILIFEROUS
P PLANT FRAGMENT
B BIOTURBATED
T TRACE FOSSILS
W DEWATERING VEIN
X CROSS LAMINATIONS
L LAMINATED
C CHERTY
COMMENT
FD FELDSPAR
TS THIN SECTION
GM GRAIN MOUNT
PH PHOTO
SCALE
FEET METERS
SD X SD


ЫСН 2
ROCK UNIT THICKNESS LITHOLOGY SAMPLE
ACC.
BULK MINERALOGY
MICA TILO SMECTITE OPAL-CT QUARTZ COMMENT
EXPLANATION
SANDSTONE
SAND/WACKE
SANDIARENITE
SILT/STONE
MUD/STONE
CLAYSTONE
CLAYSTONE/CLAY
CLAY
MISSING/COVERED
ACCESSORY
G GLAUCONITIC
M MICACEOUS
f FOSSILIFEROUS
P PLANT FRAGLSENT
e BIOTURGATED
T TRACE FOSSILS
W DEWATERING VEIN
X CROSS LAMINATIONS
L LAMINATED
C CHERTY
COMMENT
FD FELDSPAR
TS THI SECTION
GM GRAIN MOUNT
PH PHOTO
SCALE
FEET METERS
TALLAHATTA FORMATI
BASIC CITY SHALE MEMBER
M.Ε.
170



BULK MINERALOGY

MICA TILOLITE CLINOP- smectite OPAL-CT QUARTZ COMMENT

EXPLANATION

SANDSTONE

SAND/WACKE

SAND/ARENITE

SILT/STONE

MUD/STONE

CLAYSTONE

CLAYSTONE/CLAY

CLAY

MISSING/COVERED

ACCESSORY

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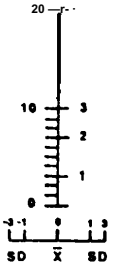
M MICACEOUS
F PO 8 SI U FERGUS
P PLAMT FRAGESENT
D BIOTWGATED
T TRACE FOSSILS
W D€ WATERING VEIN
X CROSS LAMINATIONS
L LAMINATED
C CHENTY

COMMENT

FD FELDSPAR
TS THIN SECTION
GM GRAIN MOUNT
PH PHOTO

SCALE

FEET METERS



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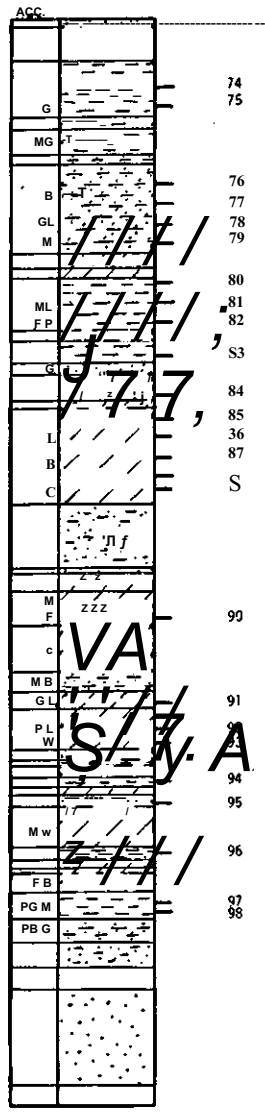
ROCK UNIT THICKNESS LITHOLOGY SAMPLE

CLAIBORNE GROUP

ZILPHA FM.

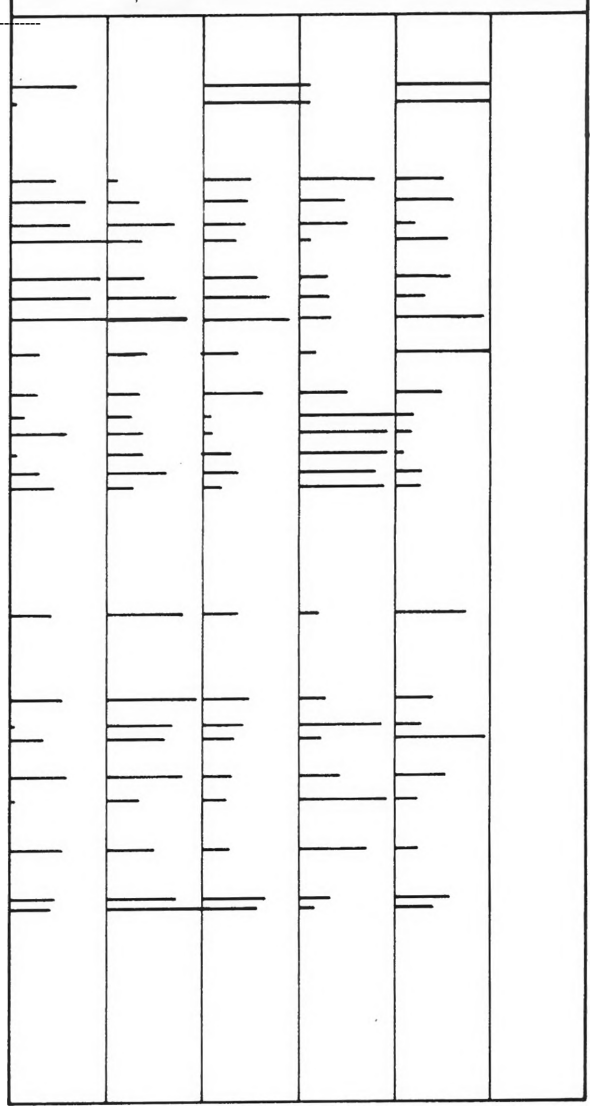
TATTA FORMATION

ACCOTITY SHALE MEMBER



BULK MINERALOGY

CLINOP– MICA TILOLITE SMECTITE OPAL-CT QUARTZ COMMENT



EXPLANATION

SANDSTONE

SAND/WACKE

SAND/ARENITE

SILT/STONE

MUD/STONE

CLAYSTONE

CLAYSTONE/CLAY

CLAY

MISSING/COVERED

ACCESSORY

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T TRACE FOSSILS
W DE WATERING VEIN
X CROSS LAMINATIONS
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C CHERTY

