STRATIGRAPHY, DISTRIBUTION, AND STRUCTURAL GEOLOGY OF LOWER AND MIDDLE PENNSYLVANIAN SANDSTONES IN ADJACENT PORTIONS OF OKFUSKEE AND SEMINOLE COUNTIES, OKLAHOMA

By

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1979

Submitted to the Faculty of the
Graduate College of the
Oklahoma State University
in partial fulfillment of
the requirements for
the Degree of
MASTER OF SCIENCE
July, 1985

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PREFACE

This thesis is primarily a study of the local subsurface geology of Lower and Middle Pennsylvanian sandstones in a portion of east-central Oklahoma. In ascending order, these sandstones are known in the subsurface as the Cromwell, Gilcrease, Booch, Bartlesville, Red Fork, Lower Skinner, Upper Skinner, and Prue. Structural contour maps, log-signature maps, net-sandstone isopach maps, sandstone distribution maps, and correlation sections were prepared in this study. Data for this study were obtained from the Oklahoma City Geological Society, Oklahoma Well Log Library, Oklahoma Geological Survey, and Oklahoma State University.

The writer wishes to thank many individuals for their contributions in this study: Dr. Gary F. Stewart for his advice, assistance, and encouragement in the preparation of maps and the writing of the text; Drs. Zuhair Al-Shaieb, Ibrahim Cemen, and John W. Shelton for carefully reviewing the text and maps and their advice; and Rick Elliott and Diana Nutt for drafting of figures, log-signature maps, and cross sections.

Special thanks are given the writer's wife, Judy, for her sacrifices, patience, encouragement, and advice, in addition to the typing of the text as well as drafting of maps.

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CHAPTER I

ABSTRACT

In the study area, Lower and Middle Pennsylvanian rocks are unconformable upon rocks of the Mississippian System and thin northwestward. They are a cyclic sequence of shales, sandstones, and limestones. The shales and sandstones were deposited during generally regressive intervals. Thin limestones, which are useful as markers for transgressive-regressive couplets, were deposited during regional and local transgressions. The stratigraphic interval studied includes the following sandstones in ascending order: Cromwell, of the Morrowan Series, Gilcrease, of the Atokan Series, and Booch, Bartlesville, Red Fork, Lower Skinner, Upper Skinner, and Prue of the Desmoinesian Series.

The Morrowan, Atokan, and Desmoinesian Series are separated by unconformities.

A north-northeast trending fault zone, minor northwest-trending faults, and gentle anticlines and synclines form the principal structural features of the area. The north-northeast trending fault zone is a combination of sub-parallel faults that form a graben. Faulting in the subsurface is manifest by an en-echelon fault pattern at

the surface, which could indicate strike-slip movement at depth.

Trends of the individual sandstones vary, but the majority are oriented north-northeast. Depositional environments seem to have been alluvial-deltaic, deltaic, and shallow marine.

Stratigraphic, structural, and a combination of structural-stratigraphic traps account for the majority of oil fields in the Lower and Middle Pennsylvanian sandstones.

CHAPTER II

INTRODUCTION

Location of the Study Area

The area of investigation is located in east-central Oklahoma in adjacent portions of Okfuskee and Seminole Counties (Fig. 1). It includes approximately 216 square miles in T. 11, 12, and 13 N., R. 8 and 9 E.

Statement of the Problem

The objectives of this study were to delineate trends and geometry of the Lower and Middle Pennsylvanian sandstones within the study area, to describe local structural geology, and to combine this information in an attempt to explain locations of undiscovered oil and gas fields. Two major problems that occurred during this project were the correlation of the Oswego and Pink Limestones. Neither marker is well developed over the area of investigation; also, other limestones were nearby in the stratigraphic sequence, and these non-correlative strata have similar log characteristics.

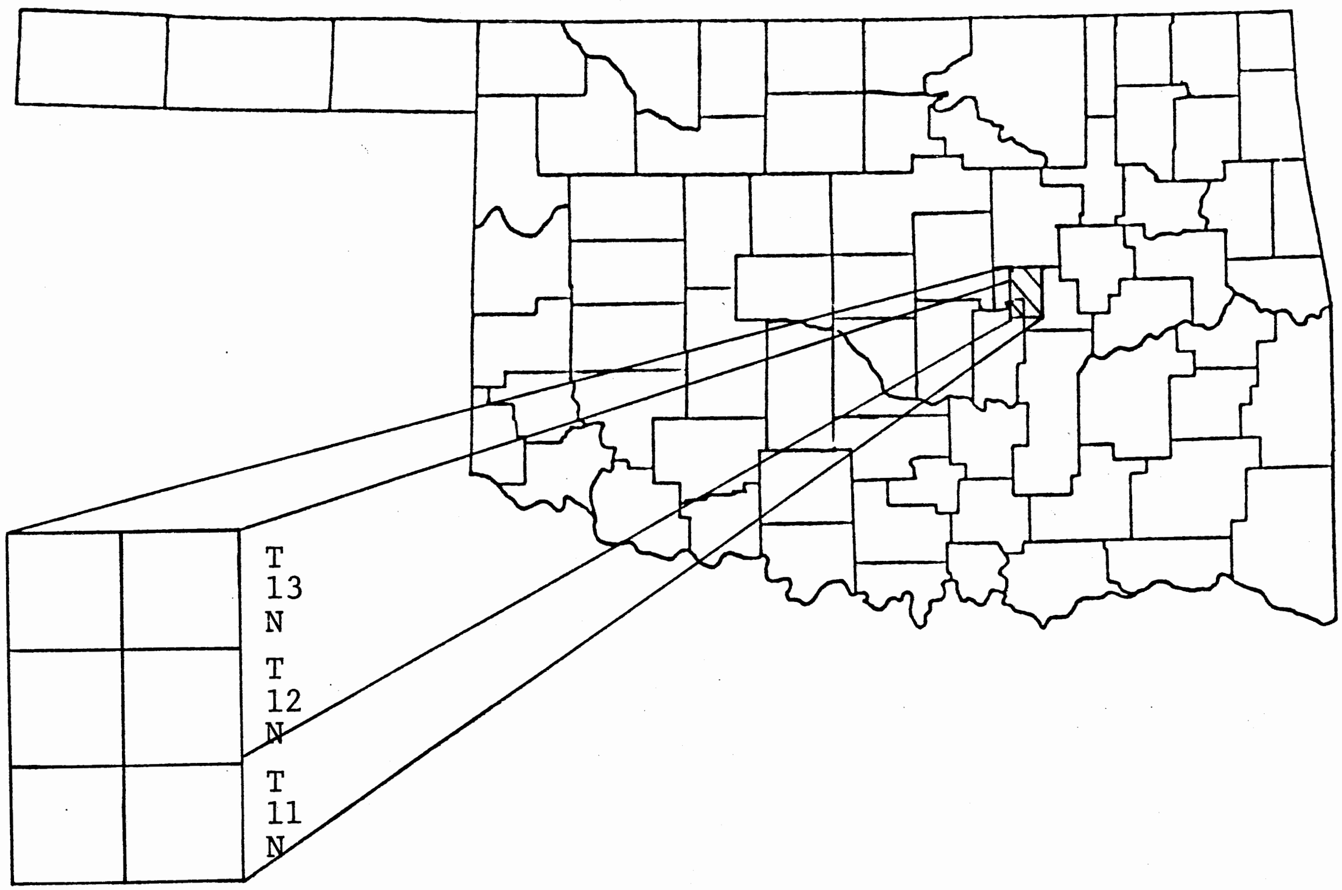


Figure 1. Location Map of Study Area.

Methods and Procedures

Approximately 980 well logs were the principal data for the study area. Correlation of the stratigraphic units was determined by two north-south and three west-east stratigraphic cross-sections (Plates 1-5).

Three structural contour maps were prepared to determine the general configuration of the Lower and Middle Pennsylvanian sandstones. In descending order, they were made on the base of the Oswego Limestone (Plate 6), the base of the Inola Limestone (Plate 7), and the top of the Mayes Limestone (Plate 8).

Log-signature maps were made of the prominent sandstones in the study area as an aid in determining the trends and geometries of these sandstones. Specified marker beds were used to determine the stratigraphic interval to be mapped, except where stacking of multistoried sandstones or cutouts of the marker beds altered the normal sequence. Each map depicts a format, the interval from the base of the overlying marker bed to the top of the underlying marker bed, except in instances where sandstone is absent or quite poorly developed below a defined point in a format; in these cases, only the upper part of a format was mapped.

Net-sandstone isopach maps were used to delineate trends and geometry of several of the sandstones in the study area. Generalized distribution maps were made of some sandstones that are either very widespread or that have been non-commercial, insofar as production of oil and gas is concerned.

Previous Investigations

In the study area, the Lower and Middle Pennsylvanian is composed of the Morrowan, Atokan, and part of the Desmoinesian Series. This section of strata has been described and studied elsewhere by many authors, primarily because of its exceptional petroleum reserves. Most papers concerned with this region have been restricted to the "Cherokee" Group. The "Cherokee" Group is the set of strata in the middle to lower part of the Desmoinesian Series. At the surface, the Krebs and Cabaniss Groups are equivalents of the "Cherokee" Group (Oakes, 1953).

Papers that refer to geology of the local area were written by Blumenthal (1956), Jackson (1949), Cutolo-Lozano (1969), Verish (1978), and Walker (1982). Blumenthal and Cutolo-Lozano wrote primarily on the subsurface stratigraphy and structural geology. Jackson discussed subsurface stratigraphy, and Walker and Verish dealt with trends and distributions of Lower and Middle Pennsylvanian sandstones and structural geology.

Desmoinesian rocks of the Northern Oklahoma Platform were studied by Busch (1971), Cole (1969), and Visher et al. (1971); these papers give much general information about depositional patterns of the "Cherokee" sands.

CHAPTER III

REGIONAL STRATIGRAPHY

The Mississippian System is overlain unconformably by rocks of the Lower Pennsylvanian Series throughout the region. Progressively younger Pennsylvanian rocks overlie a regionally dipping unconformity (Jackson, 1949; Verish, 1978; Walker, 1982).

The Lower and Middle Pennsylvanian are composed of shales, thin limestones, sandstones, and minor coal beds. Sediments were deposited during widespread transgressions followed by local to regional regressions. The thin, transgressive limestones commonly are used as marker beds, because they generally are consistent in position and log-signature. The sequence of strata between two successive transgressive markers, a "format", is believed to be a transgressive-regressive couplet (Astarita, 1975). Generally, sandstones within formats are lenticular and at some places, quite thick; therefore, they commonly are not used for marker beds.

Depositional environments of the Lower and Middle Pennsylvanian sandstones generally were deltaic to shallow marine (Busch, 1971; Verish, 1978). Although the purpose of this study was not to determine depositional environments of the sandstones, specific environments are generally believed to have been delta-fringe terrain, distributary channels, interdistributary bays, crevasse-splays, and shallow-marine areas (Cole, 1969; Busch, 1971; Astarita, 1975; Verish, 1978; Walker, 1982).

CHAPTER IV

LOCAL STRATIGRAPHY

Published works in the area or general region were the sources for description of local rock types. Specifically, useful papers are those of Jackson (1949), Jordan (1957), Blumenthal (1956), Shulman (1966), Cole (1969), and Verish (1978). The rock sequences are shown in Figure 2.

Morrowan Series

Cromwell Sandstone Format. The Cromwell Format is as thick as 160 feet (Fig. 2, Plages 5, 9). It is bounded above by the Union Valley Limestone, where present, and/or the dark gray Wapanucka Shale; it is underlain by Mississippian Caney Shale. Sandstone of the Cromwell generally is tan to buff, fine- to medium-grained, calcareous, and glauconitic (Blumenthal, 1956; Cole, 1969). Northeastward in the study area it seems to be increasingly calcareous, for wireline logs suggest diminishing porosity and show increased resistivity.

Atokan Series

Gilcrease Sandstone Format. The Gilcrease Sandstone Format (Plate 10) unconformably overlies the Wapanucka Shale

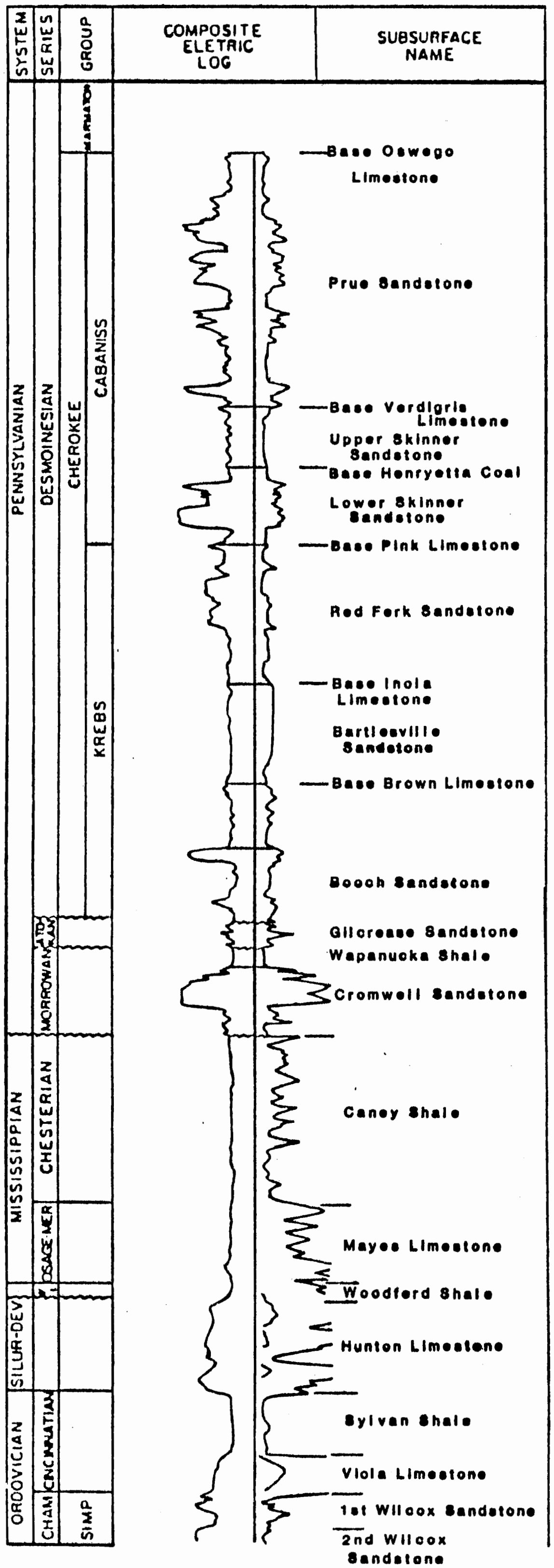


Figure 2. Composite Electric Log of Study Area (after Walker, 1982).

and in places the Cromwell Sandstone (Fig. 2, Plage 1). Maximal thickness of the format is 180 feet, in the southeastern part of the study area. Here, individual sandstones are as thick as 30 feet.

White, fine- to medium-grained, slightly micaceous, glauconitic sandstones are typical of the Gilcrease section (Blumenthal, 1956; Cole, 1969). Interbedded shales, sandstones, and limestones characterize this interval.

Desmoinesian Series

Booch Sandstone Format. In the lower part of the Desmoinesian Series is the Booch Sandstone Format (Fig. 2, Plate 11), which unconformably overlies Atokan rocks (Ries, 1954). As does the Gilcrease Format, the Booch Format thickens southeastward, some units of sandstones are about 140 feet thick (Plate 11).

Buff to white, fine- to coarse-grained, micaceous, carbonaceous sandstones with siliceous cement characterize sandstones of the Booch interval (Blumenthal, 1956; Cole, 1969).

Brown Limestone Zone. Approximately 160 to 190 feet above the stratigraphic position of the Booch Sandstone Format is the Brown Limestone (Fig. 2). As the name implies, this rock unit is composed of brown to tan, finely crystalline, fossiliferous, slightly dolomitic limestone (Blumenthal, 1956; Shulman, 1966). Ordinarily, several beds of limestone compose the marker. Thin silty shales are interbedded with these limestones.

Bartlesville Sandstone Format. The Brown Limestone is overlain by the Bartlesville interval (Fig. 2, Plate 12). The format thickens southeastward, and thickness of sandstone is more than 150 feet in the eastern part of the study area.

Mason (1982) described the Bartlesville Sandstone as being subarkosic, white to tan, and very fine- to medium-grained. Rock fragments are chert, shale, carbonate rock, and fragments of metamorphic rock. Authigenic minerals are secondary quartz, chalcedony, opal, kaolinite, illite, and chlorite.

Inola Limestone. In the study area the Inola Limestone (Fig. 2) generally is approximately five feet thick. It is tan to gray, and fine- to medium-crystalline (Blumenthal, 1956). Across the study area, the interval between the Inola Limestone and the Brown Limestone zone thickens from approximately 180 feet in the northwest to 270 feet in the southeast.

Red Fork Sandstone Format. The Red Fork Sandstone Interval (Fig. 2, Plate 13) thickens from 230 feet in the northwest to 330 feet in the southeast. It directly overlies the Inola Limestone and underlies the Pink Limestone

(Fig. 2). Thickness of sandstone ranges from 10 to nearly 200 feet.

The Red Fork Sandstone is a sublitharenite to lithic arkose as described by Robertson (1983). Rock fragments are composed of chert, shale, and low-grade metamorphic rocks. Chlorite and illite are detrital-matrix constituents. Authigenic clays are pore-filling kaolinite, pore-filling and pore-lining illite, and pore-lining chlorite.

Pink Limestone. Overlying the Red Fork Sandstone Format is the Pink Limestone (Fig. 2). The Pink and Inola Limestones are separated by 230 feet in the northwestern part of the study area to 330 feet in the southeastern part. The Pink is about five feet thick, on the average.

Correlation of the Pink Limestone is problematic in the southern part of the study area, because it is marked only by a resistivity-peak in shale. Another problem is the local occurrence of several other thin limestones in the lower part of the overlying Lower Skinner Format.

The Pink Limestone is white to tan, locally pink, finely crystalline, and locally fossiliferous (Blumenthal, 1956).

Skinner Sandstone Format. The Skinner Sandstone interval is bounded by the Pink Limestone below and the Verdigris Limestone above (Fig. 2). The Henryetta Coal is a marker bed that separates the Skinner Sandstone interval into upper and lower units (Fig. 2). It is also known as the "Second Verdigris Limestone" in this area. At some places it is gray to brown, finely crystalline limestone (Blumenthal, 1956). Sandstones are developed in both the Lower (Plate 14) and Upper (Plate 15) Skinner intervals. Southeastward across the study area, thickness of the Lower Skinner interval increases from 180 to 290 feet; the Upper Skinner interval thickens from 80 to 110 feet.

Blumenthal (1956) described the sandstone as white to tan, fine- to medium-grained and micaceous. Detailed work by Lojek (1983) on the Skinner Sandstone showed the rock to be sublitharenite. Authigenic clays are pore-filling kaolinite, pore-filling and pore-lining illite, and pore-lining chlorite.

Verdigris Limestone. As mentioned above, overlying the Skinner Format is the Verdigris Limestone (Fig. 2). The interval between the Verdigris and the Pink Limestone increases from 260 to 400 feet southeastward across the study area. The Verdigris is gray to brown, finely crystalline, mottled limestone; generally, it is about five feet thick.

Prue Sandstone Format. The Prue Sandstone (Fig. 2) is the uppermost sandstone unit in the Cherokee Group. The interval thickens from 130 to 530 feet across the study area from northwest to southeast. This thickening is marked by an increase in sandstone within the format. Individual sandstones range in thickness from 10 to 50 feet.

The Prue Sandstones are white to tan, fine- to medium-gained, and micaceous (Blumenthal, 1956).

Oswego Limestone. The Oswego Limestone (Fig. 2) is a problematic marker in the study area. It ranges from approximately 2 to 10 feet thick, and in some areas has well-log characteristics strongly similar to those of several other limestones within 50 feet of it, stratigraphically.

The Oswego is gray-white to tan, finely crystalline, and fossiliferous.

CHAPTER V

REGIONAL STRUCTURAL GEOLOGY

The area of investigation is on the so-called "Cherokee" Platform (Fig. 3), which is bounded by the Seminole Uplift to the south, the Arkoma Basin to the southeast, the Nemaha Ridge to the west, and the Ozark Uplift to the east.

Formations of the Morrowan, Atokan, and lower Desmoinesian Series strike generally northward and dip gently westward at approximately 60 to 100 feet per mile.

Two major faults, approximately one-quarter mile apart, trend north-northwest through the study area. They essentially are parallel and form a graben that dies out in the northern one-third of the study area.

These two faults are roughly sub-parallel to the Keokuk and Wilzetta faults, approximately 12 and 18 miles to the west, respectively. In the study area, surface mapping over the area of the two major faults shows a series of en-echelon faults trending northwestward (Blumenthal, 1956; Miser, 1959). The same pattern is in rocks at the surface above the Keokuk fault (Blumenthal, 1956; Miser, 1959; Walker, 1982).

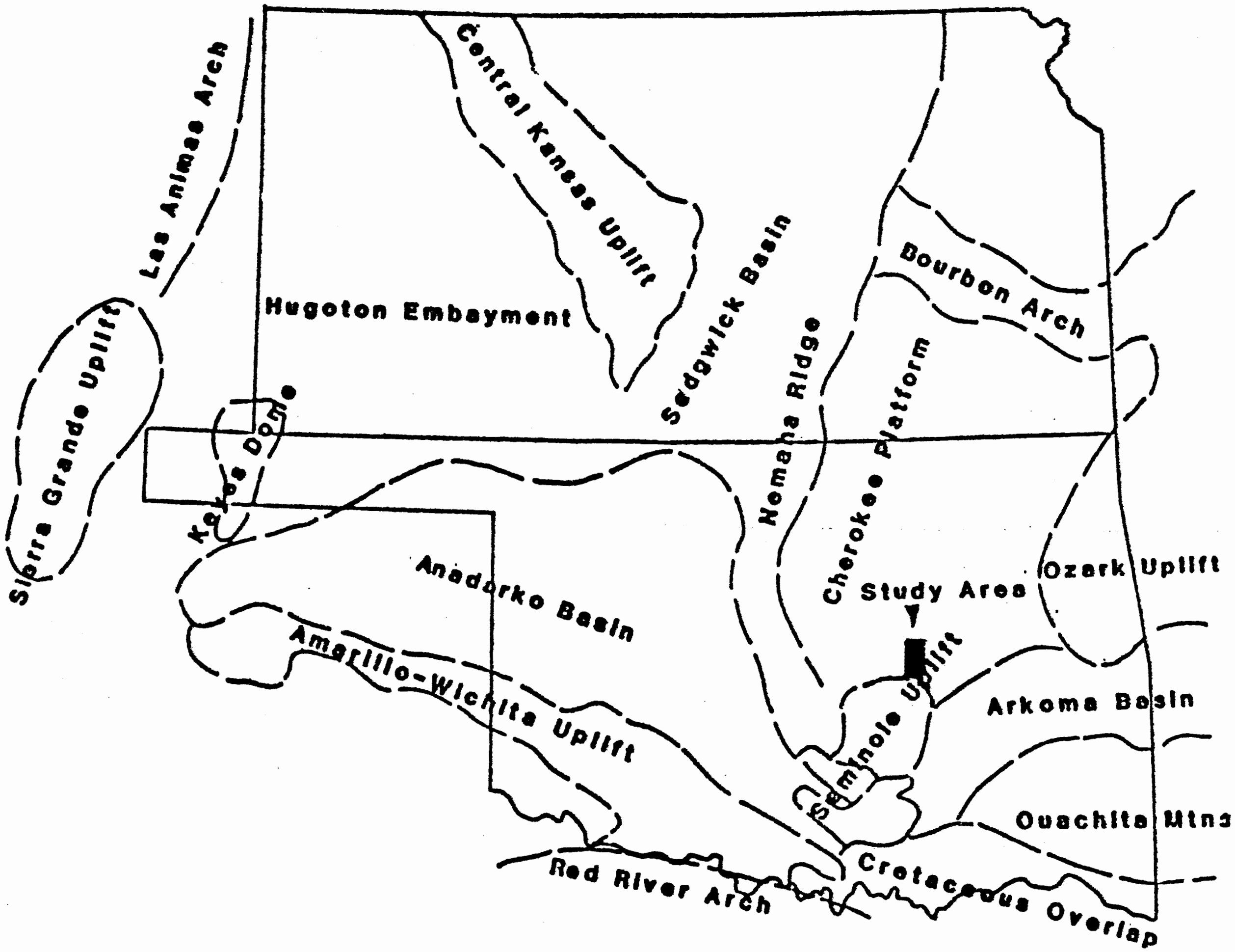
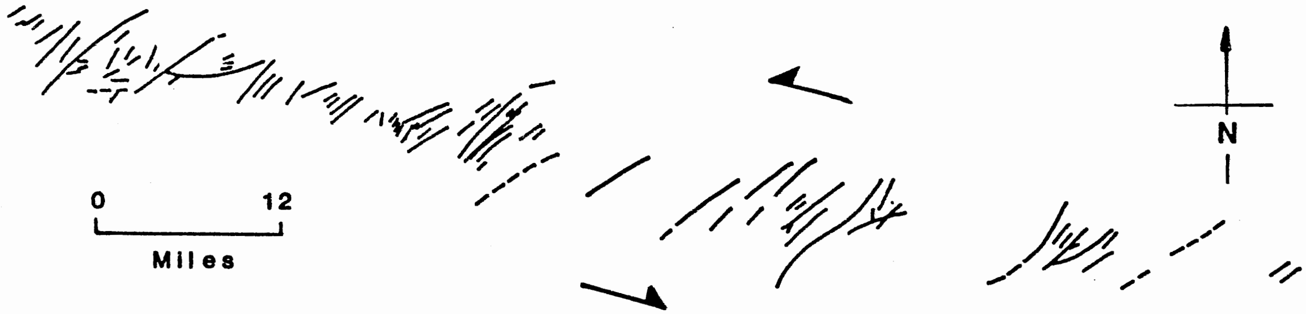
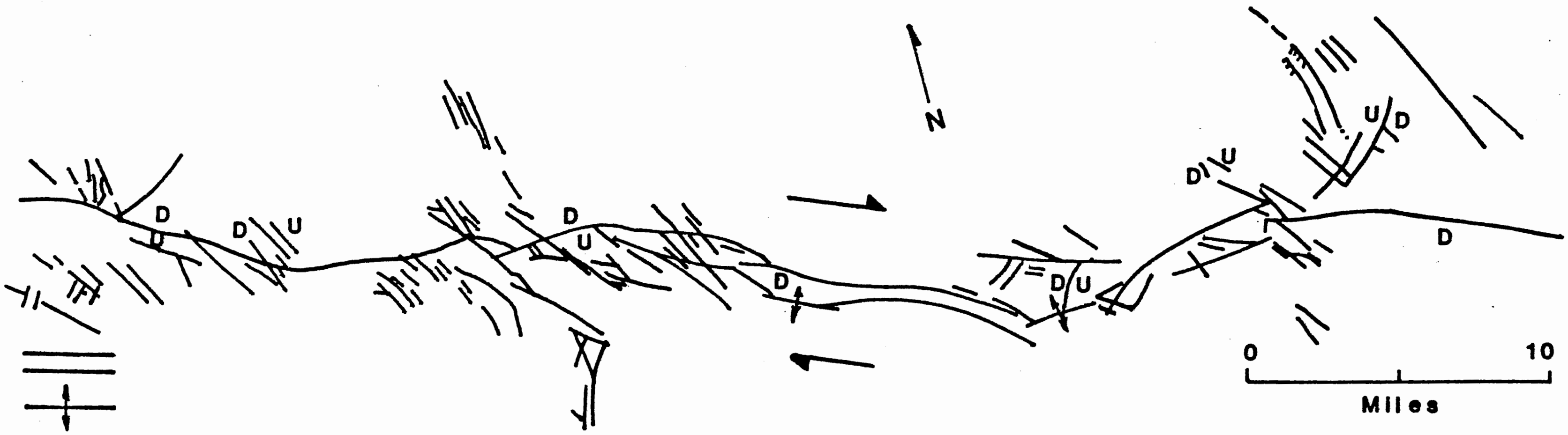


Figure 3. Generalized Tectonic Map of Region (after Walker, 1982).

