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STRATIGRAPHY AND URANIUM CONTENT OF THE CHATTANOOGA SHALE IN THE FOLDED BELT OF ALABAMA, GEORGIA, AND TENNESSEE*

By

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TEPCO, RPS, Washington, (including master)	2
	49

CONTENTS

ILLUSTRATIONS

TABLES

STRATIGRAPHY AND URANIUM CONTENT OF THE CHATTANOOGA SHALE IN THE FOLDED BELT OF ALABAMA, GEORGIA, AND TENNESSEE

By Lynn Glover

ABSTRACT

In the folded belt of Alabama, Georgia, and Tennessee, the Chattanooga shale ranges in thickness from a thin edge to over 40 feet. Most of the shale is of Gassaway age, as the Dowelltown member is present only in part of eastern Tennessee, and beds of Dowelltown age were found in a small area in Alabama and Georgia. The Chattanooga shale and the Maury formation are progressively overlapped in the vicinity of Birmingham, Ala.

Along the eastern margin of the late Chattanooga sea, which coincided roughly with the region studied, stable shelf conditions prevailed, but the degree of stability was somewhat less than that to the west in the Eastern Highland Rim area. This is shown in the east by the siltier and sandier sections, intraformational conglomerates, greater range in thickness of the shale, and occasional preservation of basal conglomerate. Phosphate nodules and minor amounts of chert were deposited in the east, and the distribution of each is areally and stratigraphically distinct. The chert probably accumulated in quieter water than did the phosphate.

Occasional influxes of greater than usual amounts of inorganic material produced the gray beds common in the Chattanooga. These beds have more clay and less organic matter than do the black beds.

Black shale lentils occur in the Maury formation in Georgia and southeastern Tennessee. In central eastern Tennessee a bed equivalent in age to the Maury is all black shale and typical Maury lithology is absent.

Less stable conditions of deposition and wide distribution of phosphatic black shale account for the generally low uranium content (less than 0.005 percent) of the Chattanooga shale in the region studied.

INTRODUCTION

Since 1944 the U. S. Geological Survey has conducted field investigations of the Chattanooga shale, a potential low-grade source of uranium, for the Atomic Energy Commission. This report is the result of a reconnaissance study of the shale in the folded belt of eastern Tennessee, northwestern Georgia, and northeastern Alabama made during the period July 1954 to March 1955. The objectives of the project were 1) to study the stratigraphy of the Chattanooga shale and related rocks in the folded belt of eastern Tennessee, northwestern Georgia, and northeastern Alabama with emphasis on environment of deposition, source of sediments, lithic character, thickness, distribution and correlation of stratigraphic units, distribution and concentration of uranium in the shale, and the character of stratigraphic control (if any) on the concentration of uranium, 2) to detect radioactivity anomalies in the shale by means of a scintillation counter, and 3) to take samples of the shale for uranium analyses.

The region studied (pl. 1) includes the southern Appalachians and the eastern folded margin of the Cumberland Plateau; it is bounded to the east and south by the limits of the Chattanooga outcrop, to the north by 36° latitude (approximately Knoxville, Tenn.), and to the west by a line of extension of the Sequatchie Valley. During the investigation, all roads that crossed the outcrop of the shale were traversed, all observed outcrops were spotted on maps, and 72 of the best exposures were measured and described in detail. An average scintillation counter reading is

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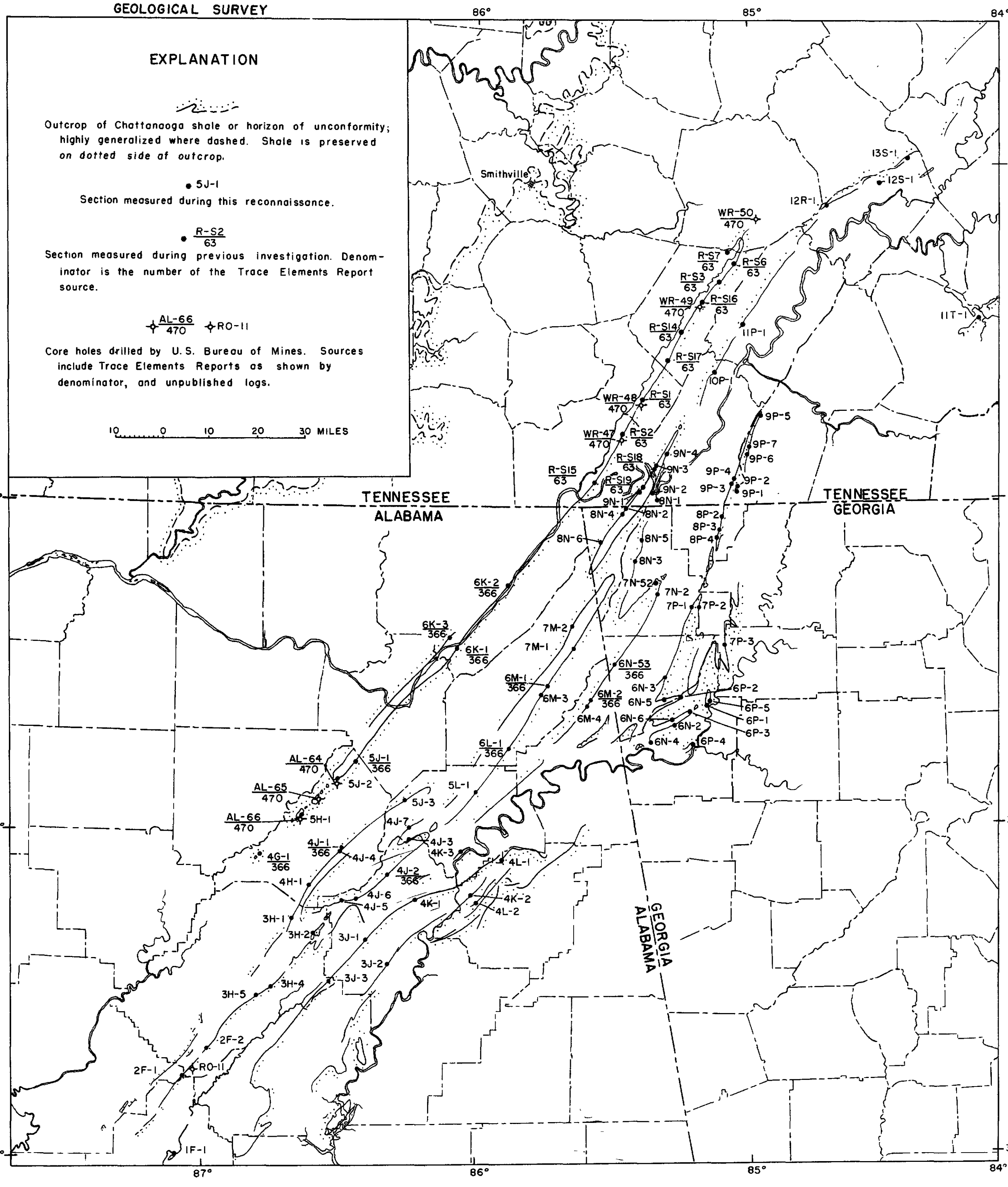


PLATE 1 -- CHATTANOOGA SHALE LOCALITIES IN THE FOLDED BELT OF ALABAMA, GEORGIA, AND TENNESSEE

herein recorded for each section or part of a section where a reliable reading could be taken. Twenty-eight samples of shale were collected for analysis from eight of these sections, and eleven faunal collections were made.

Slaughter and Clabaugh (1945), Butler and Chesterman (1945), Nelson and Brill (1947), Robeck and Brown (1950), Robeck and Conant (1951), and Swanson and Kehn (1955), investigated the Chattanooga shale in parts of the area herein discussed. Most of these reports describe only one or two localities in the folded belt, but the report by Swanson and Kehn describes seven outcrops east of the Sequatchie Valley in Tennessee and Alabama. All of the pertinent data from these reports are incorporated in the present report.

ACKNOWLEDGMENTS

This investigation was facilitated by the help of many people. Dr. Walter B. Jones, State Geologist of Alabama, and Mr. Hugh D. Pallister, Senior Geologist of the Alabama Geological Survey, offered encouragement and unlimited use of the facilities of the State Core Library. Captain Garland Peyton, State Geologist of Georgia, provided information on unpublished localities in northwestern Georgia. Mr. Stuart W. Maher, Tennessee Division of Geology, and Robert A. Laurence, U. S. Geological Survey, spent a day in the field with the writer reviewing the stratigraphy of the Chattanooga shale in eastern Tennessee. Faunal identifications were made by W. H. Hass and A. J. Boucot, U. S. Geological Survey. Uranium and trace elements analyses were made by the U. S. Geological Survey.

GENERAL GEOLOGIC AND STRUCTURAL SETTING

The outcropping rocks in the region are mainly well indurated Paleozoic sediments that range in age from Cambrian to Pennsylvanian. These rocks were folded and faulted during the formation of the Appalachians so that they now form long arcuate folds traceable on the surface as far south as Centreville, Ala. In the vicinity of Centreville, Paleozoic rocks are overlapped by poorly indurated sediments of Cretaceous age.

The regional geology is described by Butts (1926), Butts and Gildersleeve (1948), Rodgers (1953), and is shown on the State geologic maps of Alabama, Georgia, and Tennessee.

STRATIGRAPHY AND SEDIMENTATION

Chattanooga shale

General relations

The Chattanooga shale is a black organic pyritiferous marine shale that is generally very fine grained and sparsely fossiliferous. It is part of a persistent terrane of black shale deposited over much of the interior of North America during Middle Devonian, Late Devonian, and early Mississippian time.

In the southern Appalachians and along the folded margin of the Cumberland Plateau, the Chattanooga unconformably overlies at least six formations that range in age from Middle Ordovician to Middle Devonian. It is apparently conformably overlain by the Mississippian Maury formation south of the latitude of Knoxville, Tenn., except in the narrow belt of outcrop along the western margin of the Great Smoky Mountains. There,

Table 1. -- Stratigraphic nomenclature of the Chattanooga shale and Maury formation in central Tennessee.

Lower Mississippian	Maury formation		
Upper Devonian	Chattanooga shale	Gassaway member	upper unit * middle unit * lower unit *
		Dowelltown member	upper unit * lower unit *

* Informal names used by field geologists.

Breaking the monotony of the black shale succession are the middle unit of the Gassaway member and the upper unit of the Dowelltown member, which consist of alternating thin gray and black beds. This allows the two members to be further subdivided into a total of five units. A thin bed of sandstone, the Bransford sandstone of Campbell (1946), generally is present at the Dowelltown-Gassaway contact in east-central Tennessee. Near the top of the Dowelltown is a thin bed of bentonite (Hass, 1948), which has been traced over much of the Eastern Highland Rim and as far east as Dayton, Tenn. (locality 11P-1).

Previous investigations by Robeck and Brown (1950) and Glover (1954) showed that both members of the Chattanooga are present in the northern part of the Sequatchie Valley, but that the Dowelltown is missing because of overlap in northern Alabama and in Tennessee south of hole WR-48 (pl. 1). In corroboration, the typical alternation of thin gray and black beds of the upper unit of the Dowelltown member was observed during this reconnaissance only at localities 11P-1 and 10P-1, both of which are north of the latitude of hole WR-48. Farther south, however, Hass found conodonts of Dowelltown age in the lower 1 foot of the section at locality 6N-53, Menlo, Ga., and in the basal sandstone at locality 4J-3, Etowah County, Ala. There is not enough difference between the lithology of beds of Dowelltown age and those of Gassaway age at these localities in Alabama and Georgia to warrant separating the formation into members. Consequently, the term Chattanooga is applied to all of the Devonian black shale south of Chattanooga, Tenn.; the terms Gassaway and Dowelltown are useful in a time sense only.

The outcrops that contain beds of probable Dowelltown age (6N-53 and 4J-3) are both in areas of thick shale sections (pl. 1, fig. 1, fig. 2). It seems reasonable to assume that the entire area of thick shale contains beds of Dowelltown age at the base, although the beds may not be separated lithologically. This assumption is the basis for the distribution of shale of Dowelltown age in Alabama and Georgia as shown in figure 2.

Overlap

The isopach map of the Chattanooga shale (fig. 1) and the distribution of the beds of Dowelltown and Gassaway age (fig. 2) show that the general direction of overlap in the region was to the south and east. A slightly high area seems to have existed along the southern Tennessee State line because there the section is thin and only shale of Gassaway age is present. Another high area was in the vicinity of Birmingham, Ala., and farther east, where the Chattanooga (locality 3H-2) and the overlying Maury (locality 3J-2) are progressively overlapped. In Georgia and Tennessee, however, the Chattanooga can be found as far east as its

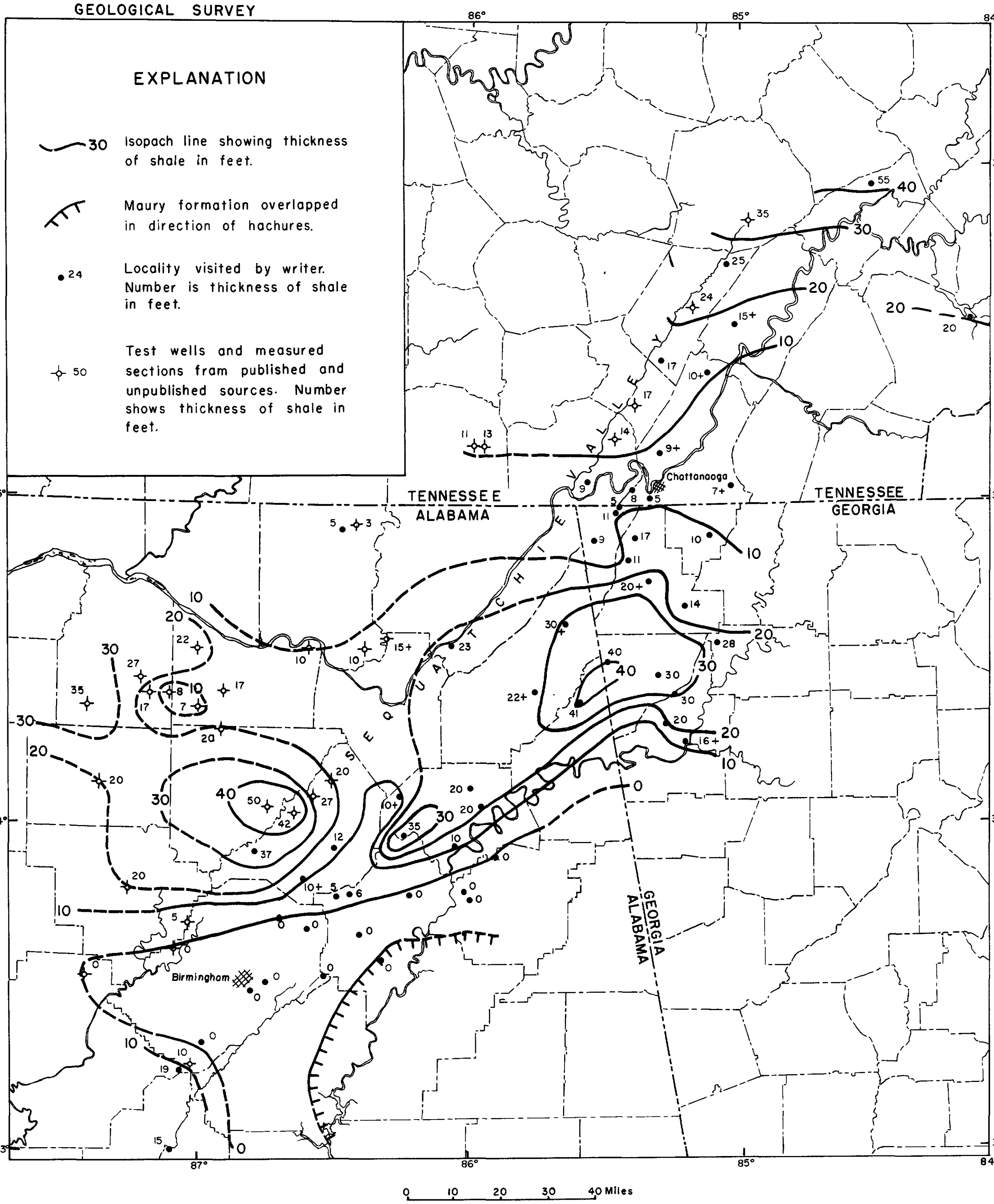


Figure 1 — Isopach map of the Chattanooga shale in the folded belt of Alabama, Georgia, and Tennessee

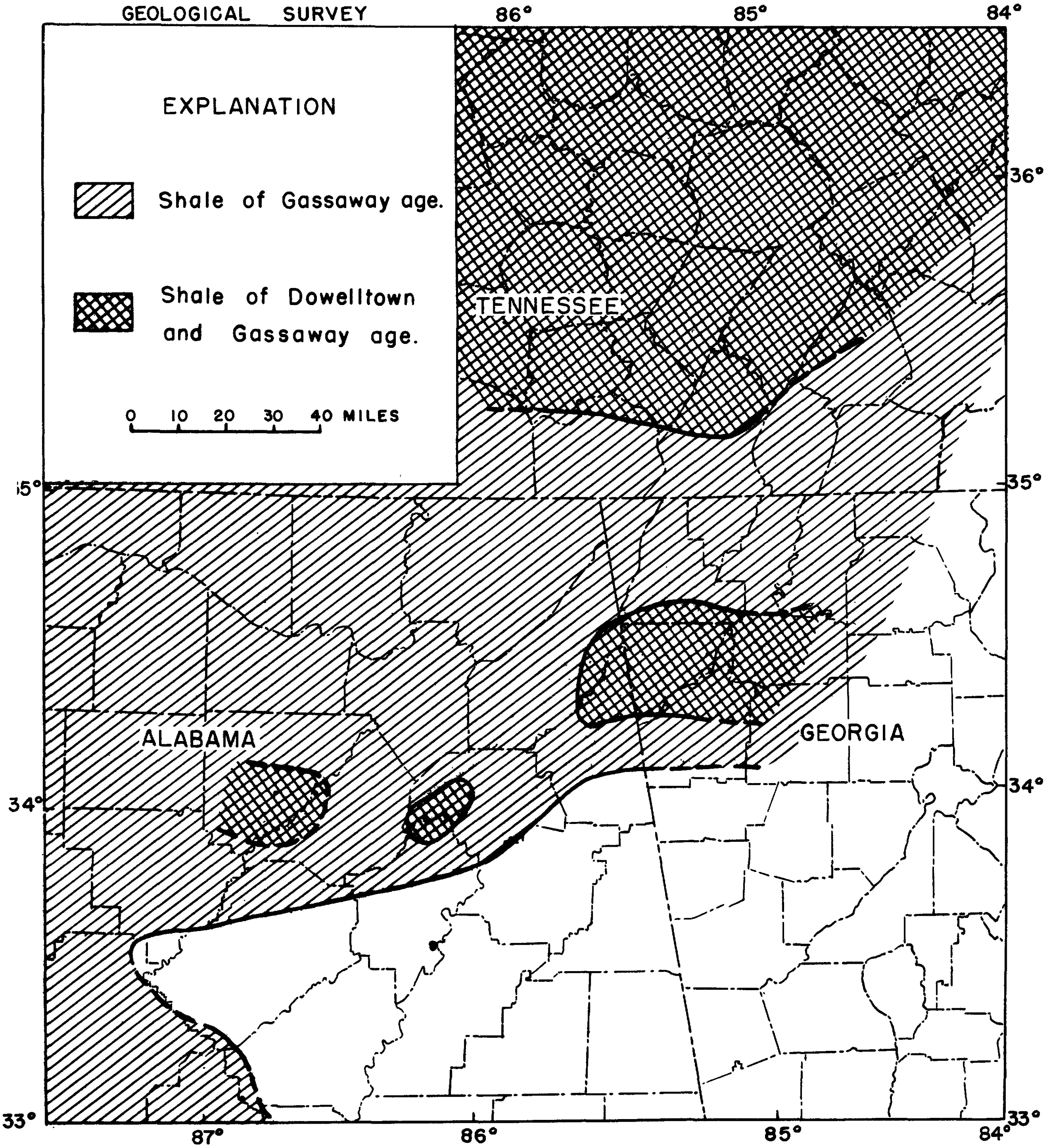


Figure 2 — Distribution of beds of Dowelltown and Gassaway age in the Chattanooga shale of northeastern Alabama, northwestern Georgia, and eastern Tennessee.

interval is preserved and exposed.

