

STRATIGRAPHIC CORRELATION OF OUTCROP
GAMMA RAY PROFILES IN FLORIDA

E&MS
QE99
.064
no.26

**State of Florida
Department of Natural Resources
Tom Gardner, Executive Director**

**Division of Resource Management
Jeremy Craft, Director**

**Florida Geological Survey
Walt Schmidt, State Geologist and Chief**

Open File Report 26

**Stratigraphic Correlation of Outcrop
Gamma Ray Profiles in Florida**

by

Richard A. Johnson

**Florida Geological Survey
Tallahassee, Florida
1989**

ABSTRACT

Stratigraphic Correlation of Outcrop Gamma Ray Profiles in Florida. R.A. JOHNSON, Florida Geological Survey, 903 W. Tennessee Street, Tallahassee, 32304. Utilizing a hand-held scintillometer, total count gamma ray profiles were run on outcrops exposing many different lithologies in Florida. Emphasis was placed upon those outcrops which exhibited one or more stratigraphic contacts in order to determine if changes in the gamma ray signature could be correlated with formation as well as lithologic changes. Since the lithologies present in each outcrop were already known from a previous detailed study, correlation of these lithologies with gamma ray response on a bed-by-bed basis allowed detailed comparisons of typical formation lithologies with total count gamma ray response. The outcrop gamma ray profiles were then correlated with subsurface borehole gamma ray logs to determine if specific lithologic entities (beds) or stratigraphic units (formations, members) could be identified in the subsurface more accurately using this technique.

NOTE

This Open File Report consists of the transcription in its entirety of a paper presented at the Florida Academy of Sciences Annual Meeting, April 1, 1989, at Florida Community College at Jacksonville, Jacksonville, Florida.

STRATIGRAPHIC CORRELATION OF OUTCROP

GAMMA RAY PROFILES IN FLORIDA

In the 1970s and 1980s, the use of borehole geophysical logs for stratigraphic correlation has been widespread in Florida. Many governmental organizations and private consultants have been involved with well logging, with the result that there are currently an abundance of borehole geophysical logs available across the state. However, until 1988, no outcrop gamma ray profiles were available for any location in Florida. This technique involves recording average gamma ray activity in counts-per-second at intervals vertically across an outcrop; plotting these intensity readings versus height or depth; then connecting the points (Ettensohn et al., 1979; Chamberlain, 1984). The result is, in essence, a gamma ray log of the outcrop which can then be compared to borehole gamma ray logs. This technique has been used in the oil industry for some time (Ettensohn et al., 1979) but the first use of the technique reported in the literature was in the paper mentioned above (Ettensohn et al., 1979). The technique was also applied to the thick sections exposed in the southwest by Chamberlain (1984). This technique is therefore essentially new.

This study was begun in order to determine if outcrop gamma ray profiles could be constructed from Florida outcrops and, if so, whether the profiles could be correlated with borehole gamma ray logs. The hand-held scintillometer used in this study

incorporates a very large 7.5 cubic inch thallium-activated sodium iodide sensing crystal which is linked to a

photomultiplier tube to form a large and sensitive gamma ray detector. Amplification and counting circuitry then convert the signal into a standardized counts-per-second digital readout which is averaged over 10 seconds in 2 second intervals of counting time. The most sensitive borehole gamma ray probe currently in use in the state uses a sensing crystal with a volume of approximately 3.1 cubic inches, less than half the volume of this hand-held scintillometer crystal. Since the sensitivity of the scintillometer to gamma rays is directly related to its crystal volume (Keys and MacCary, 1971) as well as to other lesser variables, the very large crystal in the hand-held scintillometer utilized in this study provided extremely sensitive gamma ray counts. The scintillometer was placed directly upon and in full contact with the bed being measured and the readings were taken. This technique eliminates the borehole gamma ray log variables of both changing borehole size and the effects of probe movement from the outcrop gamma ray profiles thus obtained.

At each bed or measuring station, between 3 and 5 10-second readings were taken and the arithmetic mean of the readings was recorded. Vertically across each outcrop, a spatial sampling interval of 1 foot was used, unless the section contained beds less than 1 foot in thickness. In that case, readings were taken and averaged from the middle of each thin bed, at less than 1 foot intervals.

In the office, these data points were plotted versus height

at standardized scales adjacent to a standardized section diagram showing bed lithology, thickness and weathering profile (Figure 1). The points were then connected, resulting in an outcrop gamma ray profile similar to borehole gamma ray logs. One difference between the profiles and gamma ray logs is scale. The outcrop profile is recorded at a much-expanded scale vertically and is much more sensitive to relative changes in count rate due to the large crystal size. Another difference between the two is that the borehole gamma ray log is recorded continuously over the interval being logged, whereas the profile is constructed from discrete points measured over the interval.

The gamma ray profile can thus be correlated directly with exposed outcrop lithology. Peak-and-valley patterns in the profiles can then be correlated with patterns seen in the borehole gamma ray logs.

Gamma ray profiles from 49 outcrops across the state (Figure 2) were made for this study. Emphasis was placed upon relatively thick continuous exposures and upon exposures which contained one or more stratigraphic contacts between formations or members. The profiles were correlated with borehole geophysical logs run in the same local areas and in other areas of the state.

It was found that the suites of known lithologies which compose formations as seen in outcrop were indeed correlatable as a distinct series of formational patterns between outcrop gamma ray profiles and borehole gamma ray logs. In addition, use of type outcrop profiles and profiles which included a formational contact allowed determination of typical gamma ray patterns for

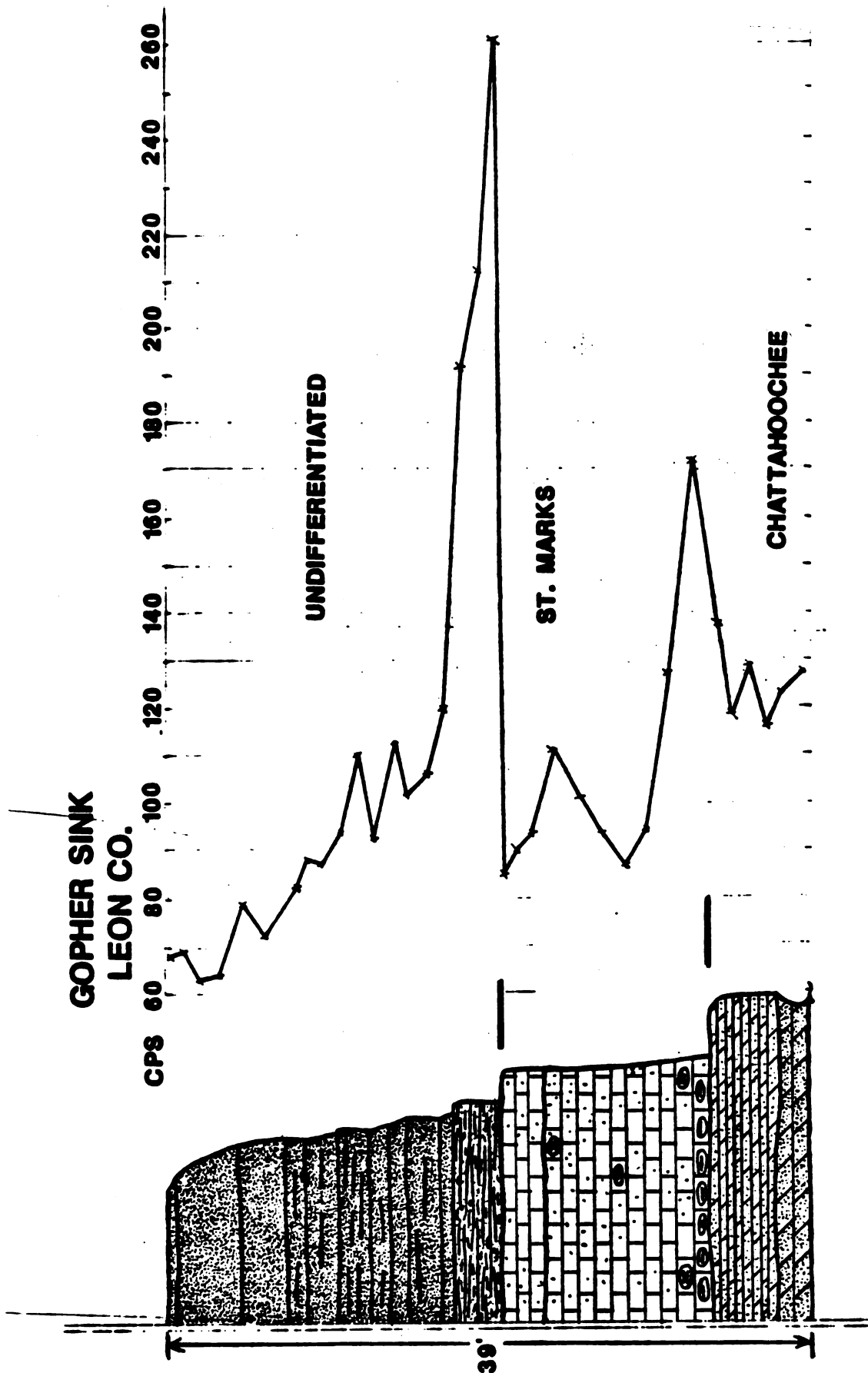


Figure 1. Typical standardized section diagram and outcrop gamma ray profile.