These examples of en-echelon faults could indicate strike-slip movement at depth (Wilcox et al., 1973). Although an in-depth structural study was not the purpose of this study, similarities between surface and subsurface faulting of this area and of the Lake Basin fault zone, Montana, and the Cottage Grove fault zone, Illinois, are quite strong (Fig. 4). As illustrated in Figure 4a, left-lateral sense of displacement is presumed in the Lake Basin fault zone, and in Figure 4b, right-lateral displacement in the Cottage Grove fault zone. Minor structural features in the present study area seem to indicate a sense of left-lateral displacement along the principal fault zone, in the western half of the study area.



a.



b.

Figure 4a. En-echelon Faulting Associated with Lake Basin Fault Zone, Montana (after Wilcox et al., 1973).

4b. En-echelon Faulting Associated with Cottage Grove Fault Zone, Illinois (after Wilcox et al., 1973).

CHAPTER VI

LOCAL STRUCTURAL GEOLOGY

Structural contour maps were prepared of the bases of the Oswego and Inola Limestones and the top of the Mayes Limestone (Plates 6, 7, and 8, respectively). General strike of the Lower and Middle Pennsylvanian beds is north-northwest with a west-southwest dip. Strata decrease in dip northeastward, from about 1½ degrees in T. 11 N., R. 9 E. to about ½ degree in T. 13 N., R. 8 E.

Gentle rotation from northeastward to northwestward in strikes of the beds occurs from the base of the Oswego Limestone to the top of the Mayes Limestone (cf. Plates 6, 7, and 8). Strike of the Oswego Limestone is northwestward with dip of 80 to 180 feet per mile in the southeast, and 60 to 70 feet per mile in the northwest. The Inola Limestone strikes generally northward with dip of 60 to 140 feet per mile in the eastern two-thirds of the area of interest, and approximately 40 to 60 feet per mile in the western one-third. Strike of the strata at the top of the Mayes Limestone is generally north-northwest, with westerly dip of 80 to 130 feet per mile in the eastern one-half of the study area and 40 to 60 feet per mile in the western one-half. The generally westerly dip indicated by the three maps is interrupted by many noses, saddles, and faults.

Two major trends are noticeable in the study area. Figures 5, 6, and 7 show a general northeasterly trend of structural axes in the northern one-third of the study area, but a northwesterly trend in the southern two-thirds of the study area. Faulting is expressed as two trends. As described previously, the major trend is a fault zone that trends north-northeastward and has formed a graben (Fig. 6). Northwest-trending faults are developed in an en-echelon pattern primarily along the trend of the major fault.

Figure 7 shows evidence that trends of structural axes, as well as of the major fault zone, were developed before deposition of Pennsylvanian rocks. Increased complexity of faults and folds with depth and the similarity of structural fabric in deep and shallow strata (Figs. 5, 6, and 7) support the hypothesis that the basic structural make-up of the area was developed before deposition of Pennsylvanian rocks.

The North Haydenville synclinal trend (Figs. 5, 6, and 7) is one of the more prominent structural features of the northeast-trending folds. However, where it crosses the Cromwell-Dill fault zone (T. 13 N., R. 8 E.) it takes on a northwestward trend. Several other prominent northeast-trending folds are evident. The Whiterose and Haydenville anticlinal trends (Figs. 5 and 6) are north and south of the North Haydenville syncline, respectively. Figure 6 shows the Iron Post anticlinal and synclinal trends, which are northwest of the North Haydenville synclinal trend.

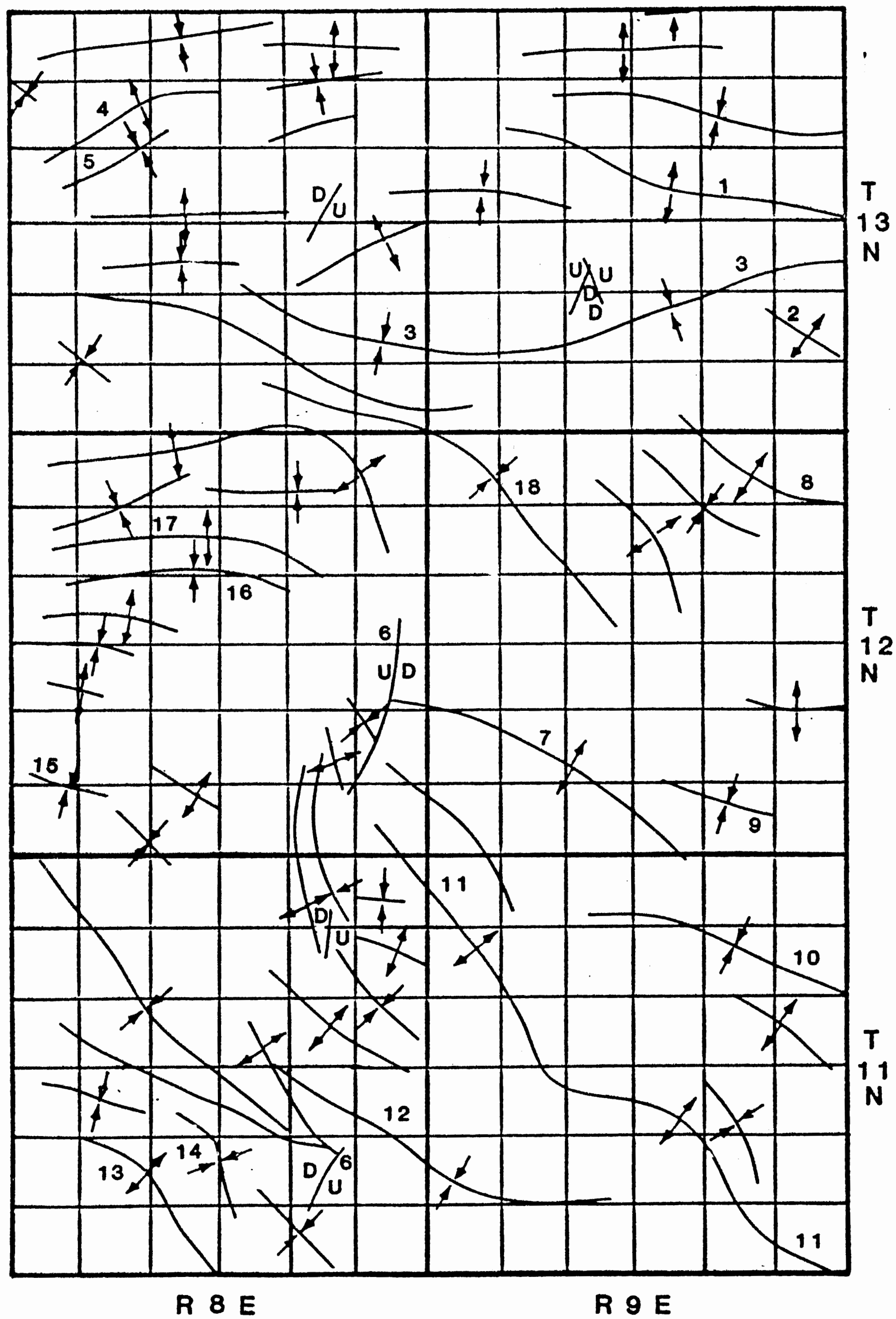


Figure 5. General Trends of Axes, Base of Oswego Limestone.

INDEX: 1-Whiterose anticline; 2-Mason anticline; 3-North Haydenville syncline; 4-Iron Post anticline; 5-Iron Post syncline; 6-Cromwell-Dill fault zone; 7-East Castle anticline; 8-Haydenville anticline; 9-North Castle syncline; 10-Southwest Castle anticline; 11-Southwest Okemah anticline; 12-Bearden syncline; 13-Cromwell anticline; 14-Cromwell syncline; 15-Boley syncline; 16-Valley Grove synclinal trend; 17-Valley Grove anticlinal trend; 18-Mason syncline.

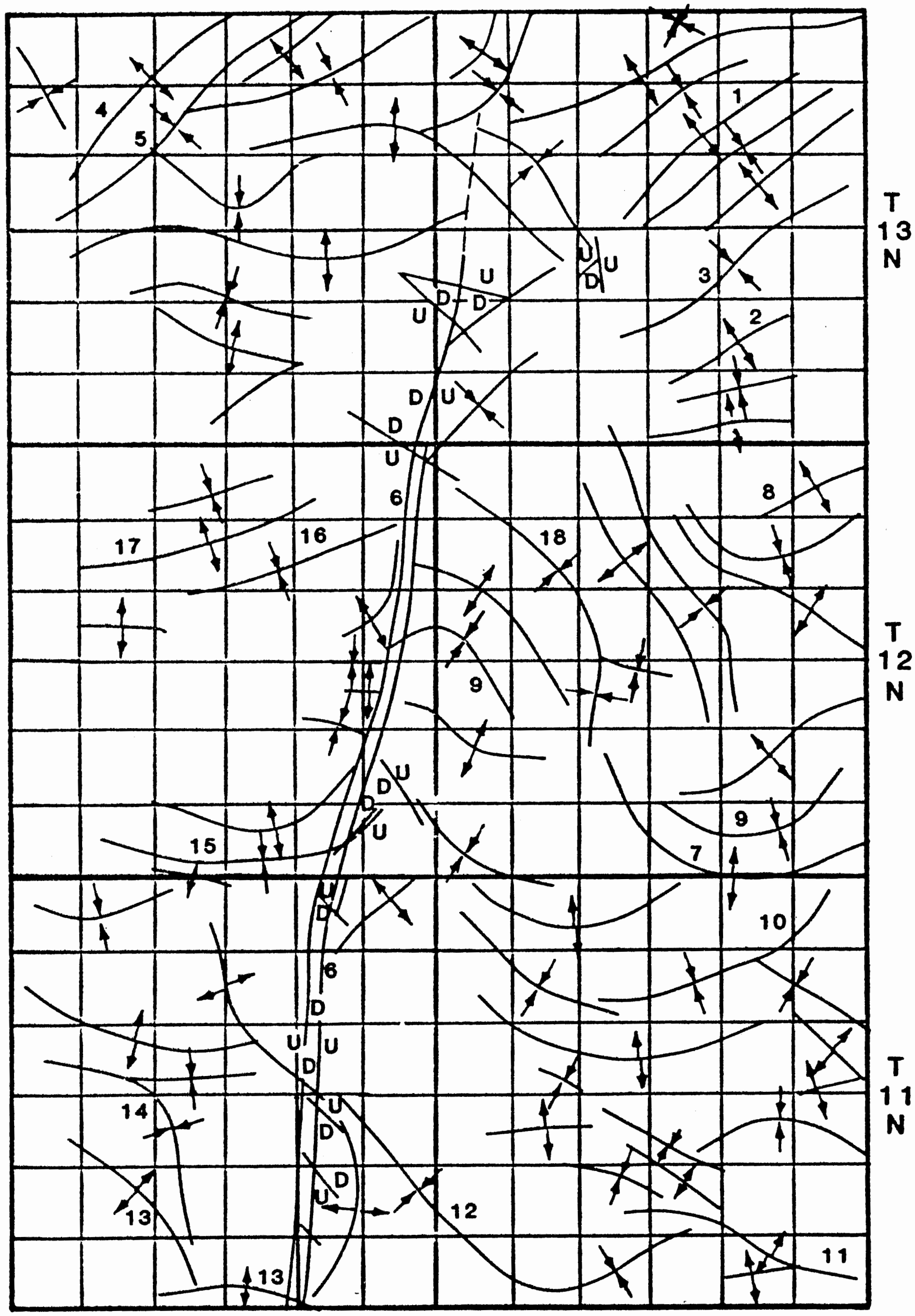


Figure 6. General Trends of Axes and Faults, Base Inola Limestone.

INDEX: 1-Whiterose anticline; 2-Mason anticline; 3-North Haydenville syncline; 4-Iron Post anticline; 5-Iron Post syncline; 6-Cromwell-Dill fault zone; 7-East Castle anticline; 8-Haydenville anticline; 9-North Castle syncline; 10-Southwest Castle syncline; 11-Southwest Okemah anticline; 12-Bearden syncline; 13-Cromwell anticline; 14-Cromwell syncline; 15-Boley syncline; 16-Valley Grove synclinal trend; 17-Valley Grove anticlinal trend; 18-Mason syncline.

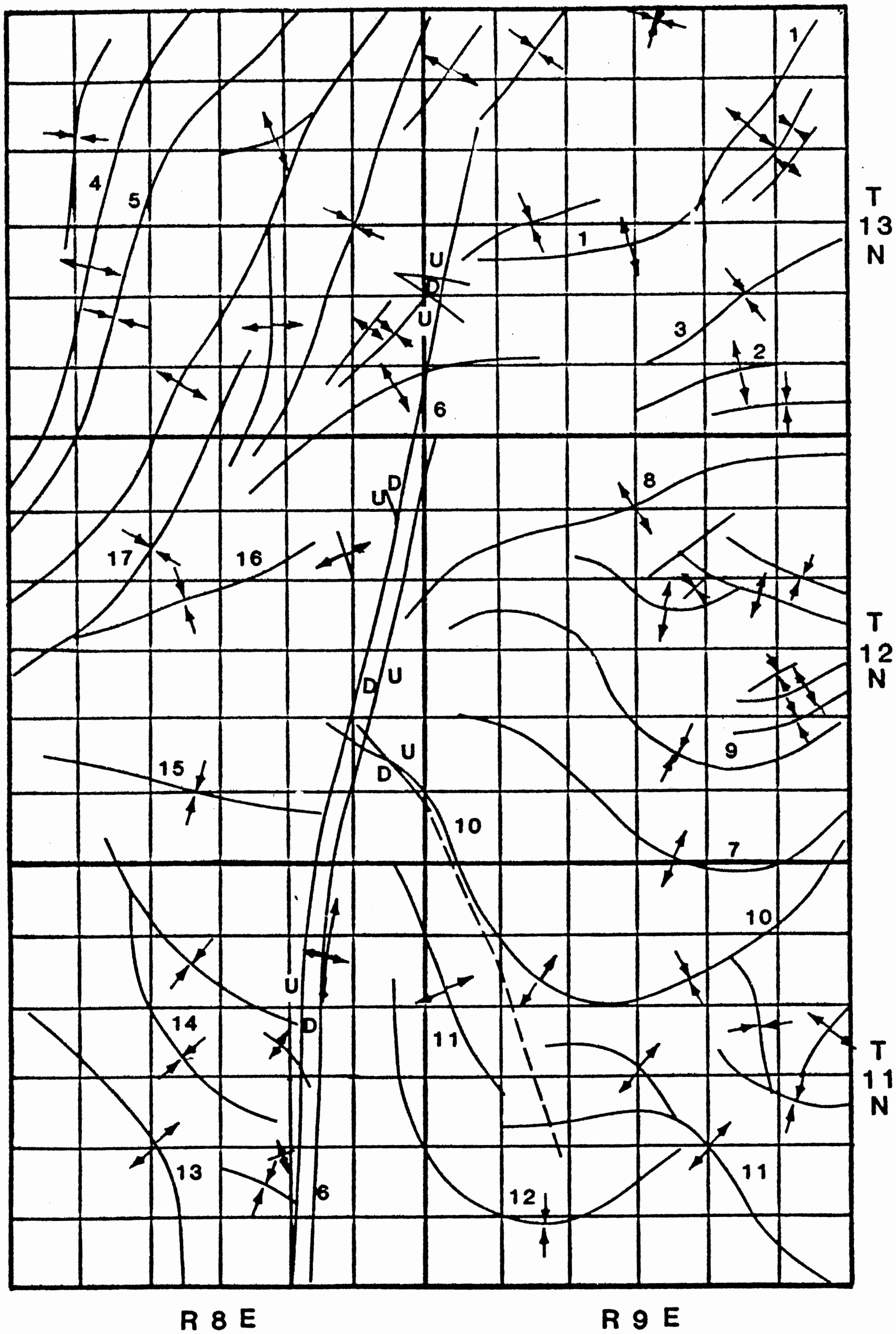


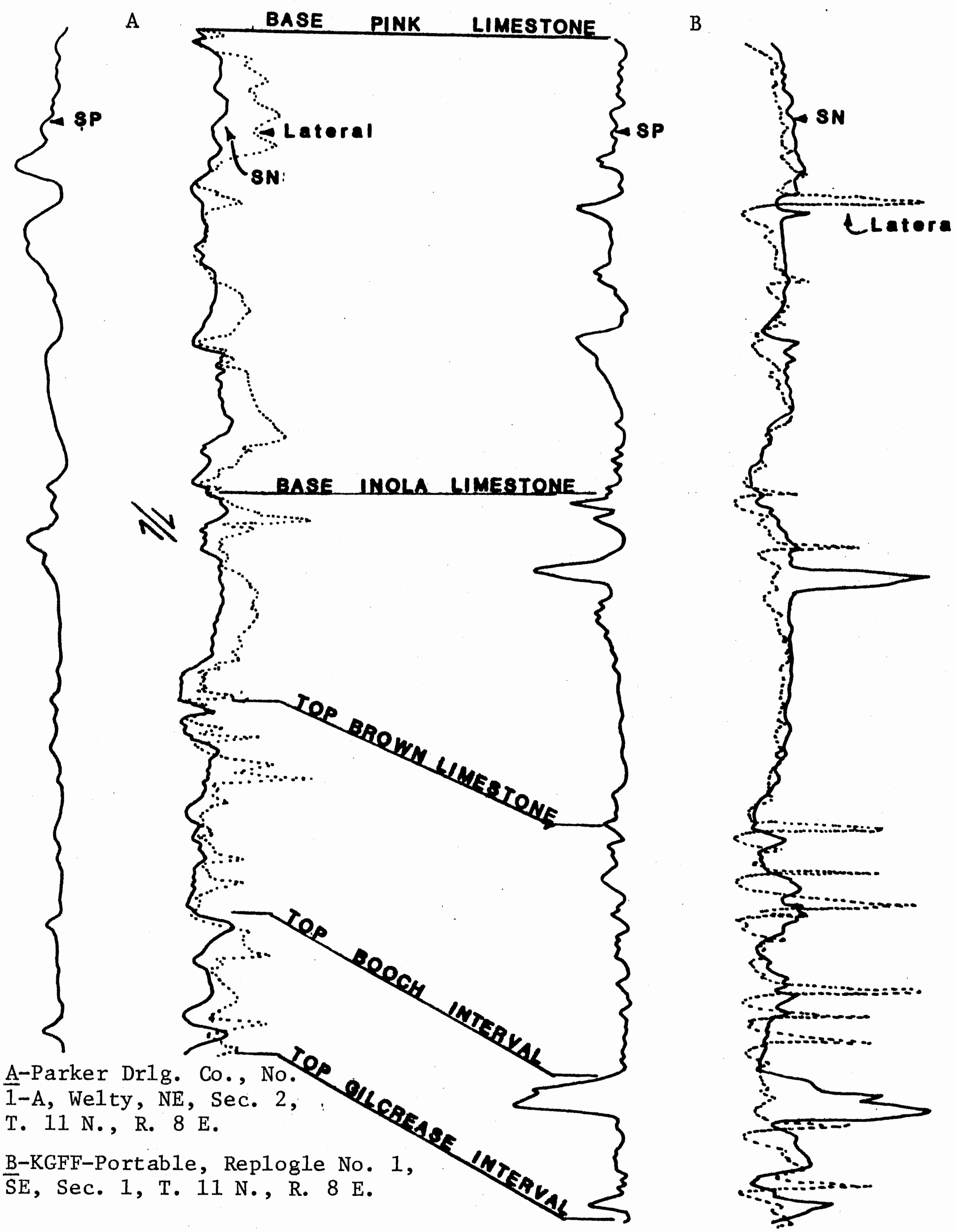
Figure 7. General Trends of Axes and Faults, Top of Mayes Limestone.

INDEX: 1-Whiterose anticline; 2-Mason anticline; 3-North Haydenville syncline; 4-Iron Post anticline; 5-Iron Post syncline; 6-Cromwell-Dill fault zone; 7-East Castle anticline; 8-Haydenville anticline; 9-North Castle syncline; 10-Southwest Castle anticline; 11-Southwest Okemah anticline; 12-Bearden syncline; 13-Cromwell anticline; 14-Cromwell syncline; 15-Boley syncline; 16-Valley Grove synclinal trend; 17-Valley Grove anticlinal trend; 18-Mason syncline.

There appears to be a definite limit to the extent of the northwest-trending folds, which is roughly along the boundary of Townships 12 and 13 North. This trend may be indicative of strike-slip movement along the Cromwell-Dill fault zone (Fig. 7). The East Castle and Southwest Okemah anticlinal trends (Fig. 6) are prominent features among the northwest-trending folds. The Mason syncline is north of the East Castle anticline; to the northeast is the North Castle syncline (Figs. 5, 6, and 7). Two noteworthy folds that are north and south, respectively, of the Southwest Okemah anticline are the Southwest Castle and Bearden synclines (Figs. 5, 6, and 7). Approximately 200 feet of displacement along the Cromwell-Dill fault zone is evident on the east flank of the Cromwell anticline (location of anticline in T. 11 N., R. 8 E., Figs. 5, 6, and 7).

The sparsity of wells that cross fault planes in these densely drilled areas strongly supports high-angle faulting. The stratigraphic intervals that can be shown to have been cut out (Figs. 8, 9, and 10) suggest that these high-angle faults are normal faults.