Basal sandstone

A basal sandstone is present throughout the region wherever the proper interval is exposed except for one locality (8N-3). It has an average thickness of 0.78 foot for 31 localities, and a maximum thickness of 5.0 feet in core RO-11, southwest of Birmingham. Characteristically the sandstone is composed of well-rounded poorly sorted quartz grains ranging in size from silt to pebble, but averaging coarse. The matrix consists of organic matter, pyrite, and abundant phosphatic fossil remains.

Conglomerate or conglomeratic sandstone is the basal unit at localities 4J-3, AL-66, 7N-52, and RO-11. The pebbles have a maximum diameter of 0.13 foot, and at the first three places are subrounded to well rounded. At the last place, core RO-11 (fig. 5), the pebbles are extremely angular pieces of chert eroded from the underlying cherty limestone. The pebbles occur where the basal sandstone is relatively thick (appendix, p. 44, 47, 55) and appear to be associated with thick shale sections and less stable areas of deposition.

Considering that the Chattanooga is underlain by six formations in this region, the identity of all pebbles with underlying rocks shows that the pebbles have not been transported far. The roundness of many of the pebbles indicates that they must have undergone considerable wave action before final deposition.

The basal sandstone is a time transgressing unit ranging in age from early Dowelltown (early Late Devonian) in the general latitude of Knoxville, Tenn., to Maury (early Mississippian) near Birmingham, Ala.

Lithology

Although the Chattanooga shale in this region closely resembles the shale in central Tennessee, it differs lithologically in several respects. In general it is coarser grained and contains much disseminated coarse sand, scattered chert beds, and intraformational conglomerates. Lithologic logs of each section are shown graphically in the appendix, p. 43.

Sand and silt.--Several thin beds of coarse-grained sandstone occur in the Chattanooga in this region. At localities 4J-5 and 4J-6 in Alabama a 0.2 foot bed of poorly sorted sandstone with silt- to granule-size quartz particles was found about 0.5 foot below the top. Localities 7N-52, 9P-2 in Georgia, and 11T-1 southeast of Knoxville, also show poorly sorted coarse-grained sandstone, but none of these can be traced beyond its own exposure. Because these sandstone beds are of small areal extent, poorly sorted, and coarse grained, they are probably lag concentrates of the disseminated coarse sand deposited in the Chattanooga sea.

Well sorted fine sand is common in the Chattanooga at several places in the region. At localities 6M-2 and 6M-4 in Alabama, the upper 18 to 21 feet of the section is practically all black siltstone and fine-grained sandstone. The silt and sand in these sections slumped before consolidation and much of the original bedding was destroyed. Rich (1951, p. 2023) maintains that all true sand beds in the shale are lag concentrates of material that has been rafted in. However, such large quantities of silt and sand as that found in the sections at 6M-2 and 6M-4 could not have been rafted in, but must have been transported by current action. In core RO-11 the micro-crossbedding in the silt found near the top of the Chattanooga also indicates that currents were active in the deposition of the shale.

Gray beds.--Beds of gray claystone, gray silty claystone, or gray shale are common to most outcrops of the Chattanooga in the region studied. The gray beds in the Dowelltown member at 11P-1 and 10P-1 are undoubtedly part of a unit that can be found over a large area of east central Tennessee, and the same may be true of the gray interval at 11T-1. However, in the vicinity of Chattanooga, Tenn., and south it does not seem possible to correlate individual gray beds over large areas.

The gray beds of the Chattanooga have more clay and less organic matter than the black shale, and in many of the eastern outcrops they are quite silty or sandy. When compared with the surrounding black shale, the gray shale is also less perfectly sorted and bedded. All of these features with the exception of the small amounts of silt and sand seem to agree with the general characteristics of the gray beds in the Chattanooga shale along the Eastern Highland Rim. Conant (1952, p. 22) suggested that post depositional oxidation of the organic matter produced the gray beds found in the Chattanooga shale. If this explanation were true, then the principal difference in composition between the gray and black beds should be difference in amount of the organic matter. Within the area of this study, less perfect sorting, general absence of bedding, and greater amounts of clay in the gray beds show that the gray beds are probably the result of increased supply of inorganic material instead of oxidation of organic muds. Consequently, the gray beds are interpreted by the writer to represent faster deposition than the black beds.

Phosphate and chert.--Phosphate nodules are widely distributed in the Chattanooga shale of northwest Georgia and east Tennessee (fig. 3). In the northern Sequatchie Valley and northern part of the Eastern

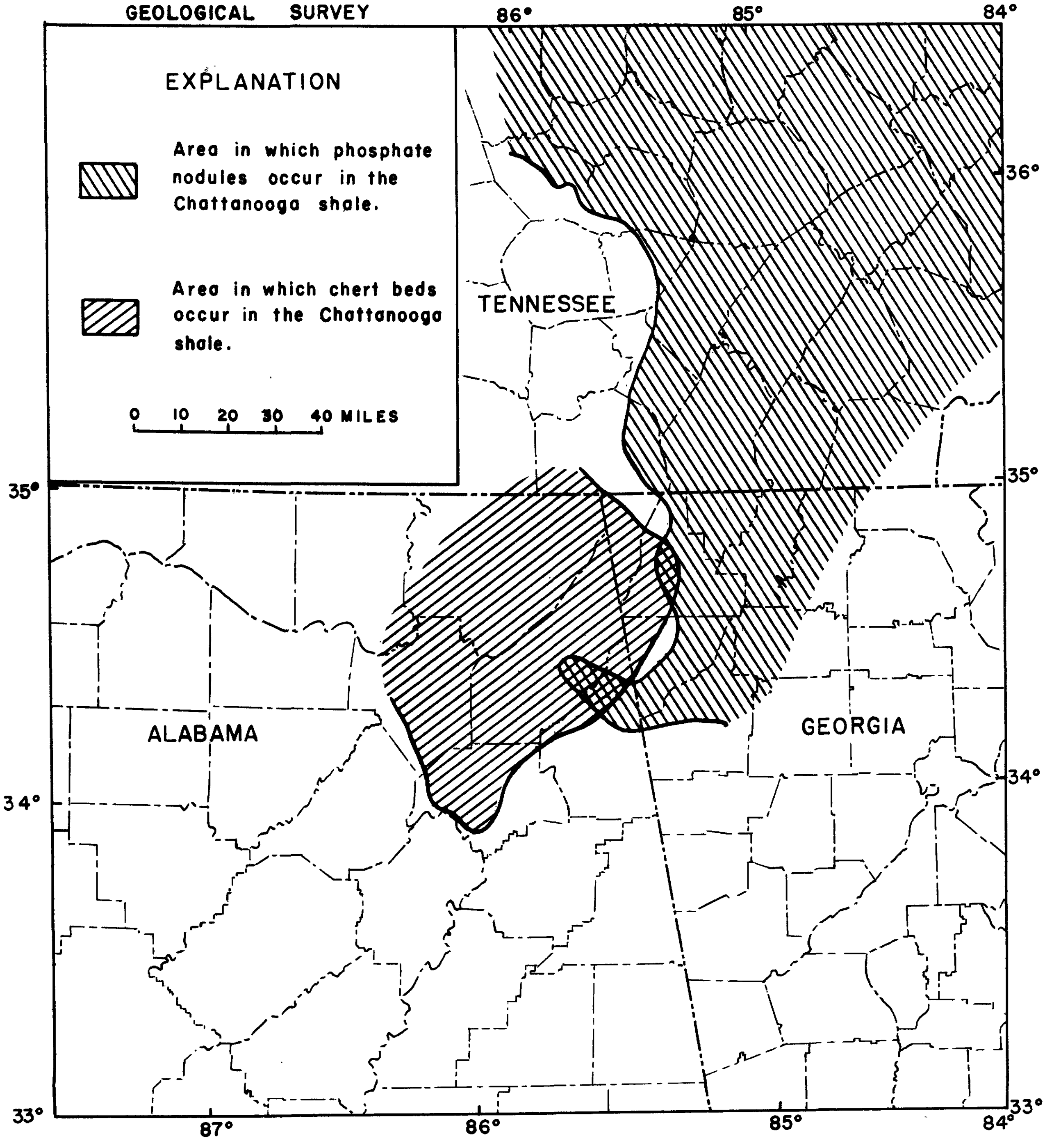


Figure 3 – Distribution of phosphate and chert in the Chattanooga shale of Alabama, Georgia, and Tennessee

Highland Rim the nodules are confined to the upper few feet of the Chattanooga, but in the easternmost exposures in Georgia and Tennessee they are found in intervals throughout the shale in both gray and black beds. The nodules range in size from small spheres 0.05 foot in diameter to large lenses about 2 feet in length. In the eastern shale outcrops most of the nodules are about 0.1 to 0.2 foot in greatest diameter.

Beds of chertified black shale were discovered during this reconnaissance in the Chattanooga shale in northeast Alabama and northwest Georgia (fig. 3). The chert beds are from 0.02 to 0.20 foot thick and give a spectacular shower of sparks when struck with a hammer. At 7N-52 the thickness of individual beds is constant for an exposed distance of 25 yards, but individual beds cannot be correlated between outcrops. Analysis of a sample of the chert showed 85 percent SiO_2, much of it as chalcedony. Normally the Chattanooga shale contains about 30 percent SiO_2 mostly as quartz grains.

Figure 3 shows that the phosphate and chert in the Chattanooga shale tend to be areally segregated. In five outcrops near the Alabama-Georgia line, 6M-1, 6M-2, 6M-4, 7N-2, and 7N-52, both phosphate and chert are present. At each place the chert-bearing interval is below the interval containing phosphate nodules, and in general the chert is in the finer grained part of the section. Because of the fine-grained impervious nature of the Chattanooga shale, chertification probably took place at the time of deposition or soon after. Apparently the environment that favored the formation of phosphate nodules did not favor the formation of chert as the two have not been found in the same interval. The fine grain of the chert-bearing shale suggests that quieter water and the availability of dissolved silica may have been the difference that favored formation of chert rather than phosphate.

Intraformational conglomerates.--A one-foot interval in the Chattanooga shale at locality 8P-3 in northwestern Georgia contains many balls and flakes of gray silty claystone in a matrix of black shale. These fragments of silty claystone are commonly subrounded, but some show a few sharp edges. Quartz grains ranging in size from silt to coarse sand are scattered through the interval, which has poorly defined bedding and breaks into irregular pieces. The interval is also notable for the presence of articulate brachiopod shell impressions. Normally these calcareous shells would have been dissolved by the acidic environment of the organic mud before they could be covered by sediment; hence the preservation of such impressions implies sudden burial. These features indicate that this interval is an intraformational conglomerate. Apparently semiconsolidated mud was stripped up presumably by current action and transported a short distance to its present site.

Such intraformational conglomerates may be a widespread occurrence in the Chattanooga. For example, most of the Bureau of Mines diamond drill cores (pl. 1, WR-48, WR-49, WR-50) that contain the upper unit of the Dowelltown member show that the contacts between the light and dark gray layers are not as definite as they seem at the outcrop. Rather, the lighter layers contain blebs, lenses, stringers, and flakes of darker claystone, and vice versa. Many of these inclusions of lighter material in darker layers, or darker inclusions in lighter layers, can be explained by flowage during compaction, but others are not so easily explained. For example, an inclusion of light-gray claystone in a dark-gray layer where the inclusion is completely isolated from a parent source is interpreted by the writer in most cases as a clastic particle.

The idea that some of these blebs and flakes have been transported by current action is further strengthened by the fact that the individual light and dark layers are actually lenses and cannot be correlated even between nearby outcrops. Normally such fine-grained sediment as that in the gray and black layers of the Chattanooga would be deposited as beds over large areas. Therefore the lenticularity of these beds suggests that they are preserved patches of once more widespread blankets of sediment. Presumably wave action reworked parts of these beds, destroying many of the original layers of the sediment by mixing and finally depositing the material elsewhere. In this manner inclusions of one type of claystone would occur in a bed of another type.

Conant (1952, p. 16, 19) cites the paper-thin laminae and thick shale section in the Flynn Creek cryptovolcanic structure to show the oft-repeated agitation of the sediments. From the evidence of lenticular bedding and intraformational conglomerates found in this region, it seems certain that the Chattanooga shale in the area of this report was not deposited in such deep water that simple and almost uninterrupted settling could explain the stratigraphic features preserved. Instead, there must have been infrequent periods of bottom scouring that redistributed the muds so that the floor of the sea was well graded most of the time.

"Bacon Bend section"

Unusual age relations are shown by the section at 11T-1 near the Bacon Bend of the Little Tennessee River in eastern Tennessee (appendix, p. 61). A collection of conodonts from the thin upper black shale is considered by Hass to be of early Mississippian age (Maury). Boucot identified a megafossil collection from the base of the underlying gray silty claystone unit as apparently of Middle Devonian age. Below the claystone, 10 feet of silty black shale of unknown age rests on a bentonite of Middle Ordovician age.

If the upper black shale is of early Mississippian age, and the next underlying unit is of Middle Devonian age, as provisionally indicated, then all or nearly all of the Late Devonian Chattanooga shale of the Eastern Highland Rim of Tennessee is absent at the Bacon Bend outcrop, and a major unconformity is present within as well as below the succession of fine grained gray and black shale. It is planned, however, to obtain and study additional fossils from this outcrop. As this locality is the first one found in the southern Appalachians where conodonts and identifiable megafossils are closely associated, it is of more than average interest.

Maury formation

General relations

The Maury formation is a widespread thin bed of claystone that is commonly green, glauconitic, pyritiferous, locally silty or sandy, and contains phosphate nodules. The formation was named by Safford and Killebrew (1900, p. 141-142) for exposures in Maury County, Tenn. Outside of the Central Basin of Tennessee the name has not been widely used, though the literature records the presence of greenish beds at the top of the Chattanooga. Hass (1947, p. 1189) pointed out that the Glendale shale of Swartz (1924, p. 24), named for an exposure near the old Glendale station in North Chattanooga, Hamilton County, Tenn., is identical to the Maury formation in lithology and stratigraphic position. Because the name Maury has priority, it is used in this report for the beds referred to as the Glendale shale by Swartz. In Alabama and Georgia the Maury has in the past generally been considered part of the Chattanooga shale.

In the region studied, the thickness of the Maury ranges from 0.3 to about 7.5 feet. The average thickness of the Maury in 54 sections east of the Sequatchie Valley is 3 feet. Both the range in thickness and average thickness are about 50 percent greater than that of the Maury in central Tennessee. The Maury appears to be present throughout the region except in the area east of Birmingham (fig. 1) where it is overlapped by the Fort Payne chert.

"Birmingham high"

In a large area around Birmingham, Ala. (fig. 1) only the Maury formation is generally present between the overlying Fort Payne chert and underlying formations that range in age from Ordovician to Early Devonian. On three sides of this area the Chattanooga shale wedges out by progressive overlap, and east of Birmingham (locality 3J-2) the Fort Payne chert rests directly on the Frog Mountain sandstone of Early Devonian age. Thus these outcrops show that the latest shore lines of both the Chattanooga and Maury seas were in the Birmingham area and that they were not far apart.

Where the Maury overlies the black Chattanooga, it retains its characteristic greenish color and the unweathered iron compounds are usually sulfides, as at outcrops 4J-5, 4J-5, 4J-6, and 4H-1, northeast of Birmingham. On the "Birmingham high" near the wedge-edge of the

Chattanooga at localities 2F-2, 3H-1, 3H-2, 4K-1, and 4L-1, red shale is present in the lower part of the Maury. At greater distances from the edge of the Chattanooga as at localities 3H-4, 3J-3, 3J-1, 4K-2, and 4L-2, red claystone and silty claystone make up most or all of the Maury. The only feature common to the Maury in these outcrops, and to the Maury in the more normal succession that overlies the Chattanooga elsewhere, is a very thin layer of dark-green silty material, which is probably glauconitic, at the Fort Payne-Maury contact. No sulfides of iron were apparent in the red shale, although sulfides are common in the thin overlying green claystone where it is present. Phosphate nodules are also absent in the red shale.

The Maury contains a basal conglomerate at outcrops 3H-1, 4K-1, and 4L-1, just south of the vanishing-edge of the Chattanooga. This conglomerate is made up of subangular cobbles and pebbles of sandstone in a matrix of quartz sand and red clay. At greater distances from the edge of the Chattanooga shale the Maury contains no basal sandstone or conglomerate.

These features strongly indicate an ancient shore line. Red coloring in the basal Maury formation is probably finely divided hematite. The red iron ores of the Silurian in the area would provide a good supply of hematite which normally would have been reduced to sulfides in the poorly aerated Maury sea. Oxygen must have been plentiful enough during the early stages of Maury deposition in this area to keep the iron from being reduced, implying a near shore, aerated environment of deposition.

Black shale

The Maury is typically a greenish claystone throughout most of the region except where it overlaps the Chattanooga. However, in the northeastern half of the region at localities 6M-4, 6M-2, 8N-4, 8N-1, 9N-1, and 12S-1 the Maury contains a bed of black shale much like the Chattanooga. At locality 8N-6, the Maury contains two beds of black shale. Plate 1 shows that these black shale occurrences are oriented geographically in an arcuate, linear pattern suggesting some sort of relationship among them. However, many intervening localities do not show black shale. It may be that they are part of one or two once widespread blankets of black shale that were each partly removed by submarine beveling.

At locality 9P-2, east of Chattanooga, and east of these black shale lentils, 2.7 feet of normal greenish Maury claystone is underlain by 3.7 feet of black shale crowded with round phosphate nodules. This black shale unit has a thin basal sandstone which rests on buff-colored silty claystone. Hass states that the phosphatic nodule-bearing black shale contains a conodont fauna of early Mississippian (Maury) age, and that the underlying buff-colored silty claystone has another conodont fauna equivalent in age to the (Late Devonian) Gassaway beds below the phosphate nodule unit in exposures along the Eastern Highland Rim. Without the paleontological evidence one would place the top of the Chattanooga shale at the top of the phosphatic black shale unit. However, reasoning that the basal sandstone of the phosphatic black shale unit indicates erosion before its deposition, it is entirely possible that the typical greenish claystone of the Maury and some of the upper Chattanooga previously deposited was removed, and a black shale lentil of the Maury was deposited directly on the gray claystone of the Chattanooga. This would result in the problematical succession seen at the outcrop. Hence, with some reluctance, the Maury-Chattanooga contact is here placed at the base of the phosphatic black shale unit of Maury age at locality 9P-2.

In the Bacon Bend section, locality 11T-1, a 3-foot black shale bed just below the Granger shale of probable early Mississippian age contains conodonts considered by Hass to be of early Mississippian age. The black shale does not have phosphate nodules, and it is not associated with any greenish claystone typical of the Maury. Below the black shale is an 8-foot bed of buff-colored, silty claystone that contains a megafossil assemblage identified by Boucot as probably Hamilton (Middle Devonian) age. The black shale is overlain by sandstone and siltstone of the Granger shale. No fossils were found in this part of the Granger to determine whether it is in part equivalent to the Maury also. Because elsewhere the Maury is an extremely fine-grained sediment, it seems unlikely that any part of the Granger is equivalent to it. The "three-fold" division of the black shale sequence at 11T-1 (see p. 61) is typical of the "Chattanooga shale" of northeastern Tennessee and south-western Virginia, and may well be a thinned southward extension of the Virginia sequence. Recent workers in this area seem to agree that the thin upper black shale is of Mississippian age. This evidence suggests that the Maury changes from greenish phosphatic claystone in the south-west to black fissile shale in the northeast.