COMMENT

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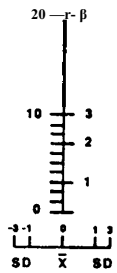
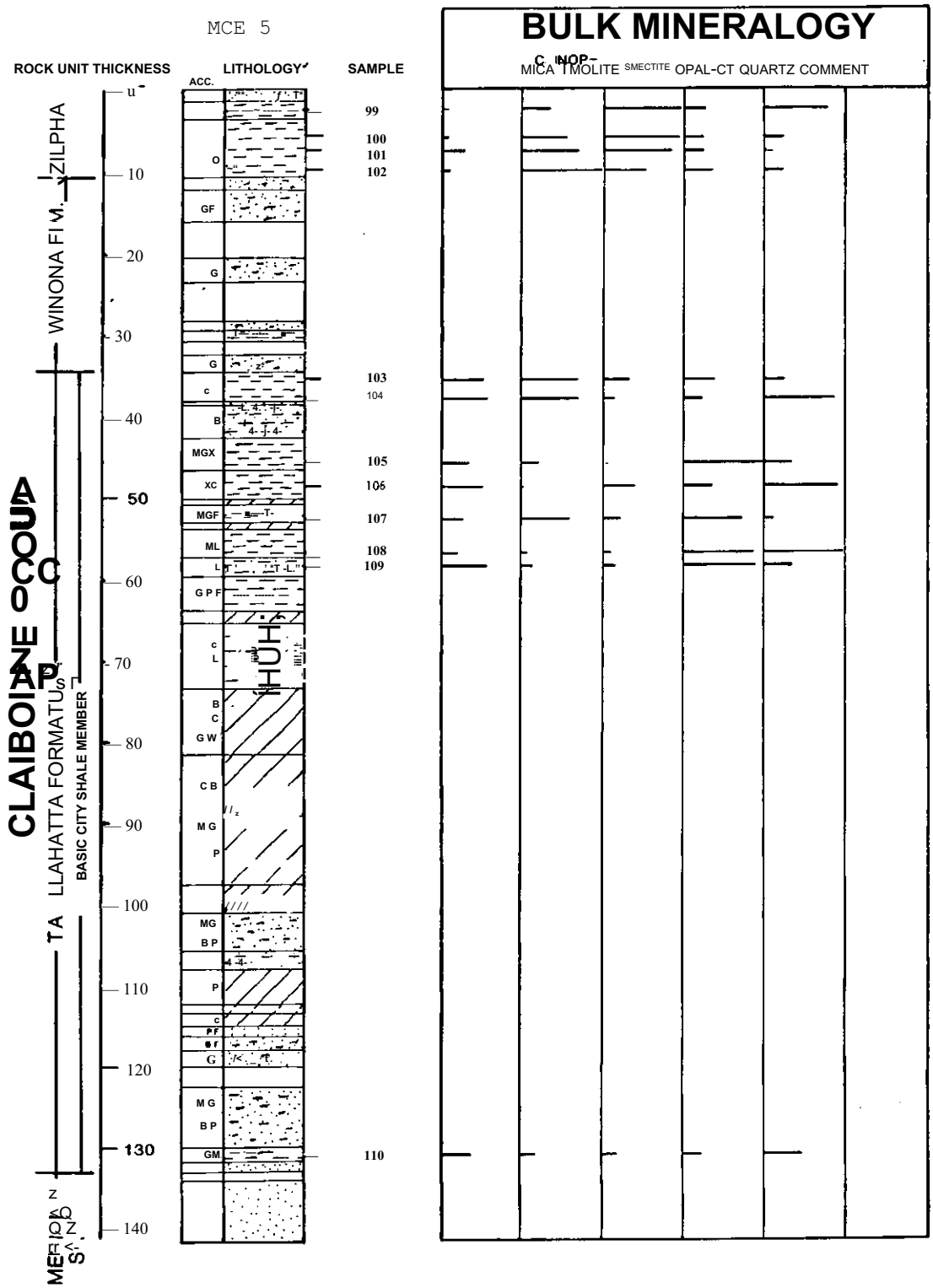
QM GRAIN MOUNT
PH PHOTO

SCALE

FEET METERS





EXPLANATION

SANDSTONE

SAND/WACKE

SANDIARENITE

SILT/STONE

MUD/STONE

CLAYSTONE

CLAYSTONE/CLAY

CLAY

MISSING/COVERED

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SCALE

FEET METERS

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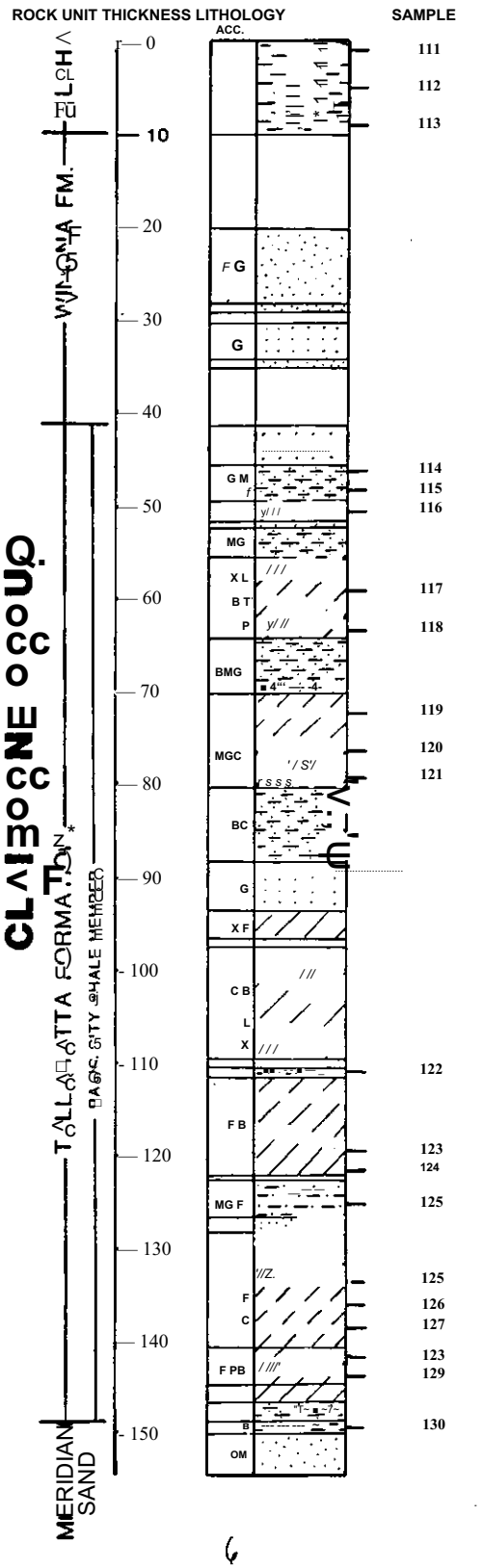
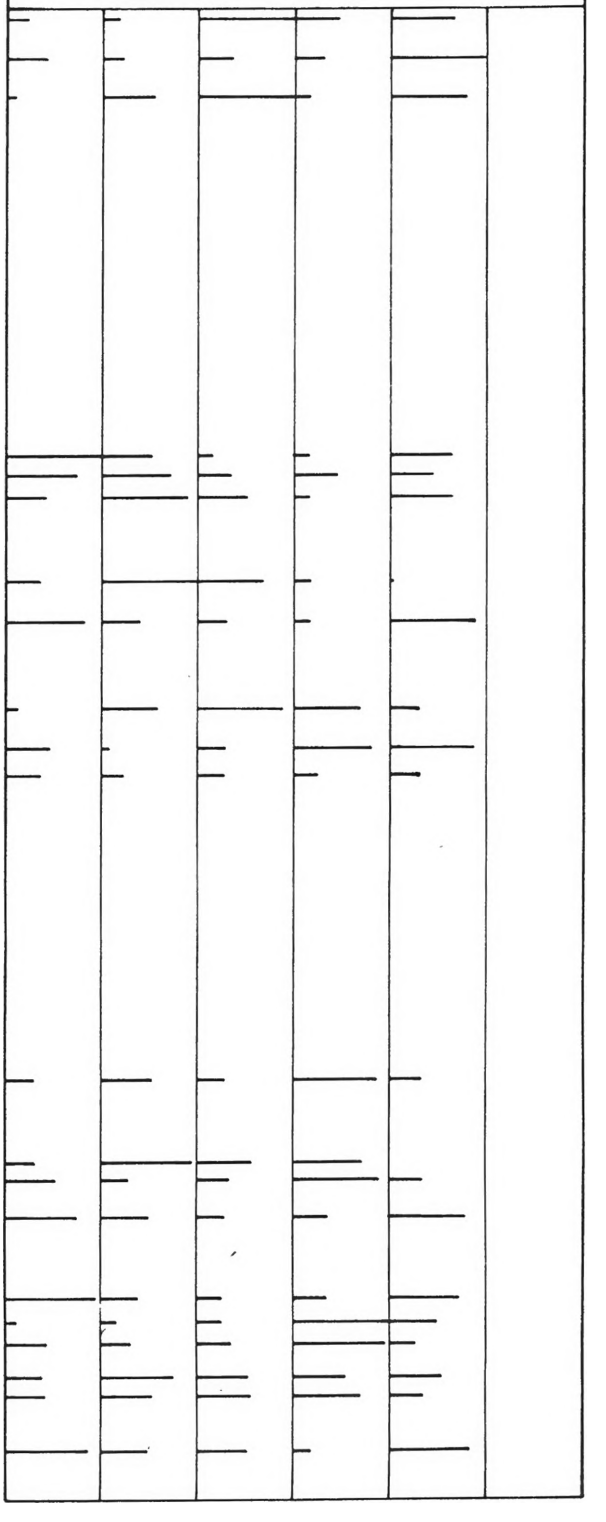
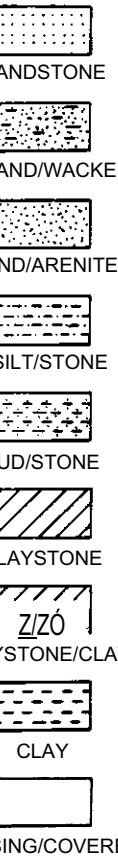