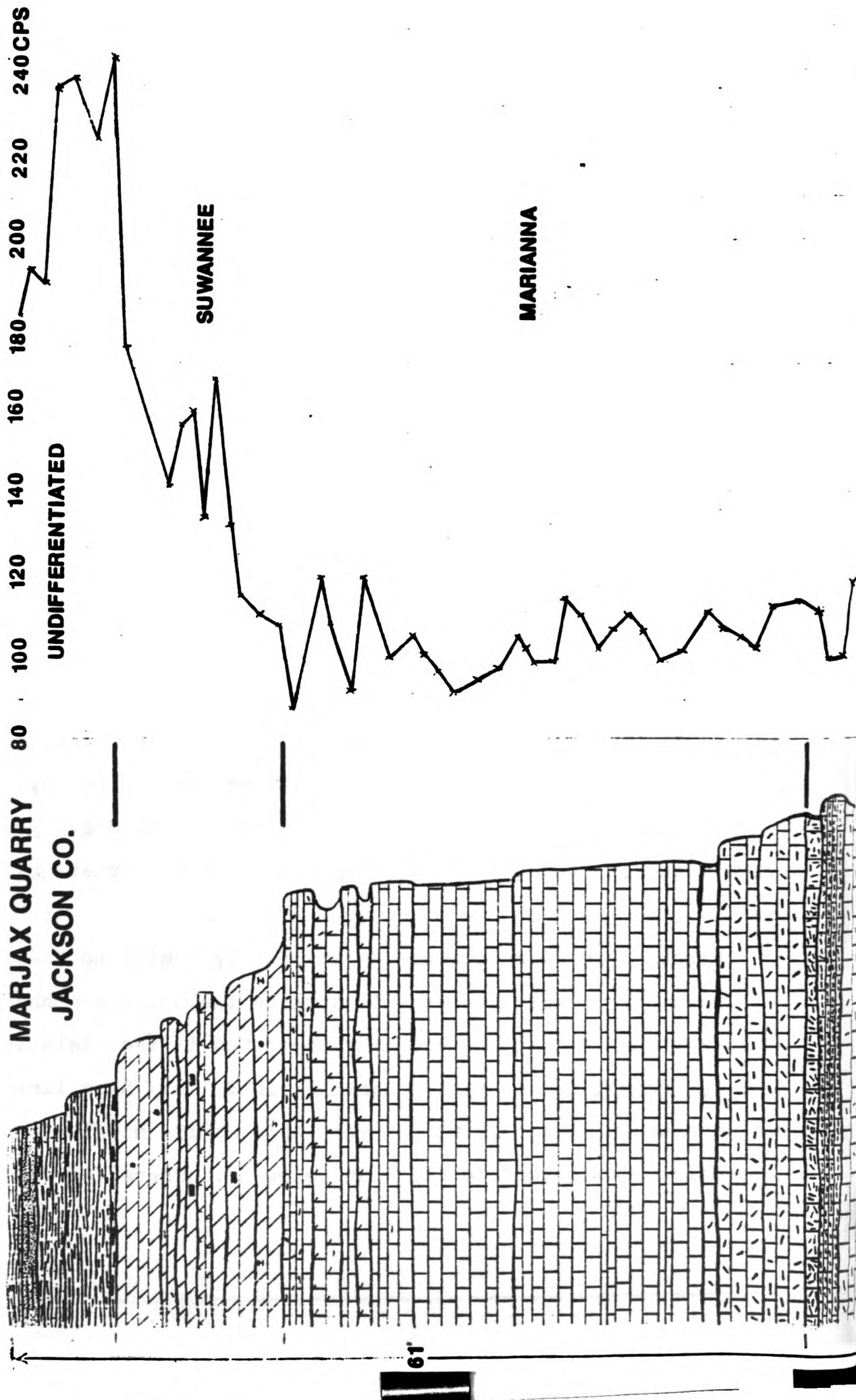


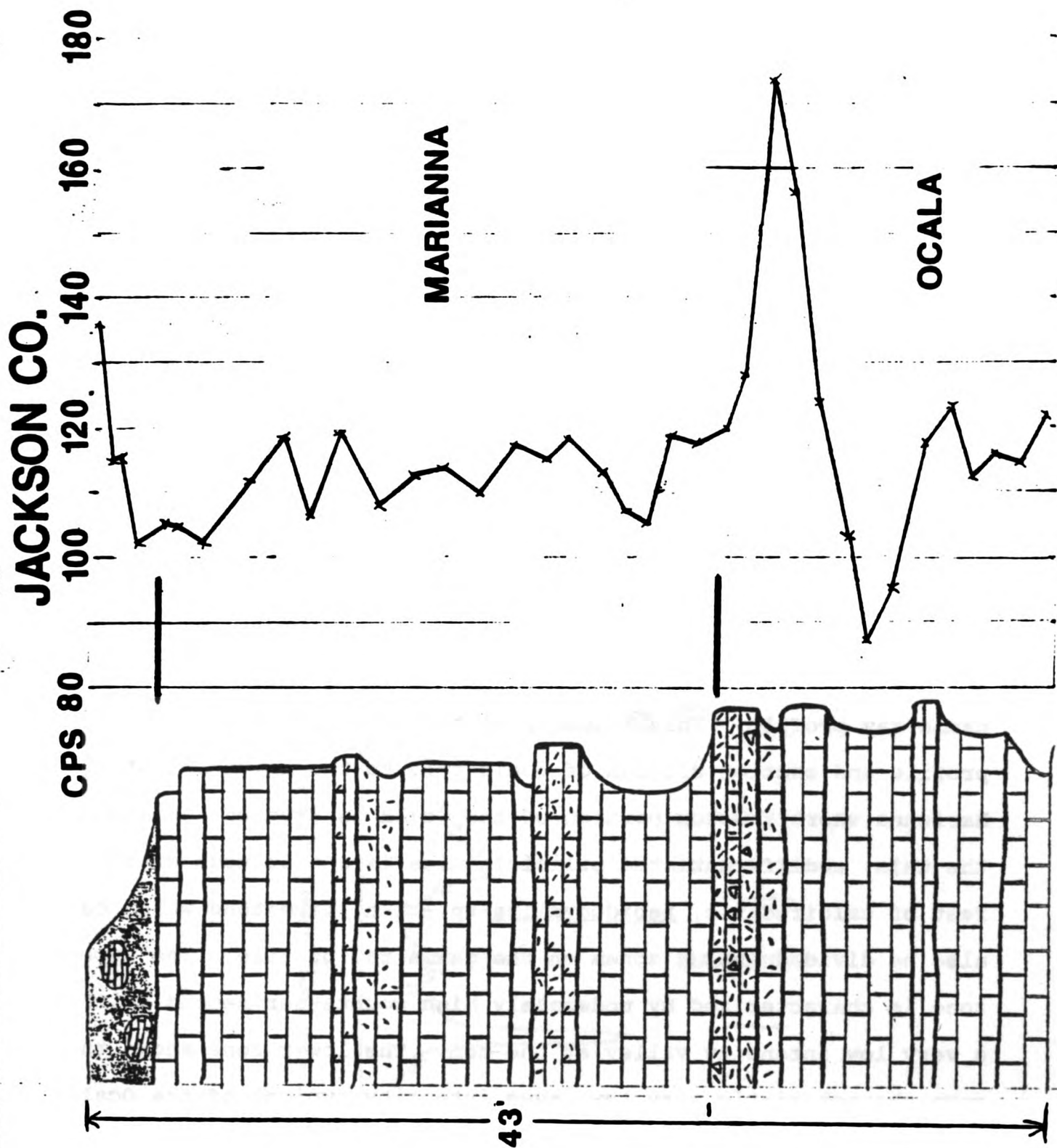
Figure 2. Locations of sections with outcrop

each formation, which could then be recognized more easily in the subsurface between borehole gamma ray logs.