Some folds show steeper dip and more closure below the post-Mississippian unconformity than above (Plates 6, 7, and 8). The basic structural make-up of the area is believed to have originated in basement rocks as suggested by increased complexity of faults and folds with depth and the similarity of structural pattern in deep and shallow strata (Kochick, 1976).



A-Parker Drlg. Co., No. 1-A, Welty, NE, Sec. 2, T. 11 N., R. 8 E.

B-KGFF-Portable, Replogle No. 1, SE, Sec. 1, T. 11 N., R. 8 E.

Figure 8. Fault-cut Between Inola and Brown Limestones. Missing Stratigraphic Interval Includes the Upper Part of Bartlesville Sandstone Interval.

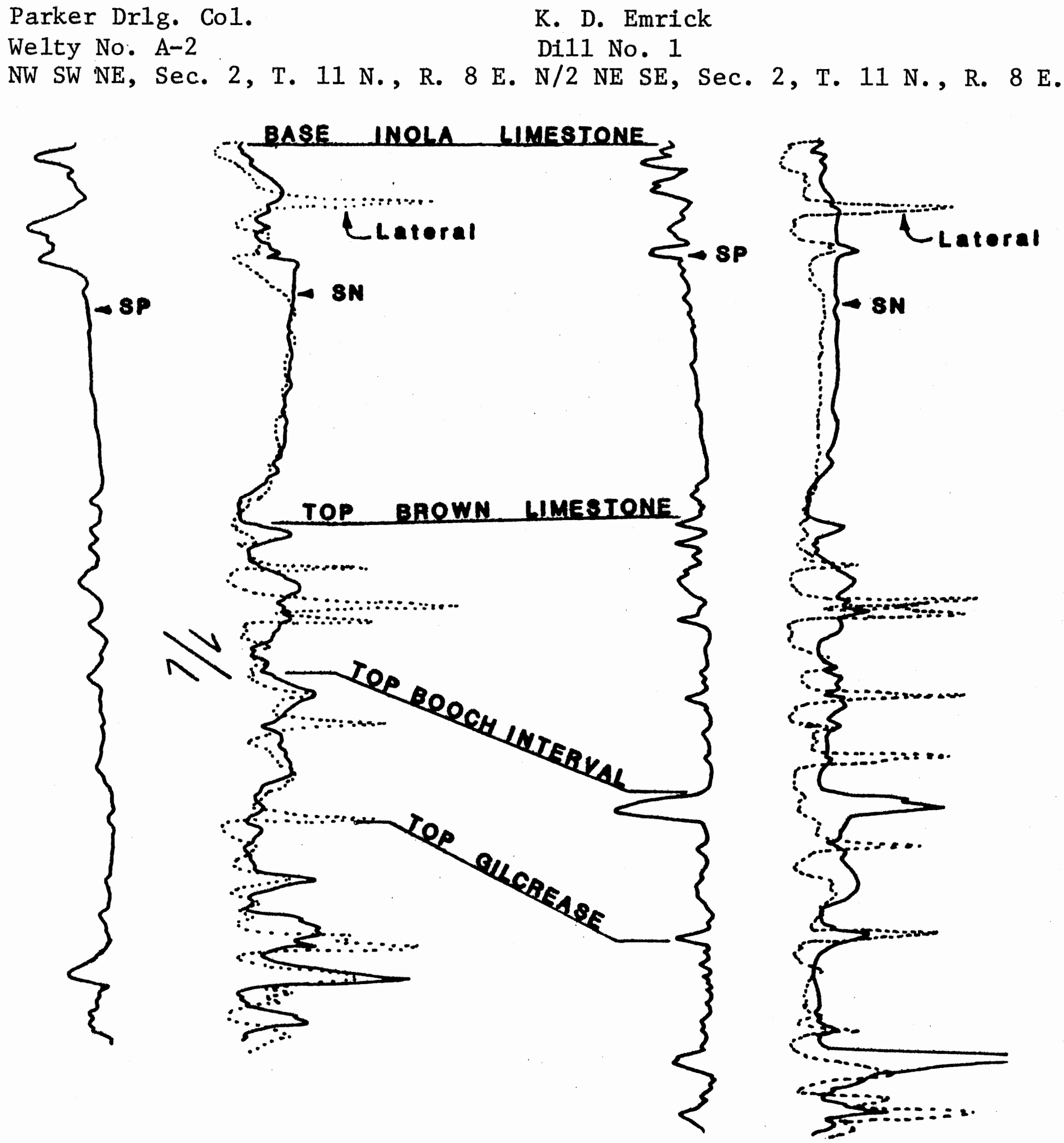


Figure 9. Fault-cut Between Brown Limestone and Booch Sandstone Format. Missing Stratigraphic Interval Includes Lower Section of Shale and Limestone Below Brown Limestone.

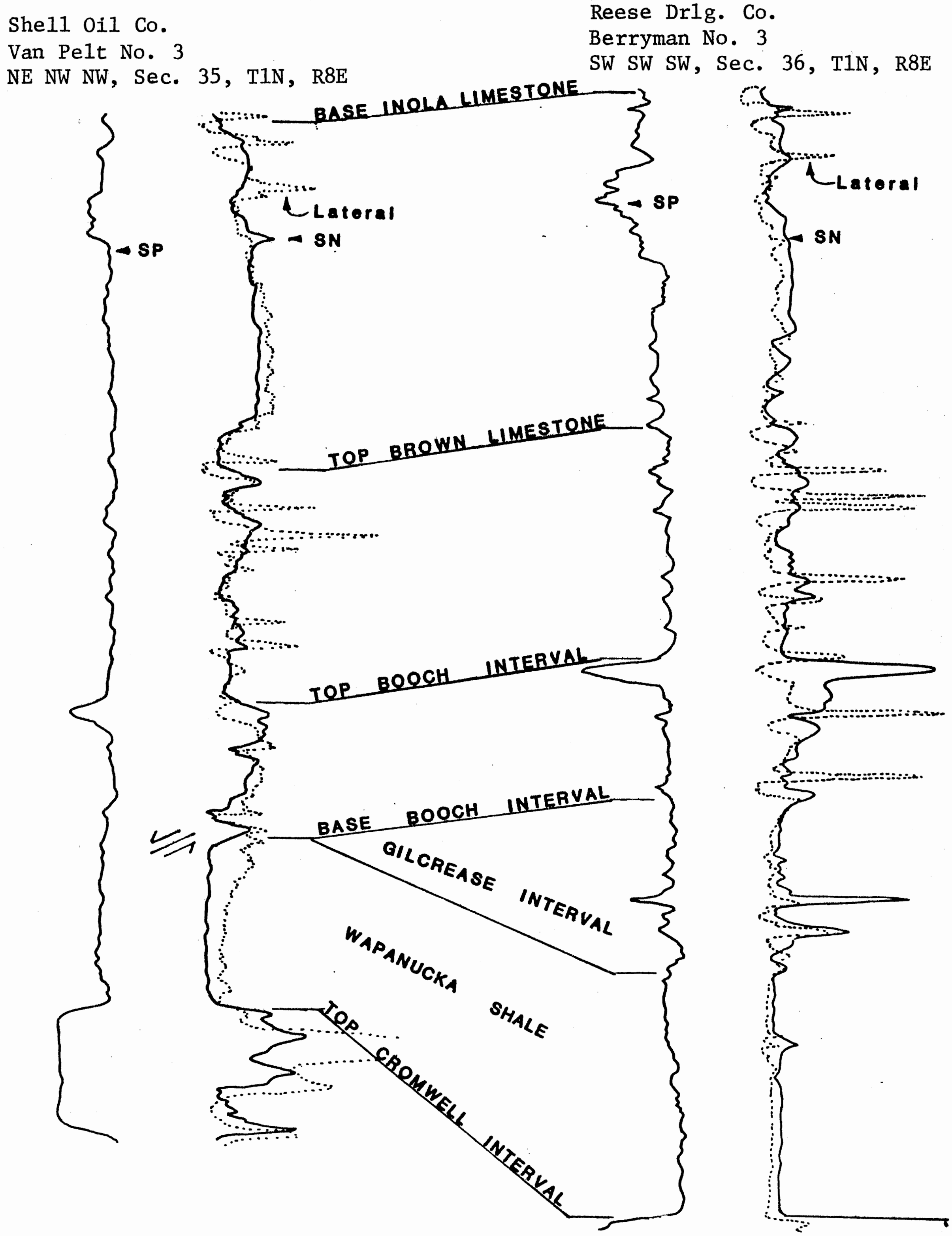


Figure 10. Fault Cut-out of Gilcrease Sandstone Format. Missing Stratigraphic Interval Is the Gilcrease Sandstone Format.

CHAPTER VII

DISTRIBUTION OF SANDSTONES

Log-signature maps, generalized sandstone-distribution maps, and net-sandstone isopach maps were used to delineate trends and geometry of Lower and Middle Pennsylvanian sandstones. Log-signature maps were prepared of the Cromwell, Gilcrease, Booch, and Red Fork Sandstones (Plates 9, 10, 11, and 13). A set of generalized distribution maps illustrated by Figures 11, 12, 13, and 14, were prepared of the Prue interval. The Cromwell, Gilcrease, Booch, Bartlesville, Lower Skinner, and Upper Skinner Sandstones were illustrated by net-sandstone isopach maps (Plates 9, 10, 11, 12, 14, and 15).

"Log" maps are very useful in documentation of varying thicknesses and stratigraphic positions of sandstone within a format (Shelton, 1952). The mapping of formats is useful in allowing the reader a simultaneous, spatially consistent view of log characteristics of the sandstones. The reader can see trends of separate sandstones in instances where a mapping of numerical values would obscure these trends at numerous localities. In some instances, log characters that have extreme deflections were not traced in entirety, because the curves would overlap those of wells nearby.

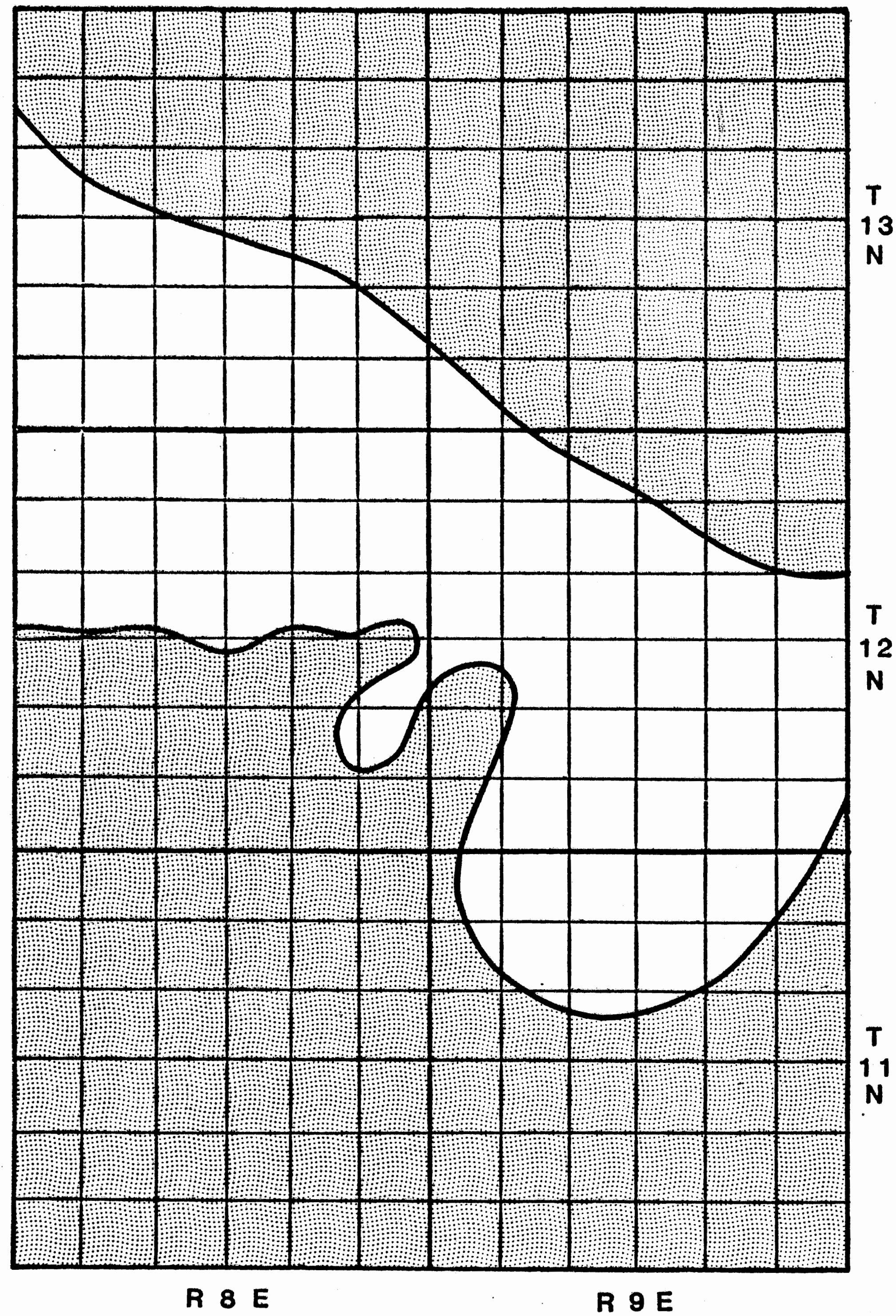


Figure 11. Distribution of Sandstones Within Lower Clastic Wedge of Prue Sandstone Format.

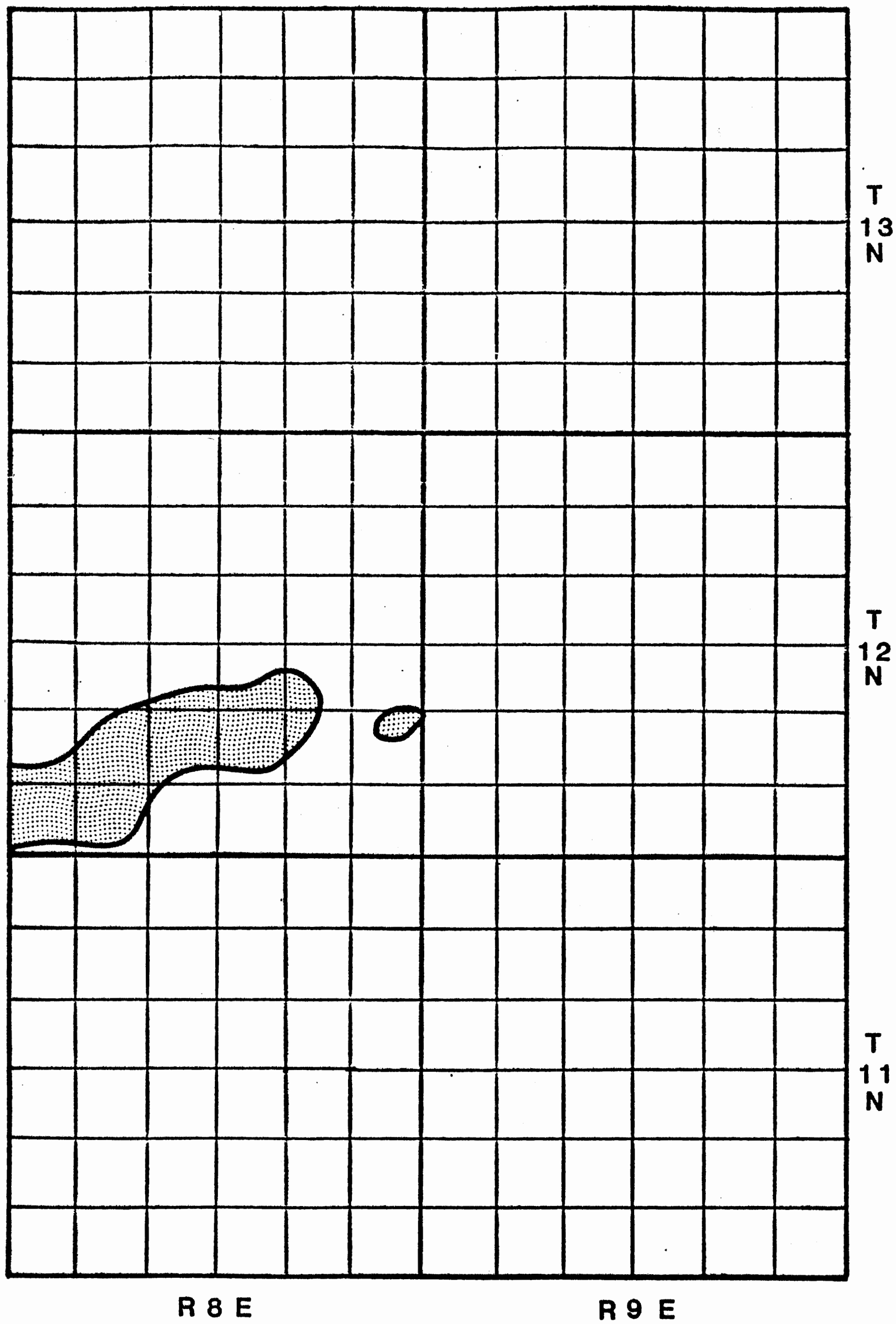


Figure 12. Distribution of Basal "Channel-like" Prue Sandstone.

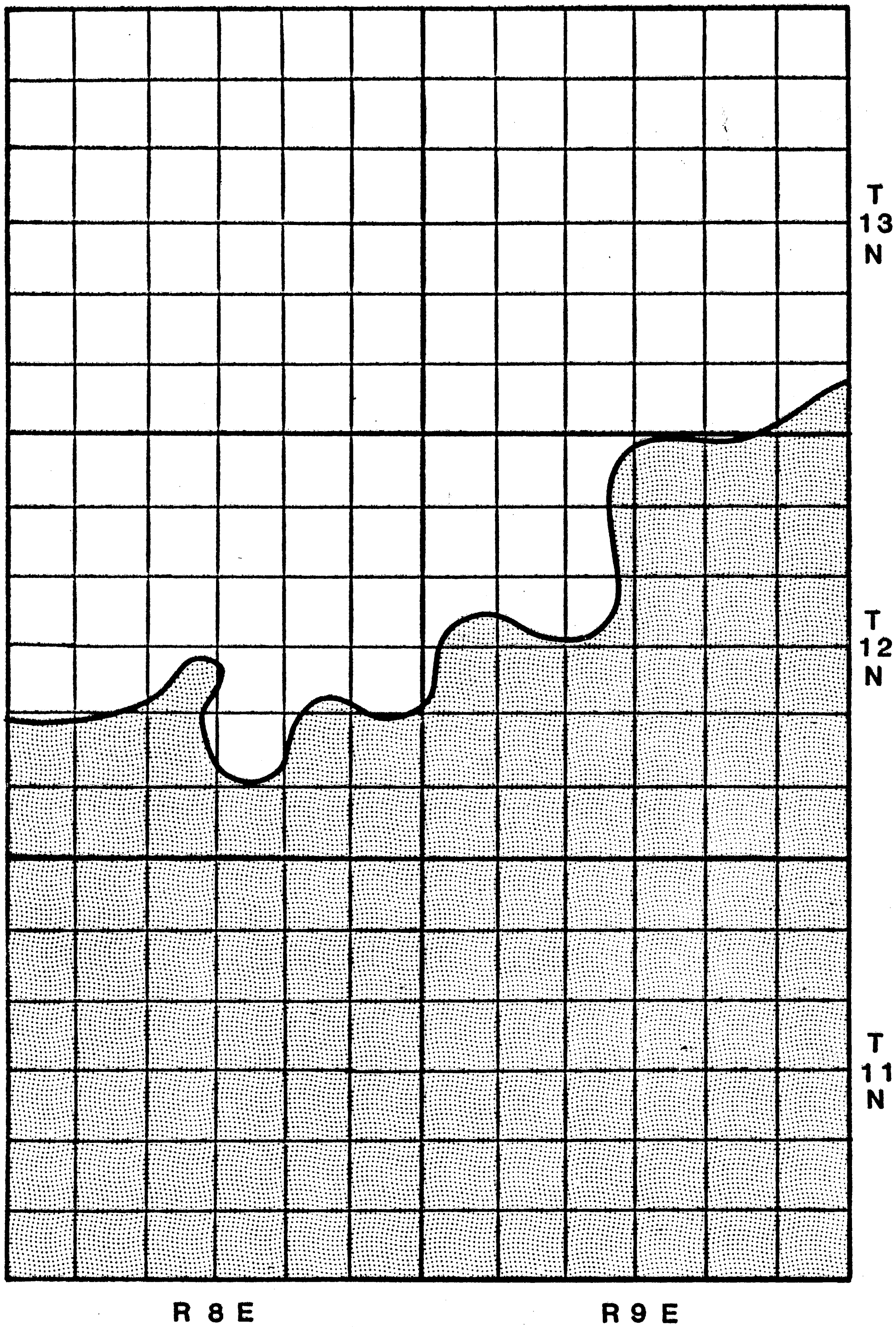


Figure 13. Distribution of Sandstones Within Middle Clastic Wedge of Prue Sandstone Format.

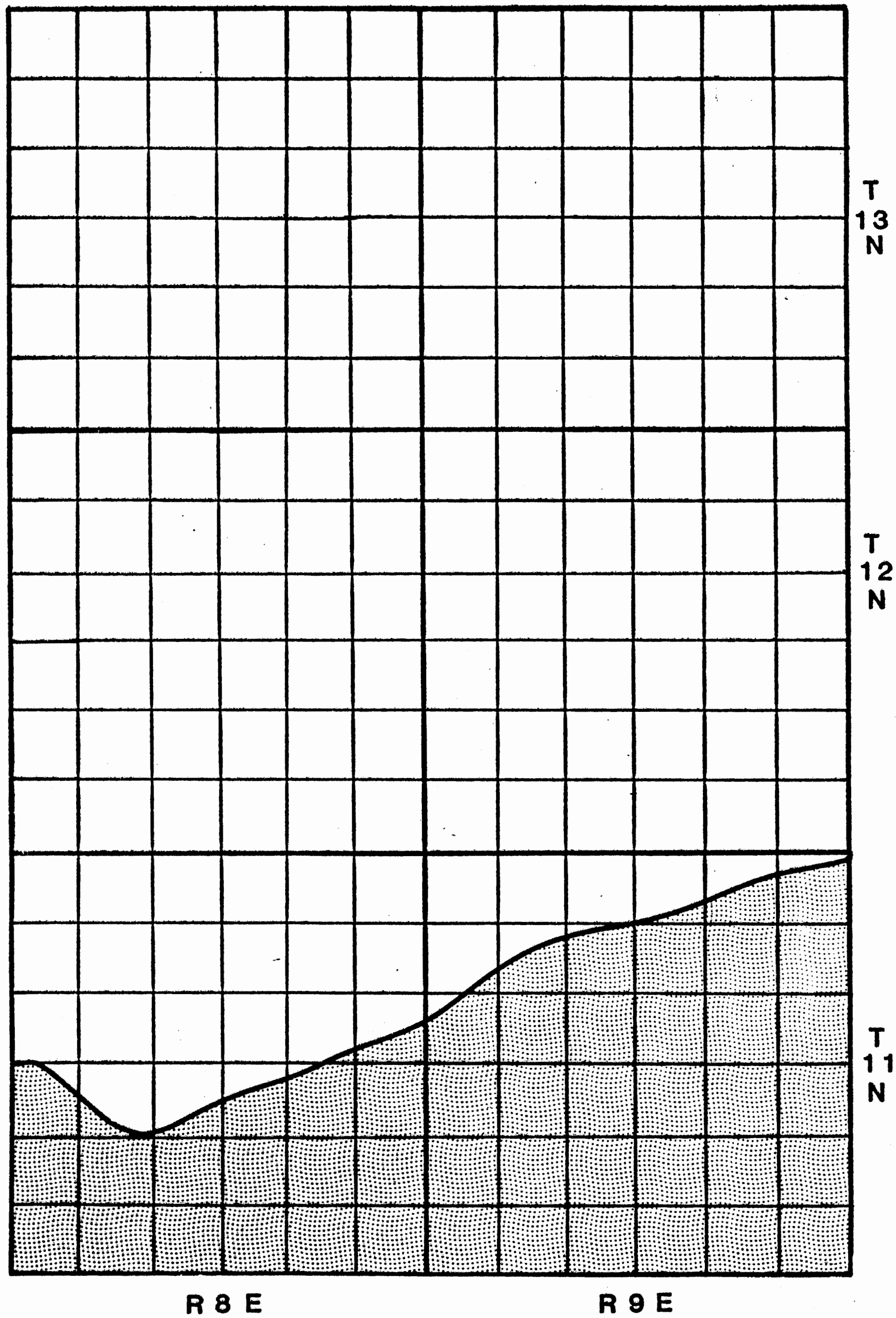


Figure 14. Distribution of Sandstone Within Upper Clastic Wedge of Prue Sandstone Format.