Fort Payne chert

The Fort Payne chert, a cherty limestone of Mississippian age, overlies the Maury formation at most places in the part of the folded belt covered in this report. Because the thick basal beds of the Fort Payne are generally the most cherty, the contact with the Maury formation usually is easily picked. At localities 7P-1, 7P-2, and 3J-2, however, the basal 1 or 2 feet is not cherty, and the limestone has weathered to a clayey residuum. Also at 9P-4 the lower Fort Payne beds are green siltstone. In every case the contact can be picked by applying one or all of the following criteria:

1. The lowest chert bed is Fort Payne.

2. Phosphate nodules do not occur in the Fort Payne.

3. A thin layer of very dark-green glauconitic siltstone usually marks the Maury-Fort Payne contact.

At 9P-4, east of Chattanooga, a small "algal reef" at the base of the Fort Payne is in contact with the underlying Maury. If the reef is truly algal, the maximum depth of the sea at the end of Maury time at this locality would be the depth limit at which algae can carry on photosynthesis.

The Fort Payne chert is supplanted by the Granger shale at locality 11T-1. The exact relationship between the two formations has not been worked out, but they are at least partial time equivalents.

PRE-CHATTANOOGA UNCONFORMITY AND ITS RELATION TO THE ORIGIN OF THE SHALE

The unconformity at the base of the Chattanooga shale is one of the greatest in terms of time in the Paleozoic rocks of the southeastern States. A proper interpretation of the nature of this contact is important to any theory of origin of the Chattanooga shale, hence it has received much attention in previous investigations. This study supports in general Conant's interpretation of the basal sandstone of the Chattanooga as a shallow water deposit derived in part from the soil of a peneplain as the Chattanooga sea advanced. New evidence from this study suggests further that the sandstone was derived in a shoreward zone of moderate wave action. In this shoreward zone of wave action sand and gravel were constantly shifted back and forth during considerable lengths of time causing them to be ground finer and at the same time removing minor irregularities of the underlying rock surface. This rock surface was eventually abraded below the zone of weathering virtually everywhere.

The pre-Chattanooga surface was formed on the rocks of three systems as shown on the highly generalized pre-Chattanooga geologic map (fig. 4); and, although many rock types are present, they are almost always beveled to the same degree of smoothness. In places there is an angular discordance of several degrees between the Chattanooga and underlying rocks, but generally the beds are parallel. The smoothness of this surface is its most significant feature. No stretch of the imagination could envision such a surface to exist beneath the soil of even the most perfect peneplain. Further, evidence of pre-Chattanooga weathering is so rare that until recently it has escaped notice. It is probable that a transgressing sea with only enough wave action to rework the soil of the peneplain would allow some evidence of pre-Chattanooga weathering to be preserved along with an undulating or pinnacled surface. The most reasonable hypothesis seems to be that during the process of inundation a considerable amount of beveling was accomplished. It is also reasonable to assume that this beveling occurred in the shoreward zone.

Further evidence of submarine beveling is afforded by the basal contact at locality 11T-1. Here the Chattanooga rests on a 4-foot bed of Middle Ordovician bentonite. If we assume that almost no beveling took place during inundation, then the bentonite must have been exposed to air by erosion at some time during the process of peneplanation. Surely the bentonite could not have withstood first the drying action of

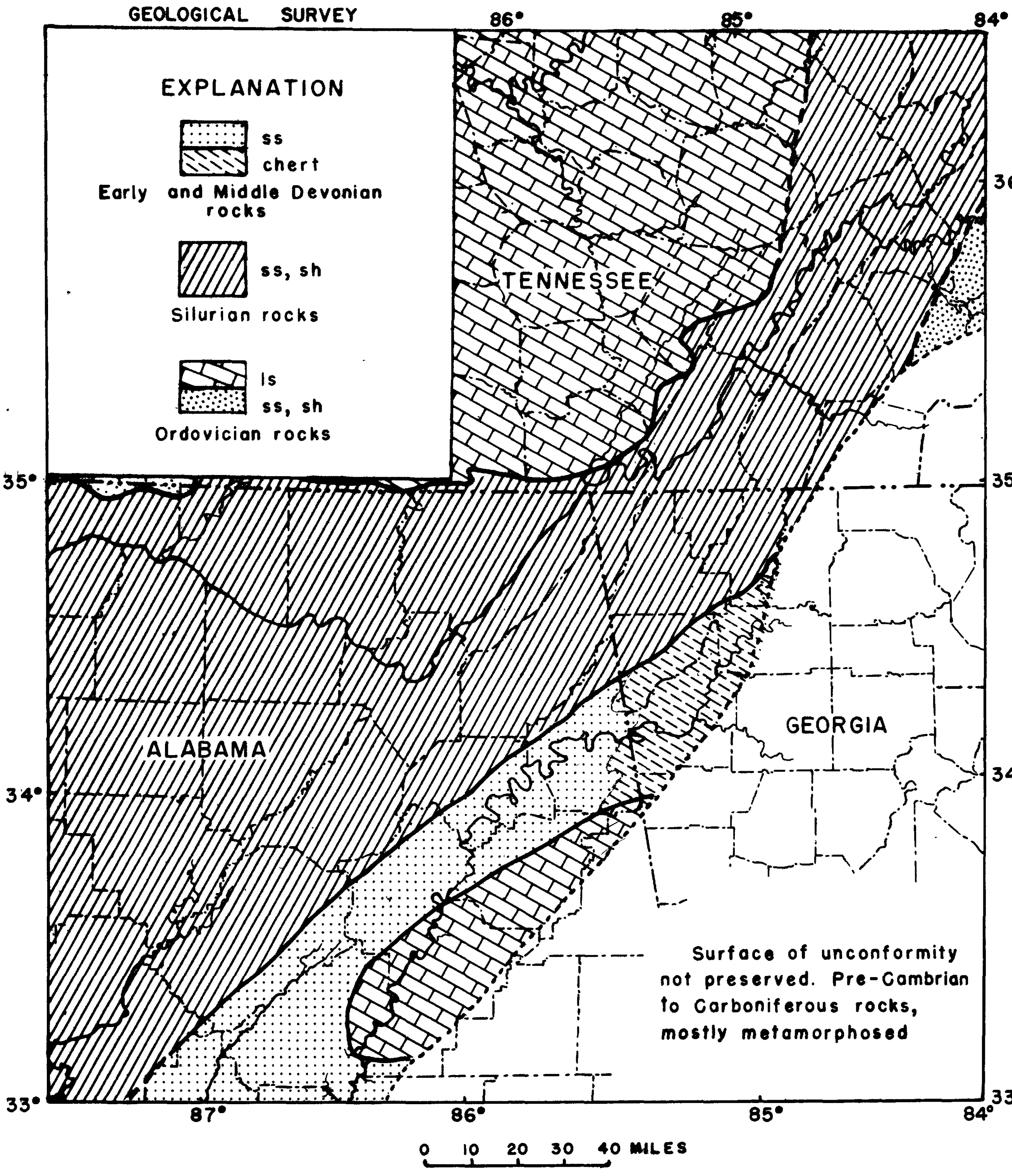


Figure 4 — Generalized pre-Chattanooga geologic map of northeastern Alabama, northwestern Georgia, and eastern Tennessee

the air, and then even the most gentle agitation of an advancing sea. Again the only reasonable hypothesis is that the erosion that exposed the bentonite was submarine in which case the bentonite could act as a wet and very compact clay considerably more resistant to erosion than many sandstones.

Apparently the pre-Chattanooga surface is the product of two different erosional processes; first, subaerial erosion that produced a peneplain, and second, a relatively minor amount of submarine erosion that removed the soil, the underlying weathered rock, and almost all of the minor irregularities of the surface.

The only agent available to do any submarine beveling was the wave-worked sand and gravel in the shoreward zone. The remains of this sand and gravel are seen in the thin basal sandstone at the base of the Chattanooga shale. To assume that the beveling was accomplished by this now thin unit is little short of remarkable unless we consider the time involved. The distribution of the members of the Chattanooga and the length of time involved in depositing such a thin formation, shows the phenomenal slowness by which the sea advanced over a surface already reduced nearly to sea level.

Directly south of the thin edge of the Chattanooga shale north of Birmingham, Ala., three outcrops show cobble or pebble conglomerates in the Maury and a fourth has a sandstone at the base of the Maury. None of the sections south of these four has sandstone or conglomerate at the base of the Maury. The relationship of the cobbles to the thin edge of the Chattanooga shale strongly suggests that they were being formed by wave action near shore at the end of Chattanooga time. The relatively sudden deepening of the sea at the beginning of Maury time must have been rapid enough to preserve locally this conglomerate below the zone of frequent wave action before it was reduced to the usual sand-sized particles of the normal basal sandstone. From this evidence it seems that during the deposition of the black Chattanooga shale there existed a transgressing near-shore zone where wave action prohibited deposition of black shale. In this zone sand and gravel were constantly being wave worked over long periods of time. This action beveled the underlying rock surface to the smooth contact preserved at the base of the Chattanooga, and at the same time reduced the sand and gravel to the thin basal deposit now preserved.

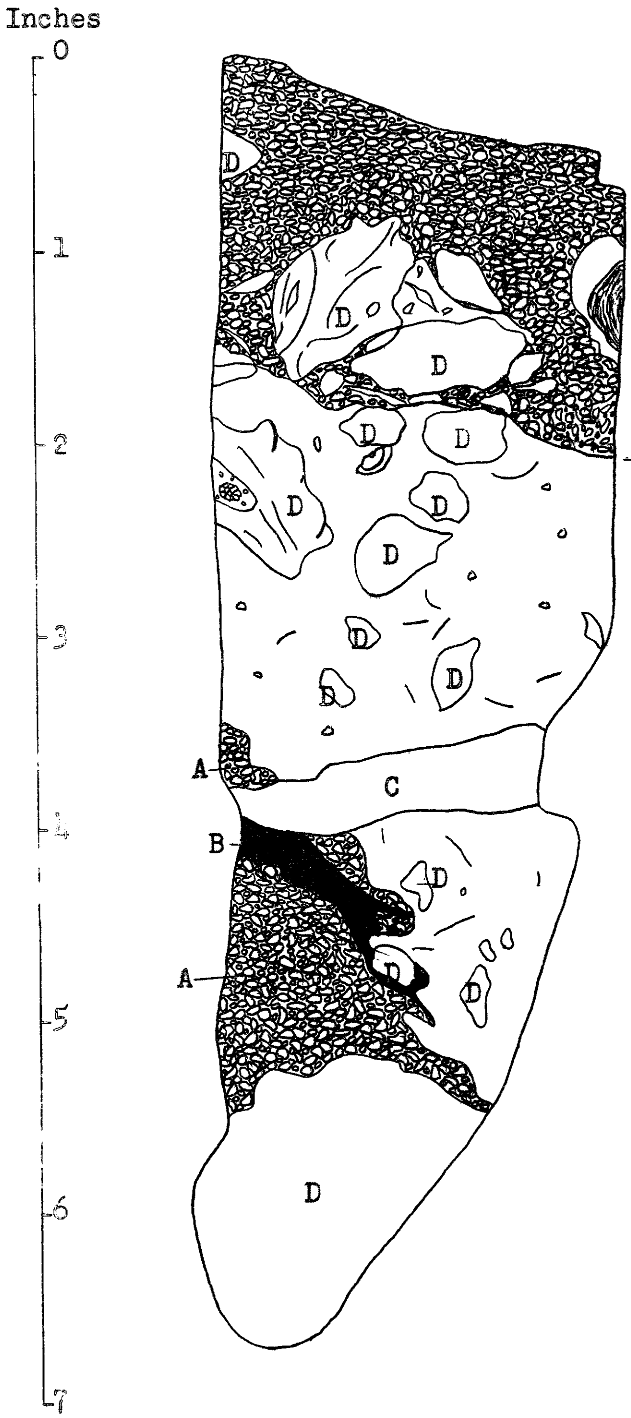
It has been difficult in the past to prove that the surface of unconformity is in greater part a product of subaerial erosion. According to the "deep water" theory as argued by Rich (1951, p. 2021) the principal beveling was pre-Devonian, and this was followed by deposition of some Lower and Middle Devonian beds. Rich believes that the unconformity between the Chattanooga and the underlying rocks was due to nondeposition rather than subaerial erosion. In this manner he could explain the absence of a "shallow water" deposit at the base of the Chattanooga, which he felt should be present if the Chattanooga was deposited in a transgressing sea.

The overlapping relationships of such time stratigraphic units as the members of the Chattanooga shale and the Maury formation prove that the sea was transgressing. The fact that the Chattanooga was the initial deposit of a transgressing sea indicates shallow water deposition. Further it has been shown that the surface of unconformity was beveled to its present degree of smoothness during the process of transgression, which would remove most evidence of subaerial erosion and weathering.

At a few places, however, such evidence has been found. This evidence is given by the basal contacts of cores from holes WR-48, WR-50, and RO-11. In cores WR-48 and WR-50 the basal sandstone of the Chattanooga fills small crevices and cavities in the underlying limy shale of the Silurian Rockwood formation. In core RO-11 (fig. 5) several small solution cavities occur in the limestone to a depth of about 1 foot below the base of the Chattanooga. The cavities range between 0.1 and 0.2 foot in greatest diameter and in cross section show a very irregular outline. Most of the cavities are filled with the basal sand of the Chattanooga and one cavity has in addition a 0.02 foot layer of black shale. For a depth of about 1.7 feet below the Chattanooga the limestone has been reworked and weathered and is full of pyrite. Surely these cavities could not have been formed during the first period of erosion and then survive unfilled from the end of the Silurian to the Upper Devonian. They must have formed during subaerial erosion just before deposition of the Chattanooga shale. The irregular outline of these cavities and their occurrence in limy shale and limestone leave no doubt that they were formed by solution. Hence the containing rock must have been not only brought out of the sea, but for a short time at least it must have been above the water table. That these cavities in the weathered pre-Chattanooga rock escaped destruction by the beveling that took place during transgression is probably explained by their location in or near a historically unstable area, the Appalachian geosyncline.

The evidence suggests that the Chattanooga shale was the initial deposit of a sea that transgressed upon an extensive peneplain. This inference in itself implies deposition in relatively shallow water.

GEOLOGICAL SURVEY



Basal conglomerate of Chattanooga shale
Coarse-grained, well-rounded quartz sand with large angular fragments of chert (D); matrix is silt, organic matter, and pyrite.

Limestone conglomerate
Angular fragments of chert and fossils in a matrix of impure limestone that has been reworked from the underlying Silurian (?) formation.

EXPLANATION

A. basal sandstone of the Chattanooga shale filling a solution cavity in the limestone

B. black shale

C. calcite vein

D. chert

Figure 5 - Sketch of core from hole RO-11 showing solution cavity filled with Chattanooga shale; SE$\frac{1}{4}$NW$\frac{1}{4}$ sec. 23, T. 20 S., R. 5 W., Jefferson County, Alabama.

URANIUM

The average uranium content of 25 samples of Chattanooga shale taken from selected outcrops in the region investigated is about 0.005 percent. This value, however, is probably too high for a regional average because many of the outcrops were selected for sampling on the basis of relatively high scintillation counter readings.

This low uranium content compared to that of the shale along the Eastern Highland Rim can probably be explained by the lithology of the shale. The beds of Gassaway age in the region studied are usually thicker, nearly always sandier and siltier, and in places phosphatic throughout. The indicated more rapid deposition and consequent smaller percentage of finely divided carbonaceous material together with the presence of phosphate probably were the principal factors that caused the lower uranium content of the shale in this region.

The greatest concentrations of uranium were found at 7M-2 and 7N-52 (table 2). The outcrop at locality 7N-52 (p. 54) has 9.7 feet of shale that averages 0.007 percent uranium. The outcrop is located near the north end of a syncline (Pigeon Mountain) that is bounded on the east side by a long reverse fault. All of the shale outcrops in the area show moderate to intense faulting and most of the outcrops have dips of more than 5^{o}. One interesting feature of the section at 7N-52 is a 4-foot chert-bearing interval, the top of which is about 4 feet below the Chattanooga-Maury contact. The interval was sampled by taking a channel sample of the whole interval and a grab sample of the chert. Analysis of the grab sample of chert shows 85.7 percent SiO_2, 0.30 percent K_2O, 0.10 percent P_2O_5, 0.013 percent eU, and 0.012 percent U.

Table 2.--Uranium content of some Chattanooga shale samples from the folded belt of Alabama, Georgia, and Tennessee.
(Analyses by U. S. Geological Survey Laboratory, Washington 25, D. C.)
(Analysts R. Moore, Grafton Daniels, Radiation measurements P. Moore, B. A. McCall.)

Locality no.	Sample no.	Sample type	Thickness (feet)	eU (percent)	U (percent)	Remarks
4J-3	1	B	16	0.008	0.003	
4J-4	1	B	5	.006	.003	
6N-53	1	A	5	.008	.006	
	2	A	5	.007	.004	Ave. 0.005% U (samples 1–4)
	3	A	5	.007	.005	
	4	A	5	.010	.006	
6P-5	1	A	3	.006	.002	
7N-52	2	A	2.2	.004	.002	
	3	A	1.7	.011	.008	
	4	A	4	.009	.006	9.7 ft. = .007% U (samples 3–5)
	5	A	4	.009	.007	
	6	A	4	.008	.006	Duplication of sample no. 4
7P-2	1	A	5	.007	.003	
	2	A	5	.007	.004	
9P-2	1	A	4	.006	.003	
	2	A	1.6	.006	.004	
	3	A	2.5	.007	.004	
7M-2	1	A	2.2	.006	.004	
	2	A	2.2	.005	.004	
	3	A	2.2	.007	.005	
	4	A	2.2	.009	.007	
	5	A	2.2	.016	.009	
	6	A	2.2	.011	.0065	
	7	A	2.2	.006	.004	
	8	A	2.2	.007	.004	

B - Chip samples
A - Channel samples

Much of the SiO_2 is in the form of chalcedony. An analysis of a channel sample of the whole chert-bearing interval showed only 0.006 percent U. This seems to indicate that the chert beds may run high in uranium, but it is not certain because only one sample of chert was analyzed. The uranium content of the chert-bearing interval is significantly lower than the uranium content of the overlying and underlying non-cherty intervals that contain 0.008 and 0.007 percent U respectively. Chert beds in other sections do not show higher than usual radioactivity as measured by a portable field scintillation counter, though this may be because they are thinner and more scattered than at 7N-52.