Figure 3 shows a typical outcrop gamma ray profile and section diagram of a quarry located in the panhandle of Florida in Jackson County, northwest of Marianna, where the Ocala-Marianna and Marianna-Suwannee contacts are both exposed. The entire thickness of Marianna is exhibited at this quarry. The gamma ray profile shows relatively high count rate intensity in the uppermost undifferentiated siliciclastics; moderate intensity peaks and valleys in the impure dolostone of the Suwannee; and a relatively low count rate in the glauconitic but relatively pure Marianna limestone. Near the top of the Marianna are two moderately low intensity peaks which correspond to two thin but widespread dolostone or dolomitic limestone beds separated and overlain by hard, recrystallized, fine-grained, Marianna limestone beds. The Ocala-Marianna contact near the base of the section is recorded as a very low counts-per-second valley at a bed of very hard, recrystallized, glauconitic, Lepidocyclina-sp.-rich limestone which marks the top of the much-coarser-grained Ocala.

Figure 4 shows an outcrop approximately 1 mile northwest of this last quarry which better illustrates the typical panhandle Ocala-Marianna contact. Here, the upper bed in the Ocala is that same Lepidocyclina-sp.-rich, coarse grained, very hard limestone bed as seen in Figure 3, with a very thin, soft, highly glauconitic, calciruditic bed just below it. These two beds mark

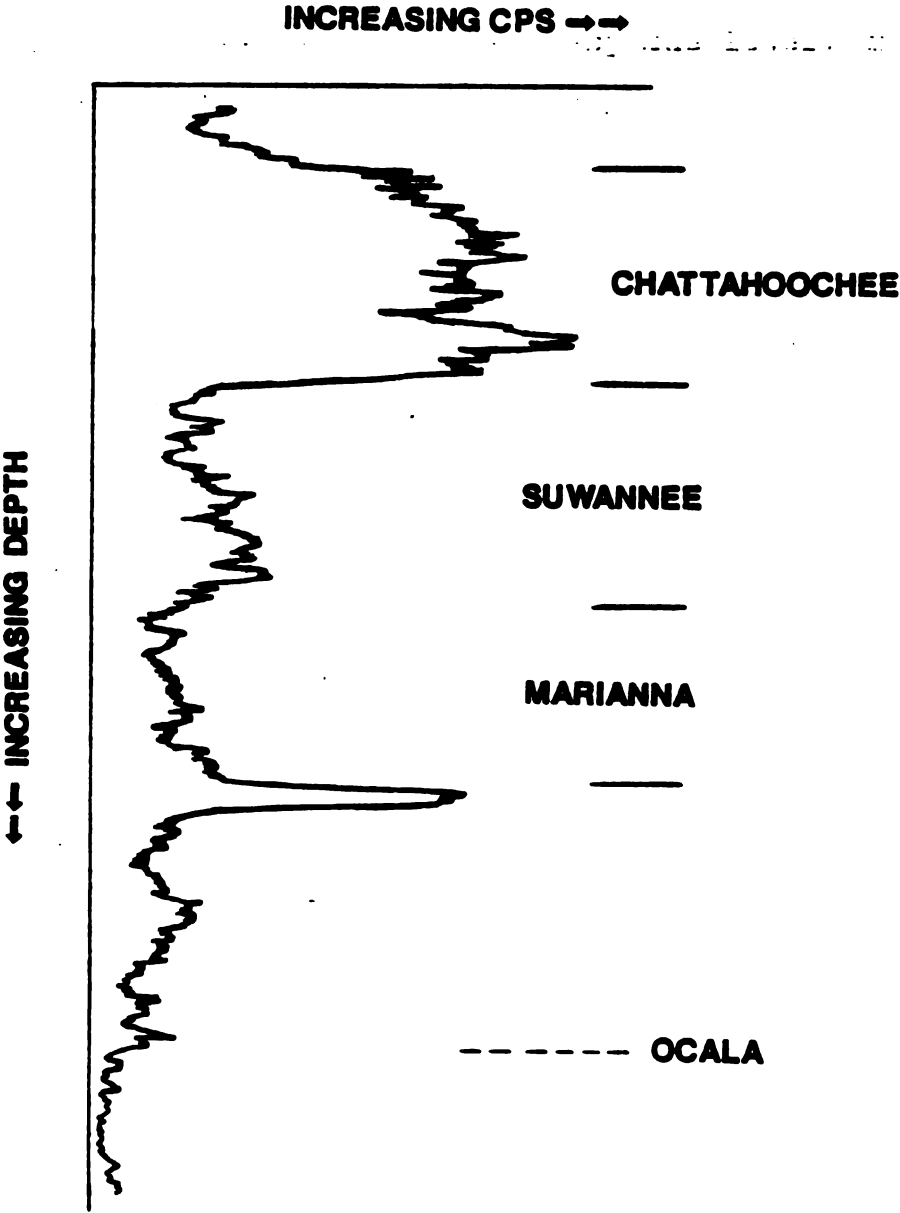




the top of the Ocala in this area. The Marianna, above, is a much finer-grained limestone, a calcilutite. The contact exhibits a moderately high counts-per-second gamma ray peak just below the contact, probably due to the high glauconite content.

This peak can be seen on many borehole gamma ray logs in the area, as shown on Figure 5 in a log from a well about 3 miles south southwest of Marianna (run by Northwest Florida Water Management District). Figure 5 also shows the moderately high counts-per-second dolostone pattern near the top of the well, which is characteristic of the Chattahoochee, followed downward by the lower, uneven trace characteristic of the Suwannee. The top of the Marianna is shown as a decrease in intensity. The Ocala can be seen in this figure to be divisible into an upper, slightly higher intensity zone, and a lower, slightly lower intensity zone. Figure 6 shows this characteristic on an outcrop gamma ray profile. This illustrates the outcrop gamma ray profile and section diagram of a sinkhole to the northeast of Marianna where the top portion of the Ocala is exposed. Below the thin, undifferentiated siliciclastics is a thickness of 50 feet of calciruditic, Lepidocyclina-sp.-rich, limestone which can also be divided into 2 zones on the gamma ray profile. The upper zone is characterized by moderately high counts-per-second, with a very low intensity valley at the top. The lower zone shows the more characteristic very low, even intensity typical of the Ocala elsewhere in the state. The upper portion is composed of very porous, soft, slightly glauconitic, Lepidocyclina-sp.-rich calcirudite which has been extensively infiltrated by clay washed

Figure 5. Borehole gamma ray log run in a well south-southwest of Marianna.