BULK MINERALOGY



EXPLANATION



ACCESSORY

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P PLANT FRAGMENT
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COMMENT

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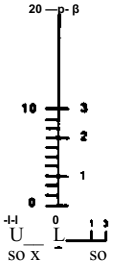
PH PHOTO

SCALE

FEET METERS



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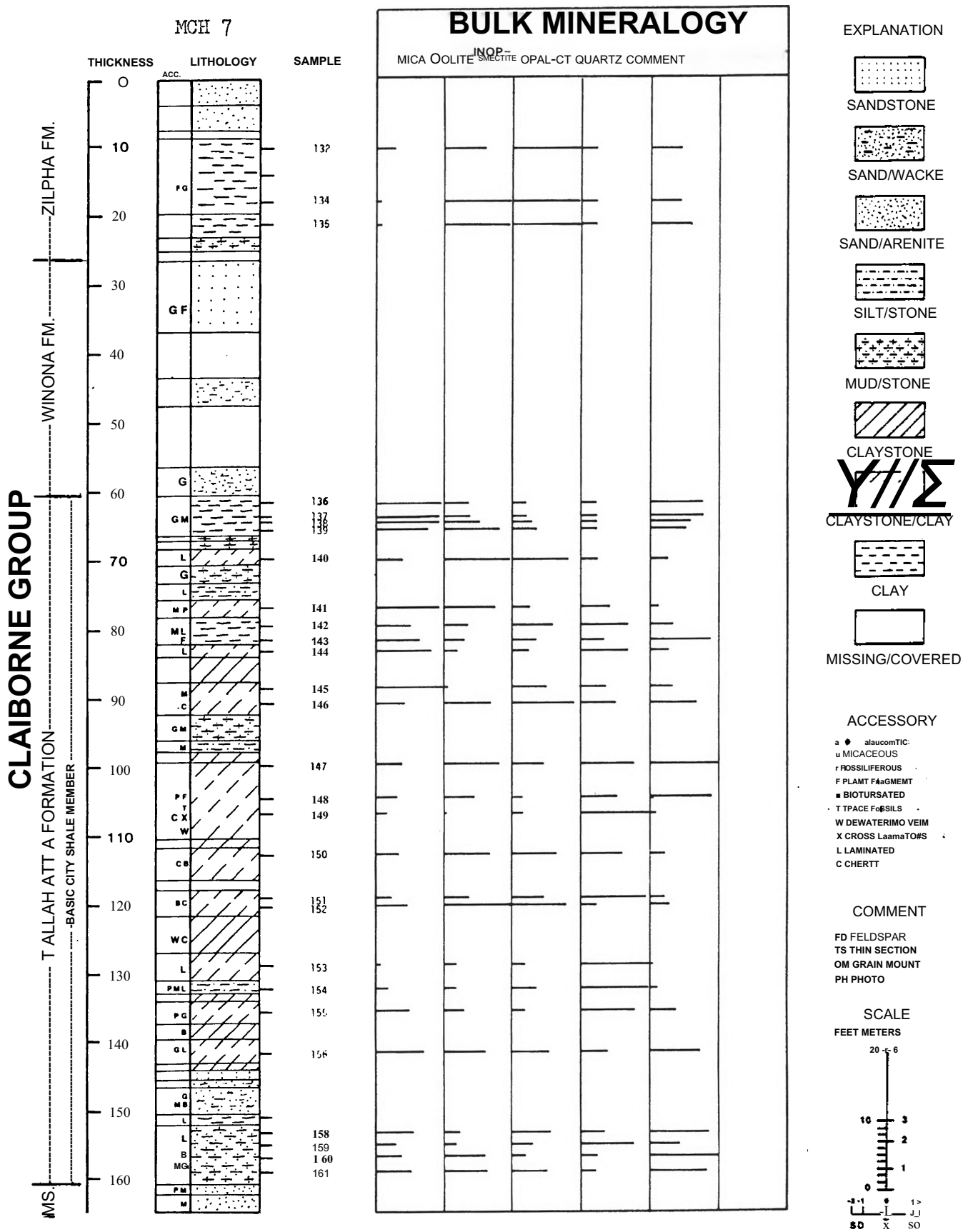
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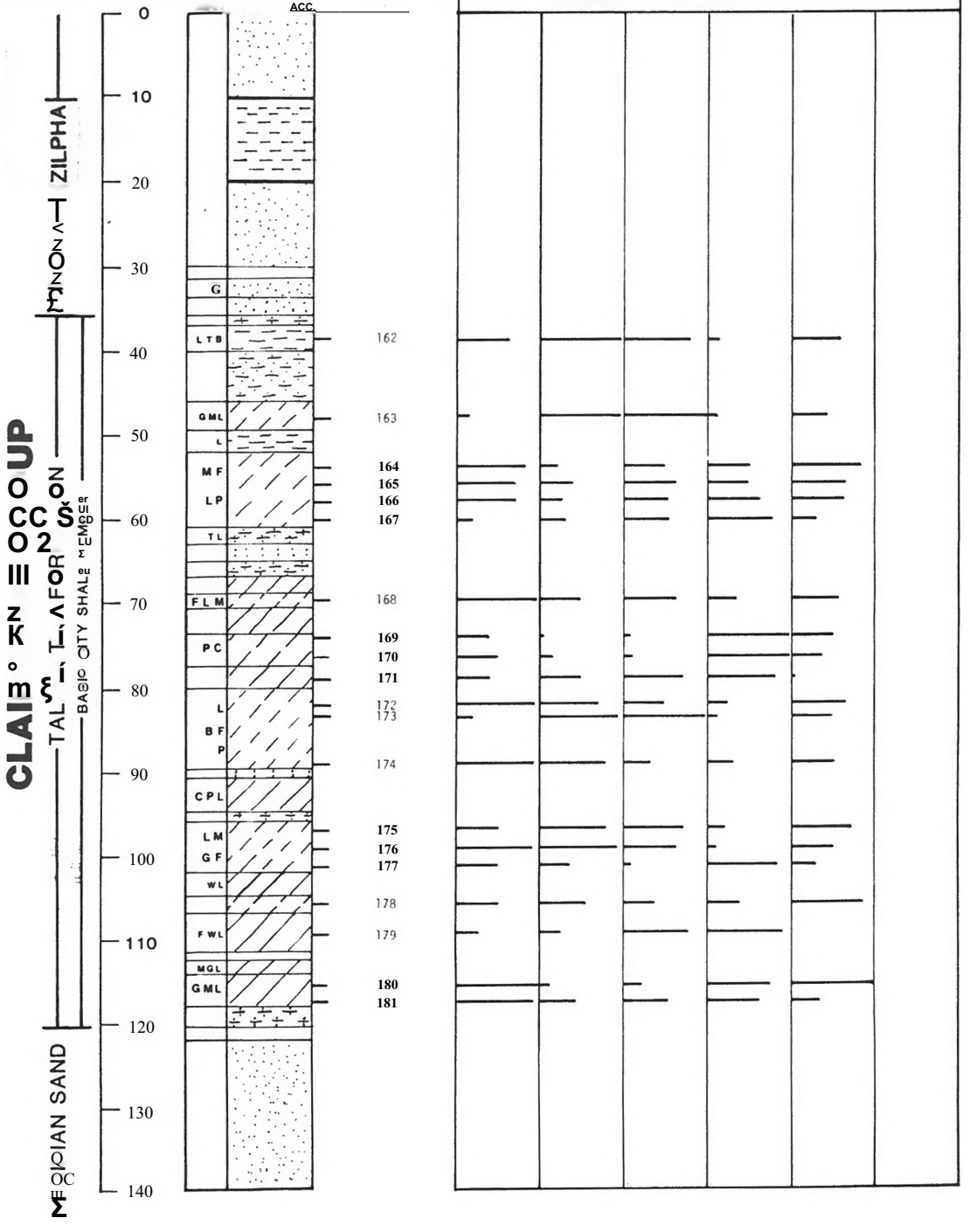
ROCK UNIT THICKNESS | LITHOLOGY | SAMPLE | MICA | CLINOP-TILOLITE | SMECTITE | OPAL-CT | QUARTZ | COMMENT