In the faulted and weathered section at locality 7M-2 (fig. 6) an unusually high uranium content for a 6-foot interval was indicated by field scintillation counter readings. Analysis showed that the uranium content of the interval ranged from 0.0065 percent to 0.0090 percent. Disequilibrium was much greater than usual, the equivalent uranium ranging from 0.009 to 0.016 percent. As shown on figure 6, the greatest concentration of uranium is at the base of and just below the most highly weathered interval in the shale. This interval is weathered to light buff and tan colors in contrast to the chocolate brown color of the less deformed and weathered interval below. Because of the isolated occurrence of this unusually high uranium concentration in the shale, it is believed that the deep weathering and deformation are responsible for enrichment. McKelvey and others (1955, p. 14) state, "If the uraninite is associated with the iron sulfides, the $(U^{+6}O_2)^{+2}$ may be retained for some time at the outcrop by adsorption on the ferric oxide of the gossan. Under humid conditions, uranium is removed by ground and surface waters." This is significant because the Chattanooga shale contains about 10

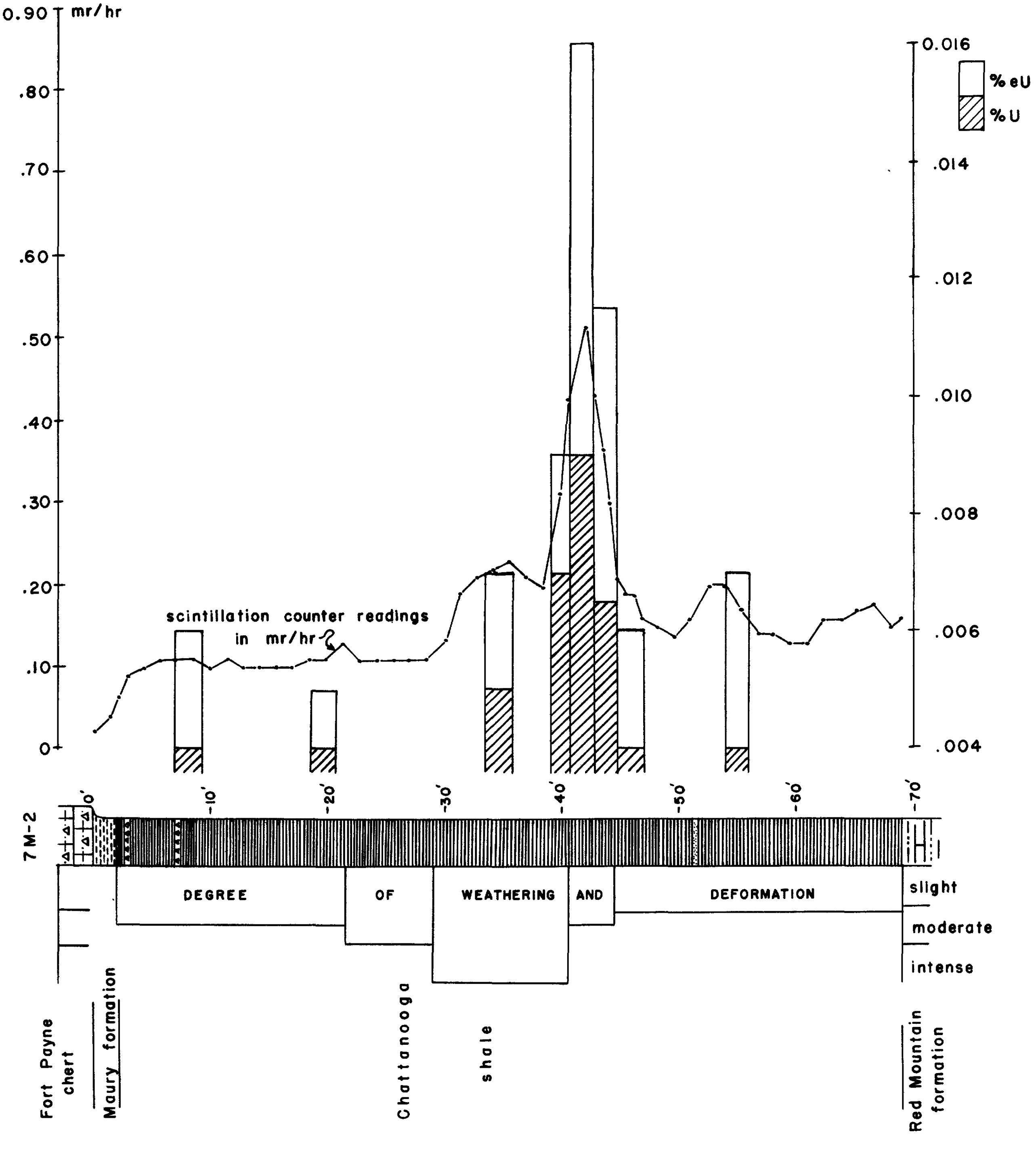


Figure 6— Comparison of radioactivity and uranium content with degree of weathering and deformation at locality 7M-2

2. The shale east of the Sequatchie Valley is considerably coarser grained than it is to the west.

3. Large quantities of bedded silt and fine sand in some outcrops indicates transportation by current action.

4. Gray beds in the Chattanooga are interpreted to be the result of greater than usual influxes of inorganic material, and so represent faster deposition than do the black beds.

5. Phosphate nodules and chert beds occur in the Chattanooga shale and seem to be areally and stratigraphically segregated.

6. Intraformational conglomerates and lenticular bedding in the Chattanooga shale indicate infrequent periods of bottom scouring.

7. The range in thickness and average thickness of the Gassaway member and the Maury formation are greater in the region studied than to the west.

8. The Chattanooga shale and Maury formation are overlapped and wedge out in the vicinity of Birmingham, Ala. The overlapping relations and the presence of red shale and a basal conglomerate in the Maury show that the latest shore lines of the Chattanooga and Maury seas were near Birmingham.

9. Black shale beds are present in many of the eastern exposures of the Maury, and at an outcrop near the Bacon Bend of the Little Tennessee River strata of the Maury consist entirely of black shale. This suggests that the Maury changes to black shale in northeastern Tennessee.

10. A shoreward zone in the transgressing Chattanooga sea probably was characterized by moderate wave action and no permanent deposition.

11. Indications are that the Chattanooga shale was the initial

deposit of a sea that transgressed upon an extensive peneplain, and as such the shale must have been deposited in relatively shallow water.

12. No area containing a combination of structural setting, shale thickness, and uranium content that would compare favorably with the area near Smithville, DeKalb County, Tenn., was found in the region studied.

LITERATURE CITED

Butts, Charles, 1926, The Paleozoic rocks, in Adams, G. I., Butts, Charles, Stephenson, L. W., and Cooke, Wythe, Geology of Alabama: Alabama Geol. Survey Spec. Rept. 14.

Butts, Charles, and Gildersleeve, Benjamin, 1948, Geology and mineral resources of the Paleozoic area in northwest Georgia: Georgia Geol. Survey Bull. 54.

Campbell, Guy, 1946, New Albany shale: Geol. Soc. America Bull., v. 57, no. 9, p. 829-908.

Hass, W. H., in press, Age and correlation of the Chattanooga shale and Maury formation: U. S. Geol. Survey Prof. Paper 286.

Hass, W. H., 1947, The Chattanooga shale type area: Geol. Soc. America Bull., v. 58, p. 1189.

____________, 1948, Upper Devonian bentonite in Tennessee: Am. Assoc. Petroleum Geologists Bull., v. 32, p. 816-819.

Hayes, C. W., 1894, U. S. Geol. Survey Geol. Atlas, Kingston Folio (no. 4.)

Rich, J. L., 1951, Probable fondo origin of Marcellus-Ohio-New Albany-Chattanooga bituminous shales: Am. Assoc. Petroleum Geologists Bull., v. 35, no. 9, p. 2017-2040.

Rodgers, John, 1953, Geologic map of East Tennessee with explanatory text: Tennessee Div. Geology Bull. 58.

Safford, J. M., and Killebrew, J. B., 1900, The elements of the geology of Tennessee. Nashville, Tenn.

Staff, U. S. Geol. Survey, 1955, Geologic investigations of radioactive deposits, Semiannual progress report, December 1, 1954 to May 31, 1955: U. S. Geol. Survey TEI-540, issued by U. S. Atomic Energy Comm. Tech. Inf. Service, Oak Ridge.

Swartz, J. H., 1924, The age of the Chattanooga shale of Tennessee: Am. Jour. Sci., 5th ser., v. 7, p. 24-30.

____________, 1926, The age of the Big Stone Gap shale of southwestern Virginia: Am. Jour. Sci., 5th ser., v. 12, p. 512-531.

____________, 1927, The Chattanoogan age of the Big Stone Gap shale: Am. Jour. Sci., 5th ser., v. 14, p. 485-499.

Swartz, J. H., 1929, The age and stratigraphy of the Chattanooga shale in northeastern Tennessee and Virginia: Am. Jour. Sci., 5th ser., v. 17, p.431-448.

UNPUBLISHED REPORTS

Butler, A. P., Jr., and Chesterman, C. W., 1945, Trace Elements reconnaissance in Alabama, Georgia, and North Carolina: U. S. Geol. Survey Trace Elements Inv. Rept. 12.

Conant, L. C., 1952, Origin of the Chattanooga shale: U. S. Geol. Survey Trace Elements Inv. Rept. 237.

Conant, L. C. and Swanson, V. E., Prof. Paper, manuscript in preparation.

Glover, Lynn, 1954, Chattanooga shale investigations along the Sequatchie anticline of Tennessee and Alabama: U. S. Geol. Survey Trace Elements Inv. Rept. 470.

McKelvey, V. E., Everhart, D. L., and Garrels, R. M., 1955, Origin of uranium deposits: U. S. Geol. Survey Trace Elements Inv. Rept. 504.

Nelson, J. M., and Brill, K. G., Jr., 1947, Radioactivity of the Chattanooga shale east of the Mississippi River and south of the Ohio River, an interim report: U. S. Geol. Survey Trace Elements Inv. Rept. 22.

Robeck, R. C., and Brown, Andrew, 1950, Black shale investigations, Block 3, Tennessee: U. S. Geol. Survey Trace Elements Inv. Rept. 63.

Robeck, R. C., and Conant, L. C., 1951, Reconnaissance search in parts of Kentucky, Tennessee, Indiana, Virginia, and Ohio for areas where uraniferous black shale may be mined by stripping: U. S. Geol. Survey Trace Elements Inv. Rept. 64.

Slaughter, A. L., and Clabaugh, S. E., 1945, Eastern black shale reconnaissance, a preliminary report: U. S. Geol. Survey Trace Elements Inv. Rept. 1.

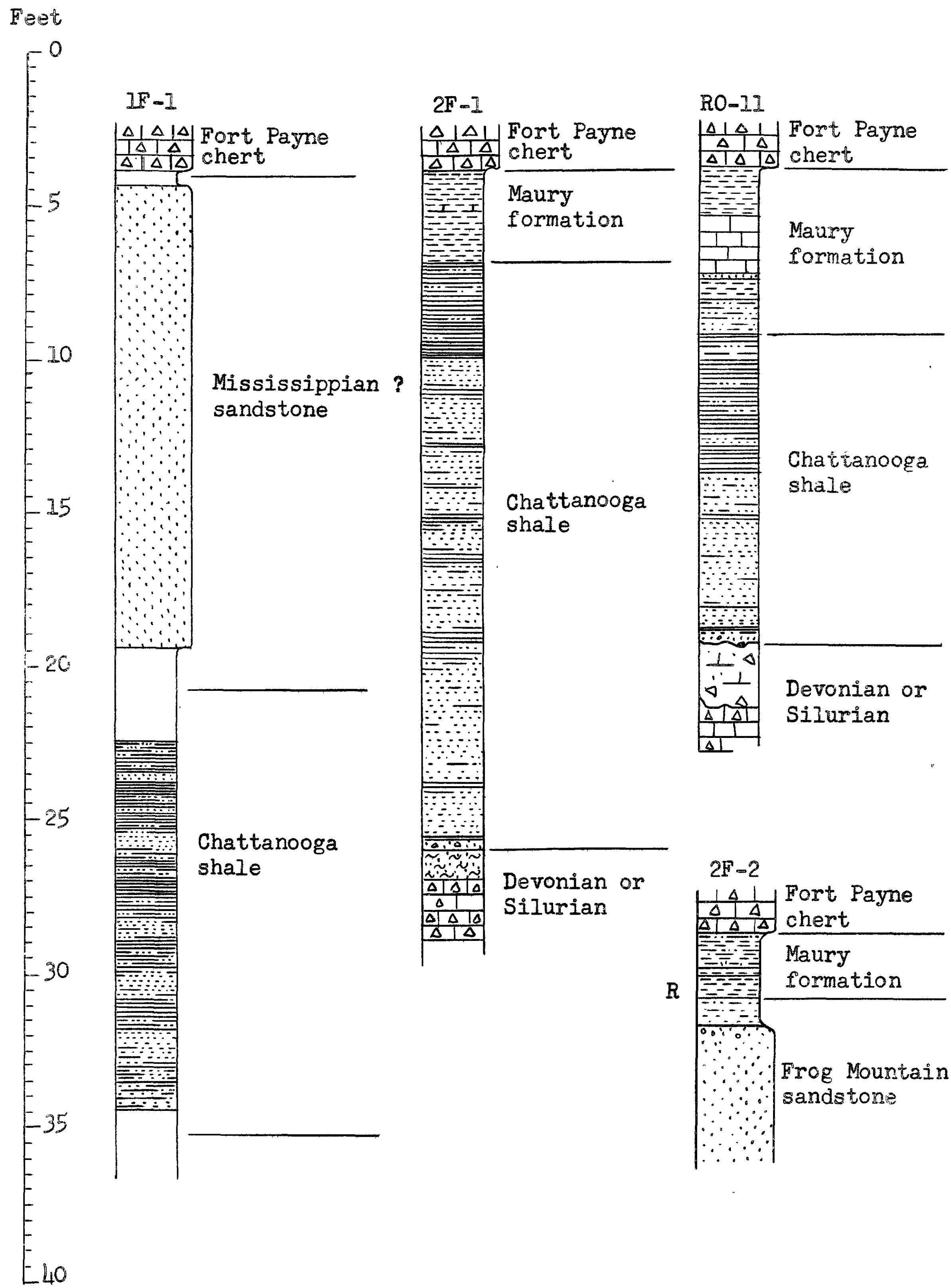
Swanson, V. E., and Kehn, T. M., 1955, Results of 1952 sampling of Chattanooga shale in Tennessee and adjacent states: U. S. Geol. Survey Trace Elements Inv. Rept. 366.

APPENDIX

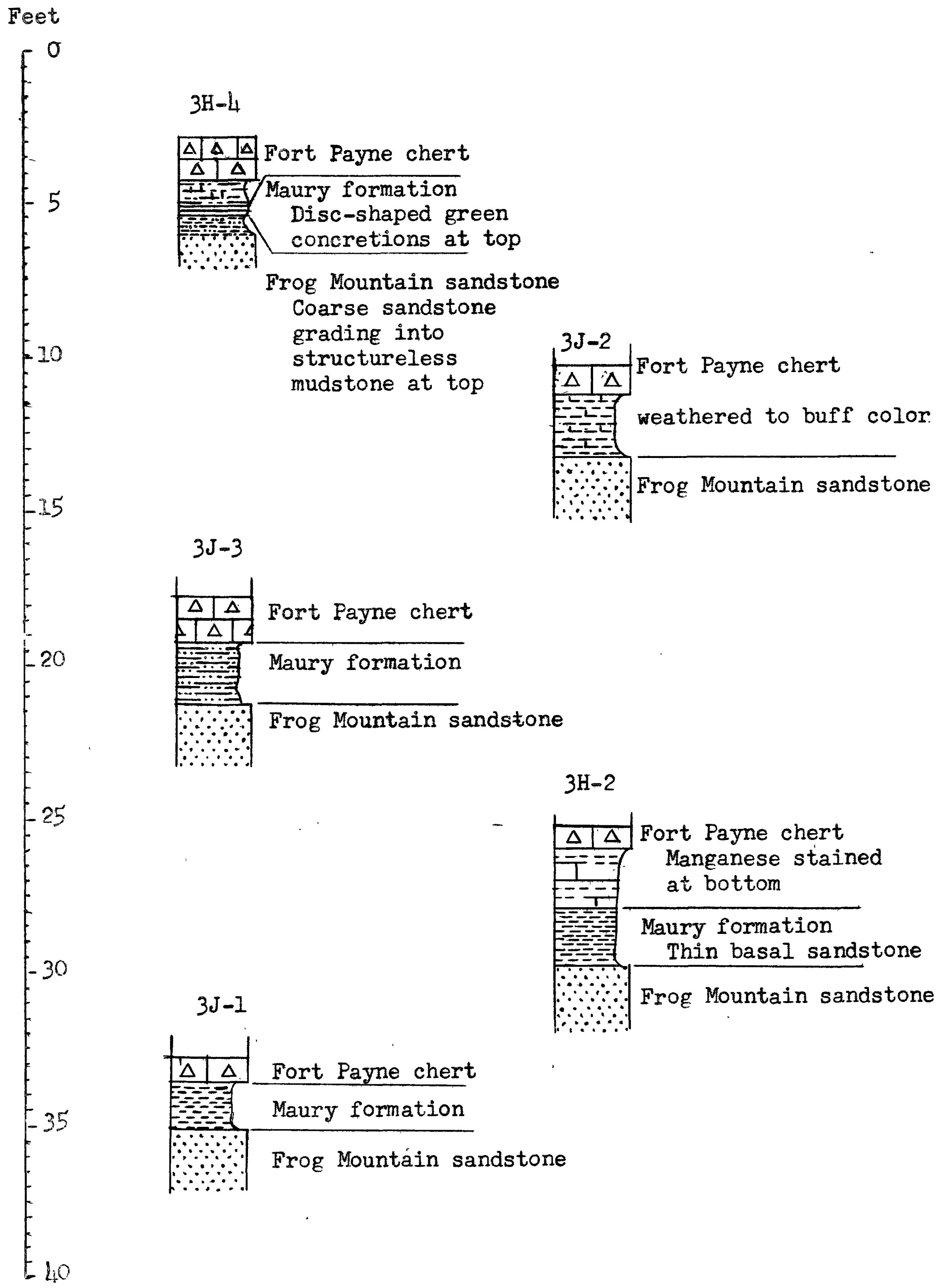
On the following pages, arranged geographically from south to north, are graphic illustrations of shale sections that were measured during this investigation. An explanation of lithology symbols is shown on page 61. The thicknesses shown are believed to be within 85 to 90 percent of the true stratigraphic interval. Readings obtained by a portable scintillation counter at the outcrop are shown in milliroentgens per hour (mr/hr) opposite the sections.

On page 62 is a faunal list.

A locality register on page 66 gives detailed descriptions of the locations of all reported shale localities in the region, indexed by locality number.