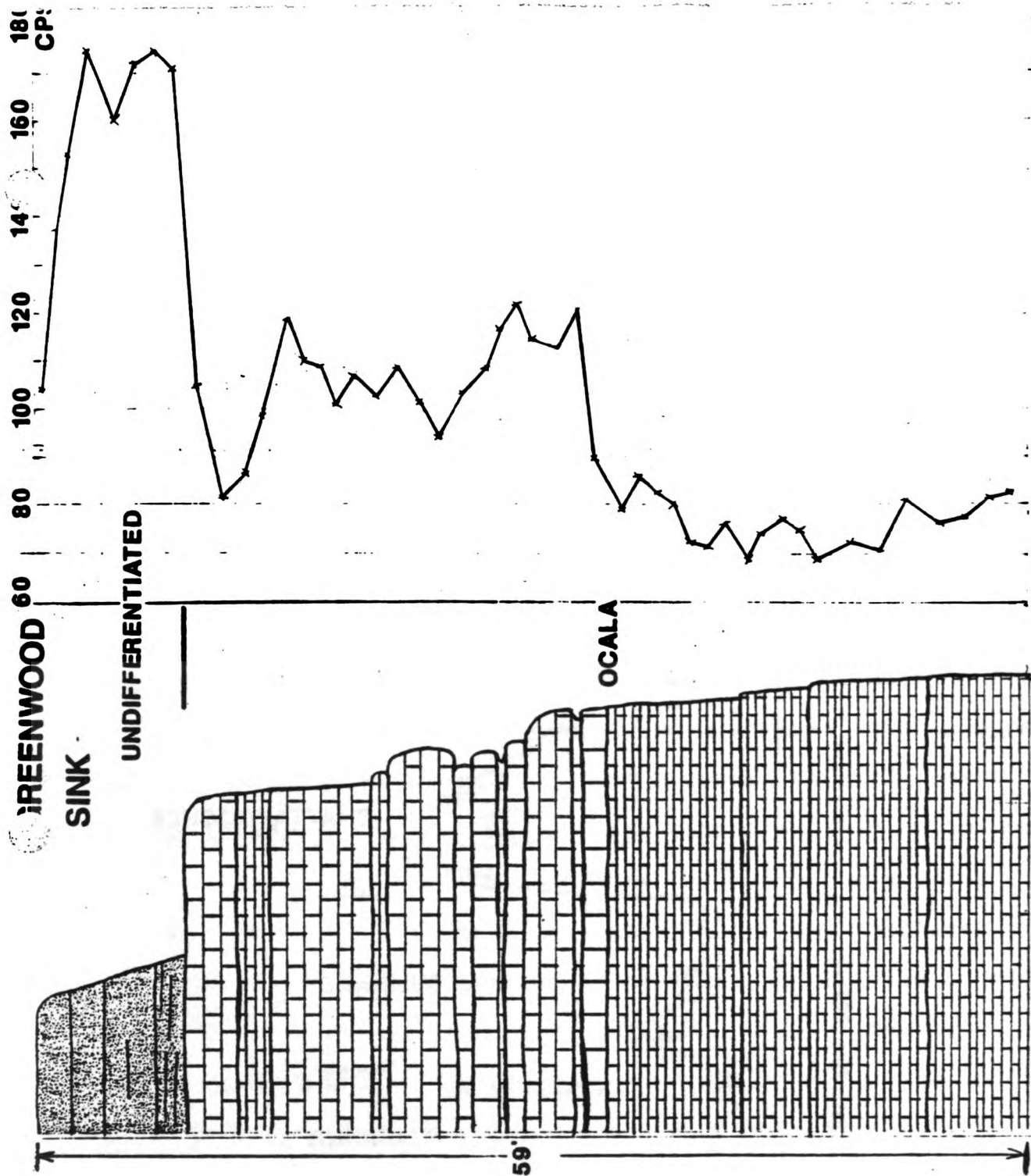


Figure 6. Section diagram and gamma ray profile of a sinkhole to the northeast of Marianna.

in through the very high intergranular and moldic porosity. This clay, along with glauconite, is probably responsible for the upper-Ocala, higher counts-per-second zone on the gamma ray profile. Lithologically, the lower zone is composed of much-lower-porosity, massive, very hard, recrystallized Lepidocyclina-sp.-rich calcirudite, and shows the typical very low intensity gamma ray trace characteristic of the Ocala statewide. The top of this section of limestone as shown on this gamma ray profile matches exactly the trace seen on the two last figures at the top of the Ocala; that is, a very low counts-per-second valley just above a slight but sustained increase in intensity throughout the remainder of the upper Ocala. This pattern seems to be characteristic of the top of the Ocala in the panhandle.

Figure 7 shows the section diagram and outcrop gamma ray profile of the thickest exposure in the area of Miocene-age, post-Suwannee carbonate, here called the Chattahoochee Formation. This section is located on the east side of Jim Woodruff Dam along the access road, the so-called type Chattahoochee. Here, the gamma ray profile can be divided into two zones, a stratigraphically upper, lower-intensity zone and a stratigraphically lower zone characterized by many moderate intensity peaks. This pattern is typical of the Miocene-age carbonates in Florida. In general, the pattern of a stratigraphically lower zone with higher intensity and a stratigraphically higher zone with lower intensity can be seen in

EAST JIM WOODRUFF DAM

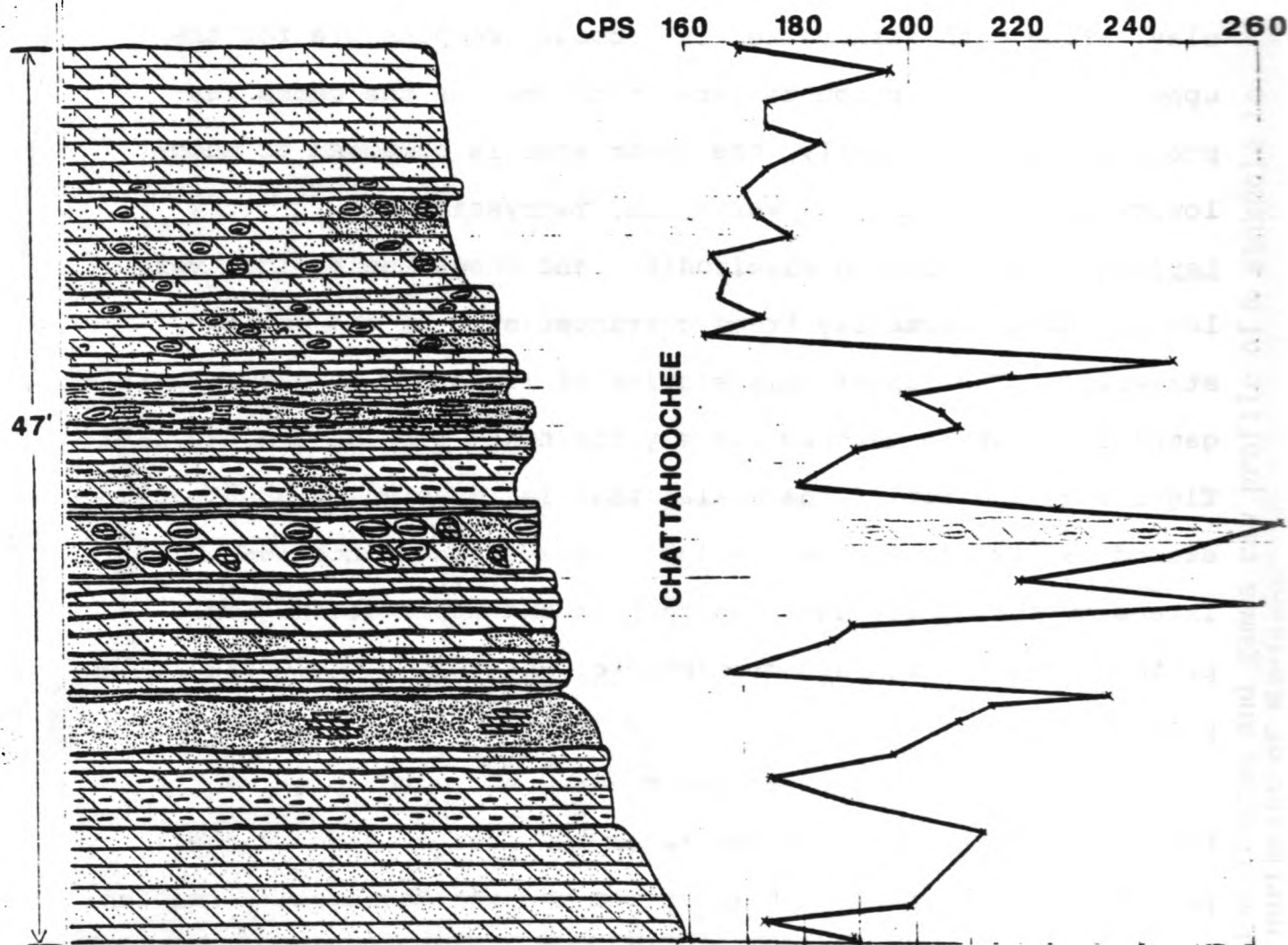


Figure 7. Section diagram and outcrop gamma ray profile of the thickest section exposed in the area of post Suwannee carbonate.

all the limestone formations in Florida, on both outcrop gamma ray profiles and borehole gamma ray logs. In addition, the overall gamma ray intensities found in the limestone sequence in both the panhandle and the peninsula tend to decrease with age; that is, the Miocene-age carbonate units show higher average intensity than the Suwannee which, in turn, records as higher than the Marianna, and the Marianna shows slightly higher average intensities than the Ocala.

Figure 8 shows a composite of panhandle carbonate section profiles which illustrates the appearance of a hypothetical outcrop profile for an outcrop in which all four formations are present and developed to more or less typical extent for the area. The absolute intensity scales of each of the profiles were matched and each profile was plotted in its correct stratigraphic position. A general decreasing intensity with increasing depth and age can be clearly seen.