EXPLANATION

SANDSTONE

SAND/WACKE

SAND/ARENITE

SILT/STONE

MUD/STONE

CLAYSTONE

CLAYSTONE/CLAY

CLAY

MISSING/COVERED

ACCESSORY

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PH PHOTO

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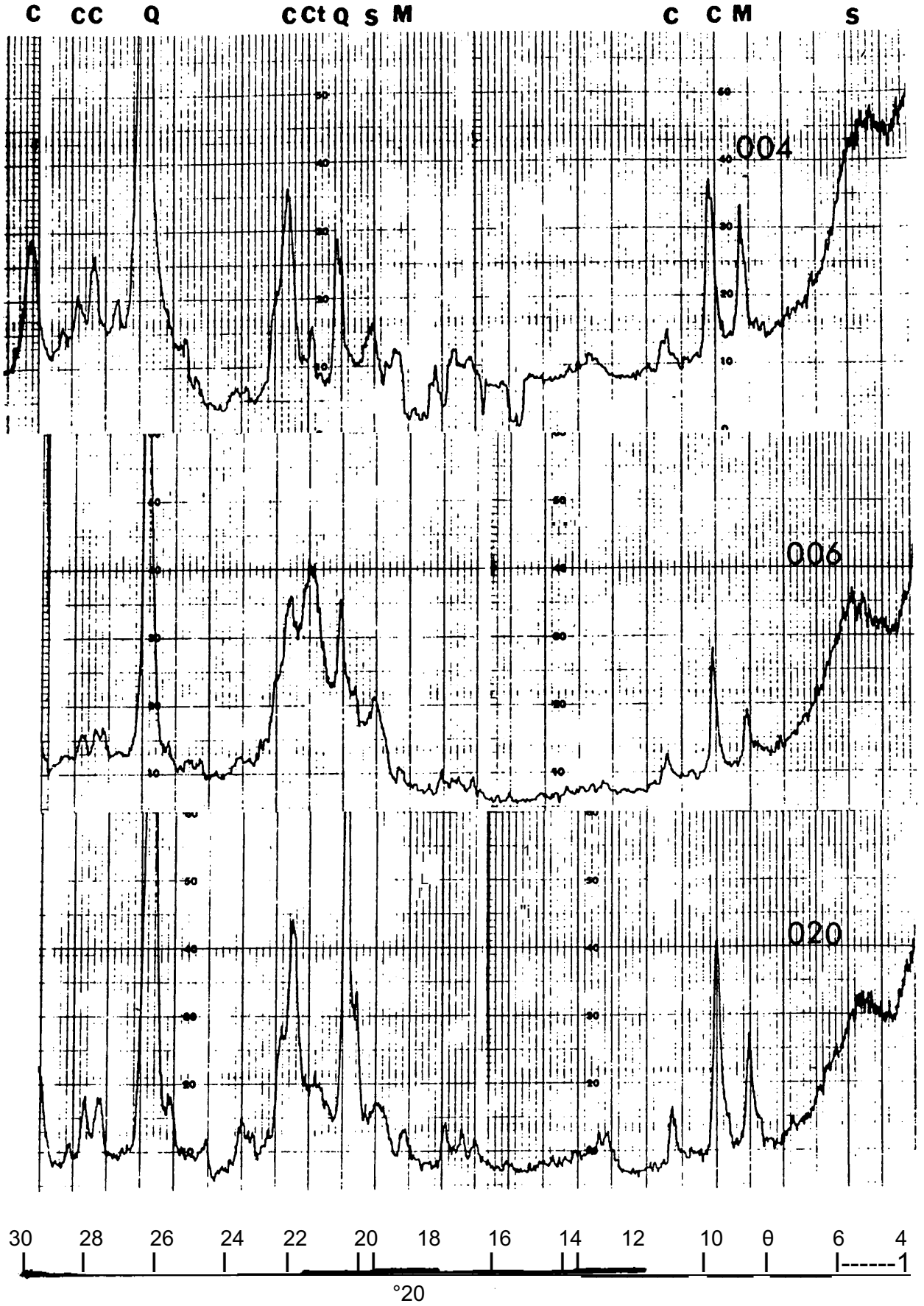
APPENDIX D