Generalized sandstone-distribution maps were prepared of four sandstones within the Prue Sandstone interval (Figs. 11, 12, 13, and 14). As can be seen from Plates 1-5, this interval thickens markedly southeastward with an accompanying increase in sandstone. Thickening southeastward of three clastic wedges that compose the Prue section is associated with this sandstone-buildup.

Cromwell Sandstone

A log-signature map with an overlying net-sandstone isopach map shows that north-northeast trend is characteristic of the Cromwell Sandstone (Plate 9). Three major sandstone units ar evident. All show high resistivity readings in the northern one-third of the study area, which probably is indicative of a large content of calcite within the sandstone. This evidence would support the correlation by Jordan (1957) of the Cromwell Sandstones grading eastward into the calcareous Union Valley Sandstone.

The easternmost trend of Cromwell Sandstone is not clearly shown in mapping. The central northeast-trending unit is one to three miles wide (Plate 9), with sandstones of 10 to 100 feet thick. The westernmost unit is three to greater than six miles wide. Thickness of sandstone is 10 to more than 140 feet. In the central and western trends, lateral contacts tend to be gradational and lower contacts generally are abrupt.

Gilcrease Sandstone

Overall trend within the Gilcrease Sandstone interval is northeastward (Plate 10). A large portion of the central and western areas of the study area are almost void of sandstone deposits. Log-signature maps of this interval show that several sandstones are developed. Perhaps the most pronounced of these is a lower sandstone with an abrupt basal contact; this unit overlies the Mississippian System in the westernmost part of the study area and the Wapanucka Shale to the east. Individual units of sandstones are as thick as 50 feet and have gradational to sharp lateral contacts.

Plate 10 illustrates a marked thickening of the Gilcrease interval east of the Cromwell-Dill fault zone, which extends from Secs. 34 and 35, T. 11 N., R. 8 E. to Sec. 17, T. 13 N., R. 9 E. Areas in which permeable sandstone is sparse are shown by only one log-trace per section, in order to provide the reader a general assessment of this stratigraphic interval.

Booch Sandstone

Generally, the trend of the Booch Sandstone is north-northeastward (Plate 11). Sandstone extends throughout the study area, with the exception of the northwestern one-third. A log-signature map (Plate 11) is extremely useful in study of this interval, for it shows that "buildup" of sandstone tends to be downward in the stratigraphic section. A net-sandstone isopach superimposed on the log-signature map shows evidence of channel-fill sandstones more than 120 feet thick. Lower and lateral contacts of sandstone and shale tend to be abrupt. Sandstones outside of these linear trends tend to have gradational lower and lateral contacts. Almost certainly the linear sandstones were deposited in deltaic distributary channels (Busch, 1971).

Bartlesville Sandstone

Generally, the Bartlesville Sandstone (Plate 12) trends southward through the study area. However, several narrow channel-like sandstone units are developed that trend east-west. A net-sandstone isopach map shows data that includes all sands within the Bartlesville interval (Plate 12). A thin delta-fringe, locally well-developed sandstone extends across much of the study area. This unit has gradational lateral and lower contacts, and thickness of 5 to 15 feet is common. Apparent channel-fill sandstones within the interval have sharp lower and sharp to gradational upper contacts, and are more than 150 feet thick in the northeastern one-third of the study area.

Red Fork Sandstone

Several kinds of log profiles are apparent in the Red Fork interval; the most common of which is a thin sandstone developed in the middle part of the mapped interval (Plate

13). In the northern part of the study area it is approximately 100 to 120 feet from the base of the Pink Limestone, but in the southern townships it is 140 to 170 feet from the base of the Pink. It has gradational lower and lateral contacts and seems to coarsen upward. These rock units probably are lateral equivalents of a middle channel deposit but they may be delta-fringe deposits (Walker, 1982).

For the purposes of this study, channel-like (probably distributary-fill) sandstones have been divided into lower, middle, and upper units (Plate 13), although definite stratigraphic markers are not apparent. In many instances stacked multistoried units make precise division impractical.

Trend of the lowermost unit is northwest-southeast and northeast-southwest (Plate 13). The unit is discernible clearly only in the central part of the study area. Possibly movement along the Cromwell-Dill fault zone (Figs. 6 and 7) was influential in deposition of this unit as it is present in proximity to the fault zone. Thickness of the sand is 10 to 50 feet. "Channels" are approximately one-half mile wide.

The middle linear deposit trends generally northeastward, whereas the upper unit varies from northwestward to southeastward. Both units appear to terminate abruptly in several instances. They range in width from one-half mile to more than three miles (Plate 13).

All sandstone units in the channel-like deposits have generally sharp basal contacts and gradational to sharp lateral contacts.

Lower Skinner Sandstone

The Lower Skinner Sandstone trends east-west to north-south (Plate 14). Although sandstone was mapped as if it were one unit, several discrete units are within the interval. Two sands that may have been deposited during transgressive events are more or less throughout the study area. They are 5 to 10 feet thick, and show evidence of gradational lower and lateral contacts. In many instances the sandstones are poorly developed, and therefore are not evident on the net-sandstone isopach map. In the southern one-third of the study area, the random pattern of deposition of these sands is apparent.

Several channel-fill sandstones are clearly visible, and their inferred origins are supported by abrupt basal contacts and cut-out of underlying beds. They are limited to the northern two-thirds of the study area. Thickness of more than 60 feet is shown in Sec. 19, T. 12 N., R. 9 E. (Plate 14).

Upper Skinner Sandstone

Two Upper Skinner units are shown on Plate 15. Both trend northeast-southwest. One is located in the upper one-third of the study area, the other in the southeastern quadrant.

A thin, poorly developed, apparently delta-fringe sandstone extends across much of the area, but is not readily visible on the net-sandstone isopach map. Two channel-like deposits approximately 1-1/2 miles to 2-1/2 miles wide are readily detected on Plate 15. Both deposits have log characteristics that indicate sharp basal contacts and gradational to sharp lateral contacts. Thickness of sandstone is 10 feet to more than 100 feet.

Prue Sandstone

Generalized distribution maps were prepared for the Prue interval (Figs. 11, 12, 13, and 14). As mentioned previously, three clastic wedges are apparent within the Prue (Plates 1-5).

The lowermost unit (Fig. 11) is throughout the entire area. It is poorly developed, except in the northwestern area of T. 13 N., R. 8 E., where it is fairly well developed and is marginally productive. A basal channel-like sandstone (Fig. 12) trends eastward in the southern one-third of the study area. Log characteristics indicate sharp basal and lateral contacts. Thickness of sandstone is 10 to more than 40 feet.

Figure 13 illustrates a middle clastic wedge that thickens southeastward. Many individual sandstones are developed within this interval, but the overall trend is northeastward. Individually, they are 10-20 feet thick and where stacked, compose a stratigraphic section as thick as 50 feet.

The uppermost sandstones (Fig. 14) of the Prue Format are in T. 12 N., R. 9 E., and similar to the middle units, are present southeastward. Generally, they are 10 to 20 feet thick, but stacking of units results in overall thicknesses of as much as 50 feet.

CHAPTER VIII

PETROLEUM GEOLOGY

The Iron Post Field, the oldest field in the study area, is located in the northwest part of T. 13 N., R. 8 E. (Fig. 15). Discovered in 1917, it produces from the Cromwell, Gilcrease, and Prue Sandstones. As can be inferred from Plates 9 and 10, and Figure 11, trapping mechanism in the three reservoirs is primarily stratigraphic.

The next-older discoveries were the Cromwell and East Cromwell Fields (Fig. 15), where production has been primarily from the Cromwell Sandstone. The Booch and "Wilcox" Sandstones and Hunton Group (Fig. 2) have also been very productive in the field. The two fields are on anticlinal features separated by the north-south trending Cromwell-Dill fault zone (Fig. 7). Structural influence of the two anticlines perhaps was a stronger influence on entrapment in the Booch and Cromwell Sandstones than were stratigraphic limits of the sandstones.

The North Okemah Field (Fig. 15) was discovered in 1940. It is a combination stratigraphic-structural trap in the Gilcrease and Cromwell Sandstone intervals. The Hunton Group also produces in this field.

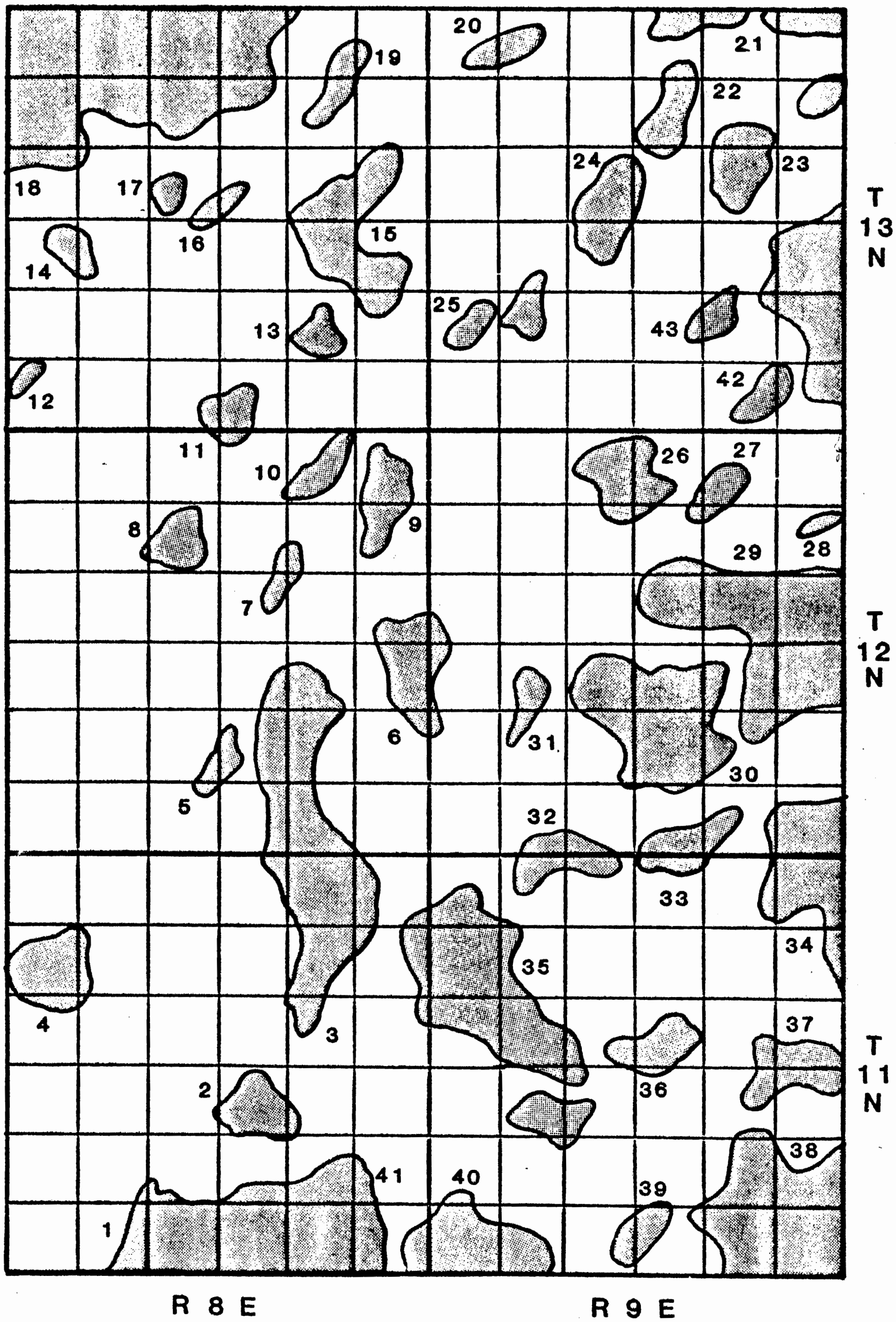


Figure 15. Oil and Gas Fields of Study Area.

INDEX: 1-Cromwell; 2-S. Dill; 3-Dill; 4-Rusk; 5-E. Boley; 6-NE Dill; 7-S. Valley Grove; 8-SW Valley Grove; 9-SE Valley Grove; 10-Valley Grove; 11-NW Valley Grove; 12-E. Hillby; 13-S. Rosenwald; 14-Micawber; 15-Rosenwald; 16-SE Macawber; 17-S. Micawber; 18-Iron Post; 19-W. Welty; 20-NE Welty; 21-N. Rock; 22-NW Whiterose; 23-Whiterose; 24-SW Whiterose; 25-W. Mason; 26-Mason; 27-SE Mason; 28-W. Morse; 29-Morse District; 30-E. Castle; 31-NW Castle; 32-Castle; 33-NW Okemah; 34-N. Okemah; 35-SW Castle; 36-Greenlease; 37-SE Okemah; 38-Okemah-Bingham; 39-Greenlease; 40-NW Bearden; 41-E. Cromwell.

In 1943, the Dill and Northeast Dill Fields (Fig. 15) were discovered. As are the Cromwell and East Cromwell Fields, the Dill and Northeast Dill Fields are on two anticlinal features separated by the Cromwell-Dill fault zone (Fig. 7). The Cromwell Sandstone has been the most productive stratigraphic unit in the Dill Field, but the Wilcox Sandstones and the Hunton have also been substantially productive. Reservoirs of the Northeast Dill Field are the Booch, Gilcrease, and Cromwell Sandstones, and the Hunton Group.

The East Castle Field, in T. 12 N., R. 9 E. (Fig. 15), was discovered in 1944. A pinchout of the Cromwell Sandstone in an updip direction formed the stratigraphic trap. The Gilcrease Sandstone and Hunton Group have also been productive in this field.

Numerous other fields are in the study area. A combination of structural and stratigraphic trapping appear generally to have been the cause of entrapment of hydrocarbons in the Lower and Middle Pennsylvanian rocks. Although study of deeper formations, such as the Wilcox and Hunton was not in the scope of this study, it seems that the primary trapping mechanisms in the Wilcox Sandstones were structural and a combination of structural-stratigraphic conditions account for productivity of the Hunton.

Table I shows a summary of fields and cumulative production in the study area.

TABLE I

CUMULATIVE PRODUCTION OF FIELDS IN STUDY AREA

Field	Prod. Fm.	No. Wells (active)	Cumulative
Bearden, Norhtwest	C	1	748,801
Boley	C	---	12,836
Boley, East	C	---	42,945
Castle	C,G	3	93,526
Castle, East	H,C,G	23	3,654,270
Castle, Southwest	C,G	N.A.	N.A.
Cromwell	W,H,C,G	18	9,631,338
Cromwell, East			
Dill	W,H,C	20	10,473,028
Dill, Northeast	H,C,G,B	14	1,462,649
Dill, South	H	5	392,912
Greenlease	H,C	6	474,359
Greenlease, South	C	1	811
Haydenville, District	W,C,G	58	3,800,915
Hillby, East	C	N.A.	N.A.
Iron, Post	C,G,P	8	N.A.
Mason	H,C,G	10	398,268
Mason, East	G	2	6,862
Mason, Northeast	G	---	5,827
Mason, Southeast	G	---	1,577
Mason, West	C,G	---	170
Micawber	N.A.	---	N.A.
Micawber, South	C,G	---	
Micawber, Southeast	C,G	3	429,624
Morse, District	H,C,G,B	38	1,981,766
Morse, West	G	---	11,822
Okemah-Bingham	W,H,M,C,G	80	N.A.
Okemah, North	H,C,G	98	6,230,480
Okemah, Northwest	H,C,G	5	12,297
Okemah, Southwest	W,H,C,G	4	95,000
Okemah, West	H	4	76,506
Rock, North	C,G,B	3	91,143
Rosenwald	H,C	9	1,400,554
Rosenwald, South	C,G	---	21,155
Rusk	C	1	1,314
Valley Grove	C,G	---	37,481
Valley Grove, Northeast	G	---	14,741
Valley Grove, Northwest	H	4	89,660
Valley Grove, South	C	1	152,432
Valley Grove, Southeast	H	9	744,454
Valley Grove, Southwest	C	3	182,220
Welty, Northeast	G	---	1,123
Welty, West	P	3	26,895
Whiterose	W,C,G,B	11	358,172
Whiterose, Northwest	C,G	2	30,316
Whiterose, Southwest	G	8	204,533

Source: Oklahoma Crude Production Report. Petroleum Information Corporation. Sept., 1984; Oklahoma Abandoned Leases. Petroleum Information Corp. Through Dec., 1979.
Abbreviations: W: Wilcox, H: Hunton, M: Misener, C: Cromwell, G: Gilcrease, B: Booch, P: Prue

CHAPTER IX

SUMMARY

1. Lower and Middle Pennsylvanian rocks unconformably overlie the Mississippian System and overlap this unconformity northwestward.

2. Unconformities separate the Morrowan from the Atokan and the Atokan from the Desmoinesian Series.

3. Thin transgressive limestones are useful as markers in delineation of transgressive-regressive couplets.

4. General trends of the Cromwell, Booch, Gilcrease, and Bartlesville Sandstones are north-northeast. The Red Fork Sandstone trend is less definite. Lower Skinner Sandstones trend north-south and east-west, whereas the Upper Skinner Sandstone trends northeastward.

5. Depositional environments of sandstones in the study area almost certainly ranged from alluvial-deltaic to shallow marine.

6. A north-south trending fault zone in the study area is reflected by en-echelon normal faults at the surface; this fault zone may have had some degree of strike-slip movement, and may have influenced significantly the depositional patterns of the Red Fork Sandstones.

7. Principal trapping mechanisms in Pennsylvanian rocks are stratigraphic and structural-stratigraphic.

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APPENDIX

LOCATIONS OF ELECTRIC LOGS USED IN CORRELATION SECTIONS

<u>Correlation Section A-A' (Plate 1)</u>

1. O.K. & T. Oil & Gas Co., Baily No. 1
   NE NW SE Sec. 3, T. 13 N., R. 8 E.

2. Baily & Mora Drilling Co., Replogle No. 1
   SW SW NE Sec. 10, T. 13 N., R. 8 E.

3. Bay Petroleum Corporation, Follansbee No. 2
   SE SE SW Sec. 16, T. 13 N., R. 8 E.

4. Webco Drilling Co., Sessions No. 1
   NE NE NW Sec. 27, T. 13 N., R. 8 E.

5. Cayman Corp., Howland No. 1
   SW SW SE Sec. 34, T. 13 N., R. 8 E.

6. Devonian & Gulf, Curry No. 1
   SE NW SE Sec. 2, T. 12 N., R. 8 E.

7. Frank B. Murta & Son, Baker No. 1
   SW NW SW Sec. 11, T. 12 N., R. 8 E.

8. Manahan Oil Co., Replogle No. 1
   NW NE SW Sec. 15, T. 12 N., R. 8 E.

9. Konawa Operating Co., Droppleman-Foster No. 1
   NE NW Sec. 22, T. 12 N., R. 8 E.

10. Phillips Petr. Co., Replogle No. 5
    SE NW NW Sec. 26, T. 12 N., R. 8 E.

11. C. M. Seran, Seran No. 3
    NW SE NW Sec. 2, T. 11 N., R. 8 E.

12. E. F. McDonald, Jr., Palmer Estate No. 1
    SW NE NE Sec. 10, T. 11 N., R. 8 E.

13. Illinois Exploration Co., Frank No. 1
    NE SE NW Sec. 10, T. 11 N., R. 8 E.

14. B. C. Deardorf, Murray No. 1
    SE SE NW Sec. 15, T. 11 N., R. 8 E.

15. Pelican Production Co., Franks No. 1
    SE NE NW Sec. 22, T. 11 N., R. 8 E.

16. Shell Oil Co., Pure Oil Co. No. 1
    NW NW SE Sec. 22, T. 11 N., R. 8 E.

17. Foundation Oil Co., Barney Frank No. 1
    SE SW NE Sec. 27, T. 11 N., R. 8 E.

18. Shell Oil Co., Van Pelt No. 1
NW NE NW Sec. 35, T. 11 N., R. 8 E.

Correlation Section B-B' (Plate 2)

1. Natural Gasoline Corp., Schwab No. 1
NW NE SE Sec. 5, T. 13 N., R. 9 E.

2. Kenneth Ellison, Burke No. 1
NE NE NE Sec. 17, T. 13 N., R. 9 E.

3. Leach & Warren, Bertha Allen No. 1
SE NW SW Sec. 16, T. 13 N., R. 9 E.

4. Webco Drilling Co., Witty "C" No. 1
SE SE NW Sec. 21, T. 13 N., R. 9 E.

5. Jan Oil Co., Alexander No. 1
SE SE NW Sec. 27, T. 13 N., R. 9 E.

6. Vierson-Cochran, Collins No. 1
SE SE SE Sec. 33, T. 13 N., R. 9 E.

7. Mason Oil Co., Harjo No. 1
SE SE NE Sec. 4, T. 12 N., R. 9 E.

8. George F. Martin, Ziegler No. 1
SW NE NE Sec. 9, T. 19 N., R. 9 E.

9. The Texas Co., Montgomery No. 1
SE SE NE Sec. 16, T. 12 N., R. 9 E.

10. Gulf Coast Western, Sions No. 1
SE SE NW Sec. 21, T. 12 N., R. 9 E.

11. United States Smelting, Refining & Mining Co.,
Replogle No. 1
NE SE SE Sec. 28, T. 12 N., R. 9 E.

12. Frankfort Oil Co., Norton No. 1
NE NE NE Sec. 33, T. 12 N., R. 9 E.

13. Darby & Bothwell, Cash No. 1
NE NE NE Sec. 4, T. 11 N., R. 9 E.

14. Helmerich & Payne, Montgomery No. 1
SW SW NE Sec. 4, T. 11 N., R. 9 E.

15. Mid-Continent Petroleum Corp., Custer No. 1
NE SE Sec. 9, T. 11 N., R. 9 E.

16. Phillips Petroleum Co., Bunner No. 1
SW SE NE Sec. 16, T. 11 N., R. 9 E.

17. Crabbe-Stevens & Emrke, Boatman No. 1
NE NE SW Sec. 22, T. 11 N., R. 9 E.

18. George F. Martin, Whitfield No. 1
NE SE NE Sec. 28, T. 11 N., R. 9 E.

Correlation Section C-C' (Plate 3)

1. Mid-Continent Petroleum Corp., Weimer No. 1
SE NE Sec. 7, T. 13 N., R. 8 E.

2. Jones-Shelbourne & Pellow Oil Co., Ross No. 1
SW NE NW Sec. 8, T. 13 N., R. 8 E.

3. Shaw & Hughes, Fletcher No. 1
NW SW SE Sec. 9, T. 13 N., R. 8 E.

4. Baily & Mora Drilling Co., Replogle No. 1
SW SW NE Sec. 10, T. 13 N., R. 8 E.

5. Jan Oil Co., White No. 1
SE SW NE Sec. 11, T. 13 N., R. 8 E.

6. Haddock & Associates, Foxie Red No. 1
NE NW SW Sec. 12, T. 13 N., R. 8 E.

7. Smith-Horton Drilling Co., Curry No. 1
SW SW NW Sec. 18, T. 13 N., R. 9 E.

8. Kenneth-Ellison, Burke No. 1
NE NE NE Sec. 17, T. 13 N., R. 9 E.

9. Plateau Development Co., Replogle No. 1
NW SW SW Sec. 10, T. 13 N., R. 9 E.

10. T. N. Berry & Co., Bras No. 1
SW SW NE Sec. 11, T. 13 N., R. 9 E.

11. Tennessee Gas & Transmission Co., Bras No. 1
SE SW NW Sec. 12, T. 13 N., R. 9 E.

Correlation Section D-D' Plate 4)

1. Helmerich & Payne, Crenshaw No. 1
SE SW NE Sec. 19, T. 12 N., R. 8 E.

2. John B. Hawley, Jr., Curry No. 1
SE SE SE Sec. 17, T. 12 N., R. 8 E.

3. Monahan Oil Co., Replogle No. 1
NW NE SW Sec. 15, T. 12 N., R. 8 E.

4. Kerr-McGee Oil, Inc., Curry No. 1
SW NE SW Sec. 14, T. 12 N., R. 8 E.

5. Selby Oil & Gas Co., Dyer No. 1
SE SW Sec. 13, T. 12 N., R. 8 E.

6. Kickapoo Oils, Harjoche No. 1
NW NE SW Sec. 19, T. 12 N., R. 9 E.

7. I. R. McQueen, Parks No. 2
SW NW SE Sec. 20, T. 12 N., R. 9 E.

8. Gulf Coast Western, Sions No. 1
SE SE NW Sec. 21, T. 12 N., R. 9 E.

9. Olin Oil & Gas Co., Kunkel No. 1
NE SW NE Sec. 22, T. 12 N., R. 9 E.

10. Olin Oil & Gas Co., Jones No. 1
SE SW NW Sec. 23, T. 12 N., R. 9 E.

11. British-American Oil Producing Co., Admire No. 1
SW NW SW Sec. 24, T. 12 N., R. 9 E.

12. Wilcox Oil Co., Mackay No. 1
SE NE SW Sec. 24, T. 12 N., R. 9 E.

Correlation Section E-E' (Plate 5)

1. McIntyre et al., Cornelius No. 1
SW SW SW Sec. 18, T. 11 N., R. 8 E.

2. Keener Oil & Gas Co., Klabzuba No. 1
NE SW NE Sec. 20, T. 11 N., R. 8 E.

3. J. A. Ligon, Keys No. 1
NW SW SE Sec. 16, T. 11 N., R. 8 E.

4. Pelican Production Co., Franks No. 1
SE NE NW Sec. 22, T. 11 N., R. 8 E.

5. Shell Oil Co., Friend No. 1
NW NE NW Sec. 23, T. 11 N., R. 8 E.

6. Ambassador Oil Corp., Stovall No. 1
SW SW NW Sec. 24, T. 11 N., R. 8 E.

7. Gillespie & Sons, Weltie-Curby No. 1
NE NW NE Sec. 24, T. 11 N., R. 8 E.

8. Newt-Barrett, Bean No. 1
   NE NE NE Sec. 19, T. 11 N., R. 8 E.

9. F. L. Coogan, Davis No. 1
   SW SE NE Sec. 20, T. 11 N., R. 9 E.

10. Skelly Oil Co., Wesley No. 1
    SW SW NW Sec. 21, T. 11 N., R. 9 E.

11. Crabbe-Stevens & Emrke, Boatman No. 1
    NE NE SW Sec. 22, T. 11 N., R. 9 E.

12. Mapco, Inc., Ommen No. 1
    NW NE Sec. 23, T. 11 N., R. 9 E.

13. Wood Oil Co., Ogden No. 1
    SW SW NW Sec. 24, T. 11 N., R. 9 E.

14. Petco Oil & Gas, Inc., Cowen No. 1
    NE NW NE Sec. 24, T. 11 N., R. 9 E.

VITA 2

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Biographical:

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Education: Graduated from Red Rock High School, Red Rock, Oklahoma, in May, 1974; received Bachelor of Science degree in Geology from Oklahoma State University, Stillwater, Oklahoma, in July, 1979; completed requirements for a Master of Science degree at Oklahoma State University in July, 1985 with a major in Geology.