Moving to the peninsula, Figure 9 shows an exposure along the Cross-Florida Barge Canal at the 19 and 98 bridge in Citrus County, in the west-central peninsula of Florida, near Inglis. The Avon Park-Ocala contact is shown by the abrupt lithologic change from brown and orange dolostone below to white Ocala limestone above, with a thin organic peat seam separating the formations. The gamma ray profile clearly shows the contact by a moderate intensity peak at the peat seam. The pure limestone of the Ocala above is recorded as a very low, even intensity, and the Avon Park dolostone below as slightly higher sustained intensity. This pattern is characteristic and is very common on

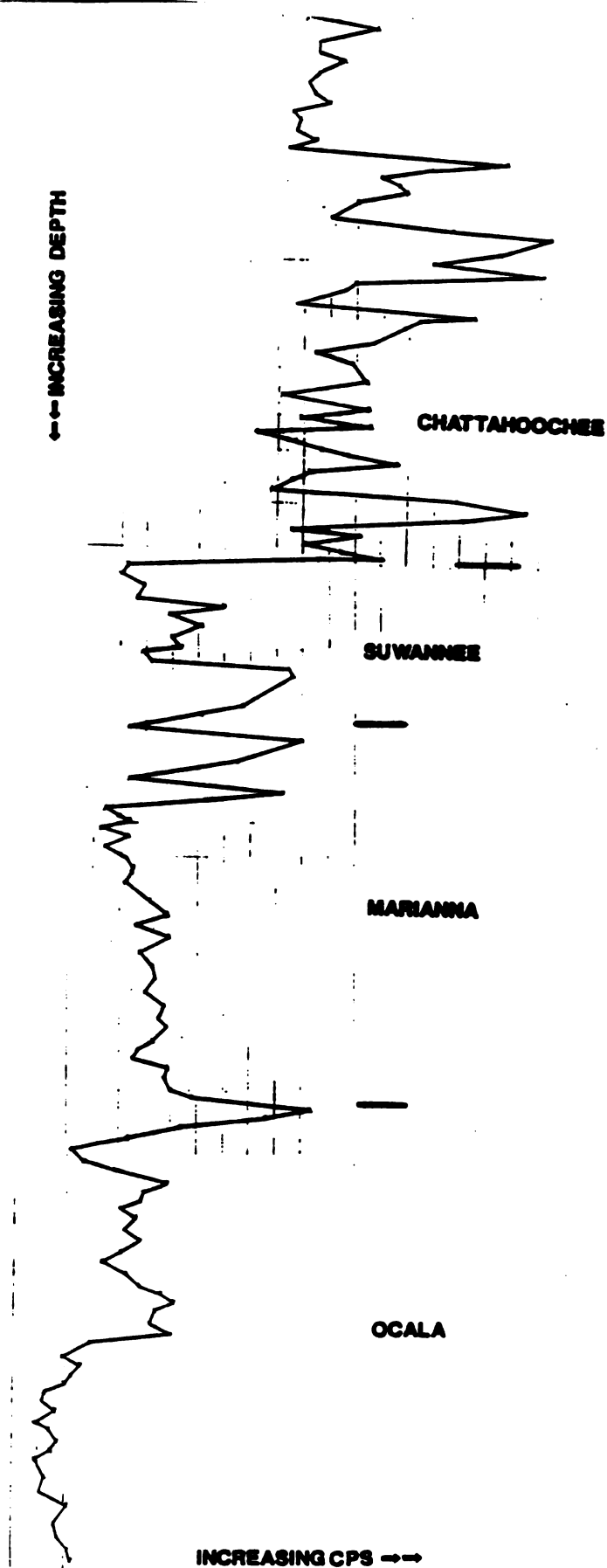
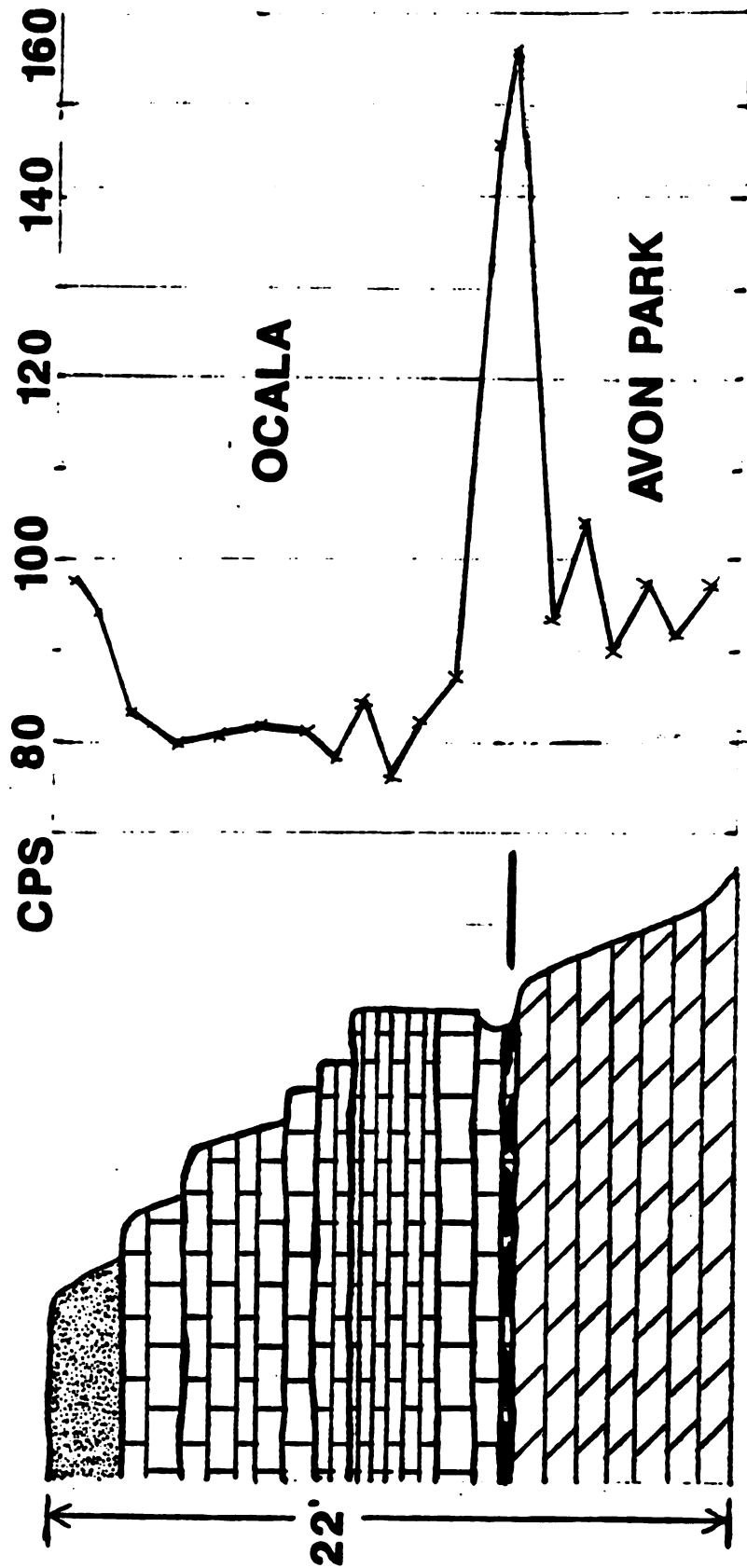


Figure 8. Composite of panhandle carbonate-section outcrop gamma ray profiles.

Figure 9. Outcrop gamma ray profile and section diagram of the Avon Park-Ocala contact in a section near Inglis.

BARGE CANAL AND U.S.19/98 CITRUS CO.



borehole gamma ray logs everywhere in the peninsula where both formations occur together. For example, Figure 10 shows a borehole gamma ray log from Lake County which illustrates a very pronounced Avon Park-Ocala contact. Typically in the Lake County area, the upper Avon Park is extremely rich in peat, organic material and organic-rich clay. It has been postulated that this material represents cavern-fill or is otherwise paleokarst-related, having formed when the top of the Avon Park was subaerially exposed before deposition of the Ocala sediments.

Figure 11 shows the lithologic section diagram and gamma ray profile of the base of the Suwannee and top of the Ocala in Hernando County, also in the west-central peninsula. This is the Lansing Quarry, the lower portion, showing the Ocala-Suwannee contact. The soft, calciruditic, Lepidocyclina-sp.-rich Ocala at the base is recorded as a low, even-intensity trace. The differentially-recrystallized, much-finer-grained Suwannee immediately above the contact is recorded as a marked and sustained increase in intensity, beginning at the contact. Lithologically, the contact itself consists of a very thin, orange, very soft, argillaceous, calcilutitic bed with very thin, very hard, recrystallized beds above and below. The Suwannee contains beds of recrystallized dolomitic limestone, whereas the Ocala is generally much more homogeneous, soft, pure limestone. In the upper portion of the section, the very hard, recrystallized, molluscan-moldic limestone and dolomitic limestone of the upper Suwannee is recorded as a low, even trace.