X-RAY DIFFRACTOGRAMS OF CORE SAMPLES

MCH 1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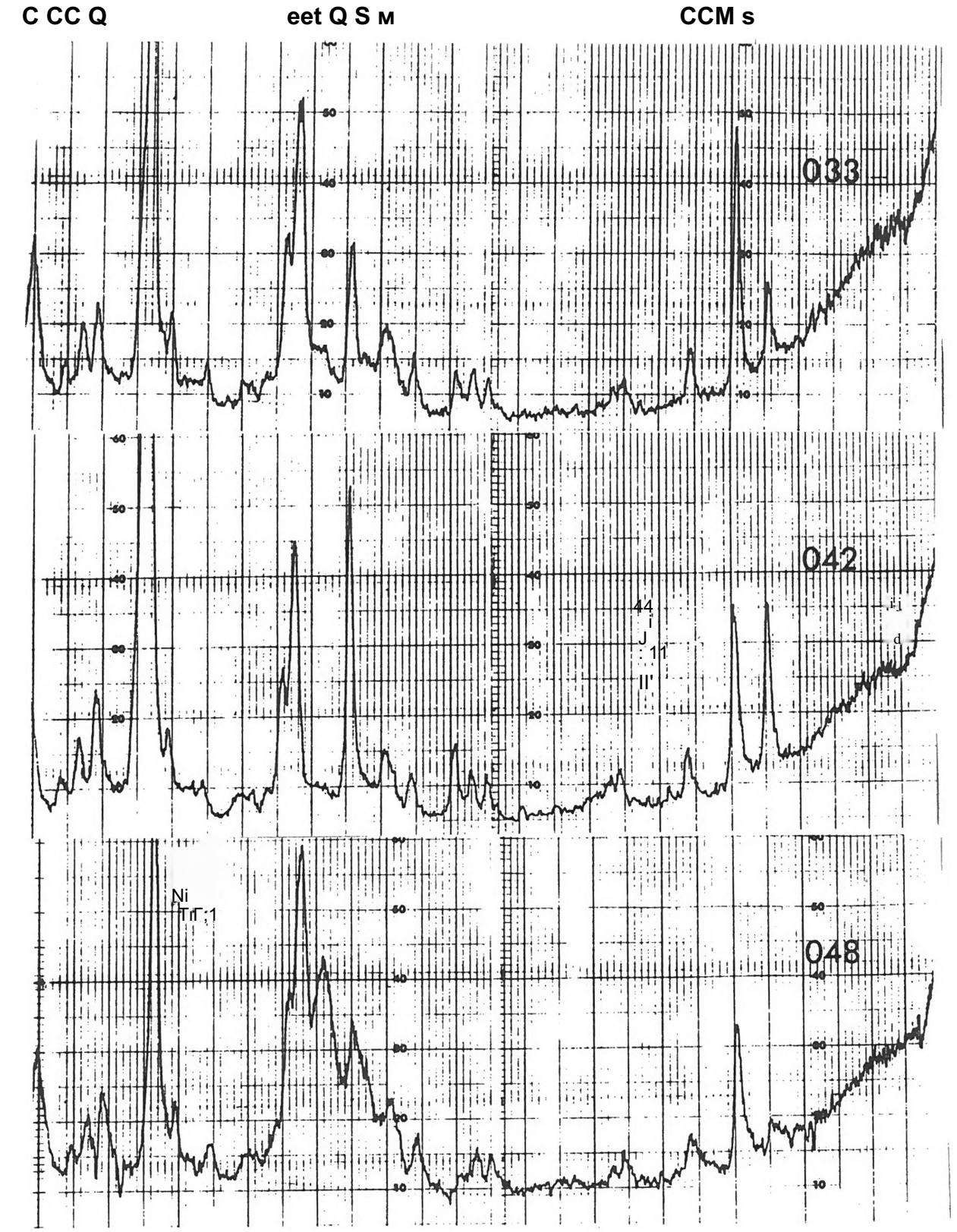
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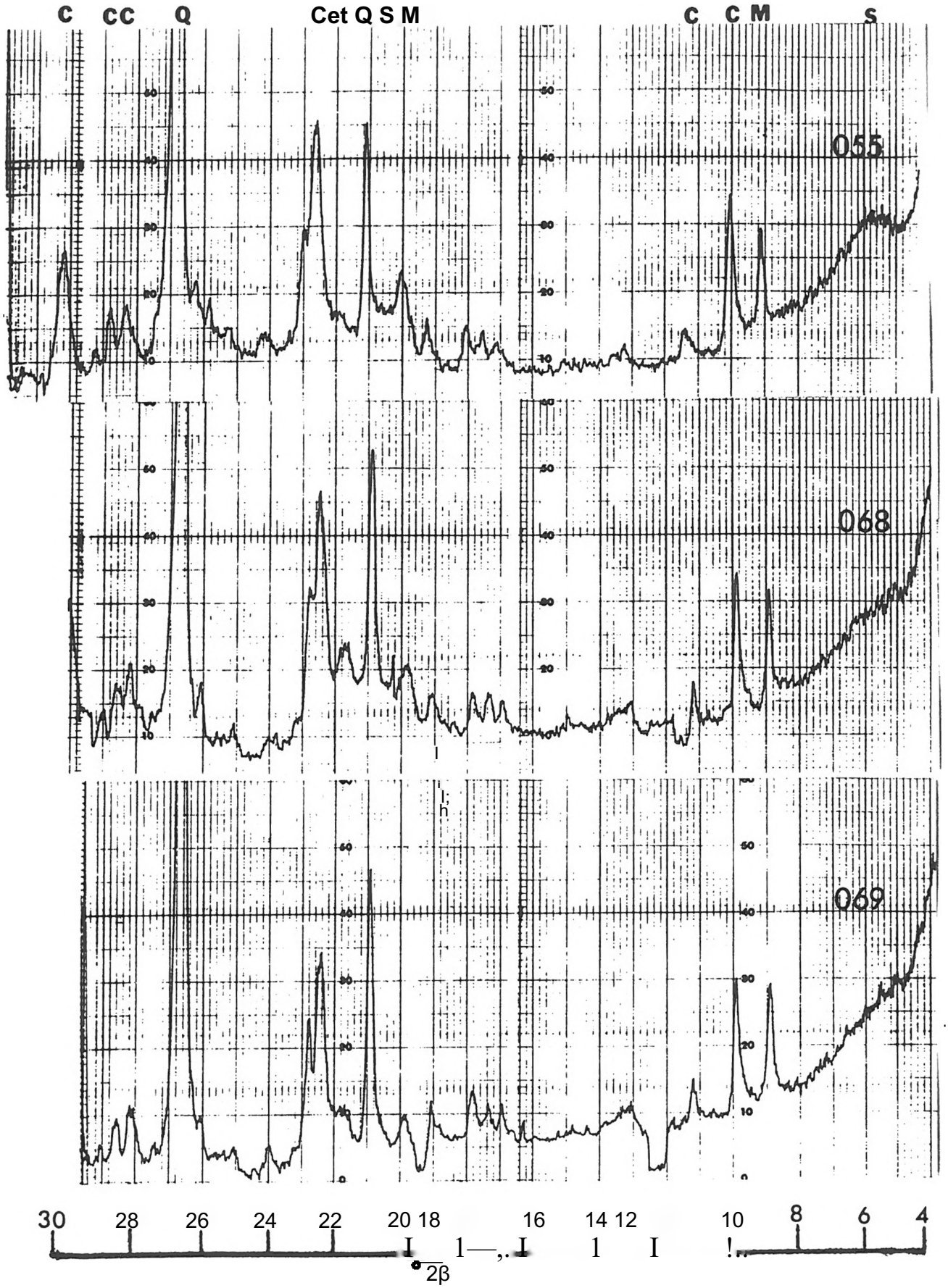