Professional Experience: Exploration Geologist, Earth Energy Resources, Inc., 1981-1982; Independent Consultant, Stillwater, Oklahoma, 1982-present. Active member of the American Association of Petroleum Geologists; member of the Oklahoma City Geological Society; member of the Society of Professional Well Log Analysts.

NORTH–SOUTH CORRELATION SECTION A–A'

Datum: Base of Oswego Limestone

100'
VERTICAL SCALE
0

= Possible Channel-fill Sandstone

T 13 N
T 12 N
T 11 N
R 8 E
R 9 E

DALE REED COCKRELL, 1985

PLATE 1

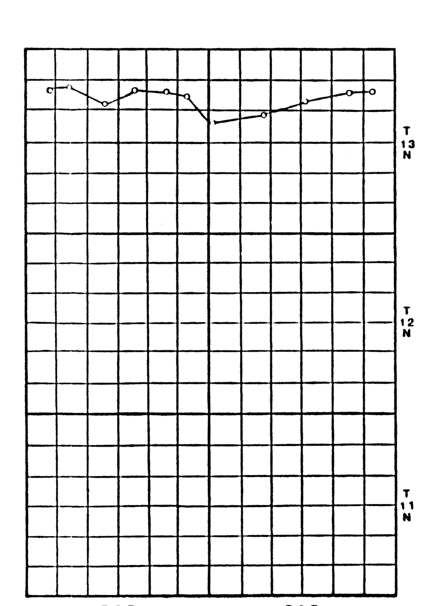
NORTH SOUTH CORRELATION SECTION B–B'
Datum: Base of Oswego Limestone

DALE REED COCKRELL, 1985
PLATE 2

WEST-EAST CORRELATION SECTION C-C′
Datum: Base of Oswego Limestone

100′
VERTICAL SCALE
0

= Possible Channel-fill Sandstone



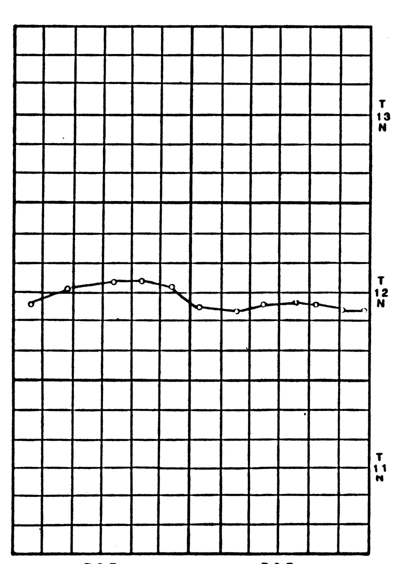
DALE REED COCKRELL, 1985
PLATE 3

WEST-EAST CORRELATION SECTION D-D'

Datum: Base of Oswego Limestone

100'
VERTICAL SCALE
0

= Possible Channel-fill Sandstone



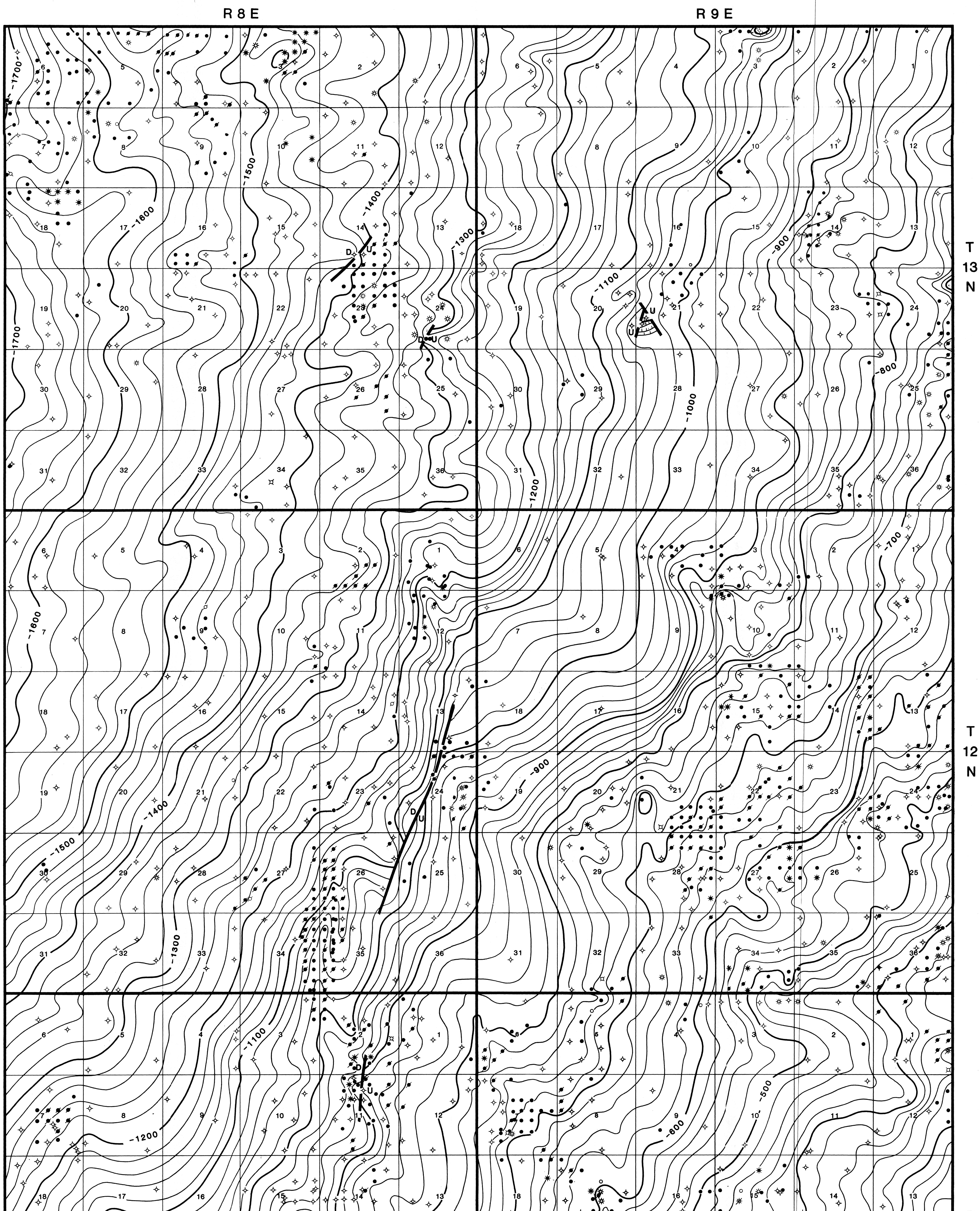
DALE REED COCKRELL, 1985
PLATE 4

WEST-EAST CORRELATION SECTION E-E'
Datum: Base of Oswego Limestone

100
VERTICAL SCALE
0

= Possible Channel-fill Sandstone

DALE REED COCKRELL, 1985
PLATE 5



STRUCTURAL CONTOUR MAP
Datum: Base of Oswego Limestone

C.I. – 20′

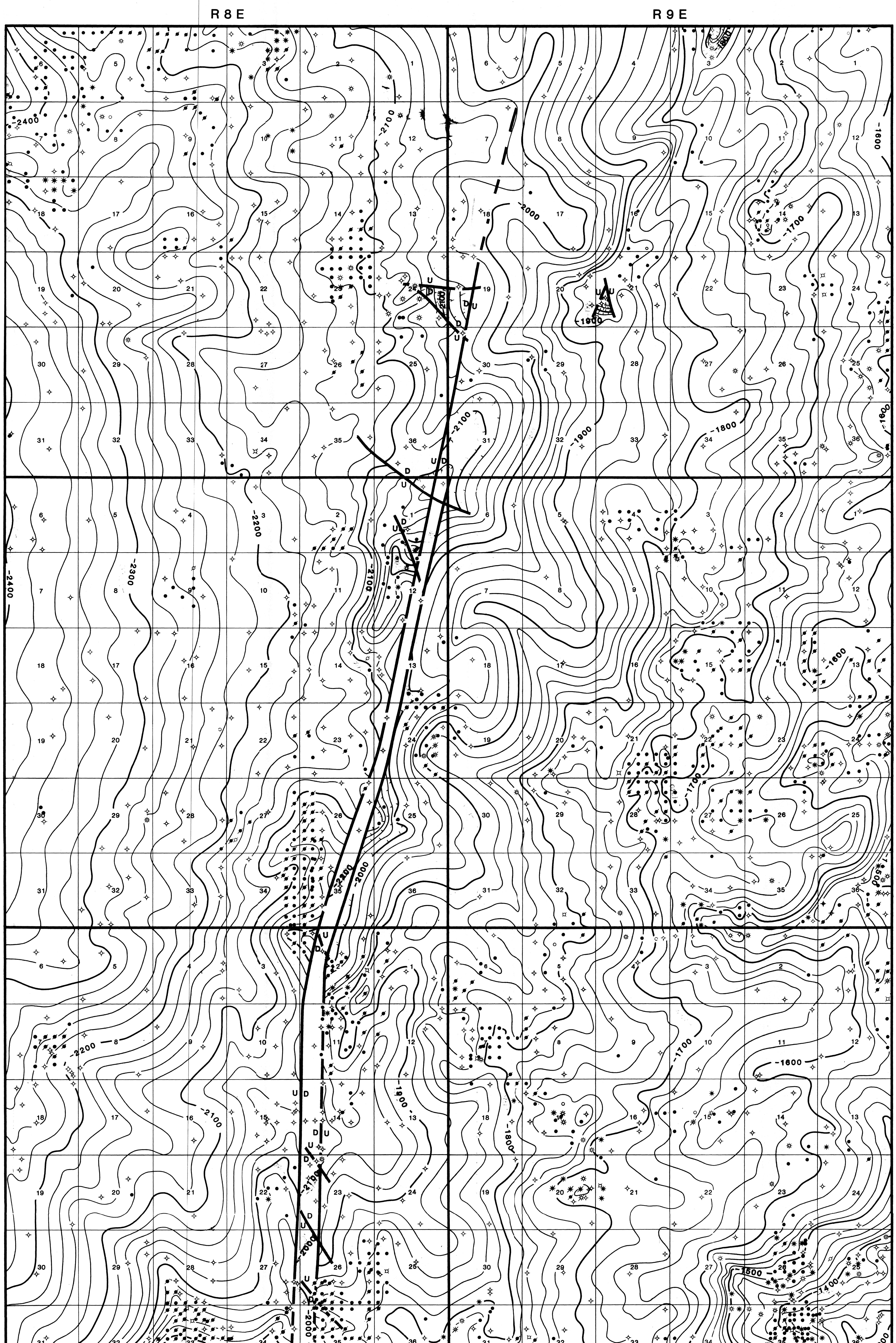
N

1 MILE 0 1 MILE

SCALE: 2″ – 1 MILE

Dale Reed Cockrell, 1985

Plate 6



STRUCTURAL CONTOUR MAP
Datum: Base of Inola Limestone

C.I. – 20′

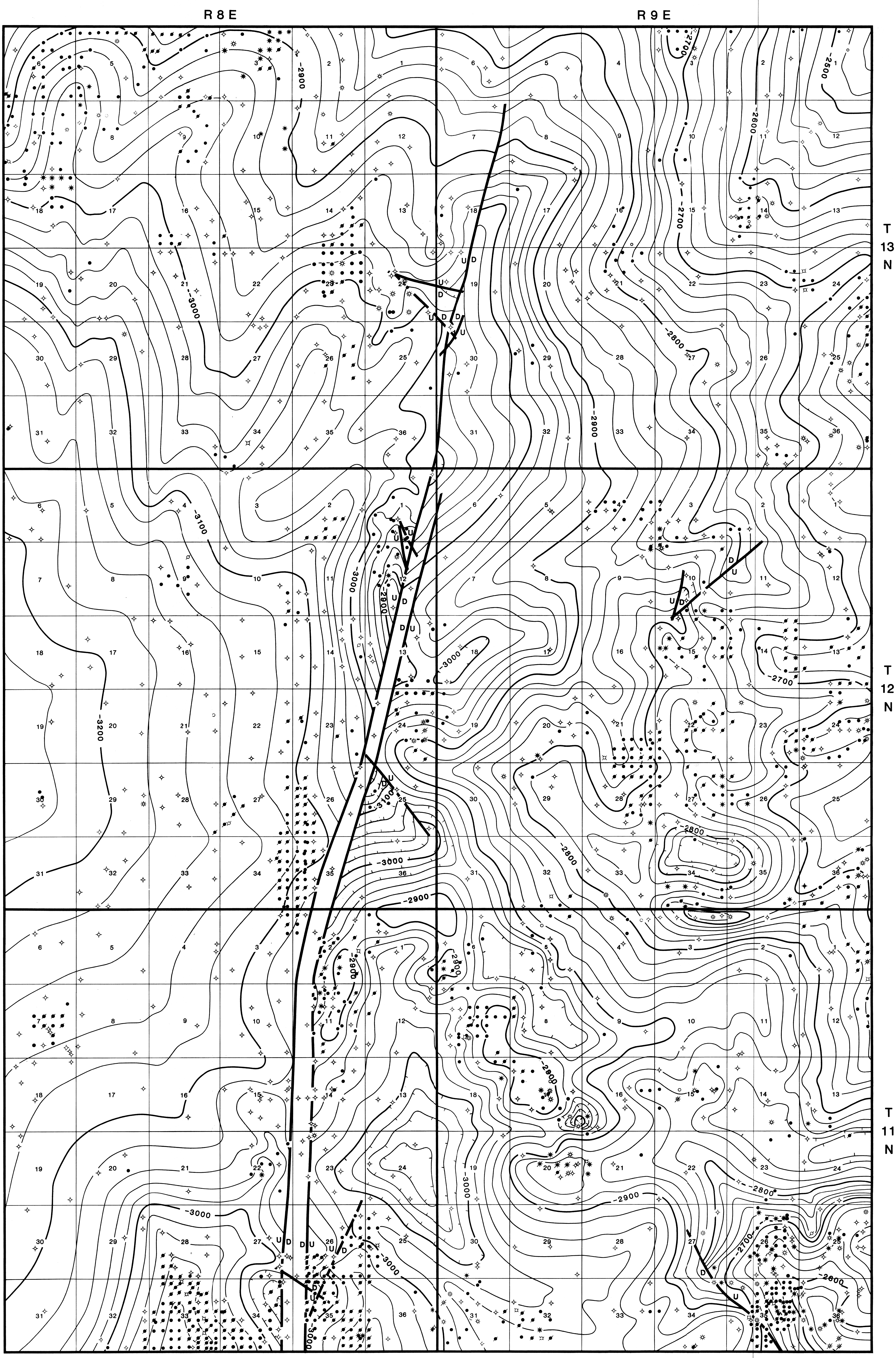
N

1 MILE 0 1 MILE

SCALE: 2″ – 1 MILE

Dale Reed Cockrell, 1985

Plate 7



STRUCTURAL CONTOUR MAP

Top of Mayes Limestone

C.I. – 20′

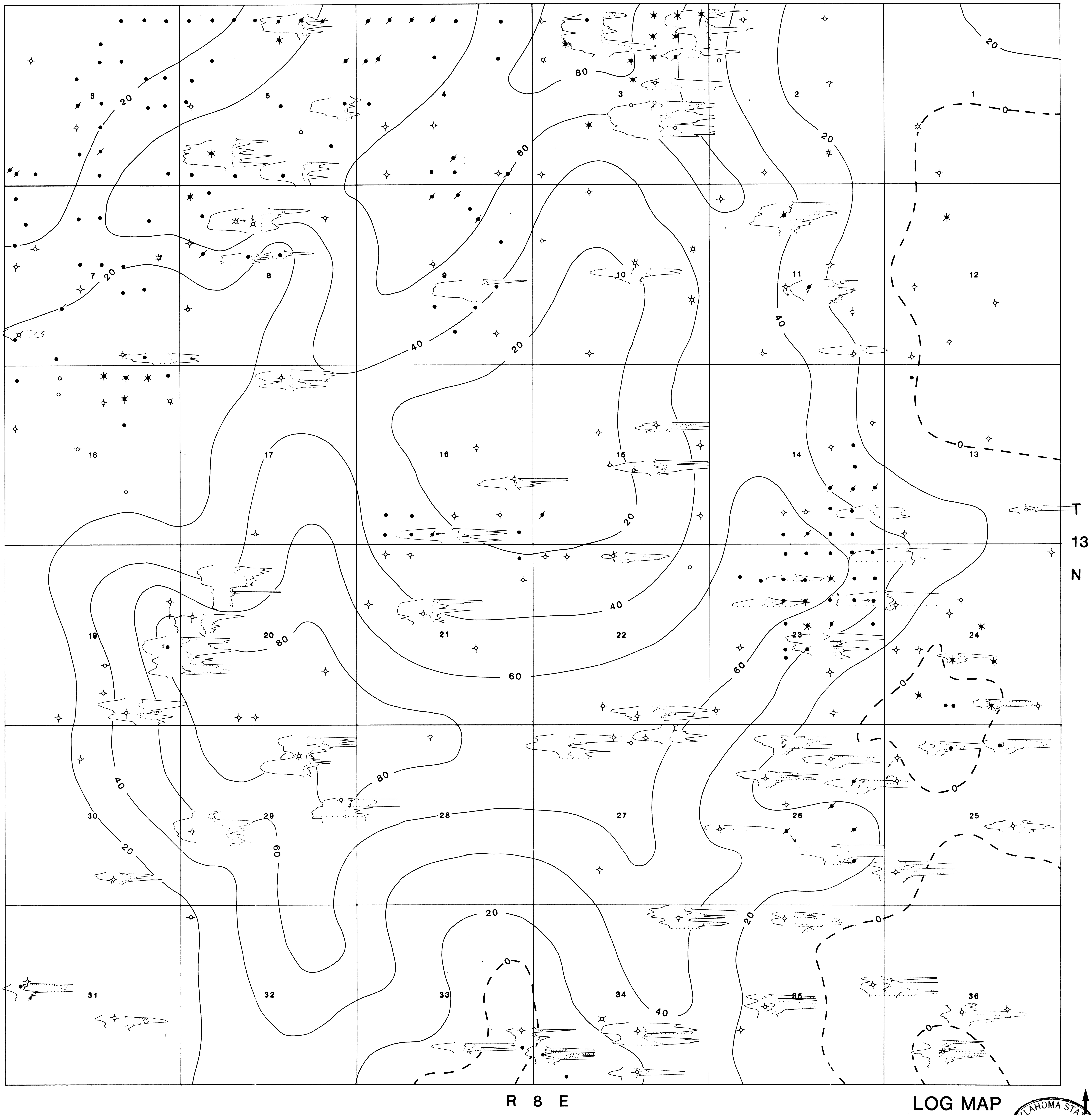
N

1 MILE 0 1 MILE

SCALE: 2″ – 1 MILE

Dale Reed Cockrell, 1985

Plate 8



LOG MAP
CROMWELL SANDSTONE
Datum: Top of Cromwell Interval

Vertical Scale: 0' – 100'

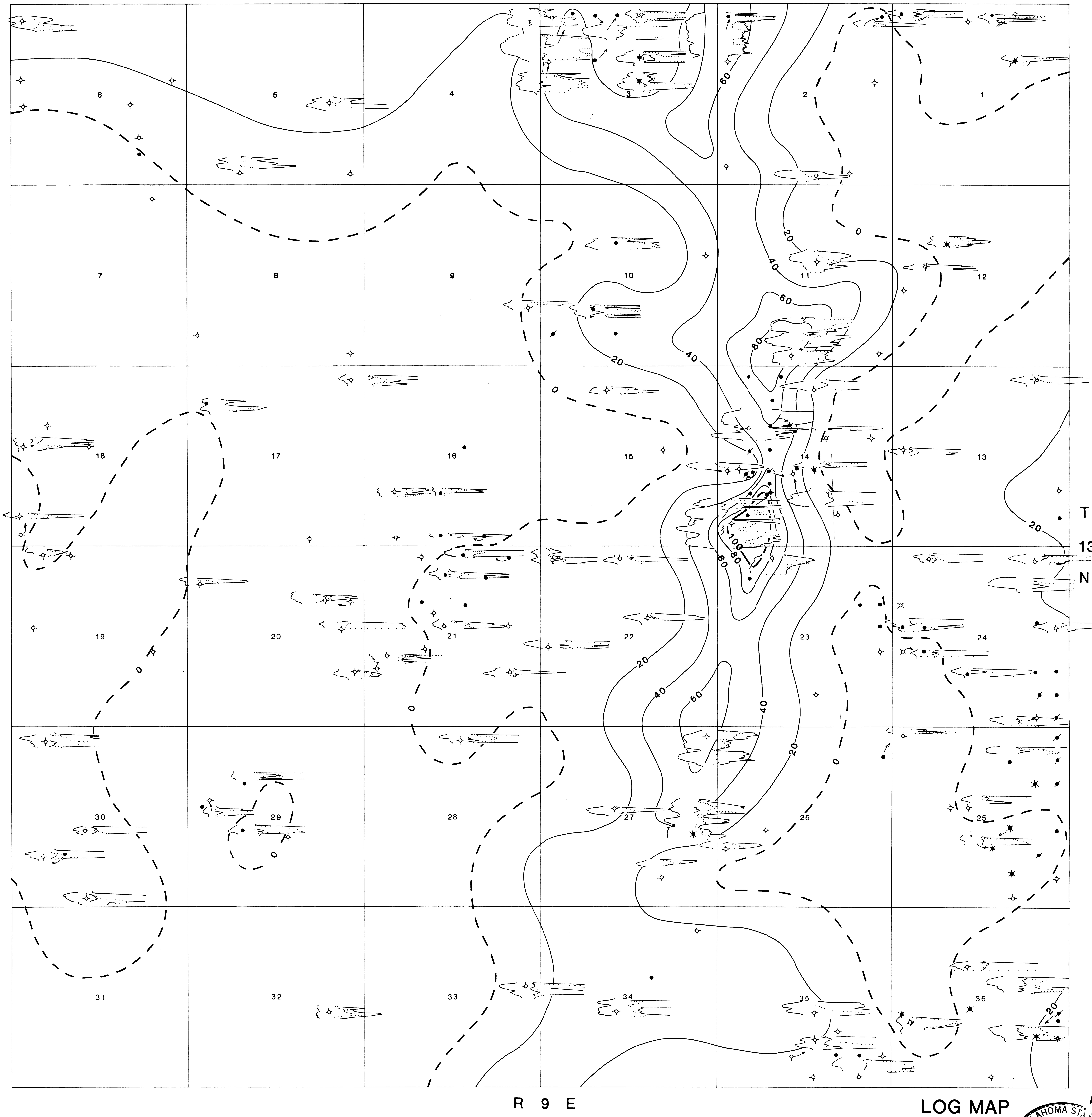
1 : 15,840

0 — 1/2 — 1 mile

EXPLANATION

P: PHANTOM MARKER
†: SIMILAR LOG CHARACTER

Dale Reed Cockrell, 1985
Plate 9a



LOG MAP

CROMWELL SANDSTONE

Datum: Top of Cromwell Interval

Vertical Scale
100'
0'