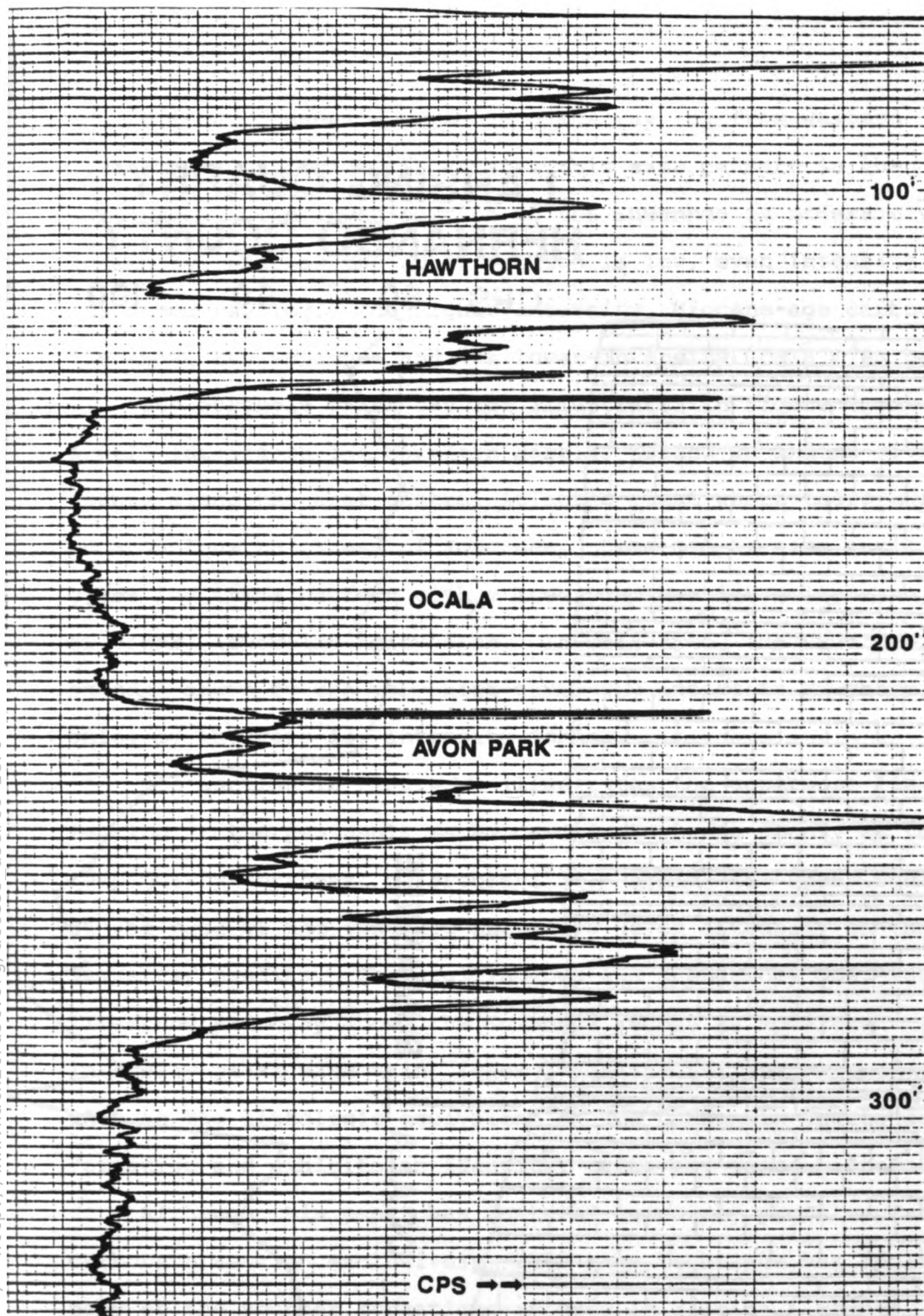


Figure 10. Borehole gamma ray log from Lake County.

LANSING QUARRY HERNANDO COUNTY

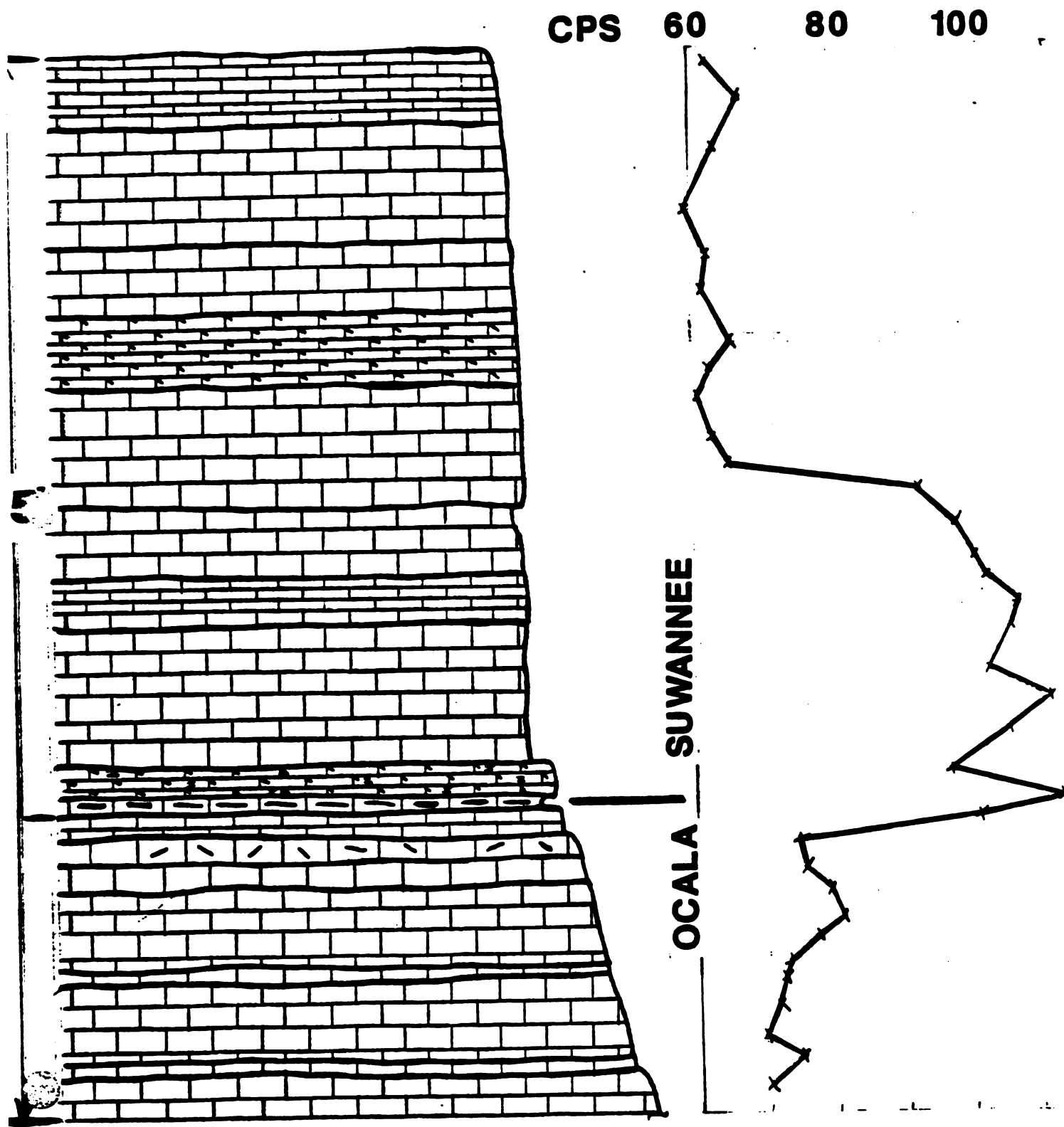


Figure 11. Section diagram and outcrop gamma ray profile of the lower portion of the Lansing Quarry, Hernando County.

Figure 12 shows a borehole gamma ray log from western Sarasota County which illustrates this same pattern in the subsurface. The lower portion of the Suwannee is moderately high intensity, whereas the upper portion is low, even intensity on the gamma ray log. The higher-intensity, Miocene-age carbonates lie above the Suwannee and the lower-intensity Ocala lies below.

The borehole gamma ray log illustrated in Figure 13 is from a well located on the southern barrier island in Indian River County along the east-central Atlantic coast where there exists an anomolous thickness of Suwannee. Here can be seen a similar gamma ray trace pattern with a lower, higher-intensity zone and an upper, lower-intensity zone. In this area, the Suwannee is bounded above by the very-high-gamma-ray-intensity Hawthorn, and below by the very-low-intensity Ocala.

The section in Figure 14 illustrates the uppermost limestone section in the peninsula as exposed in Hernando County at the old Camp Quarry northeast of Brooksville. Again, the upper Suwannee at the base of the exposure shows low, even intensity on the gamma ray profile. The argillaceous and arenaceous post-Suwannee limestone and clay above the Suwannee record as moderate intensity peaks with thin, lower intensity valleys between. This unit is the lithologic equivalent of the panhandle Chattahoochee Formation and exhibits an identical gamma ray trace pattern.