An explanation of symbols is on p.61



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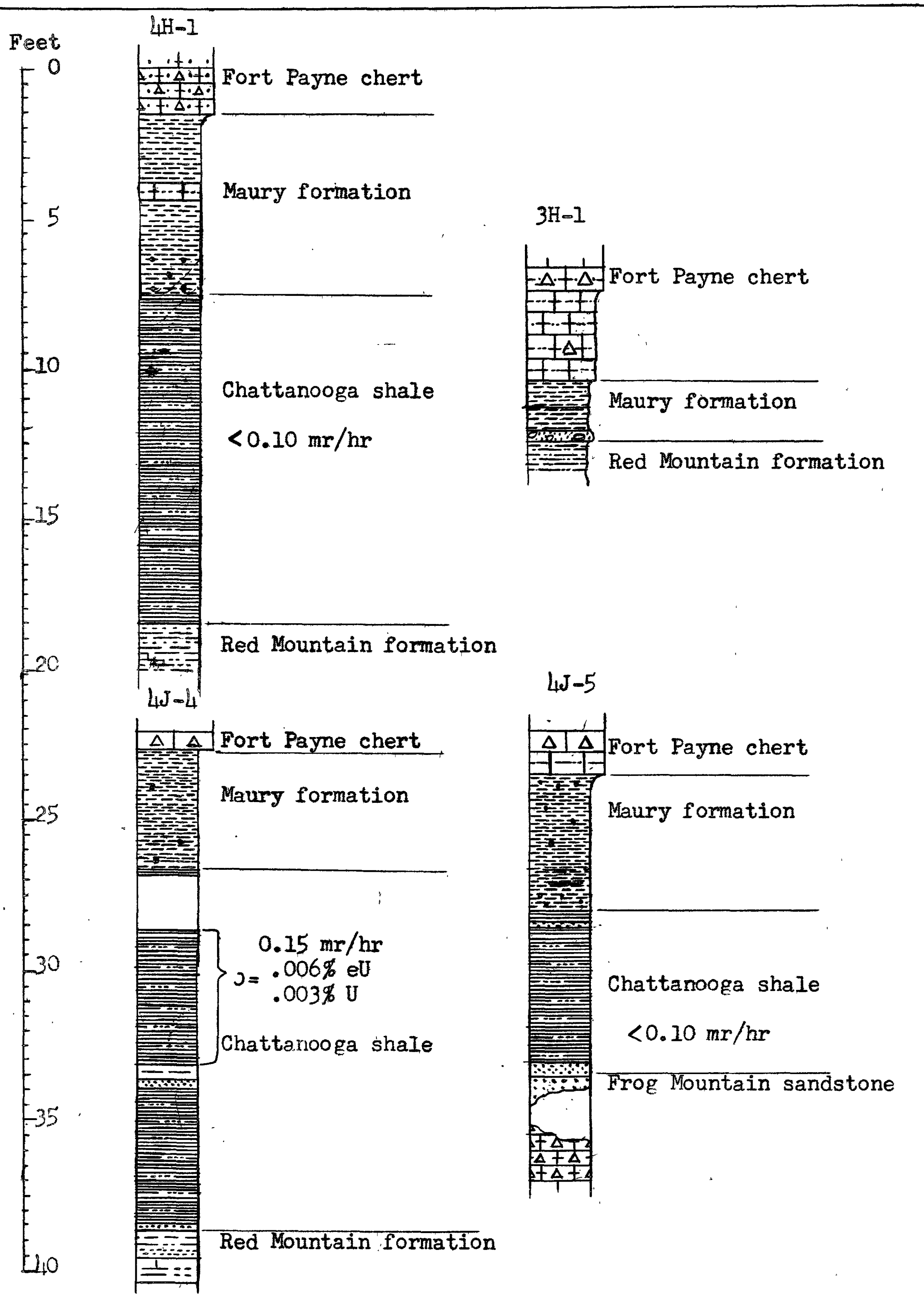

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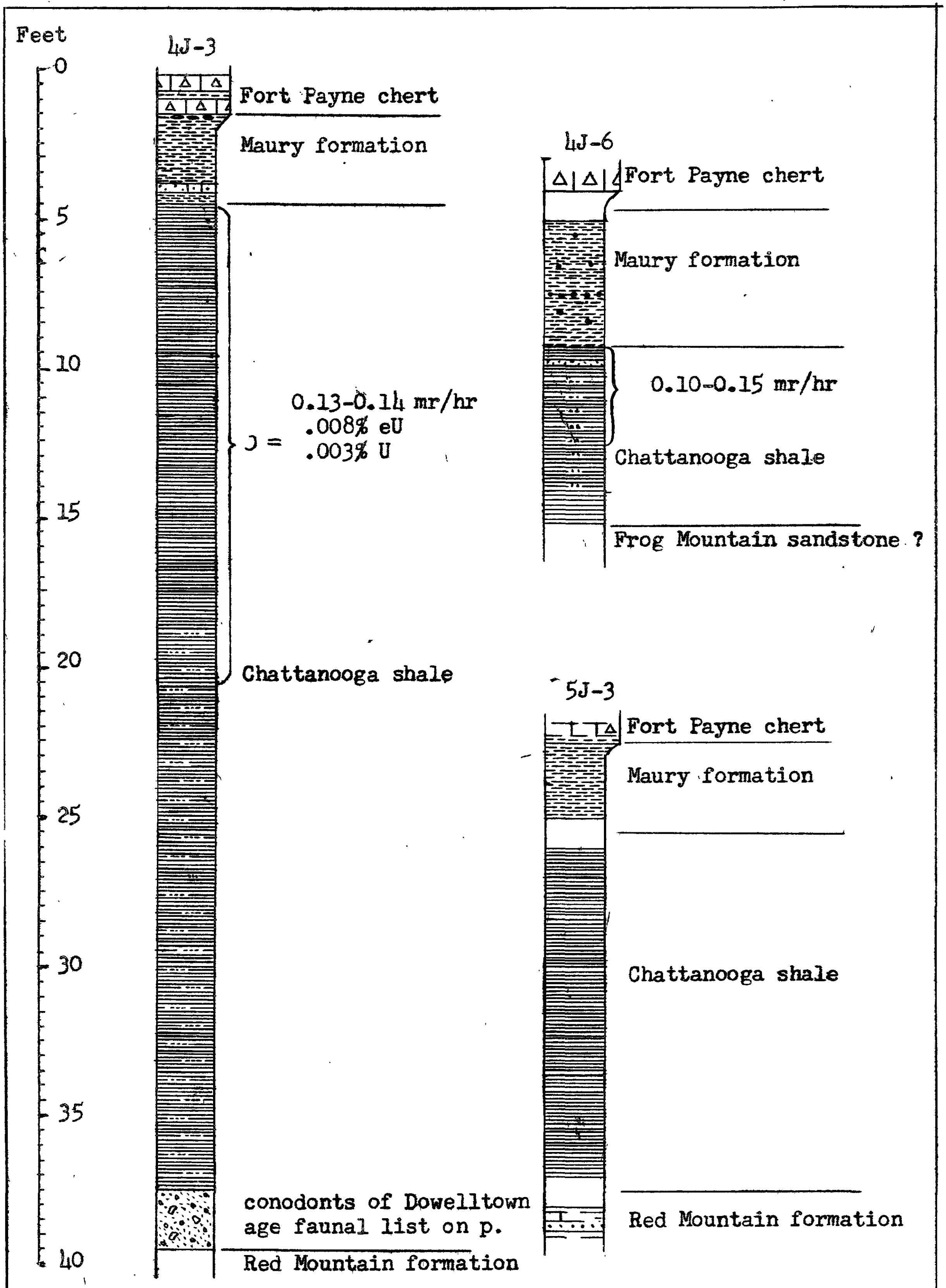

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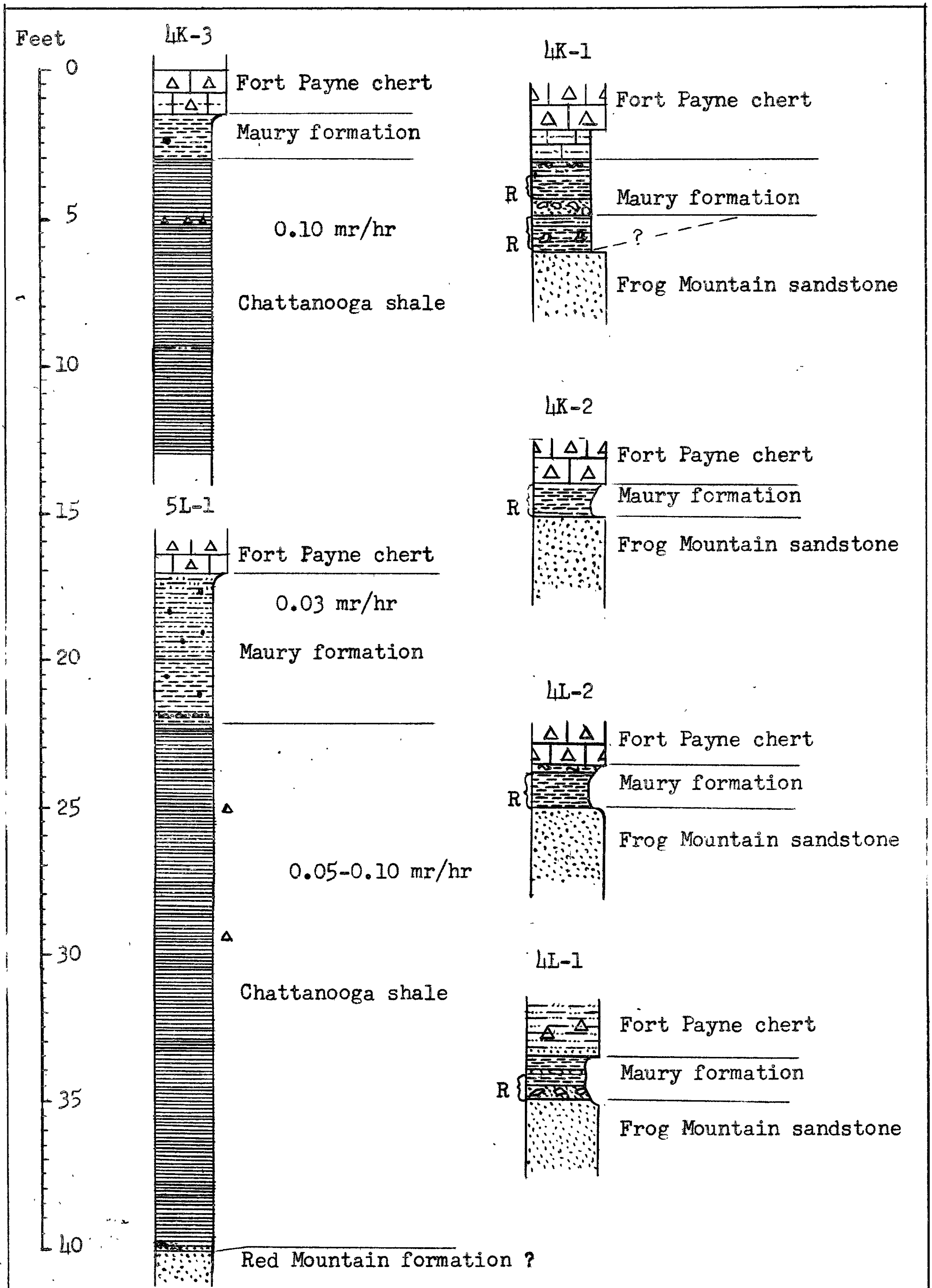

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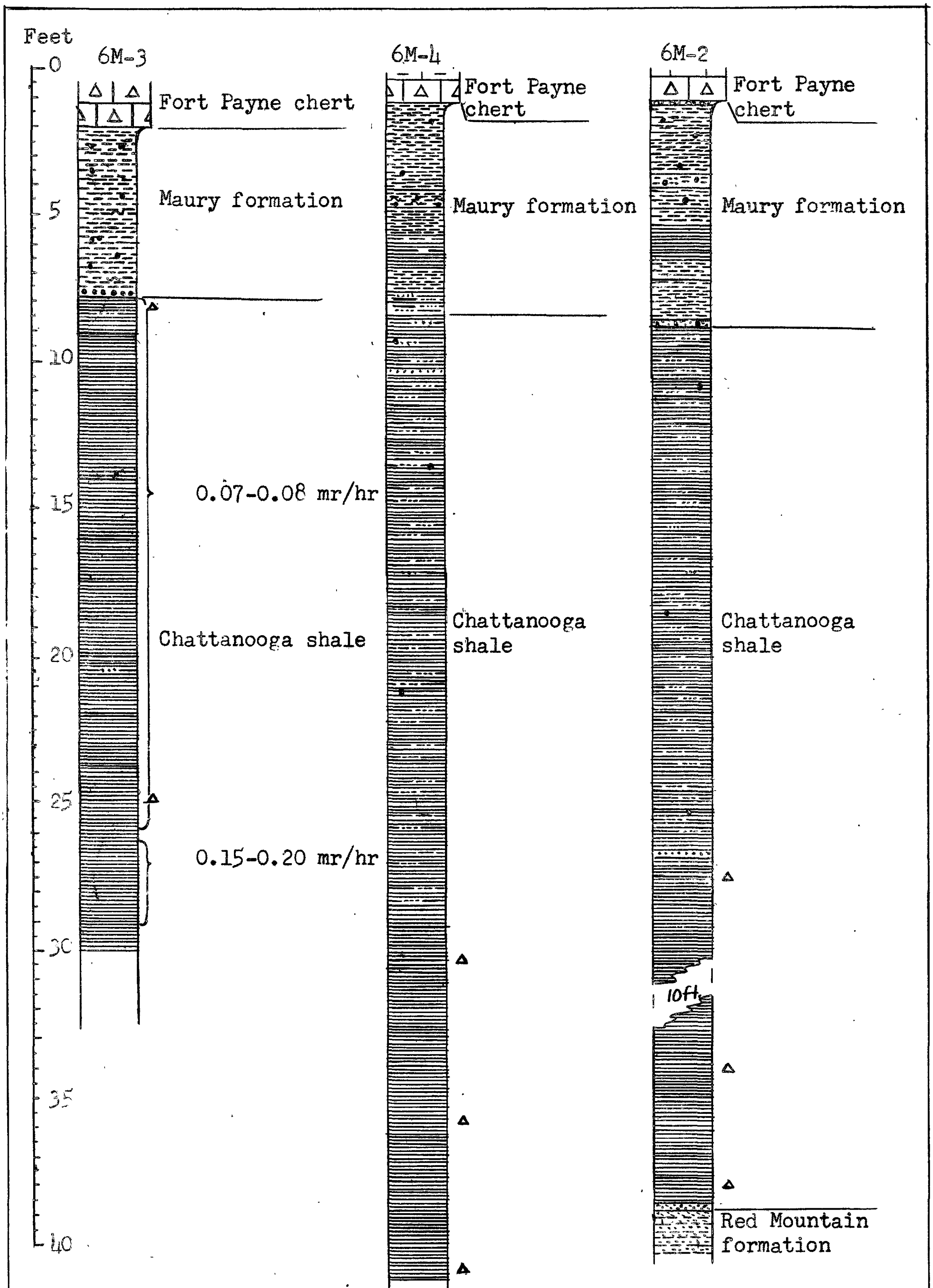

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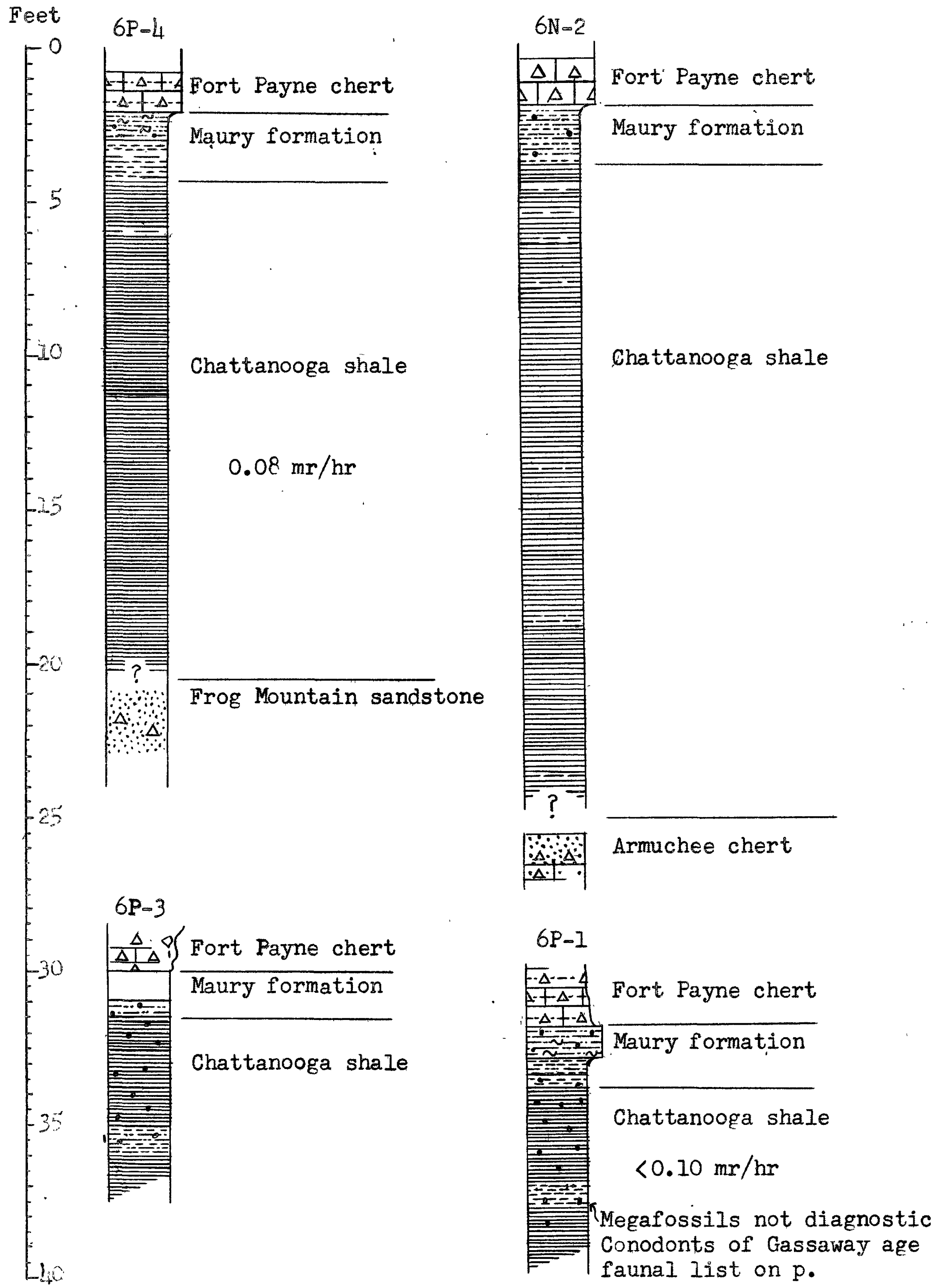

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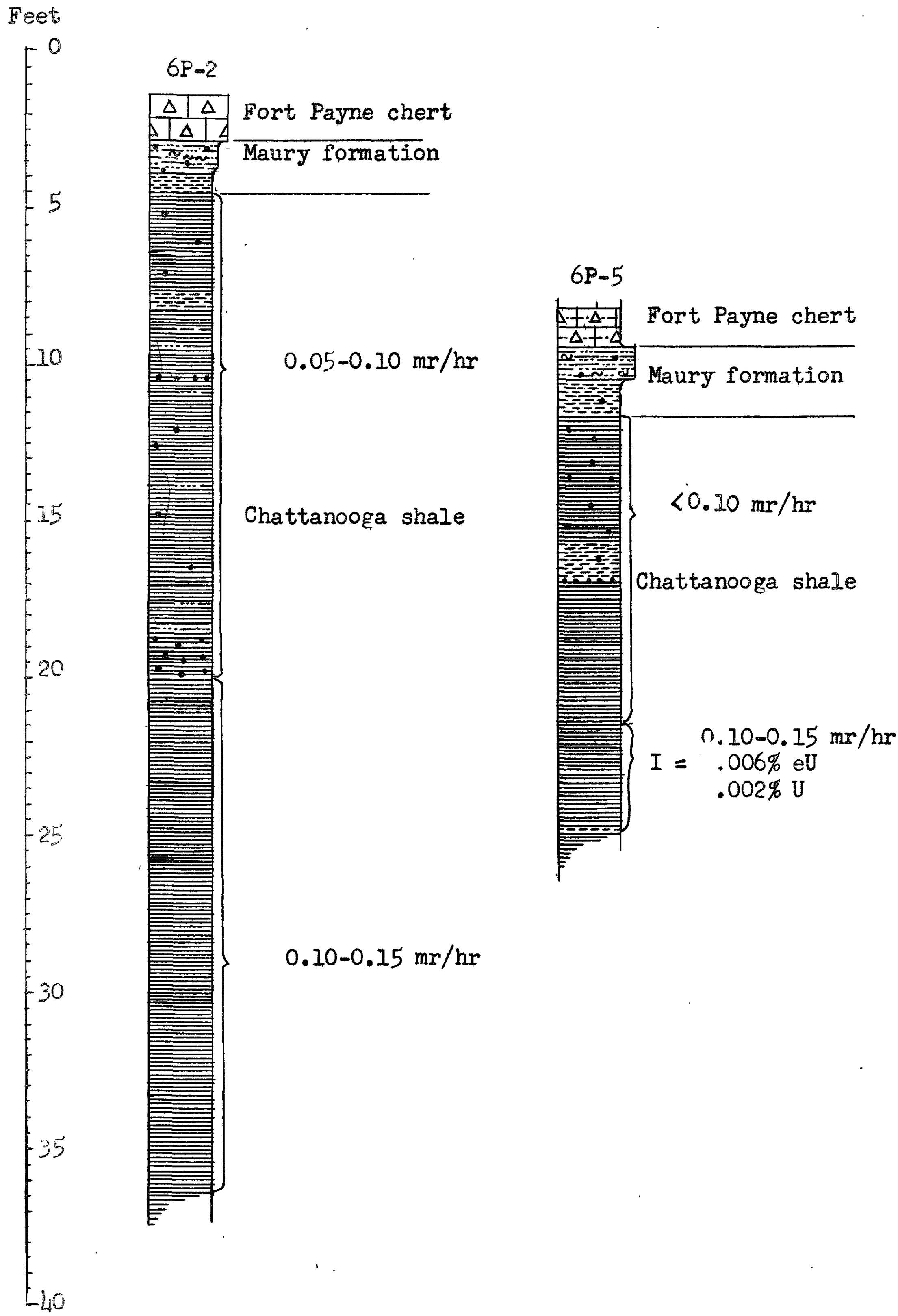