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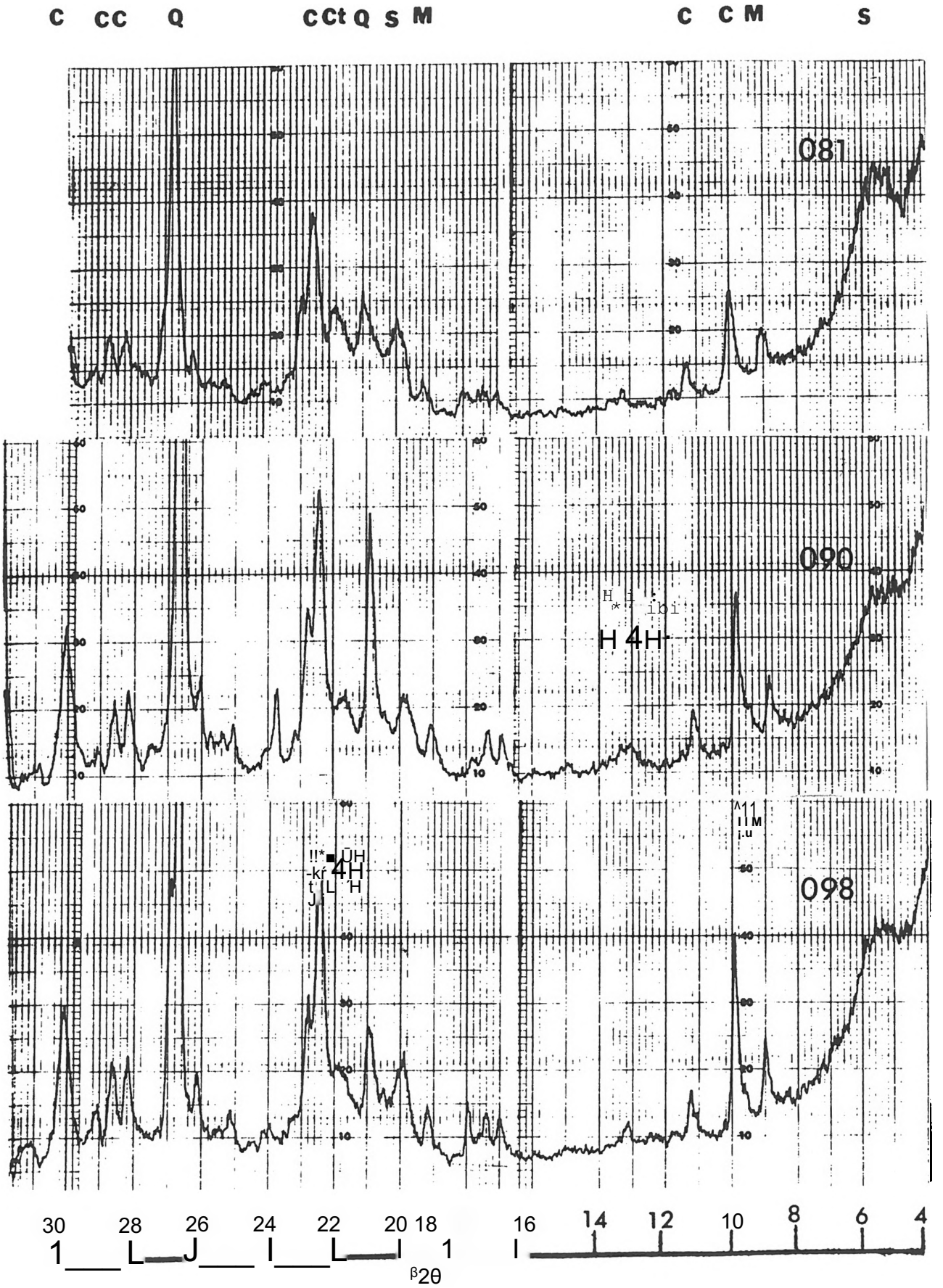
MCH 4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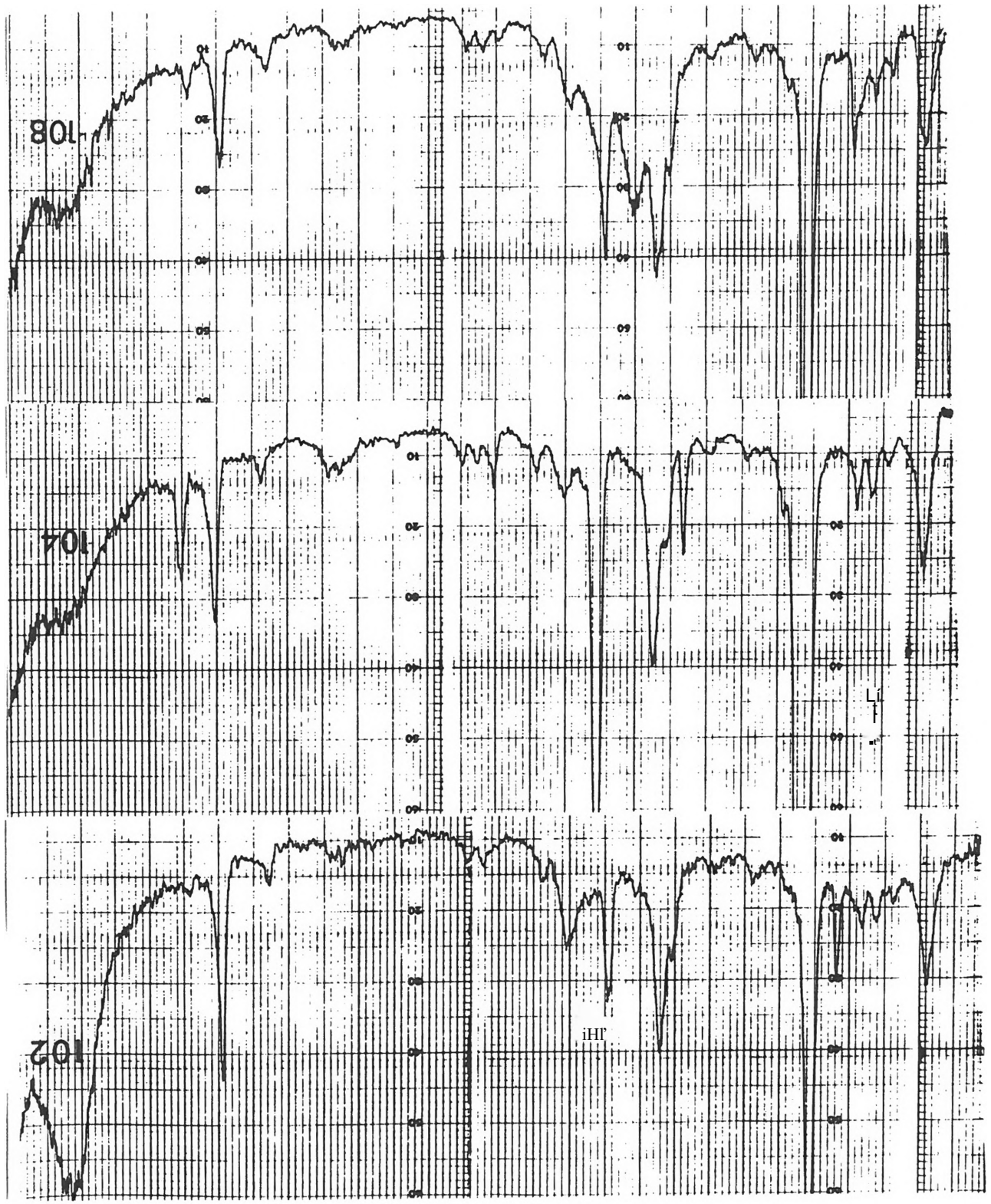