1 : 15,840
0 1/2 1 mile

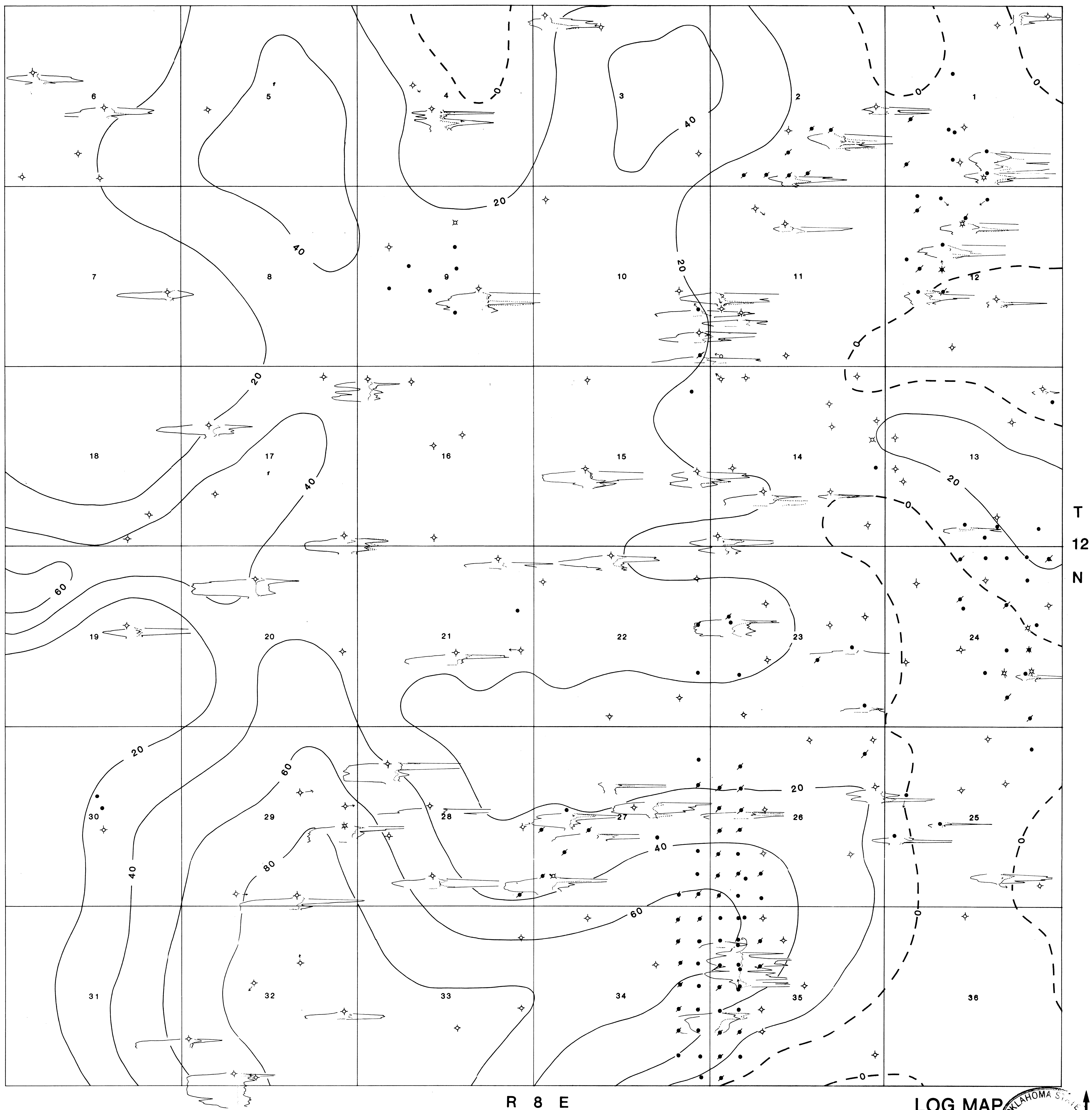
EXPLANATION

P: PHANTOM MARKER
?: SIMILAR LOG CHARACTER
C.I.: 20'

N

Dale Reed Cockrell, 1985

Plate 9b



LOG MAP
CROMWELL SANDSTONE
Datum: Top of Cromwell Interval

100'

Vertical Scale

0'

1 : 15,840

0 1/2 1 mile

EXPLANATION

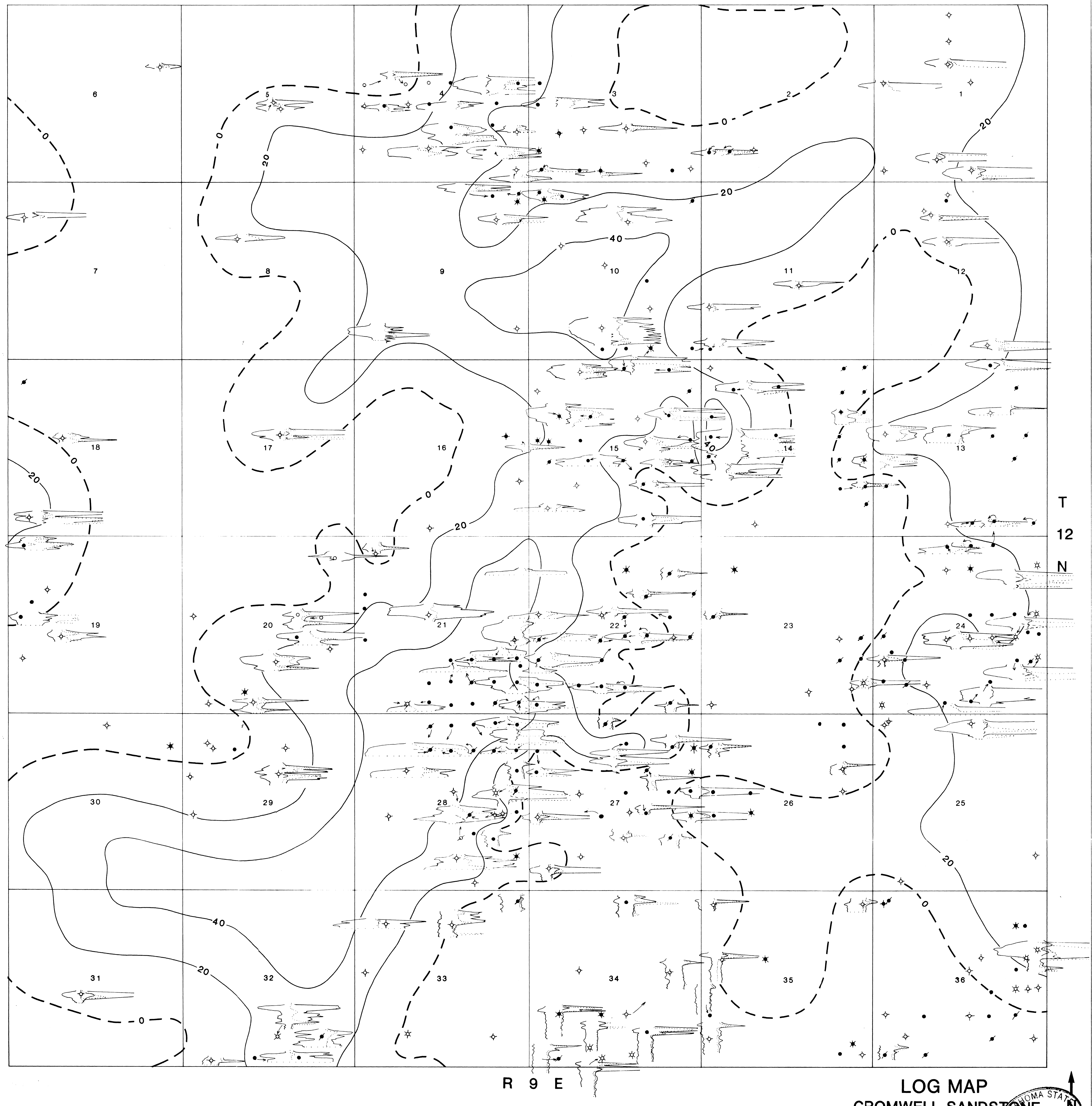
P: PHANTOM MARKER

↑: SIMILAR LOG CHARACTER

C.I.: 20'

Dale Reed Cockrell, 1985

Plate 9c



LOG MAP

CROMWELL SANDSTONE

Datum: Top of Cromwell Interval

Vertical Scale: 100' – 0'

1 : 15,840

0 — 1/2 — 1 mile

EXPLANATION

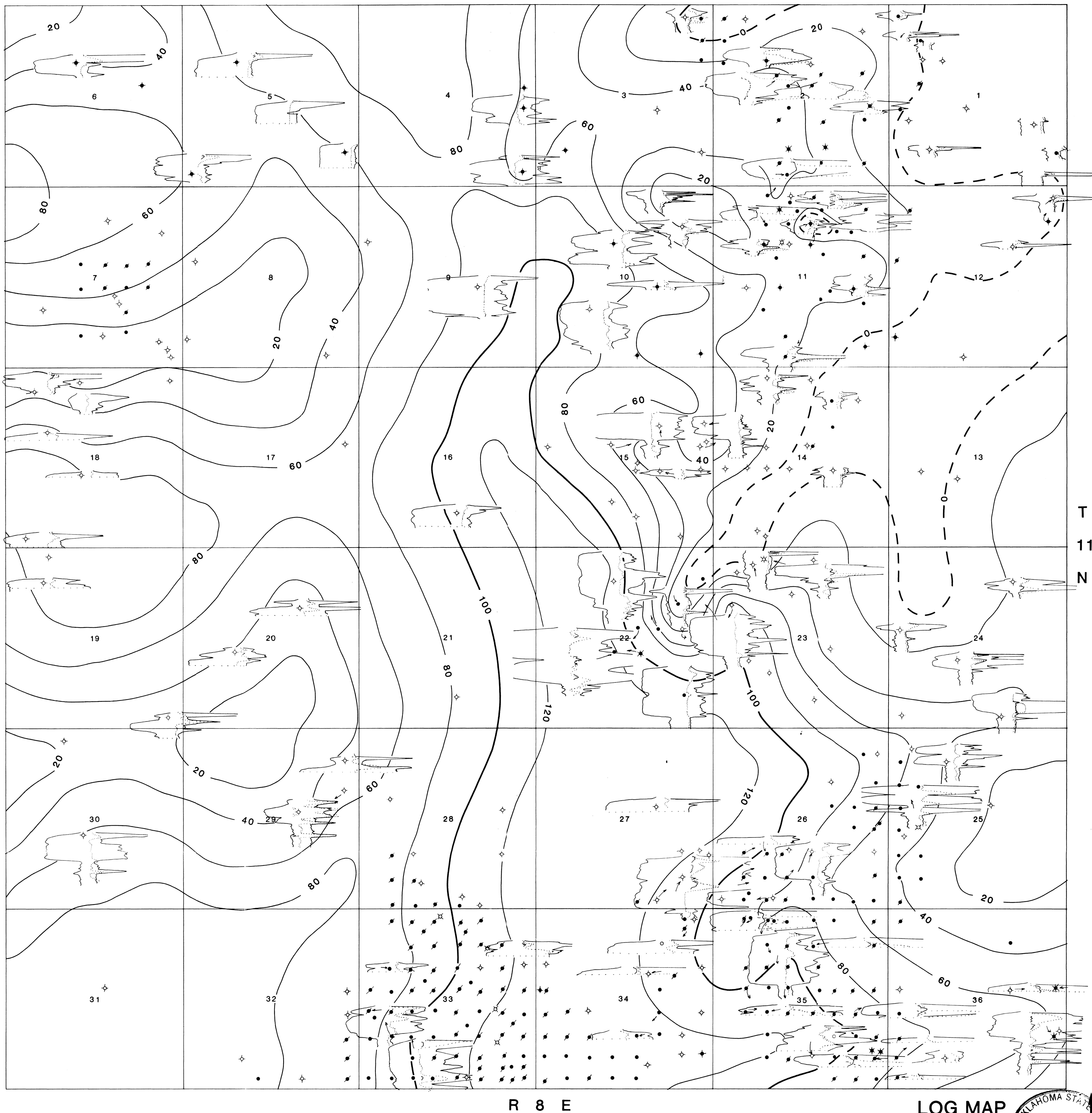
P: PHANTOM MARKER

?: SIMILAR LOG CHARACTER

C.I.: 20'

Dale Reed Cockrell, 1985

Plate 9d



LOG MAP
CROMWELL SANDSTONE
Datum: Top of Cromwell Interval

Vertical Scale
100'
0'

1 : 15,840
0 1/2 1 mile

EXPLANATION

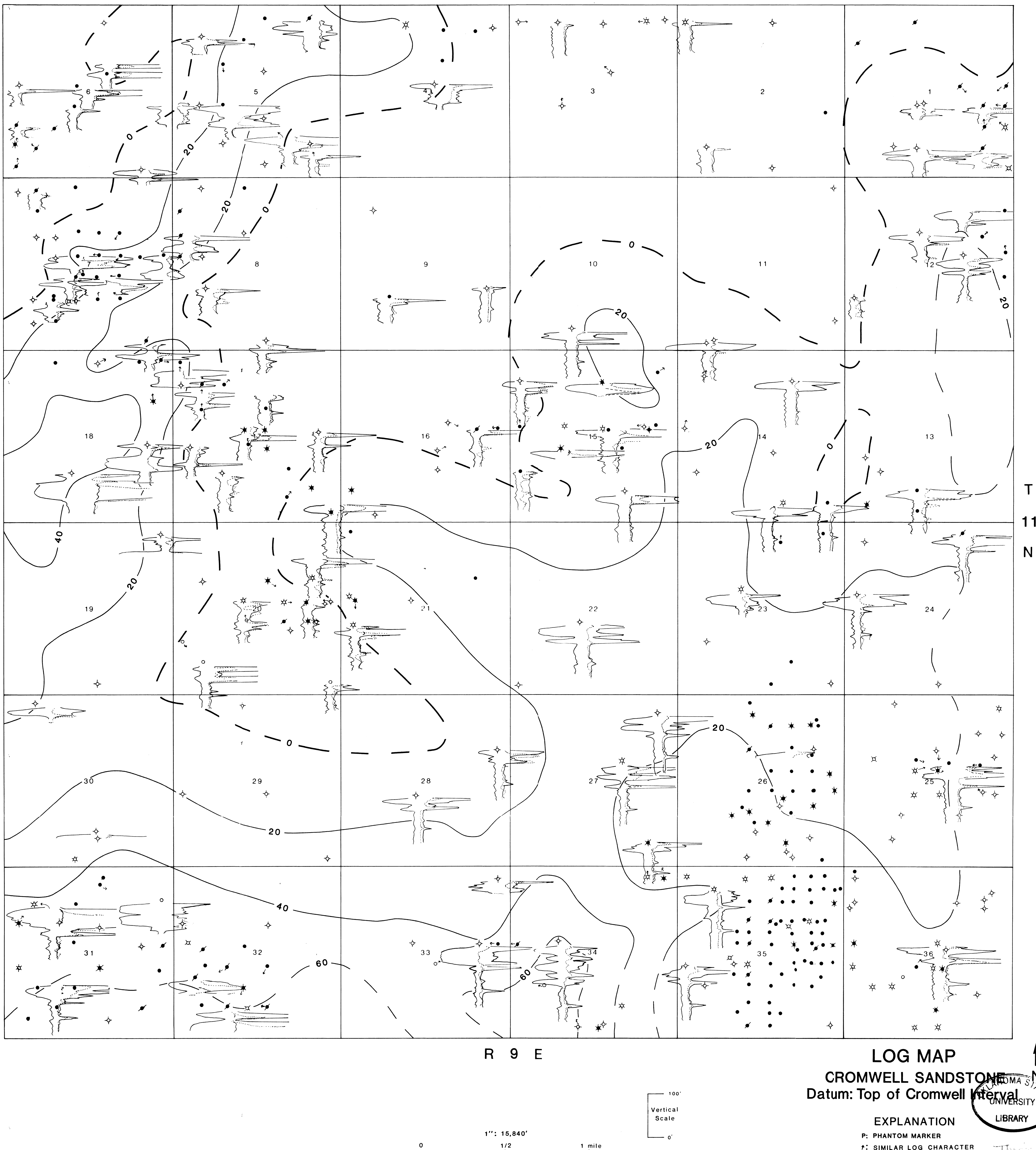
P: PHANTOM MARKER

†: SIMILAR LOG CHARACTER

C.I.: 20'

Dale Reed Cockrell, 1985

Plate 9e



LOG MAP

CROMWELL SANDSTONE

Datum: Top of Cromwell Interval

EXPLANATION

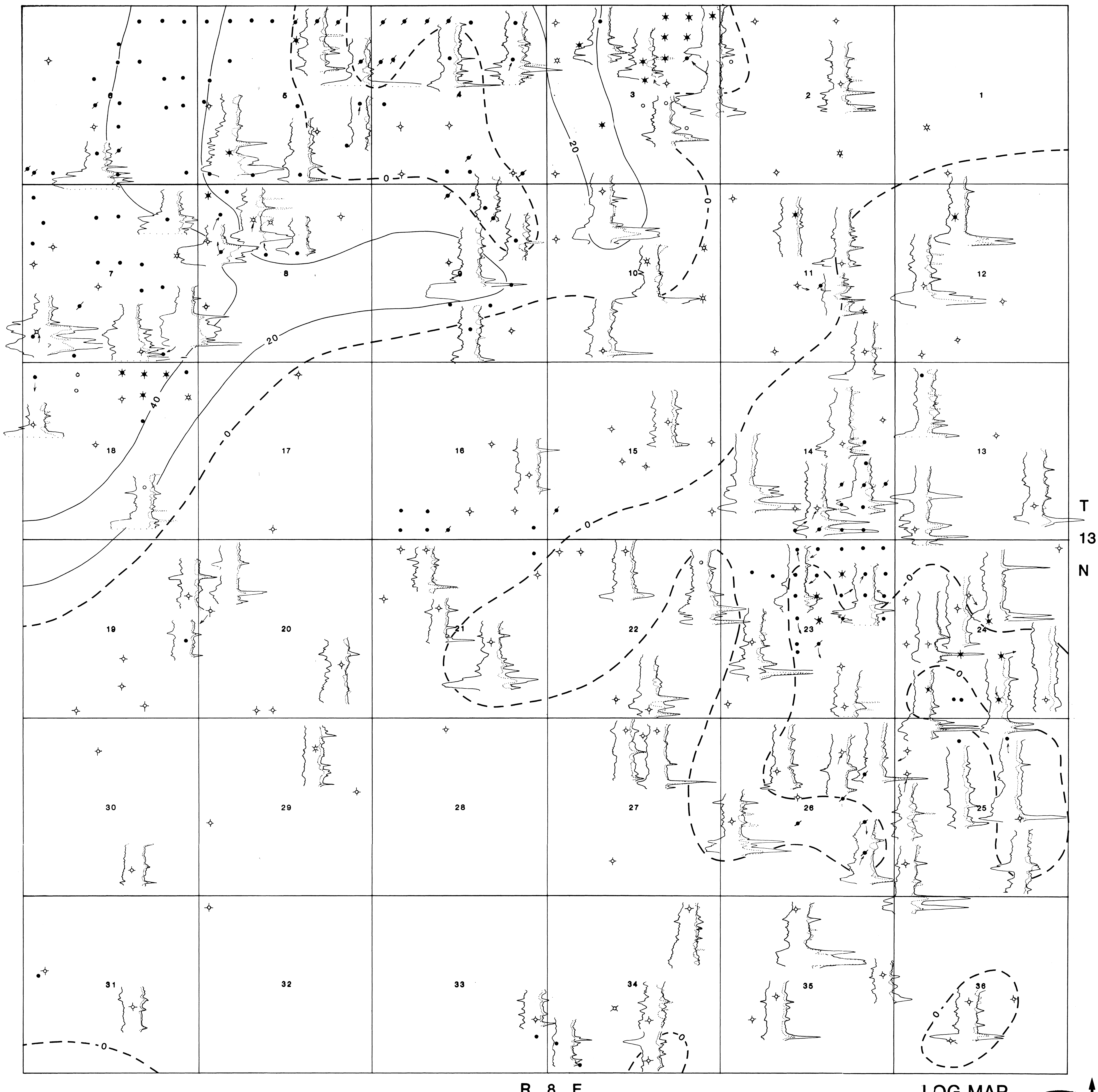
P: PHANTOM MARKER

↑: SIMILAR LOG CHARACTER

C.I.: 20'

Dale Reed Cockrell, 1985

Plate 9f



LOG MAP

GILCREASE SANDSTONE

Datum: Top of Gilcrease Interval

100'

Vertical Scale

0'

1 : 15,840

0 1/2 1 mile

EXPLANATION

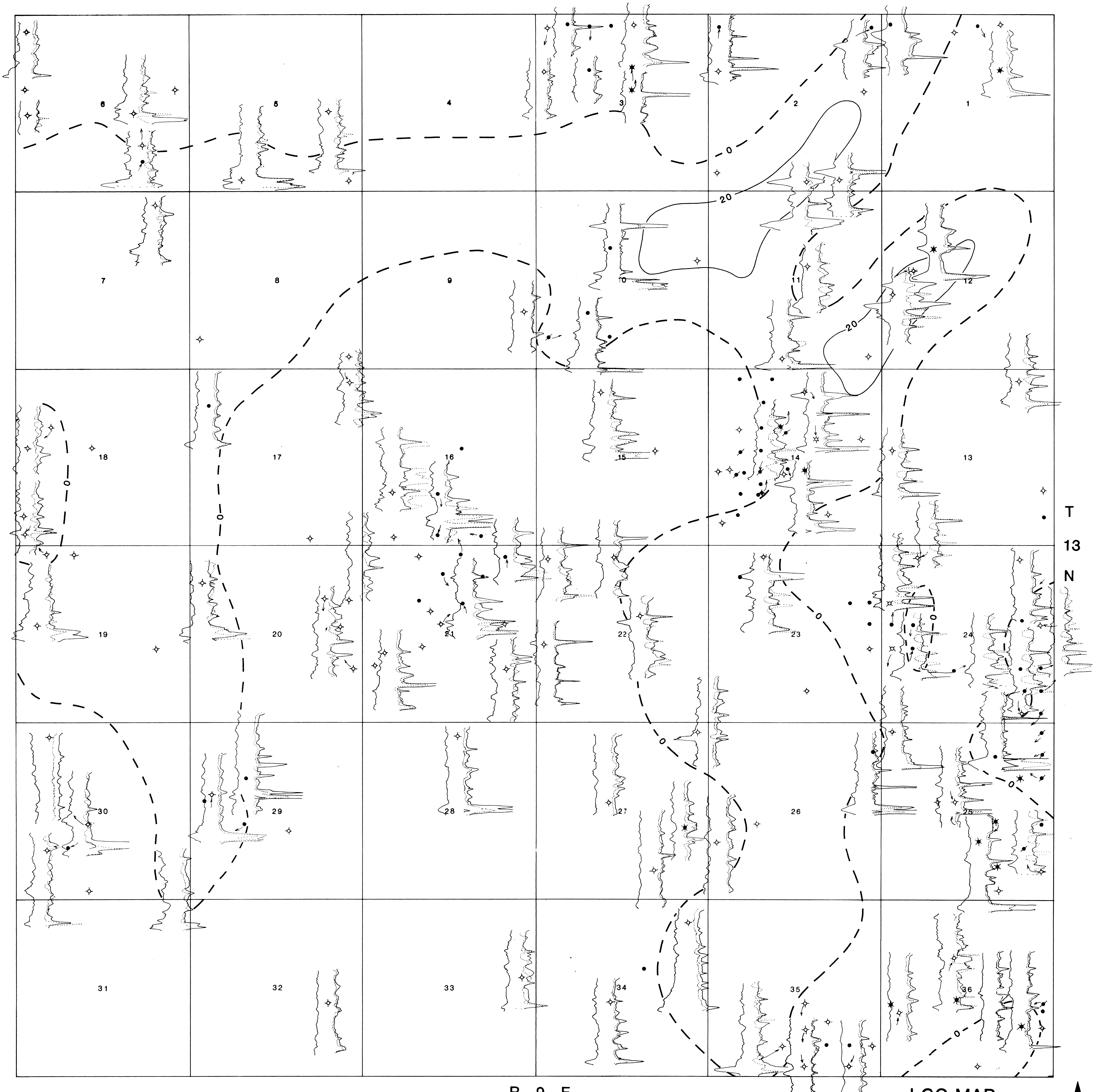
P: PHANTOM MARKER

↑: SIMILAR LOG CHARACTER

C.I.: 20'