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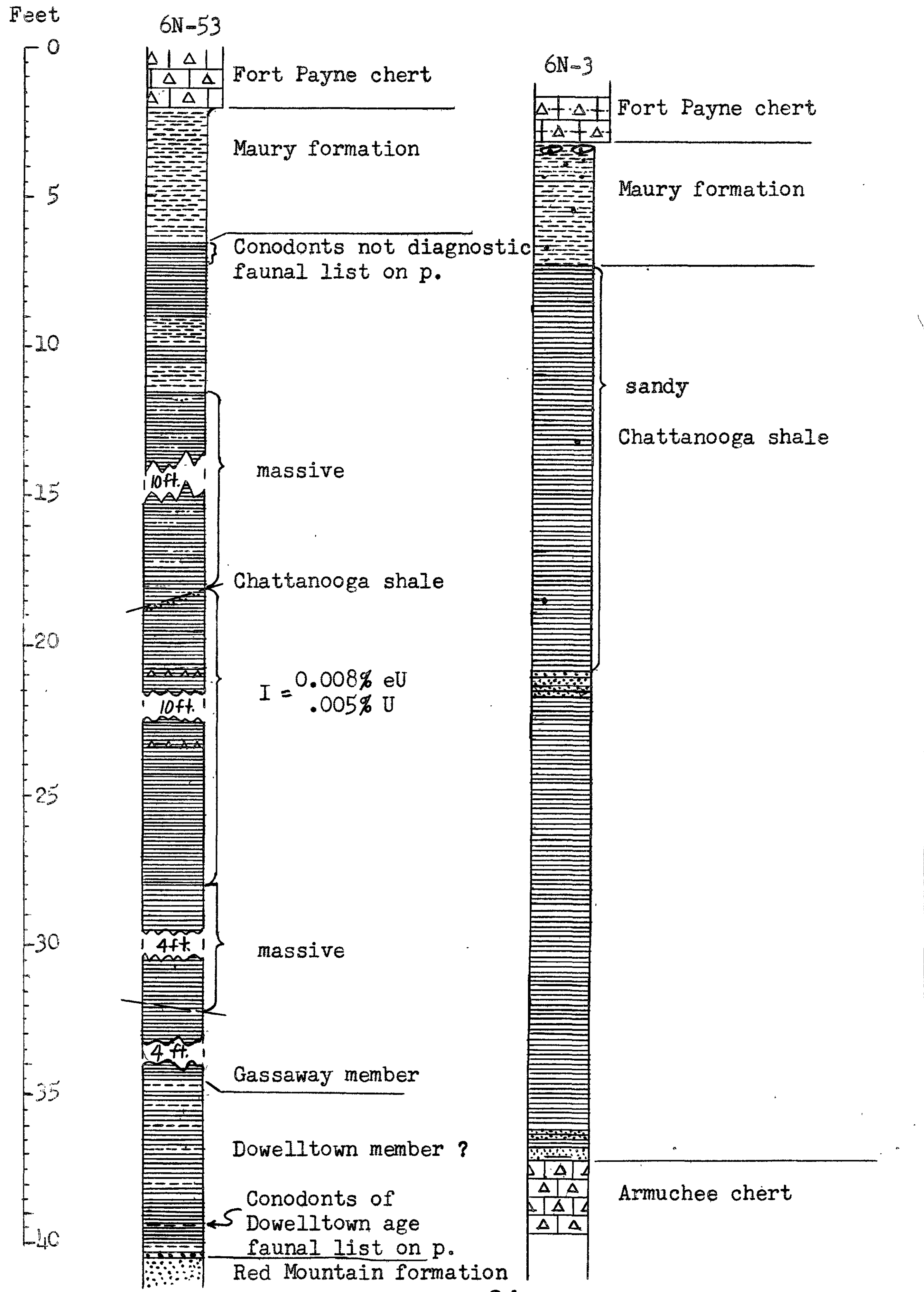

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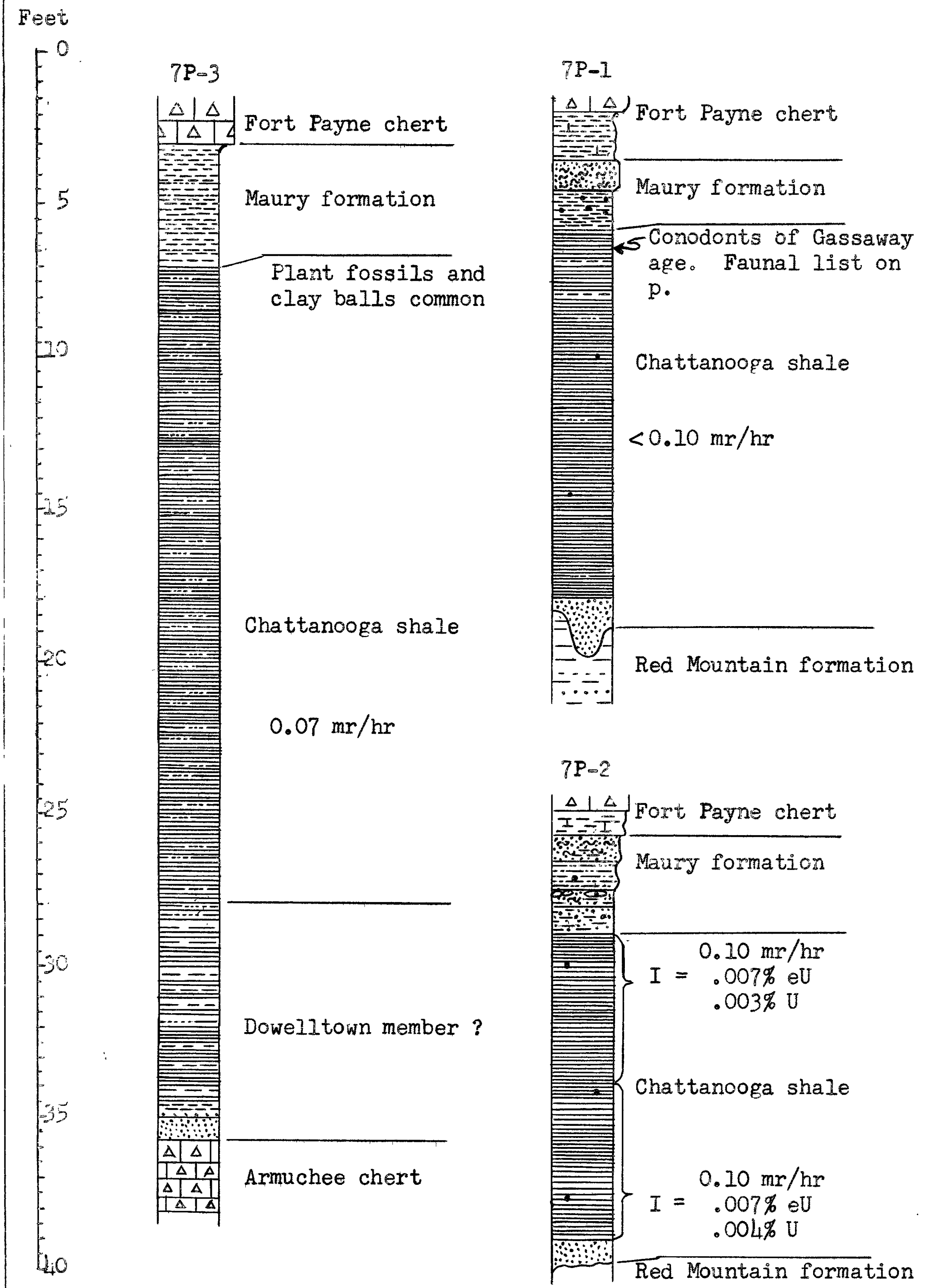

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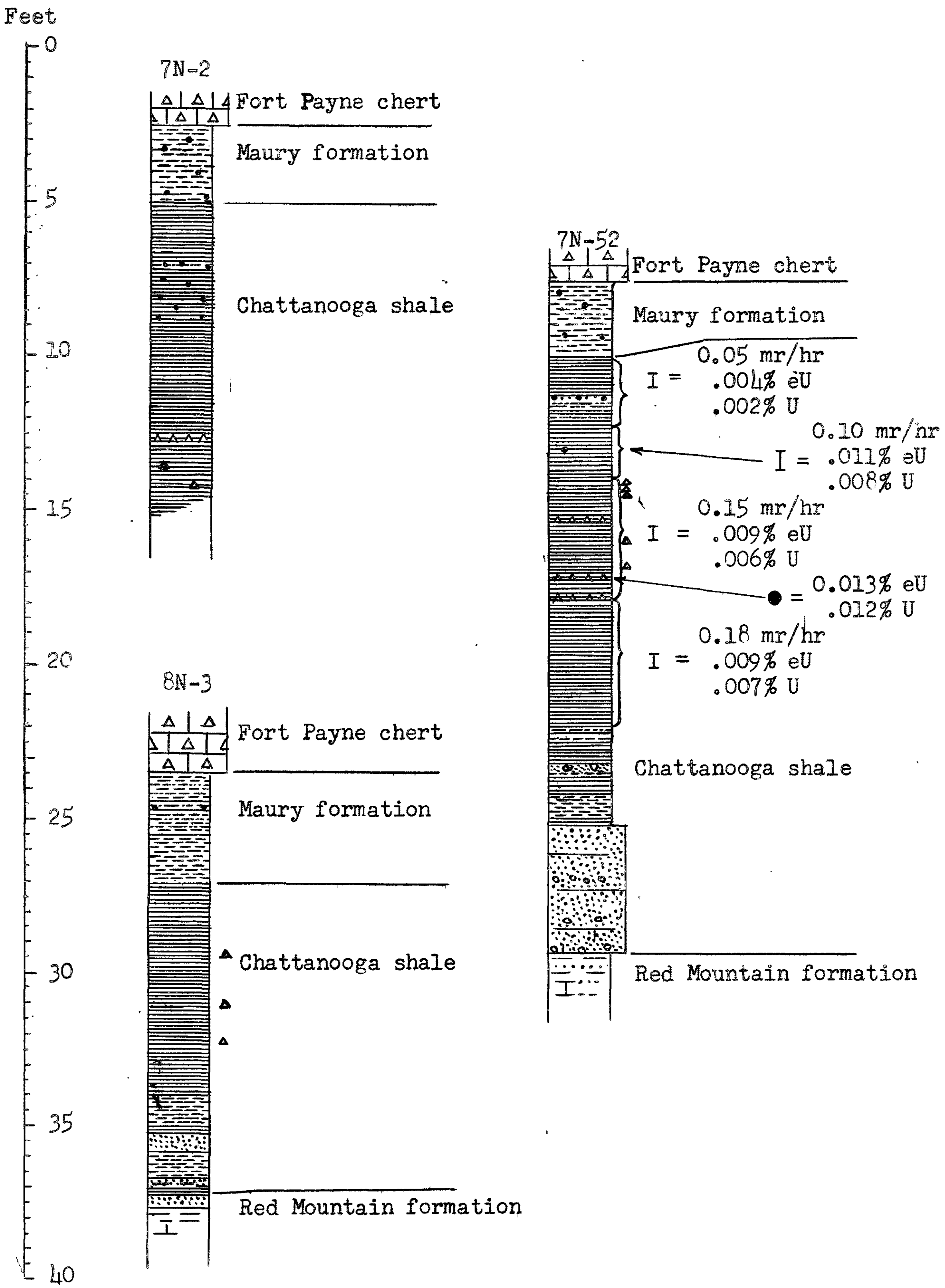

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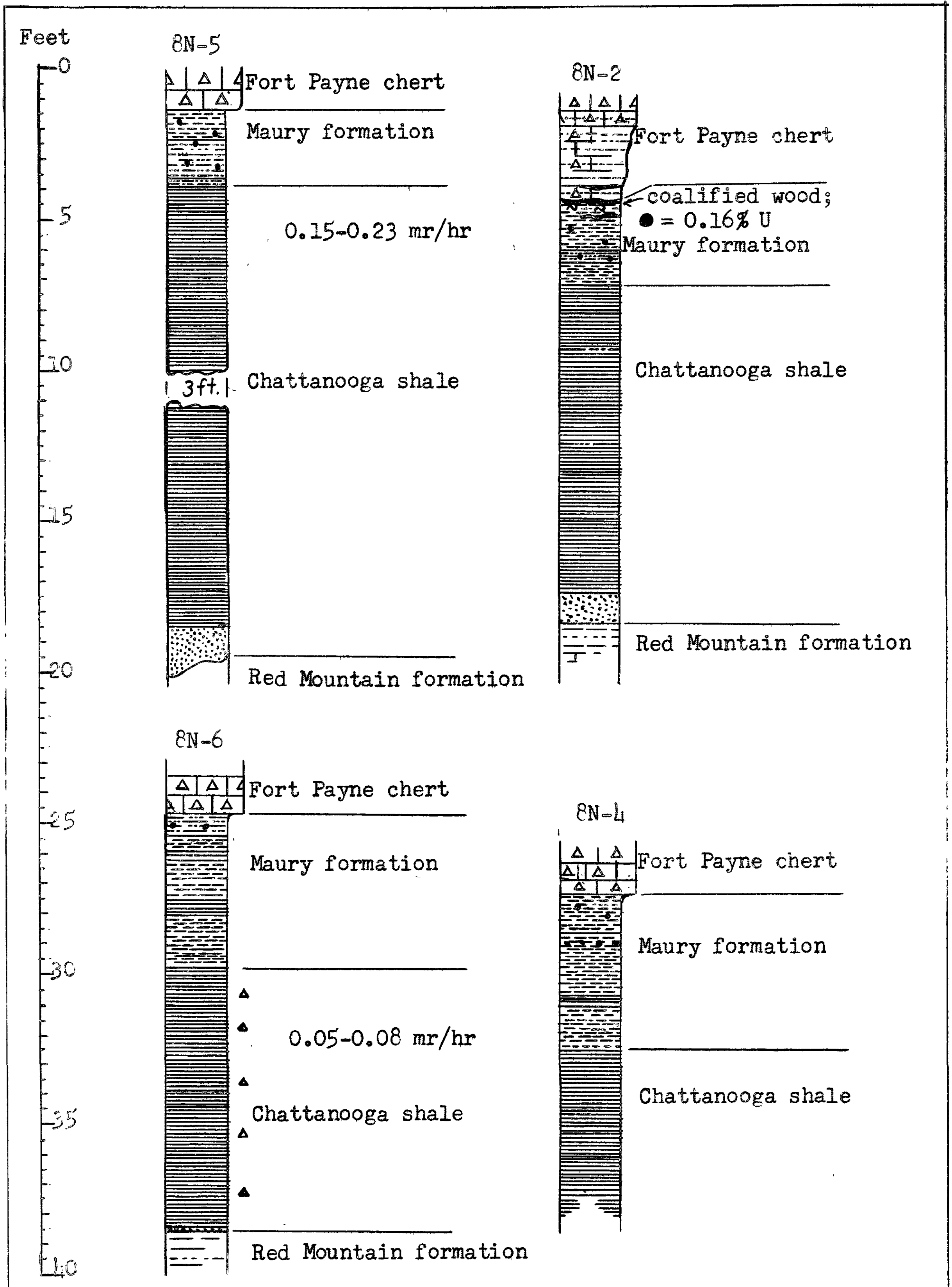

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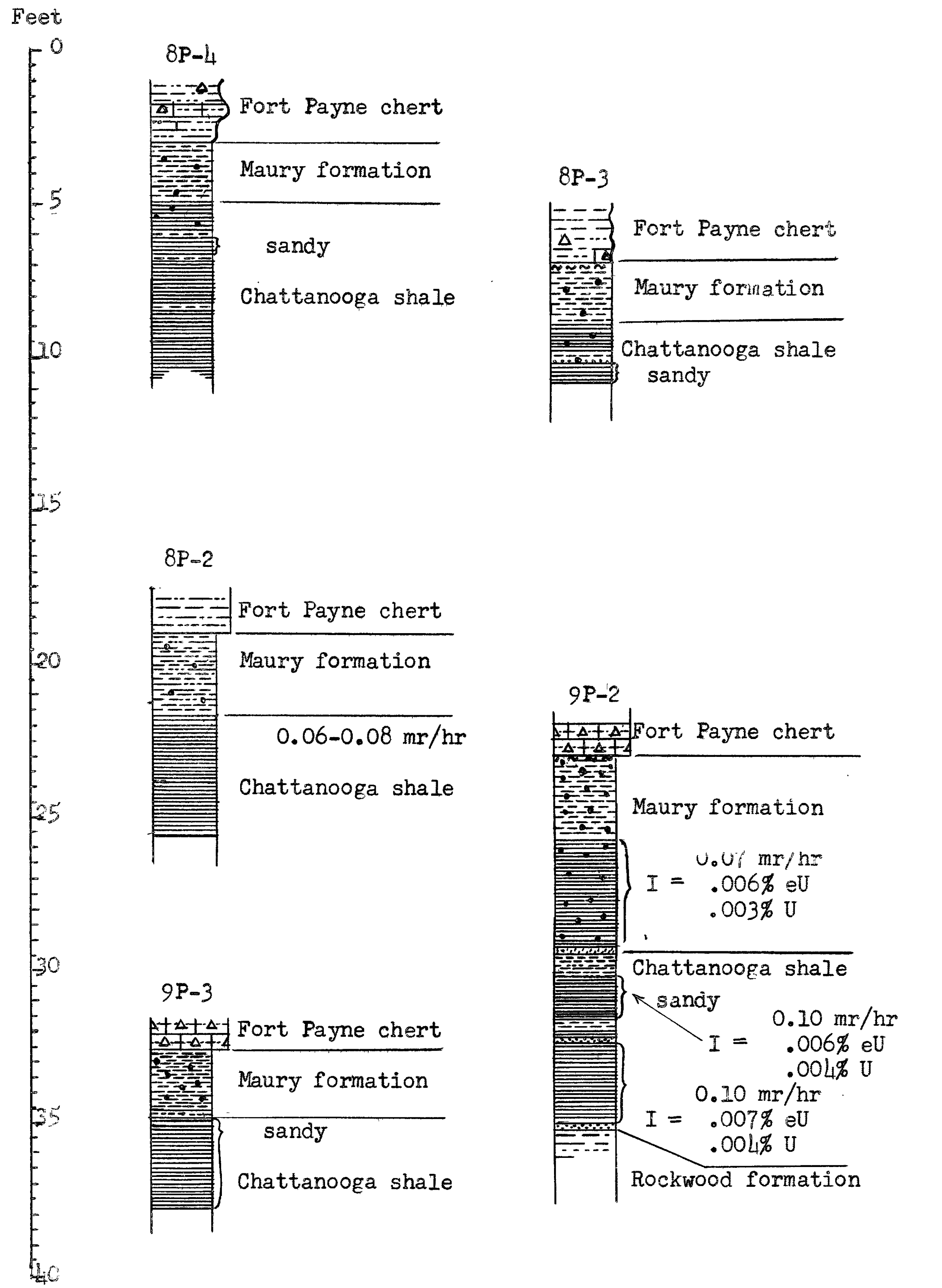