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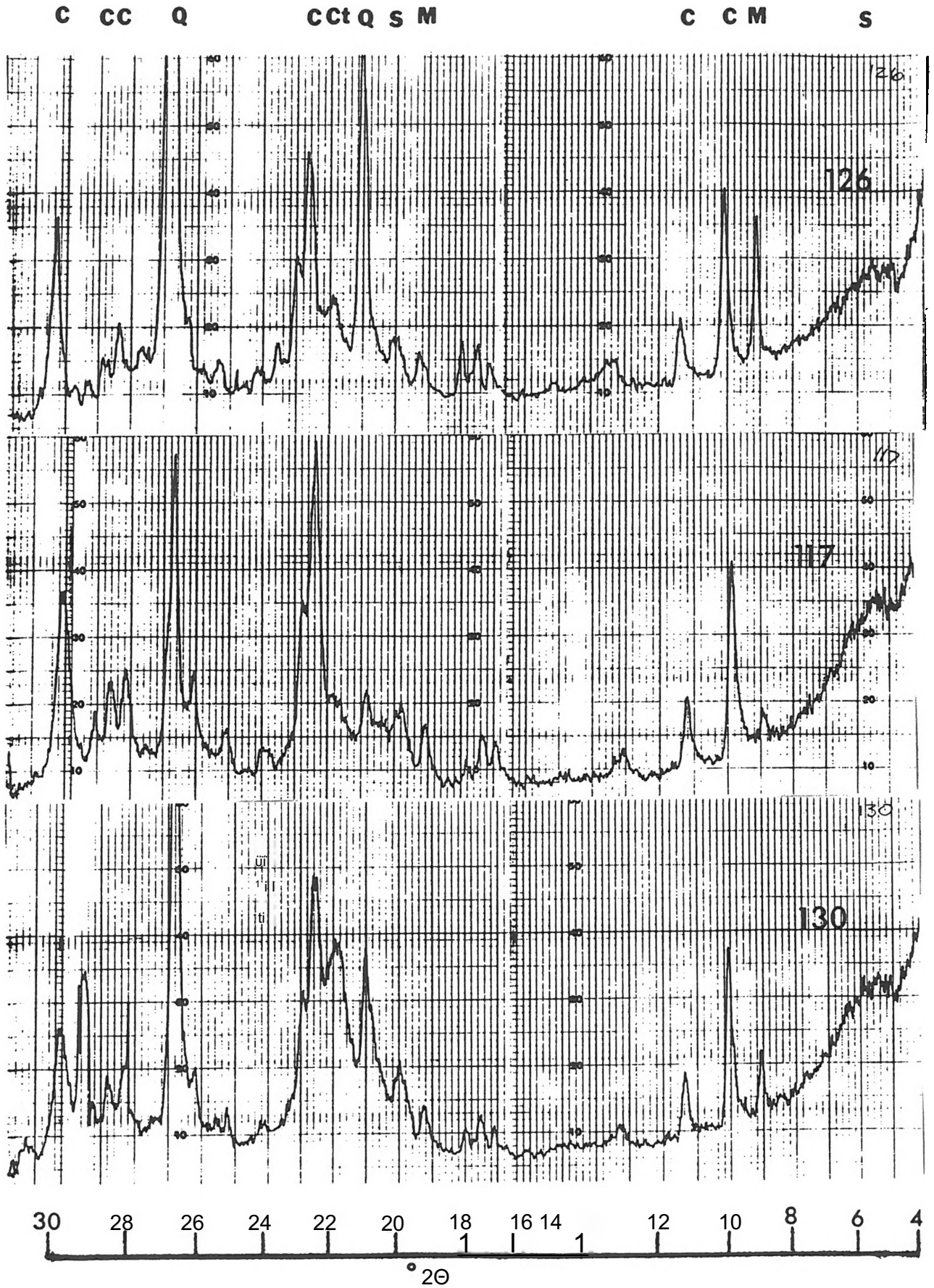
MCH 6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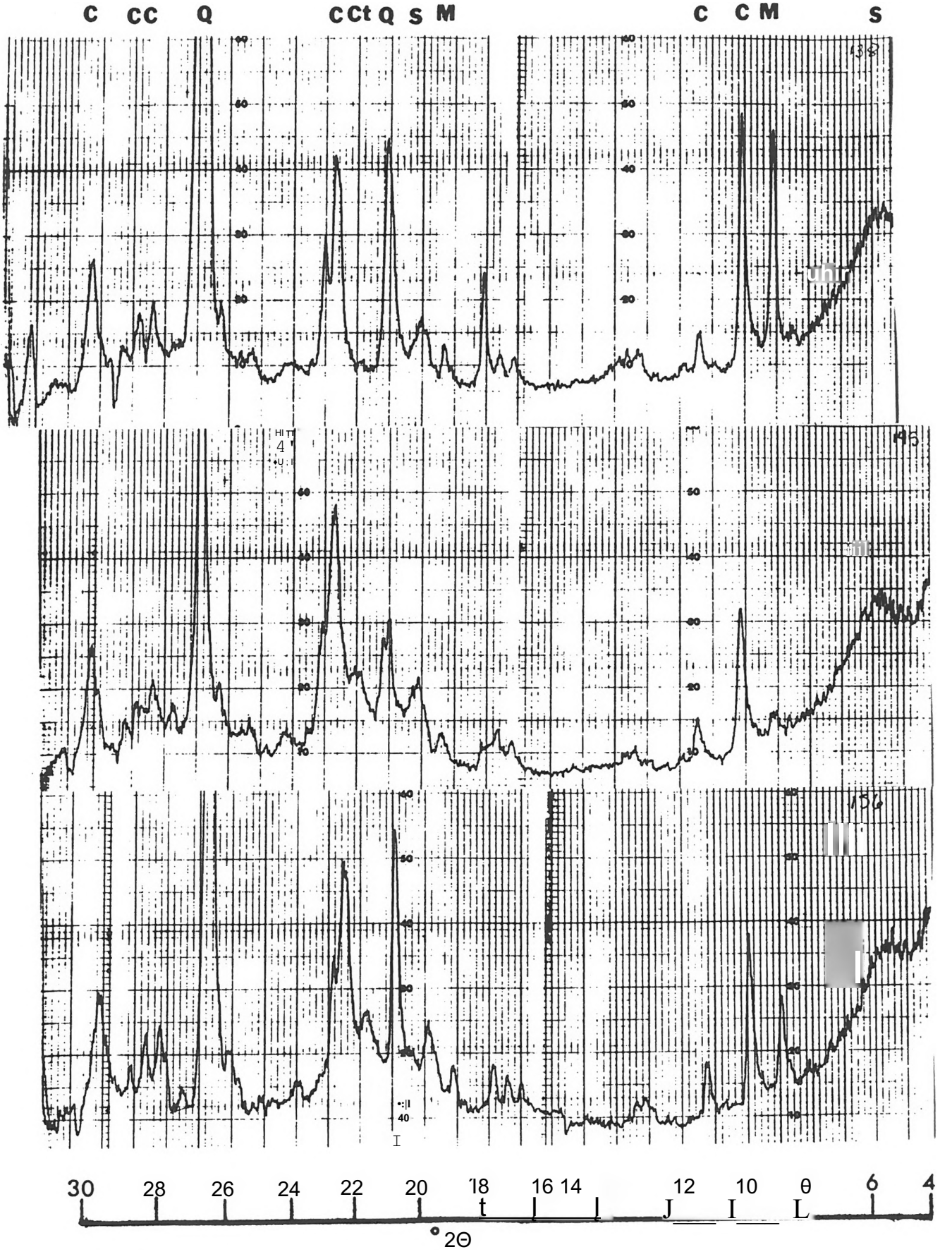
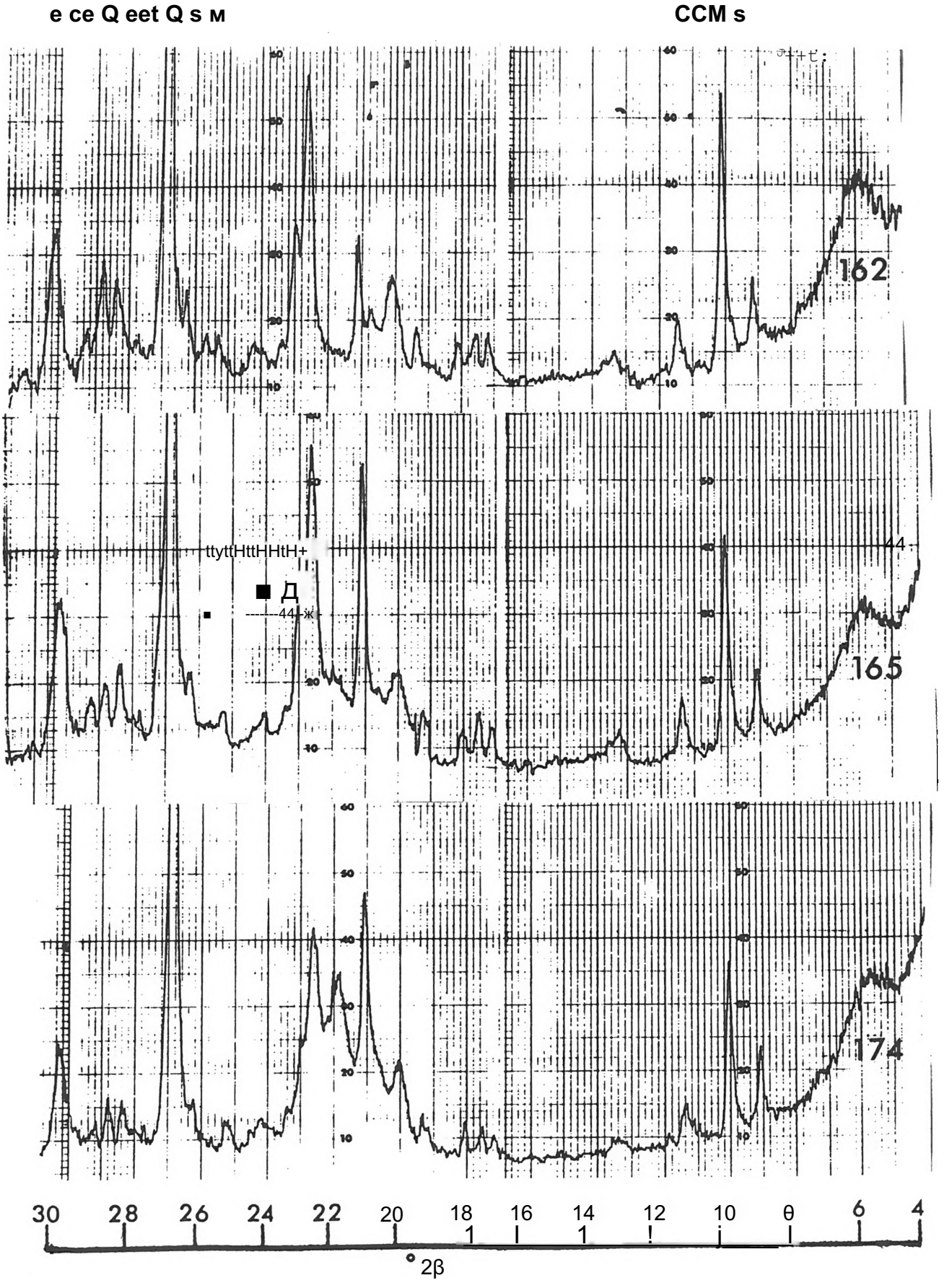
MCH 7