Although this paper has featured gamma ray profiles from the carbonate section exclusively, this same technique was applied to many of the younger formations exposed in Florida. Figure 15 shows an example. Gamma ray profiles were constructed from most

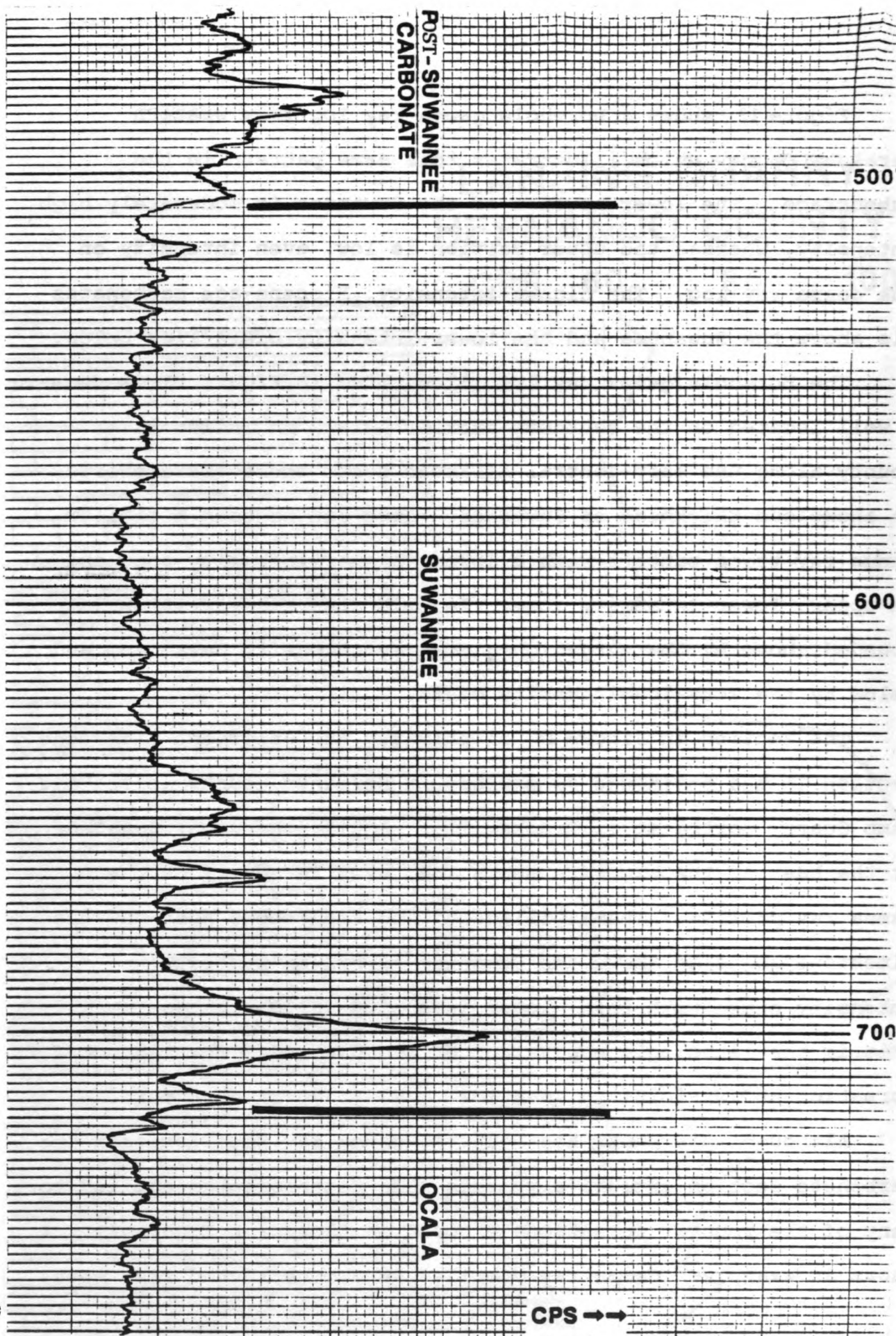


Figure 12. Borehole gamma ray log from western Sarasota County.

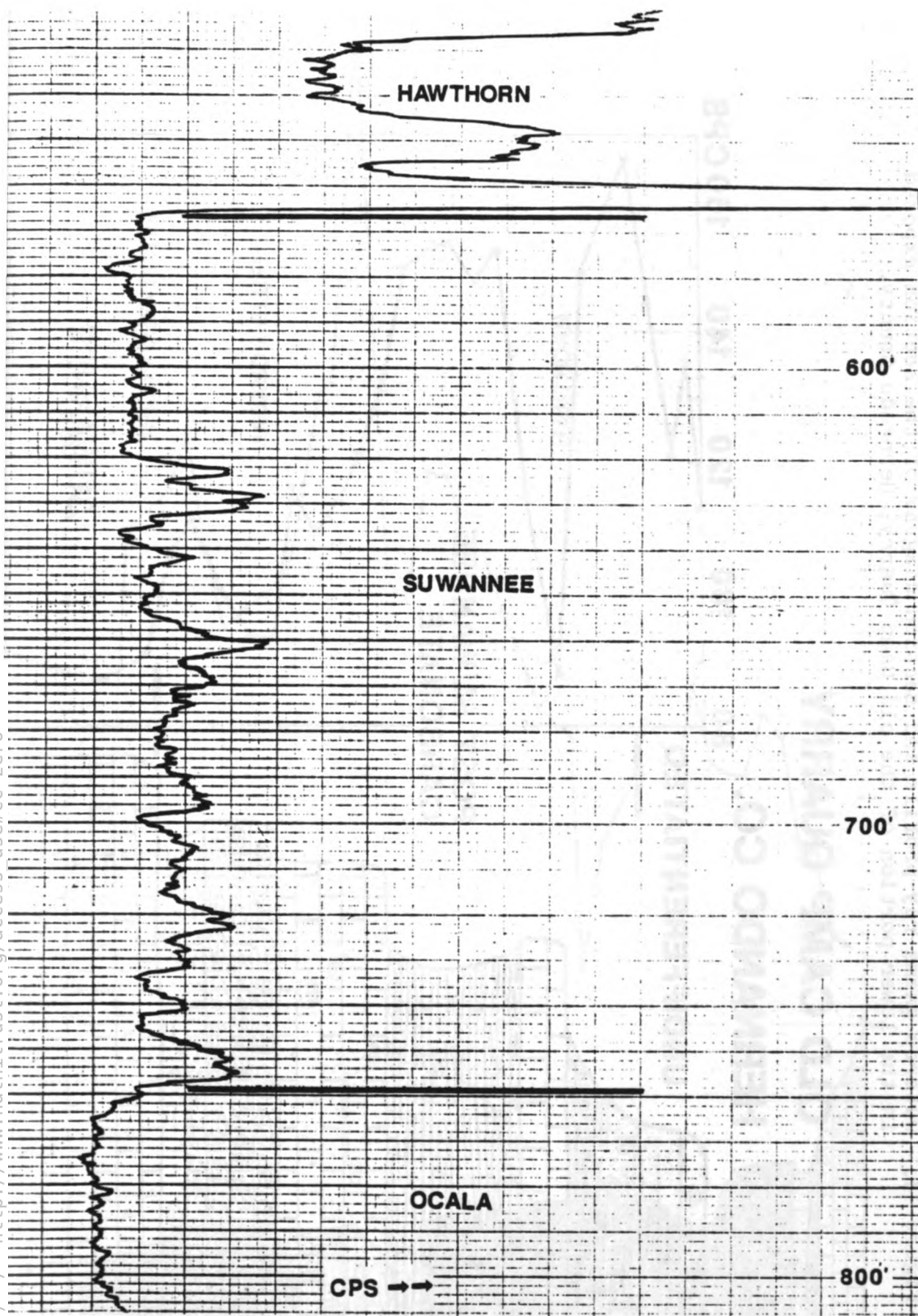
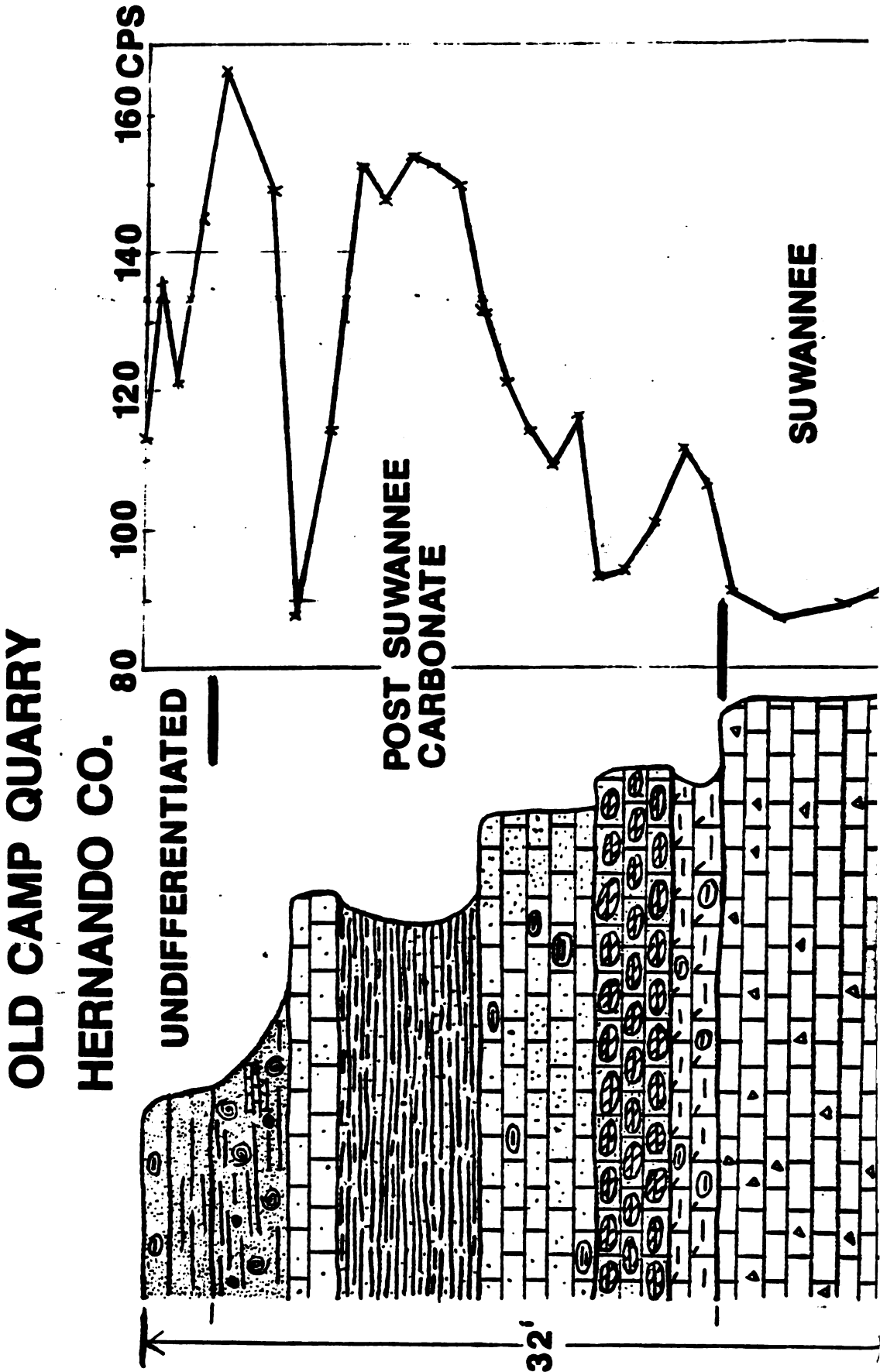