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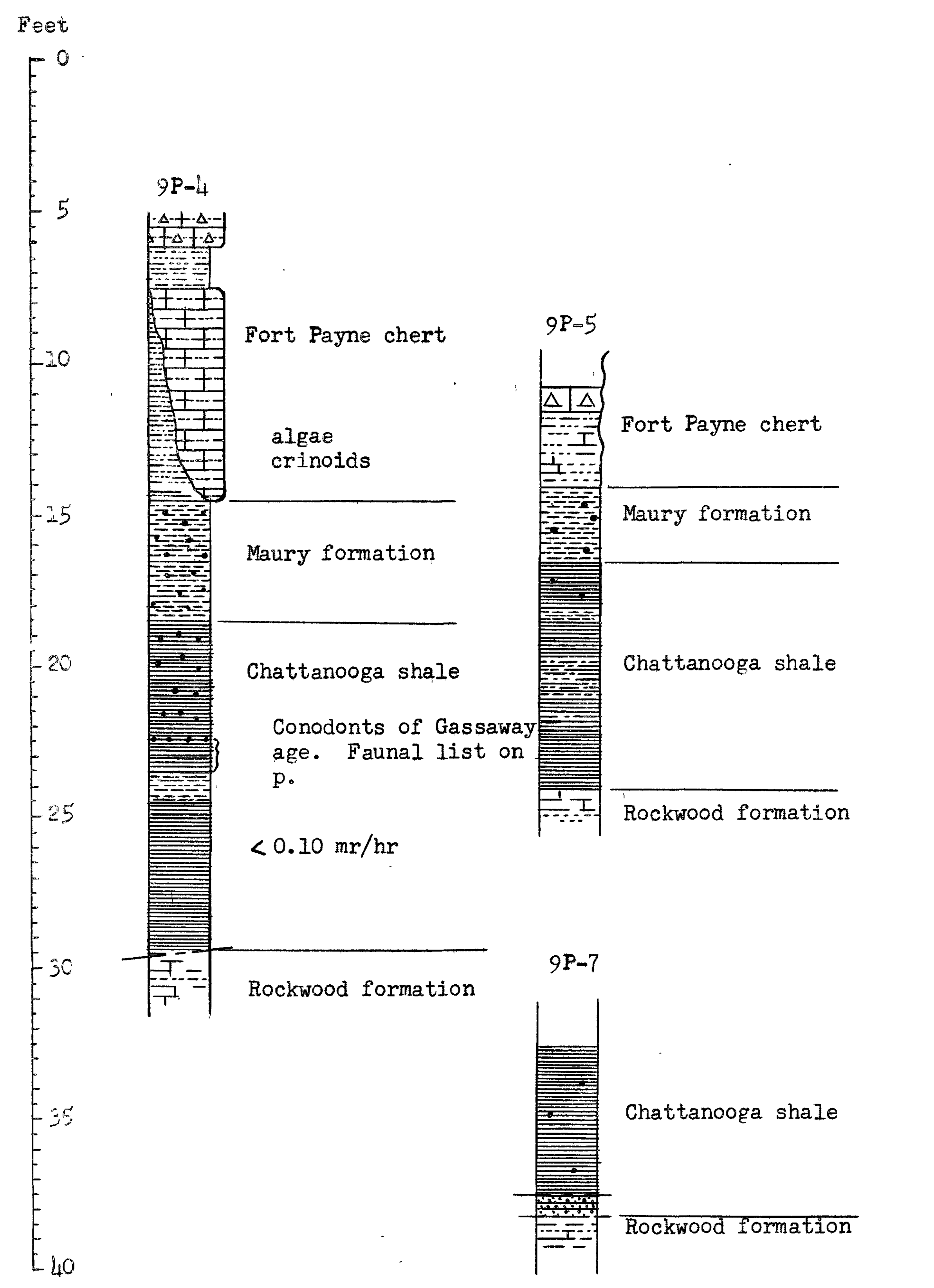

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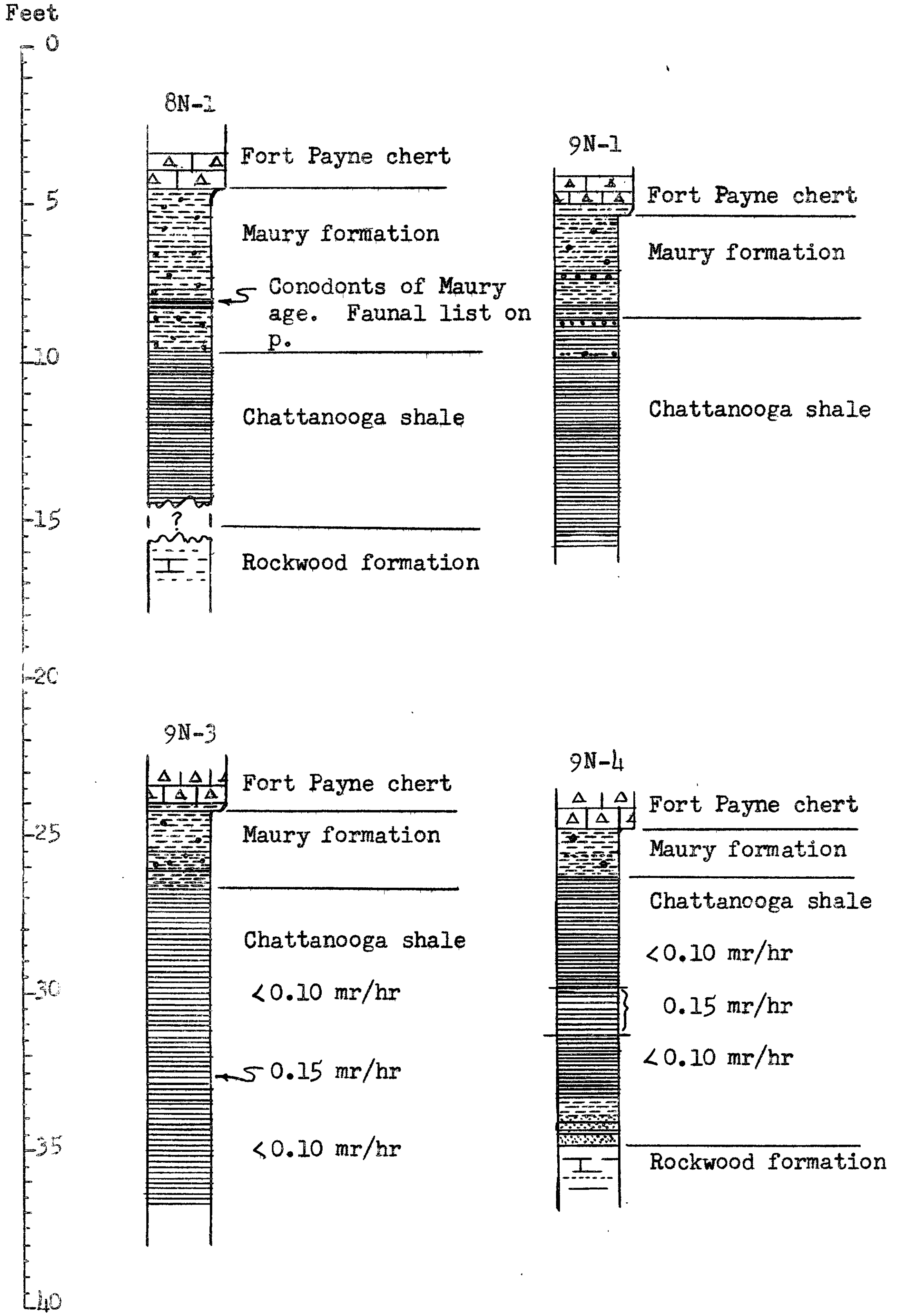

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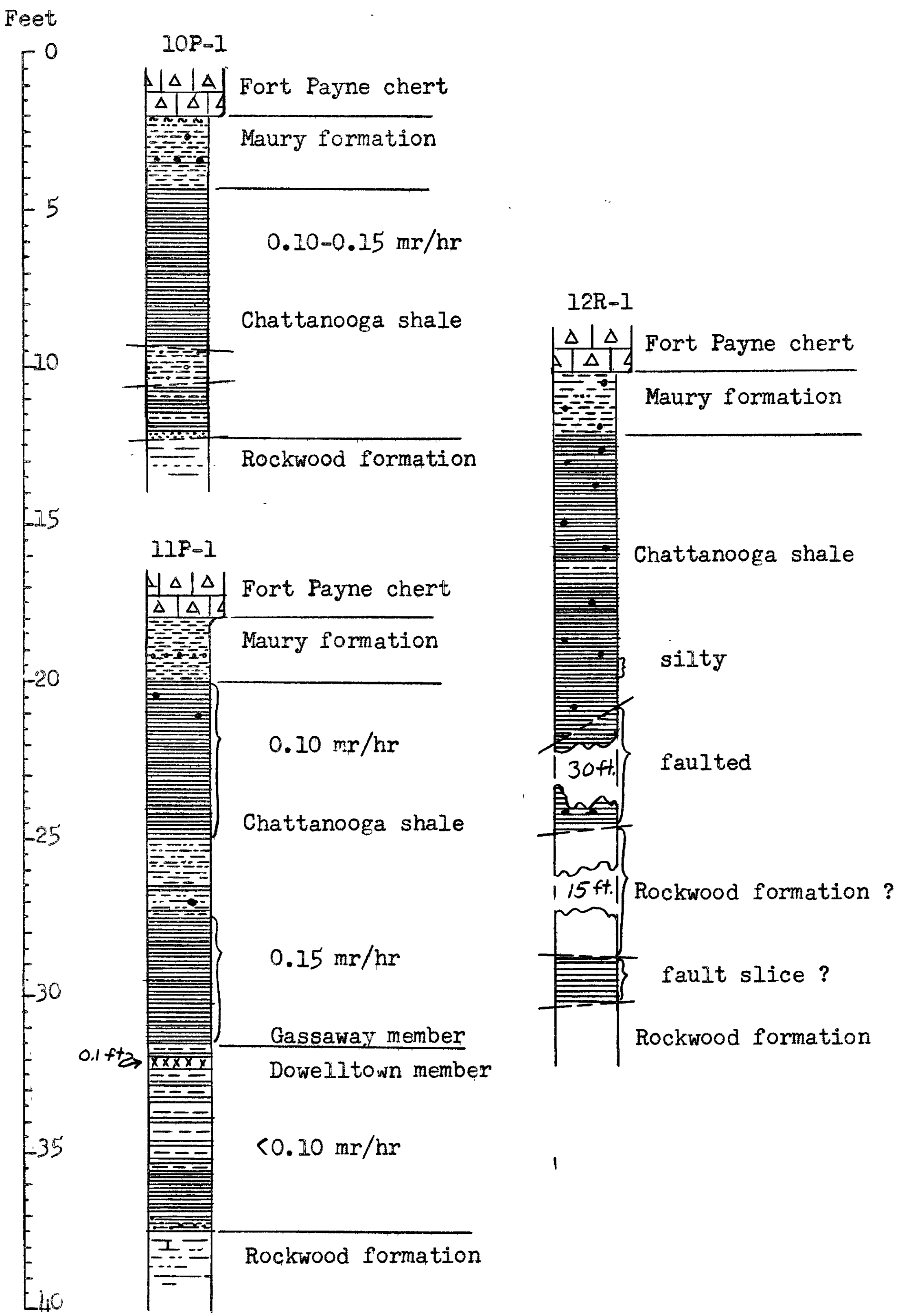

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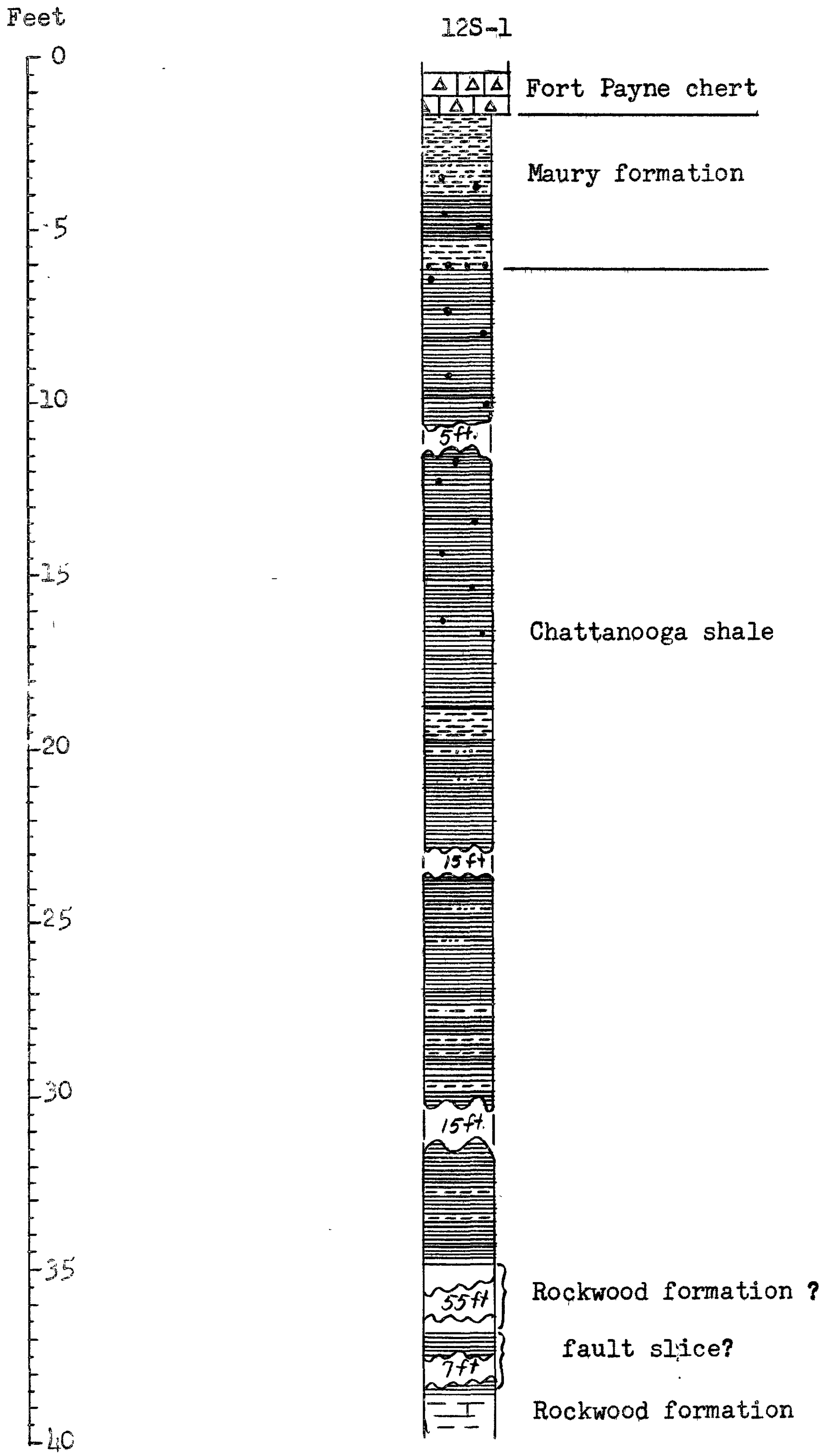

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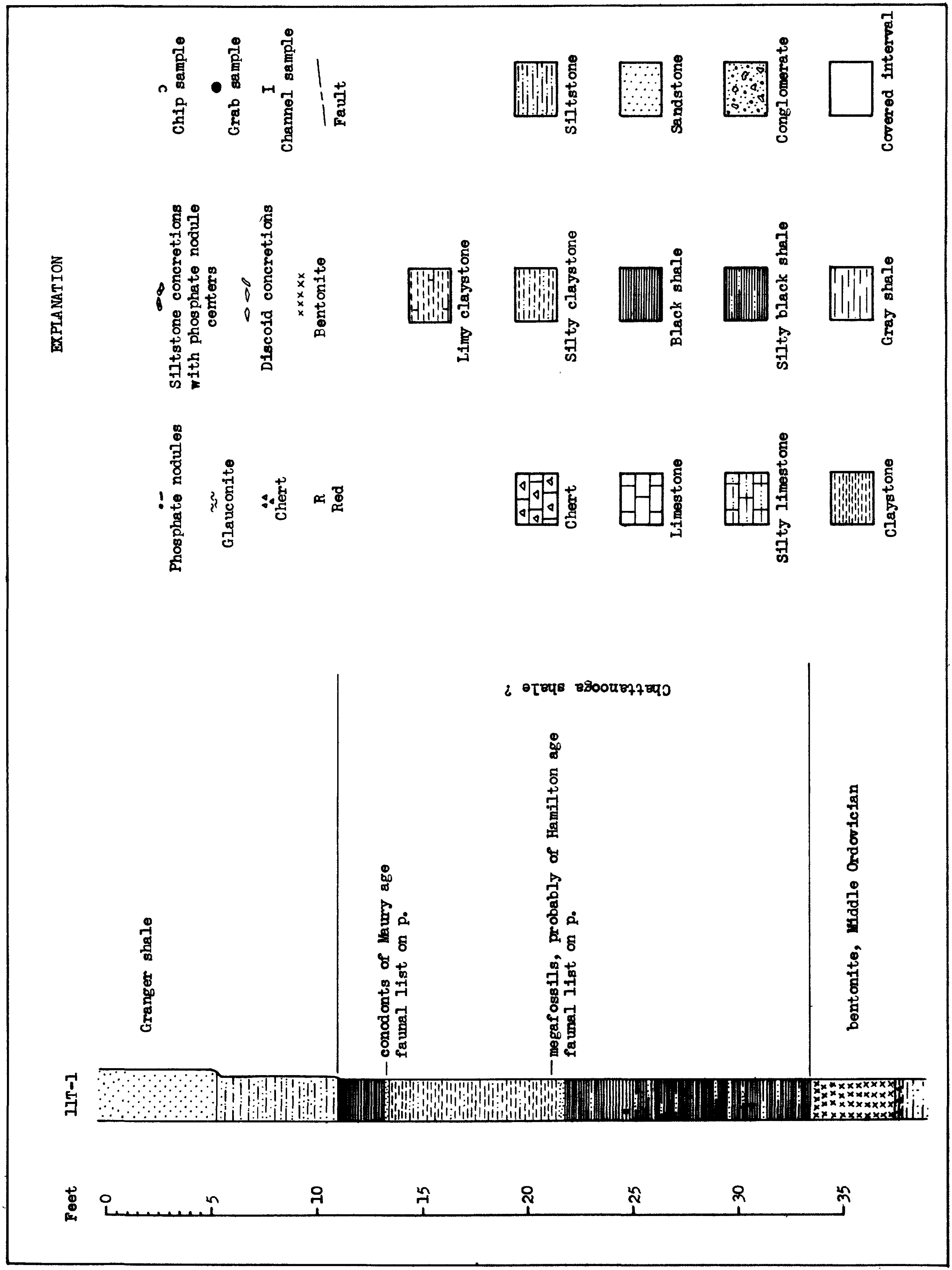

Feet
0
5
10
15
20
25
30
35
11T-1
Granger shale
conodonts of Maury age faunal list on p.
megafossils, probably of Hamilton age faunal list on p.
Chattanooga shale ?
bentonite, Middle Ordovician
EXPLANATION
Phosphate nodules
Glauconite
Chert
R
Red
Siltstone concretions with phosphate nodule centers
Discoid concretions
Bentonite
Chip sample
Grab sample
Channel sample
Fault
Chert
Limestone
Silty limestone
Claystone
Limy claystone
Silty claystone
Black shale
Silty black shale
Gray shale
Siltstone
Sandstone
Conglomerate
Covered interval

Faunal list

The following fossil collections, mostly conodonts, were identified by W. H. Hass of the U. S. Geological Survey, except for the collection of megafossils from locality 11T-1 that was identified by A. J. Boucot of the U. S. Geological Survey. Locality numbers refer to the localities shown on plate 1. Graphic sections in the appendix show the location of the fossil collections in the sections.