Dale Reed Cockrell, 1985

Plate 10 a



LOG MAP

GILCREASE SANDSTONE

Datum: Top of Gilcrease Interval

N

100'

Vertical Scale

0'

1 : 15,840

0 1/2 1 mile

EXPLANATION

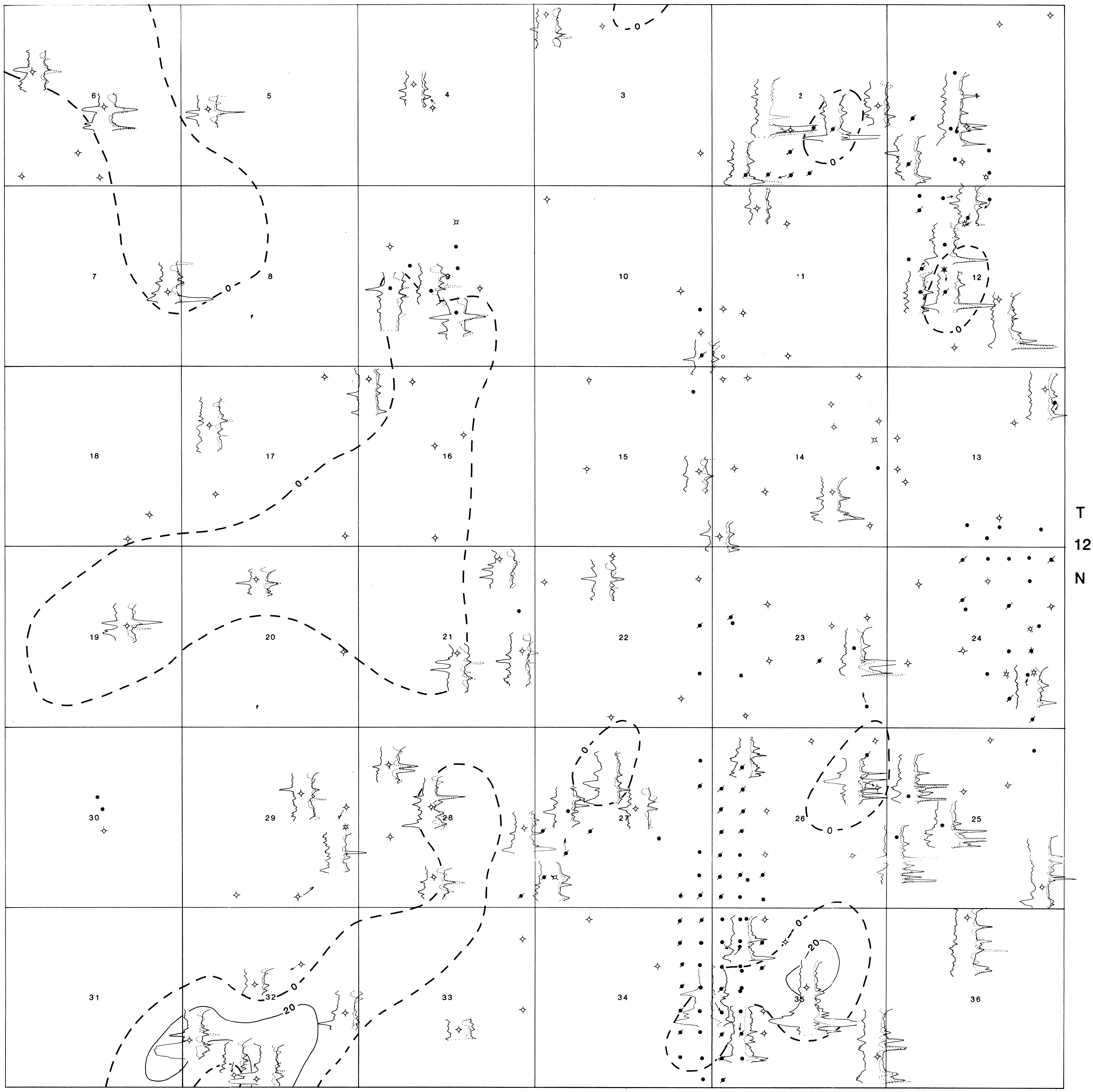
P: PHANTOM MARKER

?: SIMILAR LOG CHARACTER

C.I.: 20'

Dale Reed Cockrell, 1985

Plate 10 b



LOG MAP

GILCREASE SANDSTONE

Datum: Top of Gilcrease Interval

N

Vertical Scale
100'
0'

1 : 15,840

0 1/2 1 mile

EXPLANATION

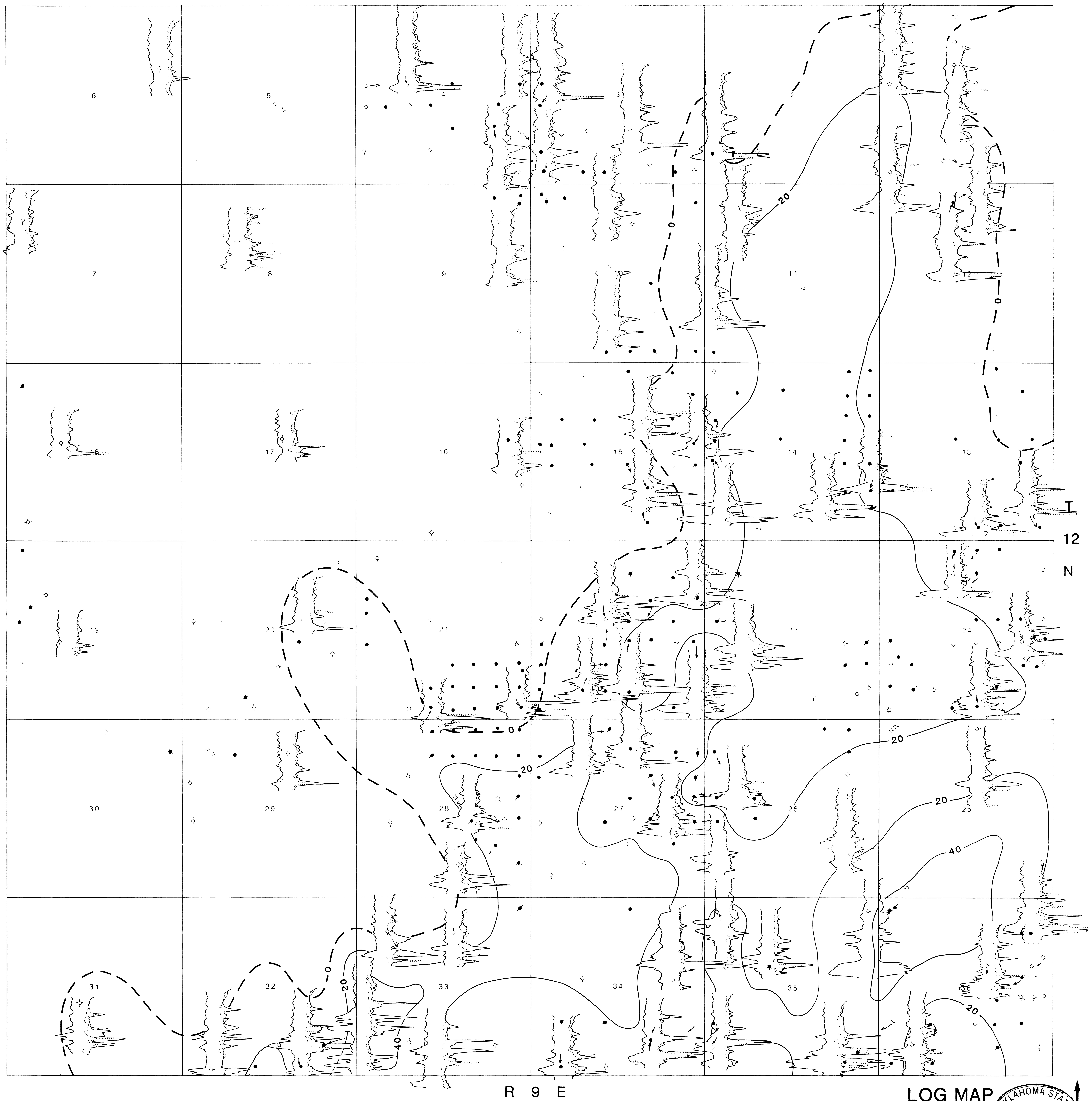
P: PHANTOM MARKER

↑: SIMILAR LOG CHARACTER

C.I.: 20'

Dale Reed Cockrell, 1985

Plate 10c



LOG MAP
GILCREASE SANDSTONE
Datum: Top of Gilcrease Interval

100'
Vertical Scale
0'

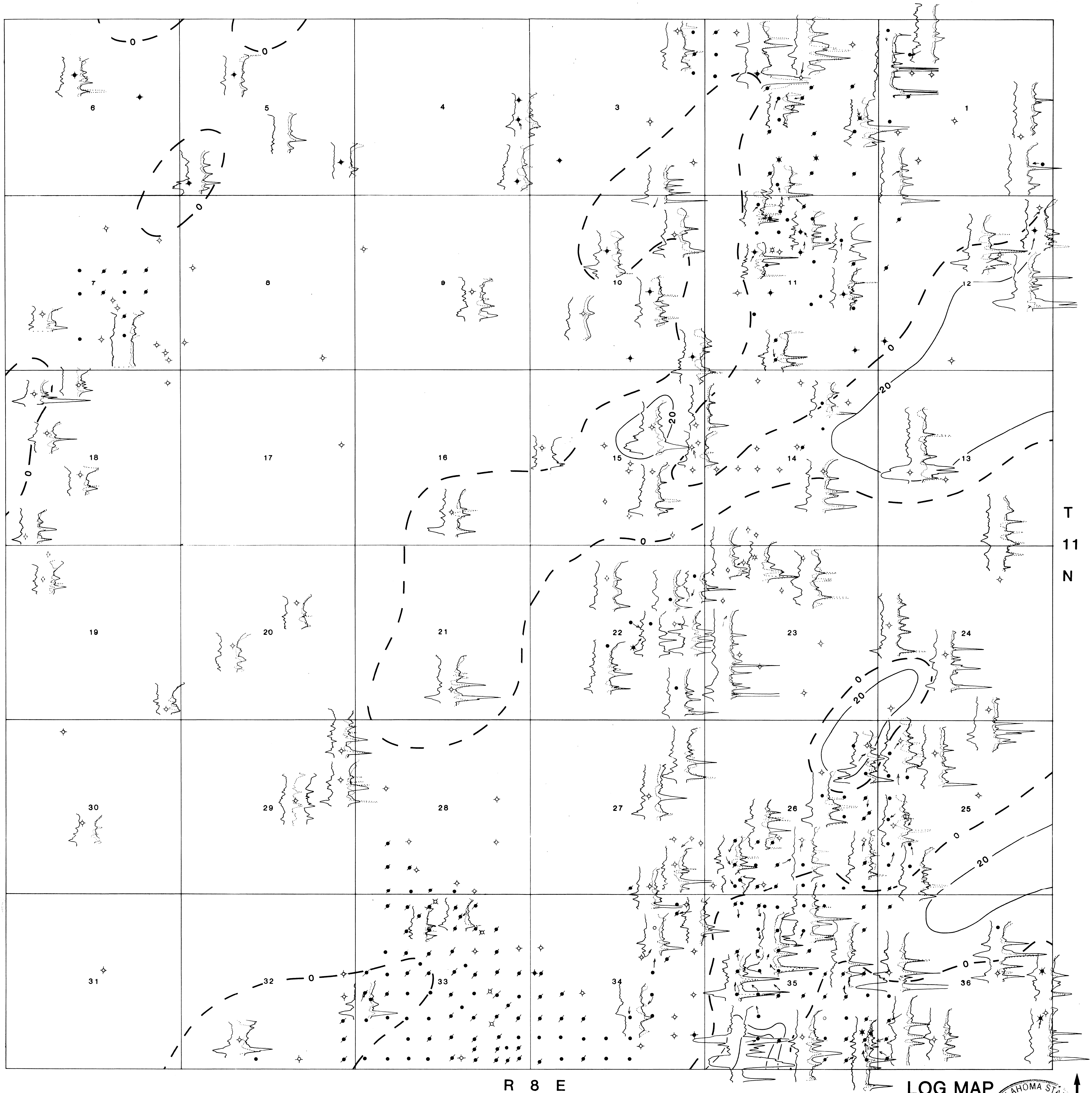
1 : 15,840
0 1/2 1 mile

EXPLANATION

P: PHANTOM MARKER
?: SIMILAR LOG CHARACTER
C.I.: 20'

Dale Reed Cockrell, 1985

Plate 10 d



LOG MAP
GILCREASE SANDSTONE
Datum: Top of Gilcrease Interval

100'
Vertical Scale
0'

1 : 15,840

0 1/2 1 mile

EXPLANATION

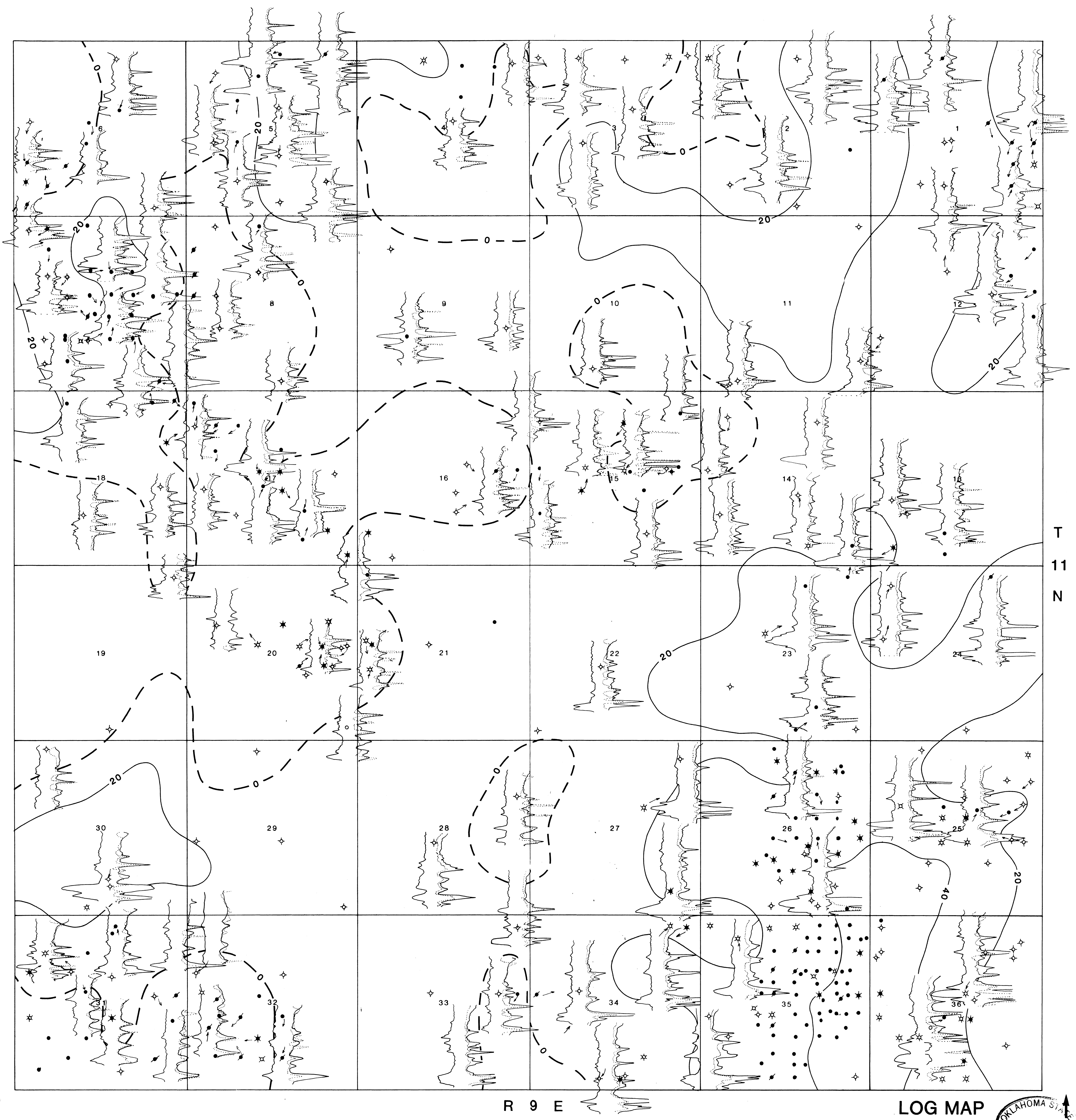
P: PHANTOM MARKER

↑: SIMILAR LOG CHARACTER

C.I.: 20'

Dale Reed Cockrell, 1985

Plate 10e



LOG MAP

GILCREASE SANDSTONE

Datum: Top of Gilcrease Interval

1 : 15,840

0 1/2 1 mile

EXPLANATION

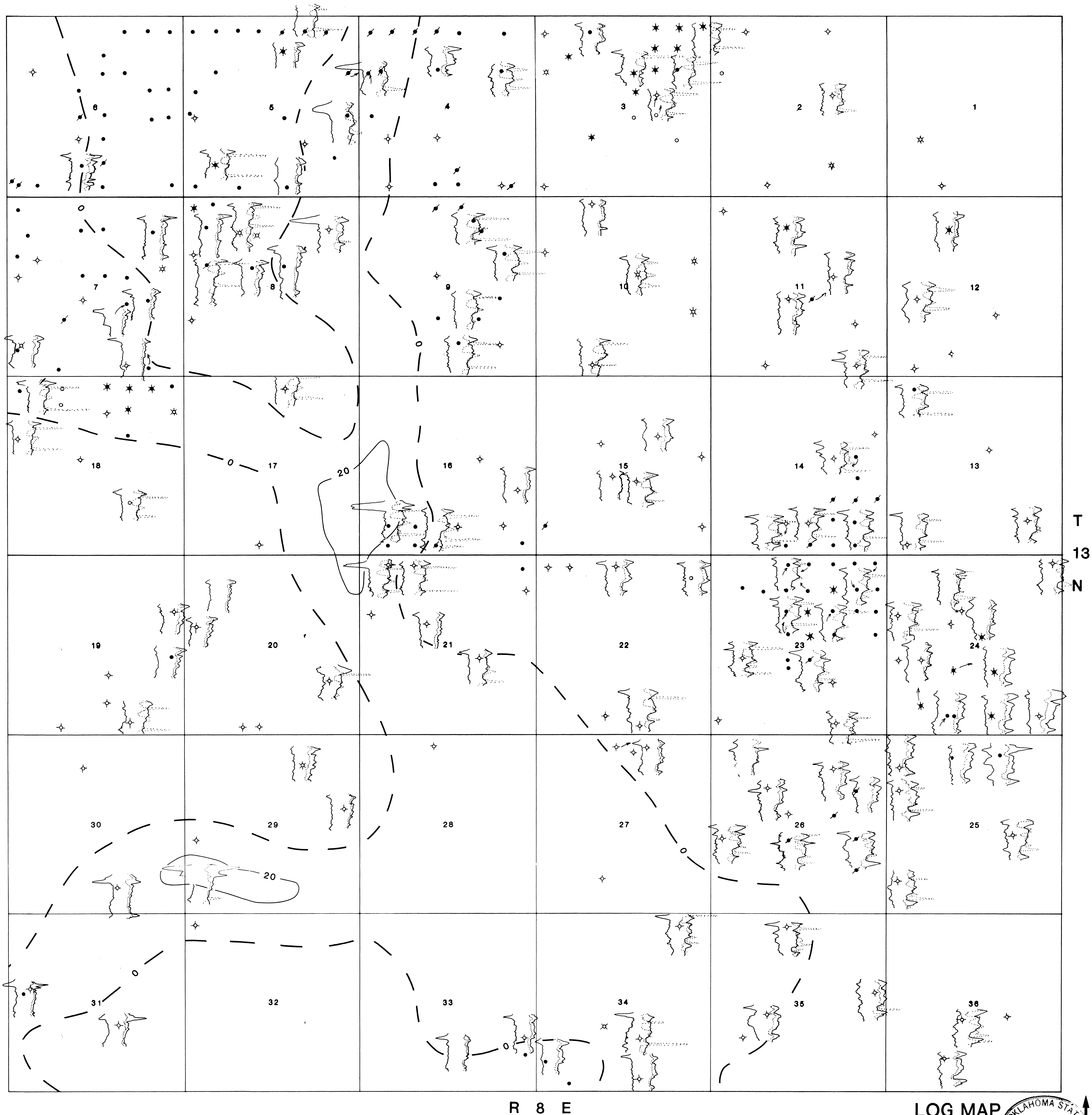
P: PHANTOM MARKER

↗: SIMILAR LOG CHARACTER

C.I.: 20'

Dale Reed Cockrell, 1985

Plate 10f



LOG MAP
BOOCH SANDSTONE
Datum: Top of Booch Interval

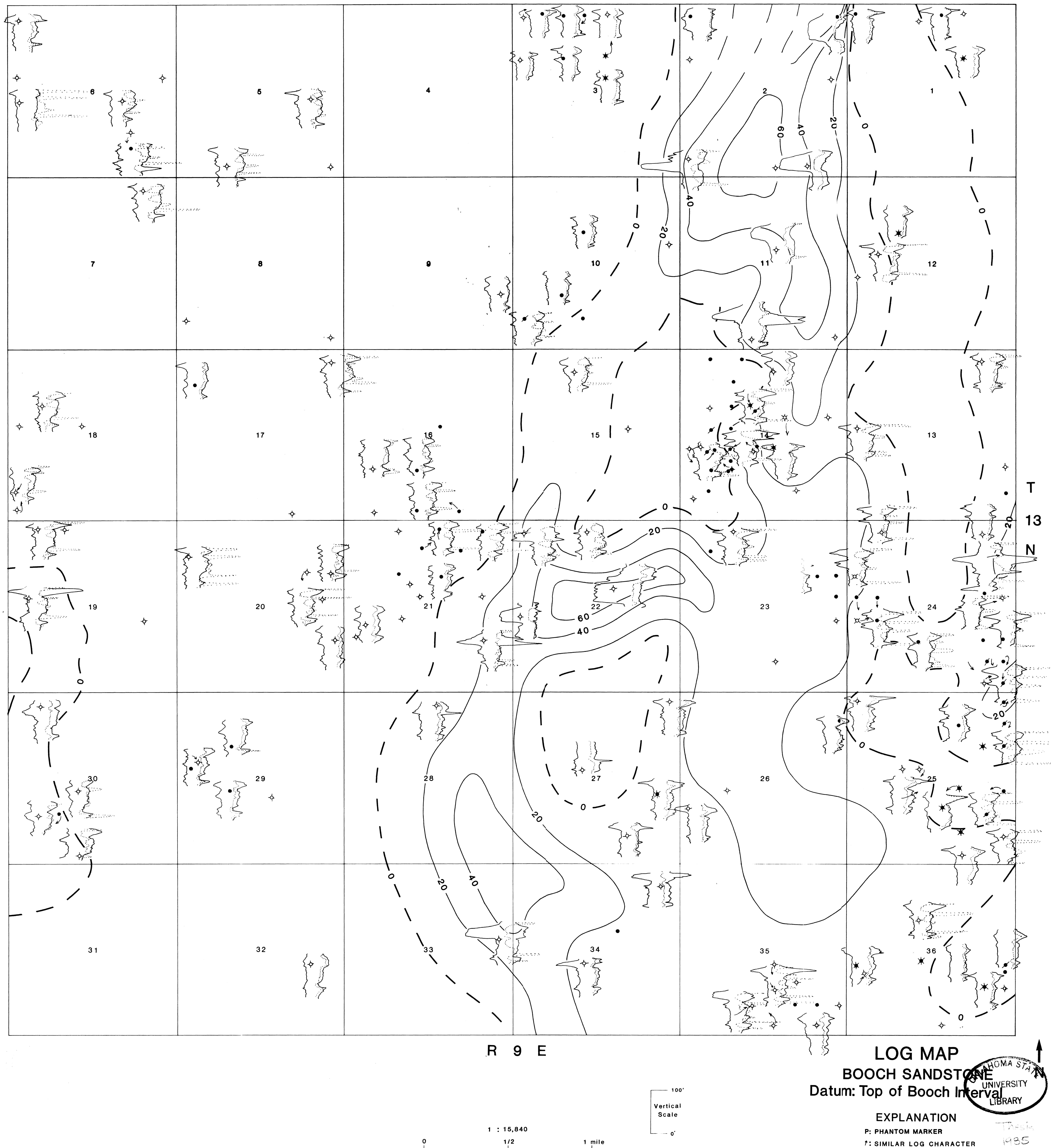
100'
Vertical Scale
0'