MCH 8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SECTION NO: MCH 6 CORE X EXPOSURE ___ SAMPLE SERIES: _____ PAGE 1

STATE: MISSISSIPPI COUNTY: CLARKE QUAD: ENTERPRISE NW

SEC. 8 T. 4N R. 14E GRID COORD.: NW¼ OF NW¼ OF NW¼

TOTAL DEPTH: 220 ft. CORE INTV.: 150 ft. MISSC.INTV.: 18 ft. REC(%): ___

DEPTH	SAMPLE	LOG	LITHOLOGY	COLOR	ACCESSORY INFORMATION
ZERO M					
10 / 3			SAND(arenite)	Red-buff	Drilled through; no core
20 / 6					
30 / 9					
40 / 12					
50 / 15			SAND(wacke)	Black	Drilled through; no core
60 / 18	111		CLAY	Chocolate	G1, G1, G15, B, A1
	112				
70 / 21	113				
80			Missed		Drilled-out 10' to set core barrel
24.5			SAND(wacke)	Olive	Quartz, arc.grd; A2, B
90			SAND(arenite) Missed	Green	Quartz,arc.grd; A2
27			SANDSTONE	Green	Quartz arenite, [illegible]; [illegible], G18
			SAND(wacke)	Olive-grn	Quartz,fn-med.grd; A2, A1
100			Missed		
30.5			SANDSTONE	Olive-grn	Quartz [illegible] A1, [illegible] B, [illegible]
	114**		MUD	Olive-grn	C1, G1, A1, [illegible]
110	115**				
33.5	116**		CLAY(opal)	Olive-grn	C1, G1, A1 [illegible]
			SAND(wacke)	Brown	Quartz,fn-[illegible]
			MUD	Olive-grn	C1, G1, A5, [illegible] G18, A4, B1, E4
120	117**		CLAY(opal)	Olive-grn	C1-C2, G1, G15; a1, [illegible], [illegible], B2a, B1, [illegible], [illegible]
36.5	118**				
130			MUD	Olive-grn	C2, G1, [illegible] A1, [illegible], B1
39.5	119*		CLAY(opal)	Olive-grn	C1, [illegible], [illegible]5, A1, A2, A4, G18, E4, G6, [illegible], [illegible], A3
	120				
140	121**				
43			MUD	Olive-grn	[illegible], G1, [illegible], [illegible], [illegible], B1, A4
150			SANDSTONE	Olive	Quartz wacke,fn-med.grd; A1, A2, A5
46			CLAYSTONE	Olive-grn	C1, G1, G17, B, A1, G15, G7([illegible]) [illegible],
			Missed		B1, B2, B2A
160			CLAYSTONE	Olive-grn	As Above
49					
170	122**		CLAY	Olive-grn	C1, G1, G6, A6
52	123**		CLAYSTONE	Olive-grn	As Above w/ [illegible]
	124*				
180					
55	125**		SILTSTONE	Olive-grn	C1, G1, A1, A2, B
			SAND(wacke)	Olive	Quartz,fn,grd; A1, A2, G15, B
	126**				
190					
58	127*		CLAY-CLAYSTONE	Olive	[illegible] ①, B, G15, G18, A7, G8(sampled)
	128*				
200	129**		CLAY(opal)	Olive-grn	A1, B2, B, A7
61	130**				
			CLAYSTONE	Grey-grn	A1, A2, B1, D3
			MUD	Grey-grn	A1, A2, B, G12
	131**		CLAY	Olive-grn	A2, G6, B
210			SAND(wacke)	Grey-grn	[illegible] fn.grd; A1, A2, G12, A9, B
64			Missed		
220					
67					

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