All of the following are quoted from written communications by Hass and Boucot.

4J-3

The conodonts in the material examined are weathered and for the most part poorly preserved. It is suggested that the basal sandstone of the Chattanooga shale at the Brothers Mill Gap locality is probably a part of the Dowelltown member.

Ancyrodella sp.
Ancyrognathus englypheus Stauffer
Bryantodus sp.
Hindeodella sp.
Palmatolepis subperlobata Branson and Mehl
Palmatolepis subrecta Miller and Youngquist
Palmatolepis sp.
Polygnathus linguiformis Hinde
Polygnathus cf. P. pennata Hinde
Prioniodus sp.
Numerous fragments of bladelike, barlike, and platelike specimens.

6P-1

The collection is considered to come from the Gassaway member of the Chattanooga shale. This opinion is based on an examination of approximately 50 conodont specimens that are preserved as molds.

6P-1--Continued

Bryantodus sp.
Palmatolepis glabra Ulrich and Bassler
Palmatolepis perlobata Ulrich and Bassler
Palmatolepis subperlobata Branson and Mehl
Palmatolepis (impressions of fragmentary specimens)
Polygnathus sp.
Prioniodus sp.
Spathognathodus inornata (Branson and Mehl)
Spathognathodus sp.
Numerous impressions of fragmentary bladelike, barlike, and platelike conodonts.
Lingula sp.
Orbiculoidea sp.
Numerous impressions of brachiopods

6N-53

The collection [which is from topmost 0.1 foot] contained nothing of significance. Only a few specimens of Hindeodella, Spathognathodus, and Lingula were seen.

This collection [which is from 0.9 to 1.1 foot above the base of the section] is from the Dowelltown member of the Chattanooga shale. The rock is a light-gray to medium-dark-gray siltstone containing numerous "worm tubes" that are filled with light-gray siltstone. About 18 molds of conodonts were examined. The assignment to the Dowelltown is based chiefly upon the presence in the collection of several good specimens of Palmatolepis subrecta Miller and Youngquist. This species ranges throughout the Dowelltown of central Tennessee. It is also found in the lowermost beds of the overlying Gassaway member of the Chattanooga shale along the Eastern Highland Rim of central Tennessee where it is associated with a distinctive set of conodonts that are not in collection 6N-53.

Ancyrodella sp.
Bryantodus sp.
Hindeodella sp.
Palmatolepis subrecta Miller and Youngquist
Palmatolepis cf. P. unicornis Miller and Youngquist

6N-3--Continued

Palmatolepis spp. (fragments)
Prioniodus sp.
Conodont fragments

7P-1

This collection is from the lower faunal zone of the Gassaway member of the Chattanooga shale. The rock is a pale-brown siltstone. About 24 specimens were examined.

Foerstia sp. (one specimen)
Hindeodella spp.
Palmatolepis distorta Branson and Mehl
Palmatolepis glabra Ulrich and Bassler
Palmatolepis perlobata Ulrich and Bassler
Prioniodus sp.
Spathognathodus sp.
Conodont fragments

9P-4

The collection is from a dark-gray shale that contains quartz sand grains. The collection consists of about 12 conodont molds and numerous specimens of the plant Foerstia. The collection comes from the lower faunal zone of the Gassaway member of the Chattanooga shale.

Foerstia sp. (numerous specimens)
Palmatolepis glabra Ulrich and Bassler
Palmatolepis perlobata Ulrich and Bassler
Palmatolepis rugosa Branson and Mehl
Prioniodus sp.
Spathognathodus sp.
Conodont fragments

8N-1

The collection contains the following genera and species. They are preserved chiefly as molds;

Gnathodus sp.
Hindeodella sp.
Lonchodina sp.

8N-1--Continued

Polygnathus communis Branson and Mehl
Prioniodus sp.
Spathognathus sp.
Bladelike, barlike, platelike impressions of conodonts
Orbiculoidea sp.

It is the writer's opinion . . . that the dark-gray bed at St. Elmo [8N-1] should be placed in the Maury formation.

11T-1

This collection [from the base of the upper black shale, which is 2 to 3 feet thick] comes from a pale-brown siltstone that contains some quartz sand. About 24 conodont impressions were recognized. It is my opinion that the bed from which the collection came is from the lower Mississippian. This opinion is based on the presence of *Siphonodella duplicata* (Branson and Mehl) and *Siphonodella duplicata* (Branson and Mehl) var. A. The latter has nodes rather than transverse ridges on the inner platform. *Siphonodella* is restricted to the Kinderhook and I have not found the above mentioned species very high up in the Kinderhook. The bed from which collection 11T-1 came should, in my opinion, be correlated with the Maury formation of the central Tennessee area.

Bryantodus sp.
Hindeodella spp.
Siphonodella duplicata (Branson and Mehl)
Siphonodella duplicata (Branson and Mehl) var. A
Spathognathodus aciedentatus (E. R. Branson)
Spathognathodus sp.
Orbiculoidea sp.

(Megafossils from middle gray silty claystone; identified by A. J. Boucot)

Devonolosia sp. (a stropholosid with concentric wrinkling on both valves, spines on the pedicle valve only)
Ambocoelia cf. *A. nana* (a spiny ambocoelid)
Athyris sp. (an unusual form with spines on both valves, but these spines are scattered and

11T-1--Continued

unlike *Cleiothyridina*)
coarse ribbed chonetid brachiopod
unidentified pelecypod
Bembexia sp.
Murchisonia sp.
Dechenella (*Monodechenella*) sp.

This fauna is probably of Hamilton age.

Locality register

Locality	Description
1F-1	At Pratts Bluff on the Cahaba River, about 5.0 miles north of Centreville, Bibb County, Ala.
2F-1	In gap through Red Mountain near Tannehill, Tuscaloosa County, Ala.; in cut of abandoned road 0.8 mile southeast of Alabama Great Southern Railway crossing at Tannehill.
2F-2	Owens Gap through Red Mountain about 5.0 miles south of Bessemer, Jefferson County, Ala.
3H-1	On road leading west from Palmers, Jefferson County, Ala.; about 1.0 mile west of intersection with State Highway 38 at bend in road.
3H-2	About 0.6 mile south of road intersection at Clay, Jefferson County, Ala.; in cut on road leading to Trussville.
3H-3	At eastern boundary of Leeds, Jefferson County, Ala.; in road cut along Alabama Highway 4.
3H-4	Along U. S. Highway 78 in gap through Red Mountain between Birmingham and Irondale, Jefferson County, Ala.
3H-5	Cut on U. S. Highway 31 at Birmingham, Jefferson County, Ala.; about 2.0 miles south of Third Avenue, just south of

Locality register--Continued

Locality	Description
	the highway crest at Vulcan Park.
3J-1	About 1.5 miles south of city limits of Odenville, St. Clair County, Ala.; in road cut along Alabama Highway 174.
3J-2	2.0 miles north of Pell City, St. Clair County, Ala. on State Highway 25; in road cut opposite E. S. Brown Grocery.
4G-1	At Blount Springs, Blount County, Ala.; about 0.5 mile east of U. S. Highway 31 on country road; road cut.
4H-1	About 8.0 miles southwest of Oneonta, Blount County, Ala. From bridge on State Highway 38 across Blackburn Fork of Warrior River go northeast about 0.7 mile on Highway 38, then west on dirt road about 2.0 miles; outcrop in cut on north side of road near intersection with dirt road leading south.
4J-1	From junction of Alabama Highways 25 and 38 in Oneonta, Blount County, Ala., 0.2 mile northwest on State Highway 38; cut on west side of road.
4J-2	About 1.0 mile west of Whitney, St. Clair County, Ala.; in road cut on north side of Alabama Highway 25, 0.1 mile west of intersection with U. S. Highway 11.
4J-3	Brothers Mill Gap in Greasy Cove, Etowah County, Ala.; on road to Camp Sumatanga about 1.8 miles south of junction with Gallant road, near county line. SE cor. sec. 19, T. 12 S., R. 4 E.

Locality register--Continued

Locality	Description
4J-4	About 0.5 mile west on Alabama Highway 38 from intersection with Alabama Highway 25 in Oneonta, Blount County, Ala., then southwest on dirt road about 0.2 mile; outcrop at road fork near old house.
4J-5	Northwest of Springville, St. Clair County, Ala.; about 1.8 miles northwest of road intersection at south edge of town; in road cut opposite artificial lake.
4J-6	Northeast of Springville, St. Clair County, Ala.; about 1.5 miles northeast of city limits turn east on dirt road; outcrop in road cut about 0.7 mile from U. S. Highway 11 and just south of fork in dirt road.
4J-7	About 4.0 miles northeast of Gallant, Etowah County, Ala. go north 1.0 mile on road crossing Louisville and Nashville Railroad; outcrop of shale in east road bank.
4K-1	Cox Gap in Beaver Creek Mountain, St. Clair County, Ala.; about 4.0 miles southeast of Ashville; in road cut.
4K-2	About 1.0 mile northwest of Ohatchee, Calhoun County, Ala.; in cut along road leading from Ohatchee to Ten Island Church.
4K-3	On Dunaway Mountain, Etowah County, south of Gadsden, Ala.; from Morgans crossroad go southwest on U. S. Highway 411 about 0.5 mile, turn left on dirt road and continue south across crest of mountain; in road cut just past first sharp turn to right.

Locality register--Continued

Locality	Description
4L-1	Alexander Gap in Colvin Mountain, Calhoun County, Ala. In road cut along U. S. Highway 241 about 0.75 mile south of Etowah-Calhoun County line.
4L-2	About 1.0 mile southeast of Ohatchee, Calhoun County, Ala.; in cut along road leading from Ohatchee to Middleton.
5H-1	Near Blountsville, Blount County, Ala. 3.0 miles west of intersection of State Highways 128 and 38 at Blountsville, turn east from Highway 128 on dirt road; Chattanooga shale is exposed in road cut 0.5 mile from intersection.
5J-1	Road cut in Hobson Gap in Dividing Ridge just south of Marshall County line in Blount County, Ala.
5J-2	About 1.4 miles west of Brooksville, Blount County, Ala.; road cut along Alabama Highway 74.
5J-3	Near Altoona, Etowah County, Ala.; from Blount-Etowah County line go 1.5 miles north on State Highway 176; outcrop in road cut at sharp bend in road.
5L-1	East side of Red Mountain, Etowah County, Ala. From intersection of U. S. Highway 11 and Alabama Highway 1 in Attalla go northeast on U. S. Highway 11 about 5.4 miles; then go 0.55 mile west on dirt road.
6K-1	From road intersection north of church at Langston, Jackson County, Ala. go about 0.5 mile west-northwest to top of hill on trail road; outcrop in bank along road.

Locality register--Continued

Locality	Description
6K-2	From railroad crossing at Hollywood, Jackson County, Ala. east 0.1 mile then east-southeast 2.6 miles; outcrop in road cut on north side of road.
6K-3	From courthouse at Scottsboro, Jackson County, Ala. about 6.5 miles southwest on Alabama Highway 32; road cut on northwest side of road 200 feet northeast of bridge crossing part of reservoir.
6L-1	At Collinsville, DeKalb County, Ala. From intersection of U. S. Highway 11 and Alabama Highway 68, west on Highway 68 for 0.1 mile; outcrop at base of west-facing bluff.
6M-1	At Fort Payne, DeKalb County, Ala.; about 300 feet north-west of U. S. Highway 11 along Alabama Highway 35; cut on north side of road.
6M-2	In north road cut through Shinbone Ridge just north of Blanche, Cherokee County, Ala.
6M-3	Near Fort Payne, DeKalb County, Ala.; 1.4 miles southwest of city limits of Fort Payne on U. S. Highway 11 go east on dirt road 10.2 miles; in new cut on north side of road.
6M-4	In south road cut through Shinbone Ridge just west of Blanche, Cherokee County, Ala.
6N-2	In road cut on southeast side of Lavender Mountain, Floyd County, Ga.; on road leading south from Crystal Springs to the Berry School in north Rome; less than 0.20 mile south of crest of mountain.

Locality register--Continued

Locality	Description
6N-3	Southeast slope of Taylor Ridge in Chattooga County, Ga.; 0.75 mile northwest of Gore in cut of U. S. Highway 27.
6N-4	Near foot of Turnip Mountain, Floyd County, Ga.; about 10.0 miles west of Rome in road cut.
6N-5	Near Silver Hill, Chattooga County, Ga.; about 6.0 miles south-southwest of Gore in road cut just northeast of Silver Hill.
6N-6	North side of Lavender Mountain, Floyd County, Ga.; go 0.5 mile northeast from Sand Spring Church then take dirt road up mountain about 0.5 mile; outcrop is in sharp bend of road.
6N-53	About 0.5 mile west of Menlo, Chattooga County, Ga.; on Georgia Highway 48; cut on north side of road.
6P-1	South of Turkey Mountain, Floyd County, Ga.; about 50 yards south of intersection of Old Dalton Road and Staton Road.
6P-2	Just west of Crystal Springs, Floyd County, Ga.; outcrop is below the Mill Dam on Little Armuchee Creek.
6P-3	West of Armuchee in cut along paved road; second bend in road across Armuchee Creek, Floyd County, Ga.
6P-4	Horseleg (Mt. Alto) Mountain, Floyd County, Ga.; 0.80 mile on Hanks Street south of intersection with Shorter Avenue.
6P-5	East side of Turkey Mountain, Floyd County, Ga.; on Old Dalton Road about 0.4 mile north of intersection with Staton Road.

Locality register--Continued

Locality	Description
7M-1	About 1.5 miles northwest of Hammondville, DeKalb County, Ala.; in road cut along Alabama Highway 58.
7M-2	In road cut across Little Ridge, DeKalb County, Ala.; about 15.0 miles north of Fort Payne. NE$\frac{1}{4}$ sec. 6, T. 5 S., R. 10 E.
7N-2	About 2.0 miles west of LaFayette, Walker County, Ga.; north side of Georgia Highway 2.
7N-52	Dug Gap, Walker County, Ga.; on Georgia Highway 2 about 6.5 miles north of LaFayette, Ga.
7P-1	Maddox Gap in Taylor Ridge about 8.0 miles west of LaFayette, Walker County, Ga.; in cut along Georgia Highway 2 at first sharp bend in road down east side of Taylor Ridge.
7P-2	Dick Ridge, Chattooga County, Ga.; in road cut along Georgia Highway 2 on south side of road; about 2.0 miles east of 7P-1 at Maddox Gap.
7P-3	About 5.0 miles west of Sugar Valley, Gordon County, Ga.; in road cut across Horn Mountain.
8N-1	Near St. Elmo, Hamilton County, Tenn.; in gap through Hawkins Ridge about 0.3 mile north of Tennessee-Georgia State line.
8N-2	Abandoned chert quarry 0.5 mile south of Hooker, Dade County, Ga.

Locality register--Continued

Locality	Description
8N-3	About 0.8 mile west of Cooper Heights, Walker County, Ga.; outcrop at crest of ridge on west side of Lookout Mountain in road cut along Georgia Highway 2.
8N-4	In road cut 0.35 mile east of road intersection at Hooker, Dade County, Ga.
8N-5	Roncoe Hollow Mine site; from intersection of Chattanooga Valley Road and Grand Center Road 3.5 miles south of Flintstone, Walker County, Ga., go south on Chattanooga Valley Road about 0.70 mile; at crest of hill go west on dirt road to end of road and walk to end of ravine (0.15 mile).
8N-6	About 1.0 mile west of Trenton, Dade County, Ga., on Georgia Highway 143.
8P-2	"Cherokee Valley Phosphate Mine"; east flank of Whiteoak Mountain in Cherokee Valley, Catoosa County, Ga.; outcrop in ravine 0.3 mile west of road intersection 1.7 miles south of Tennessee-Georgia State line.
8P-3	About 1.0 mile airline east of Ringgold, Catoosa County, Ga., and 0.2 mile north of intersection of U. S. Highway 27 and Cherokee Valley Road; outcrop of shale in west road cut.
8P-4	About 1.5 miles east of Ringgold, Catoosa County, Ga.; on Georgia Highway 41 go south on dirt road 0.25 mile; outcrop in Nashville Chattanooga and St. Louis Railroad cut.

Locality register--Continued

Locality	Description
9N-1	Wauhatchie Mine site; from Chattanooga, Tenn. go west on U. S. Highway 11 0.75 mile beyond Tennessee Highway 41 turn off; then northwest on Cummings road to first sharp bend north; outcrop marked by several adits in side of hill.
9N-2	First overpass west of north end of Lookout Mountain, Hamilton County, Tenn.; on U. S. Highway 11 just west of Chattanooga, Tenn.
9N-3	About 0.25 mile north of Glendale, Hamilton County, Tenn.; in road cut through ridge north of Mountain Creek School on "W Road".
9N-4	About 0.5 mile west of intersection at Red Bank main business district, Hamilton County, Tenn.; outcrop in road cut through Godsey Ridge.
9P-1	About 1.0 mile east of Collegedale railroad station, Hamilton County, Tenn.; cut on south side of railroad.
9P-2	In cut along Apison Pike 1.0 mile airline east of Southern Missionary College, Hamilton County, Tenn.; outcrop is in cut on north side of road just east of bridge over Chestnut Creek.
9P-3	Just north of Southern Missionary College and north of creek and railroad track; in cut of a dead end road that heads west, Hamilton County, Tenn.
9P-4	Dead Man Gap near Ooltewah, Hamilton County, Tenn.; on U. S. Highway 11 1.4 miles east of intersection with Georgetown Pike.

Locality register--Continued

Locality	Description
9P-5	About 6.0 miles airline west of Cleveland, Bradley County, Tenn. in road cut along south fork of Harris Creek 0.9 mile airline southwest of Baugh Spring on west flank of Lauderback Ridge.
9P-6	About 0.5 mile south of Lauderback Springs, Bradley County, Tenn. on old road bed now abandoned.
9P-7	About 0.5 mile north of 9P-6 and due east of Lauderback Springs, Bradley County, Tenn.
10P-1	Southern Railway cut just west of U. S. Highway 27; 1.5 miles north of Bakewell, Hamilton County, Tenn.
11P-1	Near Dayton, Rhea County, Tenn.; 1.4 miles airline north of northernmost railroad crossing in Dayton; outcrop just north of intersection of two dirt roads.
11T-1	Near Bacon Bend of the Little Tennessee River, Monroe County, Tenn. From the intersection of two unpaved roads southeast of the river bend go east about 0.25 mile to the third bend in the road; outcrop in road cut.
12R-1	Just north of Rockwood city limits, Roane County, Tenn.; in cut along road heading northeast toward Little Mission Church.
12S-1	5.0 miles about east-northeast of Harriman and just east of the community of Emory, Roane County, Tenn.; outcrop on lake just south of Highway 27.

Locality register--Continued

Locality	Description
13S-1	About 3.2 miles southwest of Oliver Springs turn northwest on dirt road; outcrop in road cut about 1.5 miles from main road.