Figure 13. Borehole gamma ray log from the southern barrier island in Indian River County.

Figure 14. Outcrop gamma ray profile and section diagram of the section exposed in the lower portion of the old Camp Quarry, Hernando County.



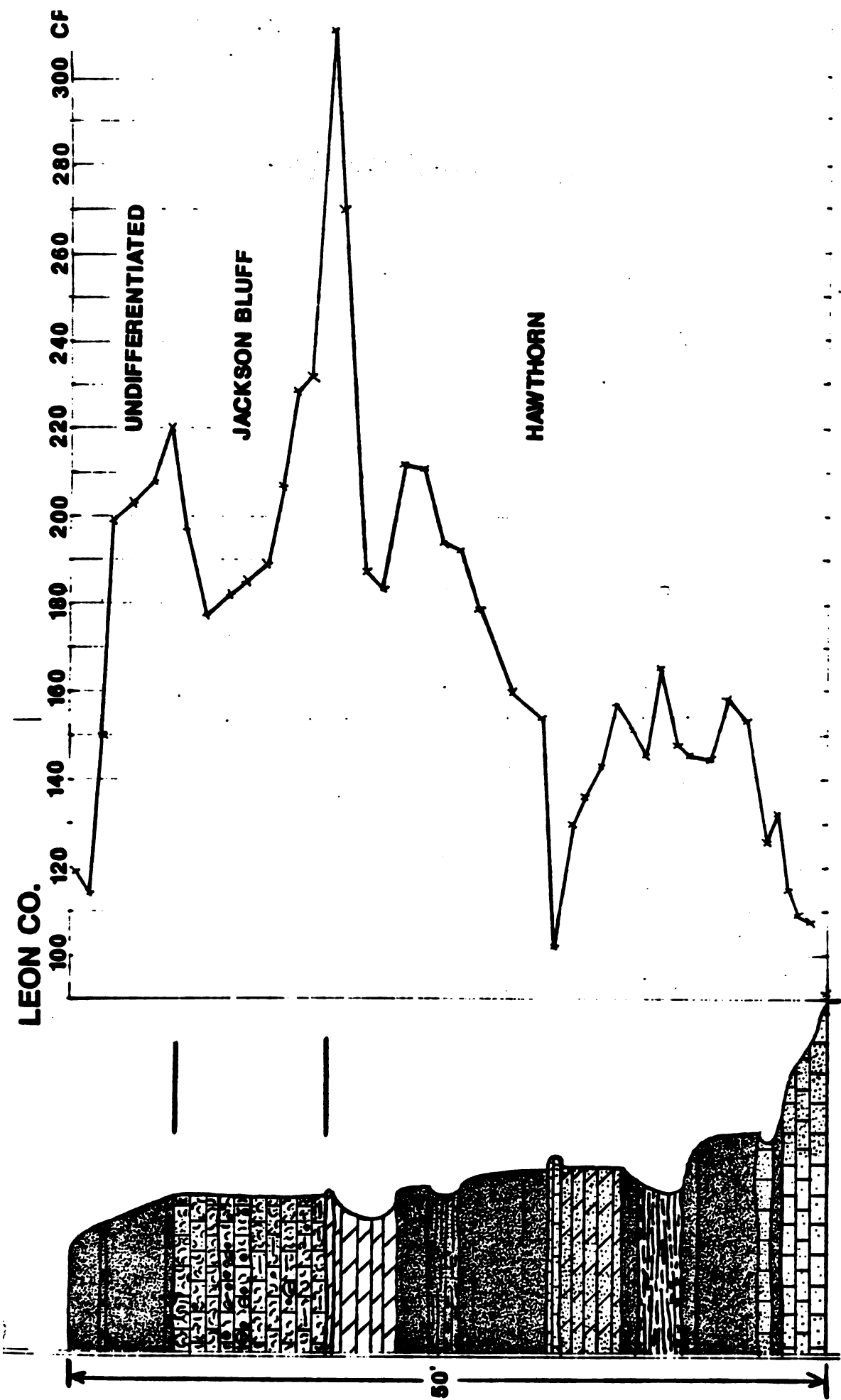


Figure 15. Outcrop gamma ray profile and section diagram of Jackson Bluff, Leon County, illustrating the construction of profiles on younger formations.

of the classic exposures in the state, such as Jackson Bluff, Leon County, shown in Figure 15. It was found that many of these formations could also be traced from outcrop gamma ray profiles into the subsurface and from well to well. However, possibly due to a greater variation in lithology, these younger formations do not always appear as well-defined patterns on borehole gamma ray logs.

In summary, this paper correlates outcrop gamma ray profiles and borehole gamma ray logs of the Tertiary carbonate section in panhandle Florida and in the peninsula. It can be seen that the technique of constructing gamma ray profiles from outcrops is indeed applicable and useful in Florida. Constructed with the use of a very sensitive hand-held scintillometer, the profiles can be used to correlate lithology and formational boundaries from outcrops into the subsurface. Correlation between outcrops is also possible, but is of limited importance in Florida due to the typically very limited thicknesses and relative scarcity of exposures in this area. However, once characteristic formational gamma ray trace patterns are determined from gamma ray profiles, correlations can also be made more confidently in the subsurface between borehole gamma ray logs.

REFERENCES

Chamberlain, A. K., 1984, Surface gamma ray logs: a correlation tool for frontier areas: American Association of Petroleum Geologists Bulletin v. 68, n. 8, pp. 1040-1043.

Ettensohn, F. R., Fulton, L. P., and Kepferle, R. C., 1979, Use of scintillometer and gamma ray logs for correlation and stratigraphy in homogeneous black shales: Geological Society of America Bulletin, Part II, v. 90, pp. 828-849.

Keys, W. S., and MacCary, L. M., 1971, Application of borehole geophysics to water resources investigations: Techniques of Water Resource Investigations of the United States Geological Survey, Book 2, Chapter E1, 126 p.