1 : 15,840
0 1/2 1 mile

EXPLANATION

P: PHANTOM MARKER
?: SIMILAR LOG CHARACTER
C.I.: 20'

Dale Reed Cockrell, 1985
Plate 11a



LOG MAP

BOOCH SANDSTONE

Datum: Top of Booch Interval

EXPLANATION

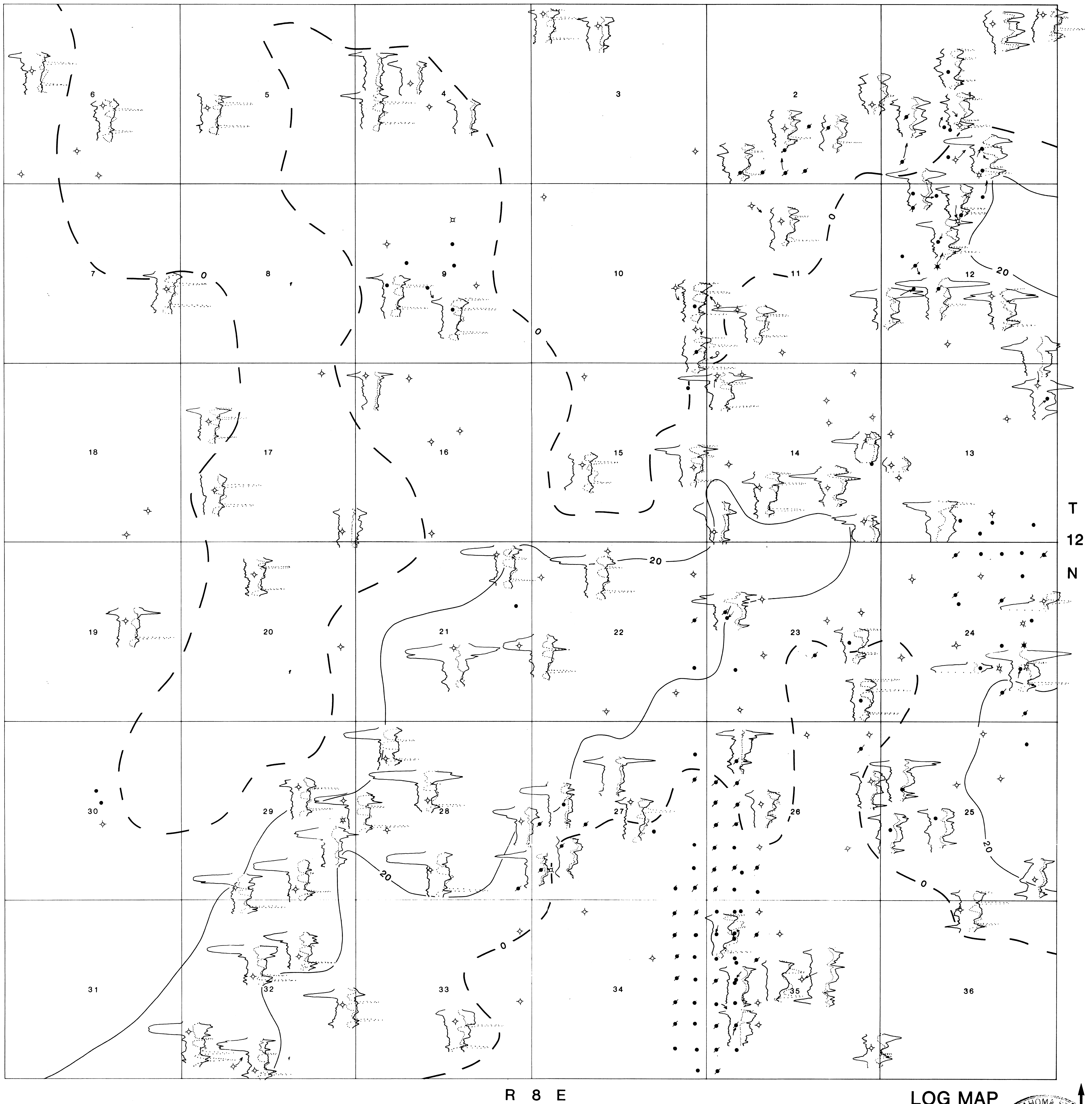
P: PHANTOM MARKER

?: SIMILAR LOG CHARACTER

C.I.: 20'

Dale Reed Cockrell, 1985

Plate 11b



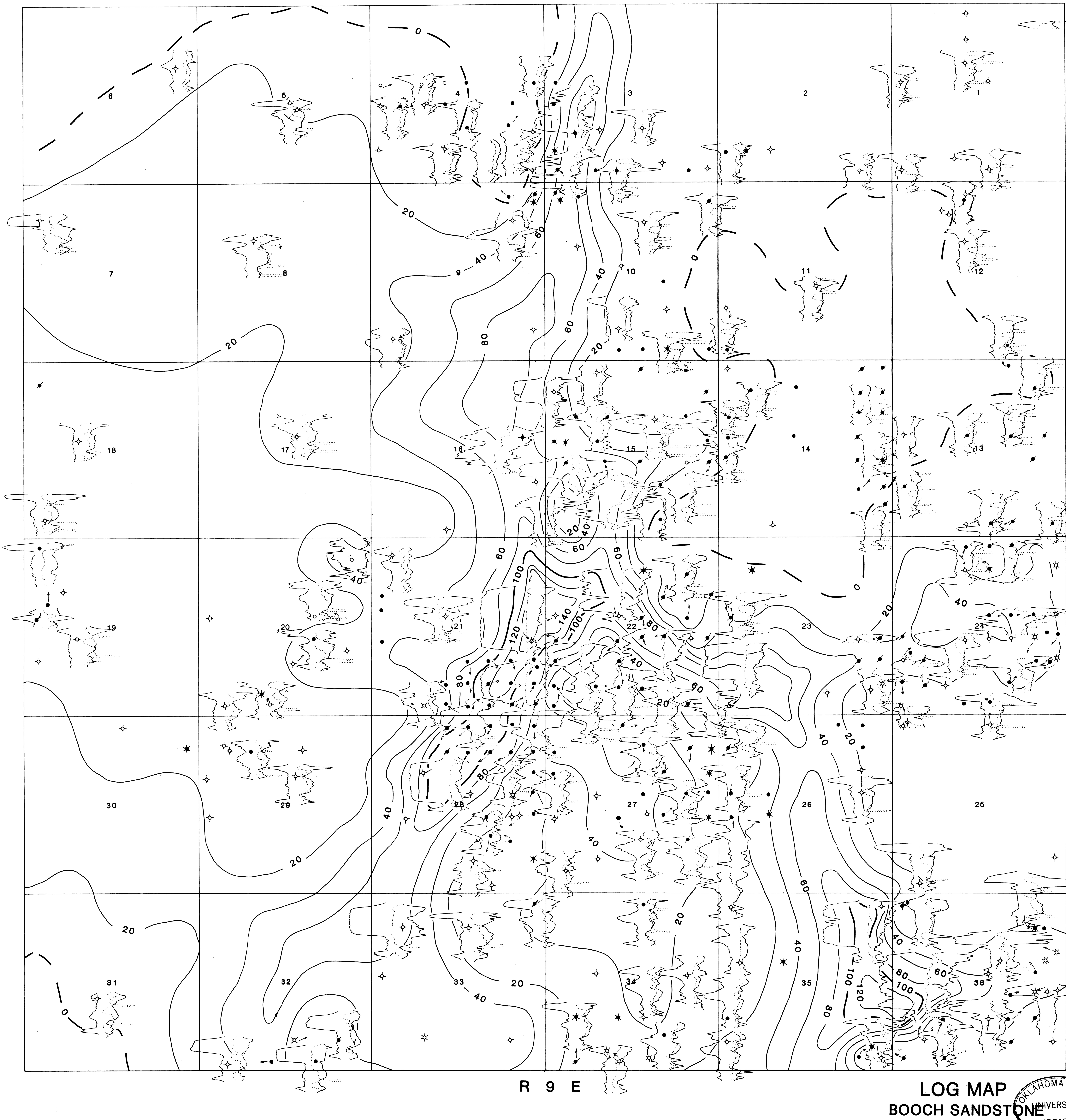
LOG MAP
BOOCH SANDSTONE
Datum: Top of Booch Interval

EXPLANATION

P: PHANTOM MARKER
↑: SIMILAR LOG CHARACTER
C.I.: 20'

Dale Reed Cockrell, 1985

Plate 11c



LOG MAP
BOOCH SANDSTONE
Datum: Top of Booch Interval

N

100'
Vertical Scale
0'

1 : 15,840

0 1/2 1 mile

EXPLANATION

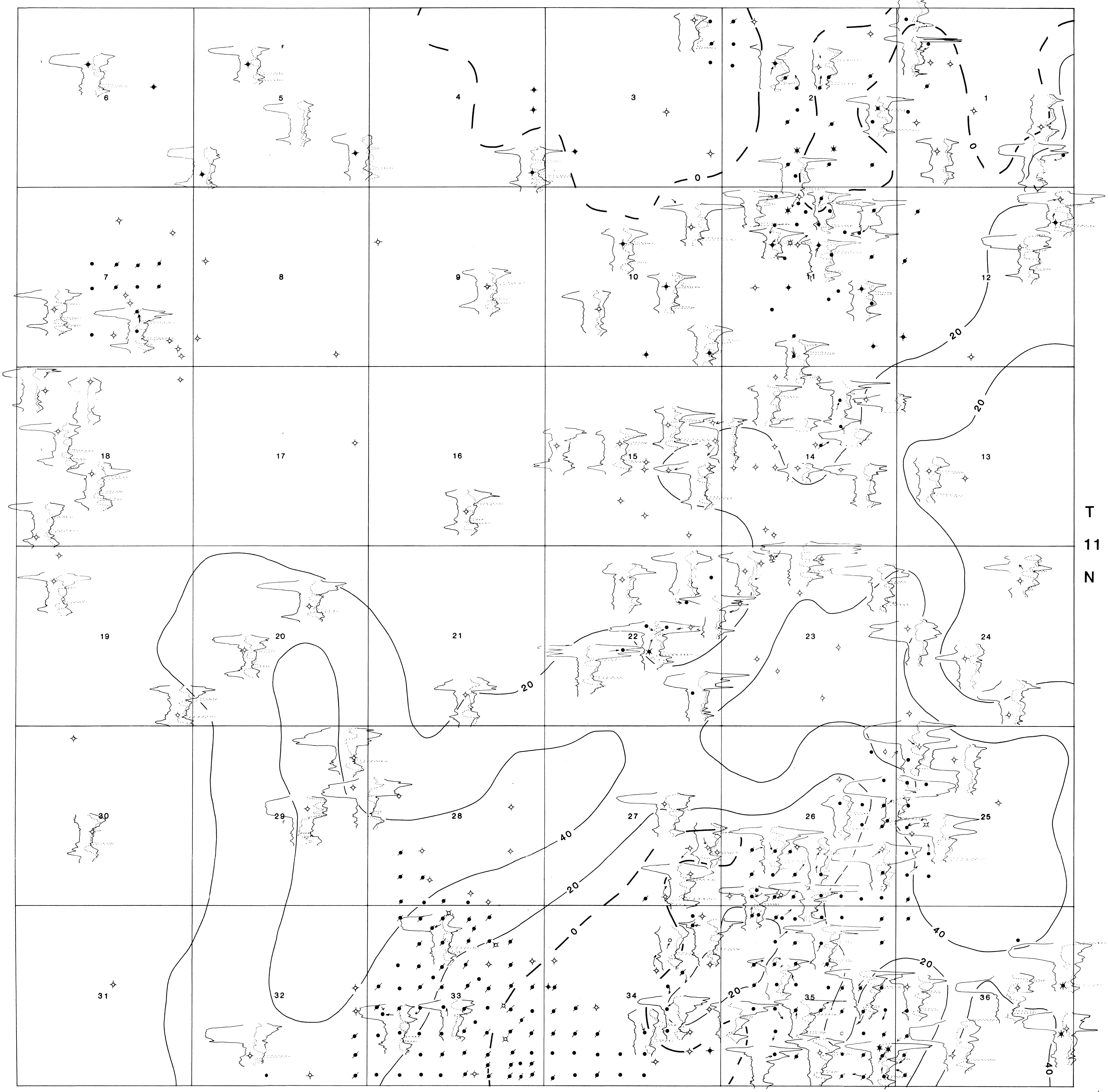
P: PHANTOM MARKER

?: SIMILAR LOG CHARACTER

C.I.: 20'

Dale Reed Cockrell, 1985

Plate 11d



LOG MAP

BOOCH SANDSTONE

Datum: Top of Booch Interval

100'
Vertical Scale
0'

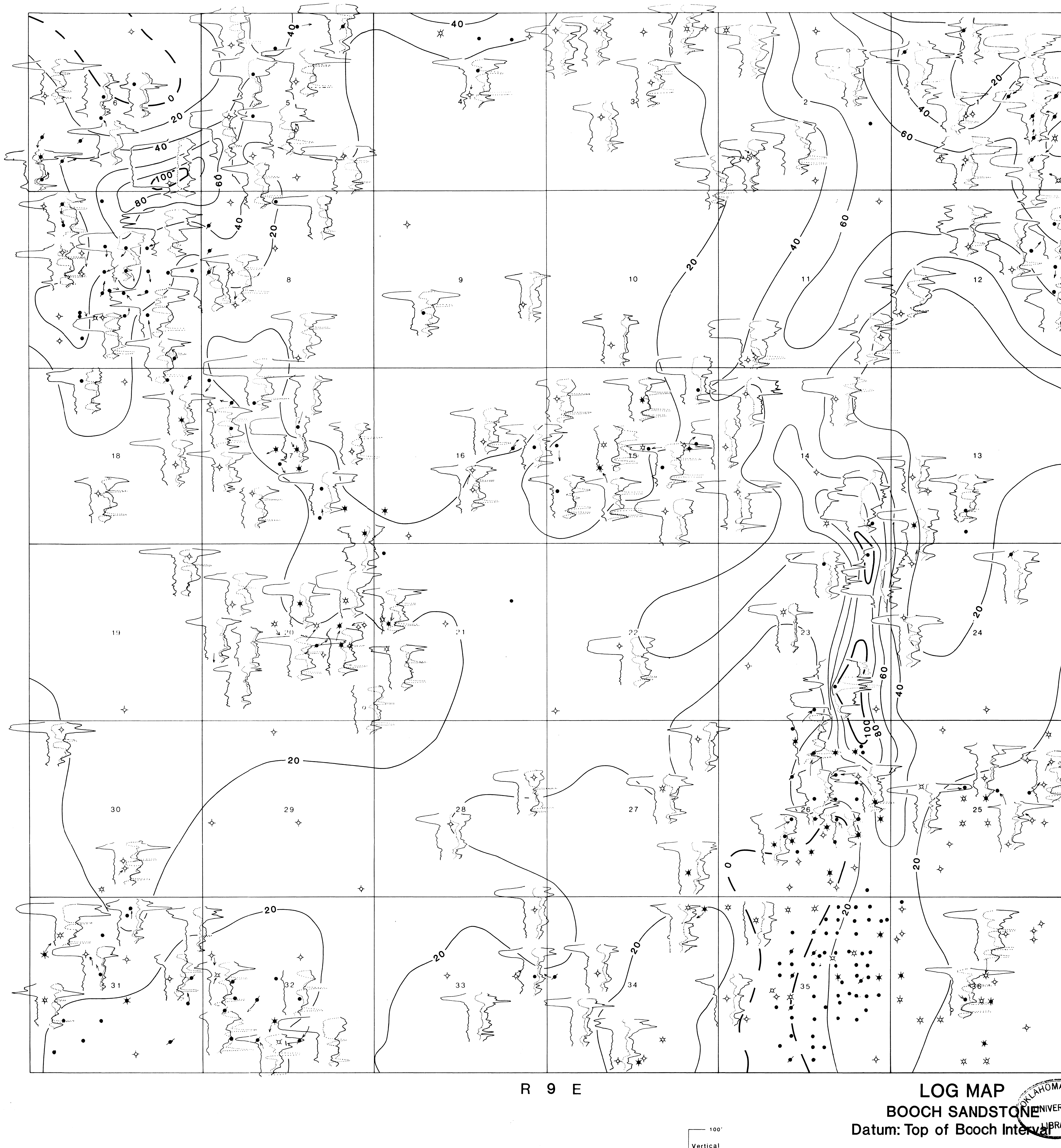
1": 15,840'
0 1/2 1 mile

EXPLANATION

P: PHANTOM MARKER
↑: SIMILAR LOG CHARACTER
C.I.: 20'

Dale Reed Cockrell, 1985

Plate 11e

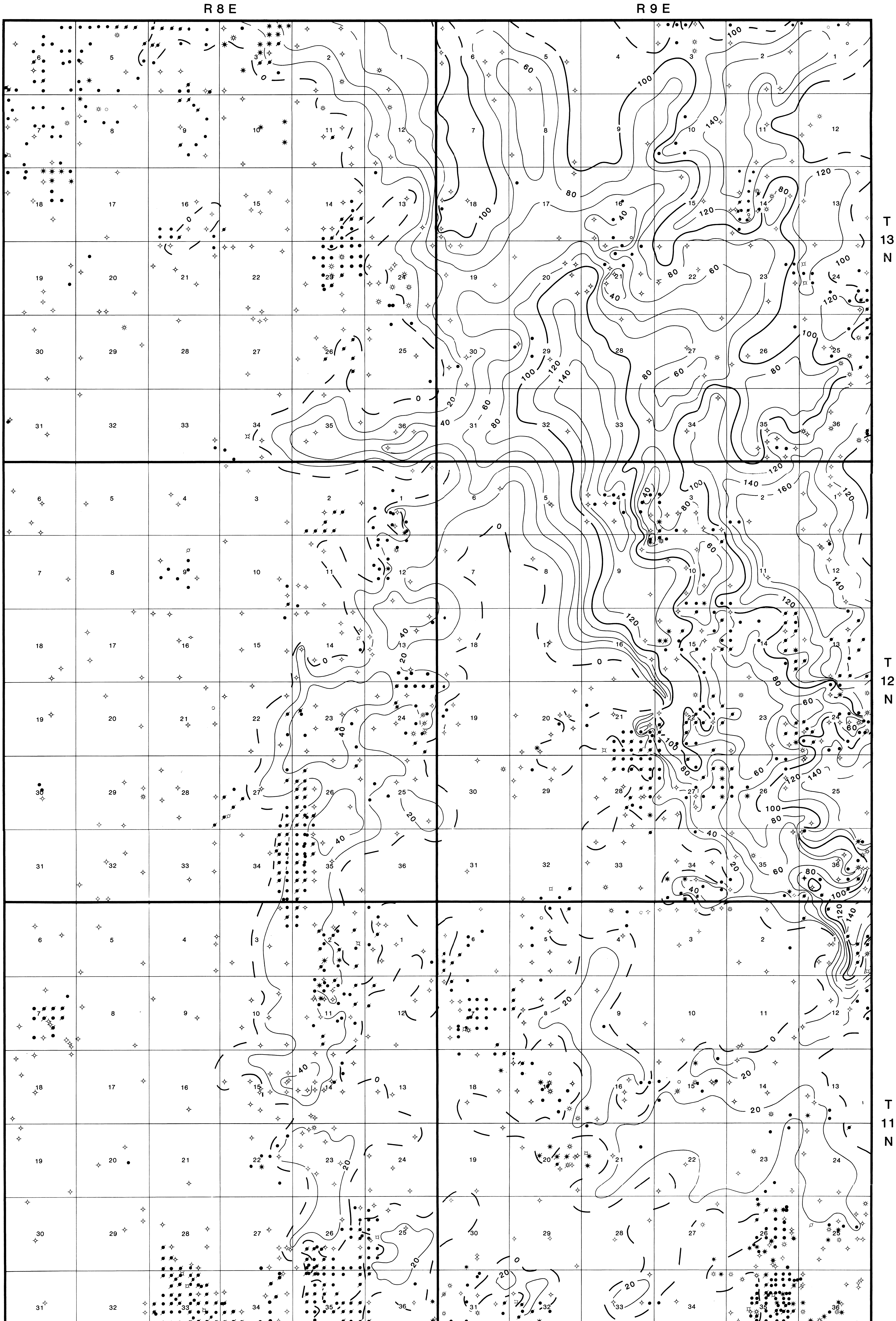


LOG MAP
BOOCH SANDSTONE
Datum: Top of Booch Interval

EXPLANATION

P: PHANTOM MARKER
↑: SIMILAR LOG CHARACTER
C.I.: 20'

Dale Reed Cockrell, 1985
Plate 11f



NET SANDSTONE ISOPACH MAP
Bartlesville Sandstone Format

C.I. – 20′

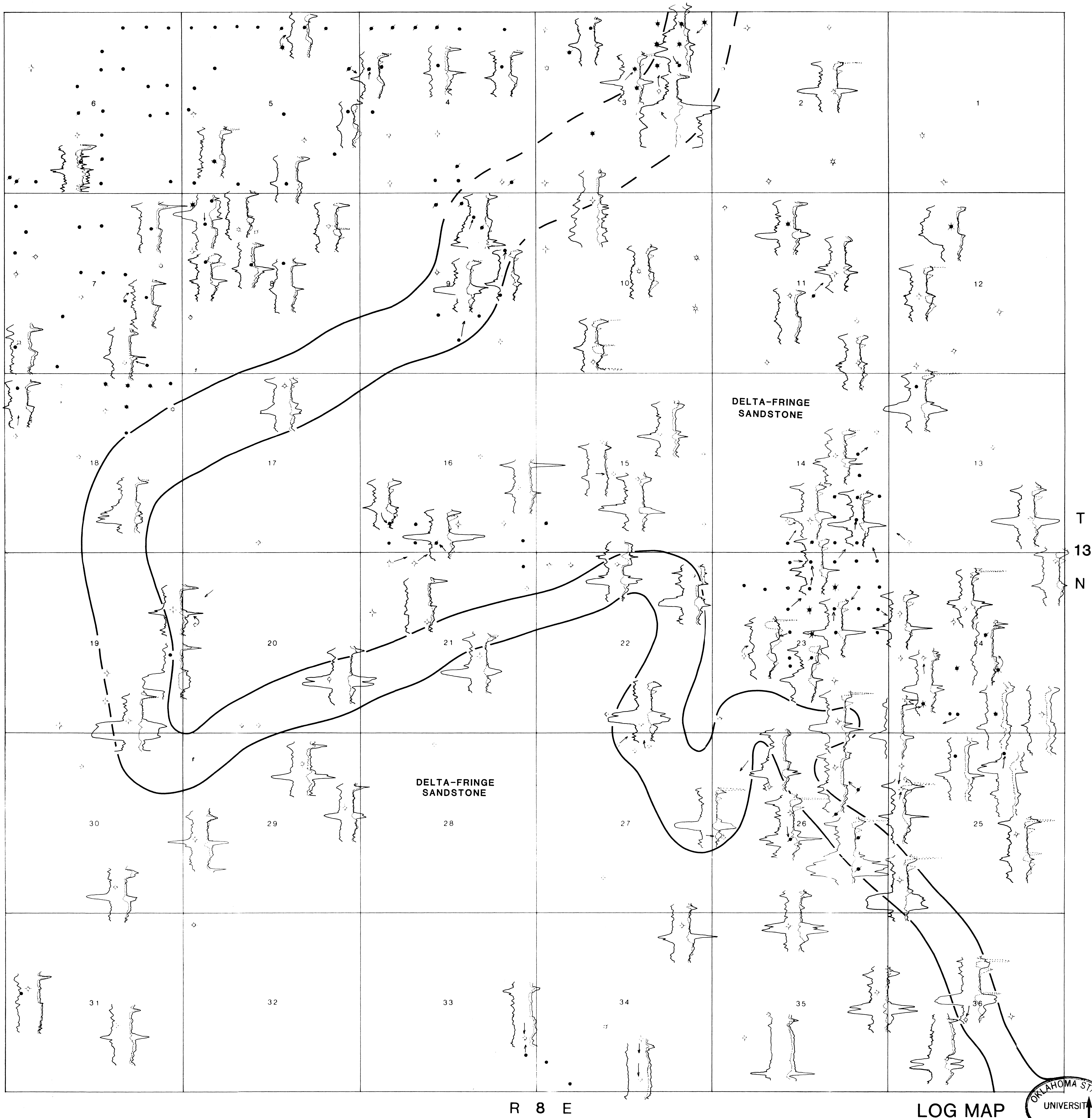
N

1 MILE 0 1 MILE

SCALE: 2″ – 1 MILE

Dale Reed Cockrell, 1985

Plate 12



LOG MAP
RED FORK SANDSTONE
DATUM: Base of Pink Limestone

N

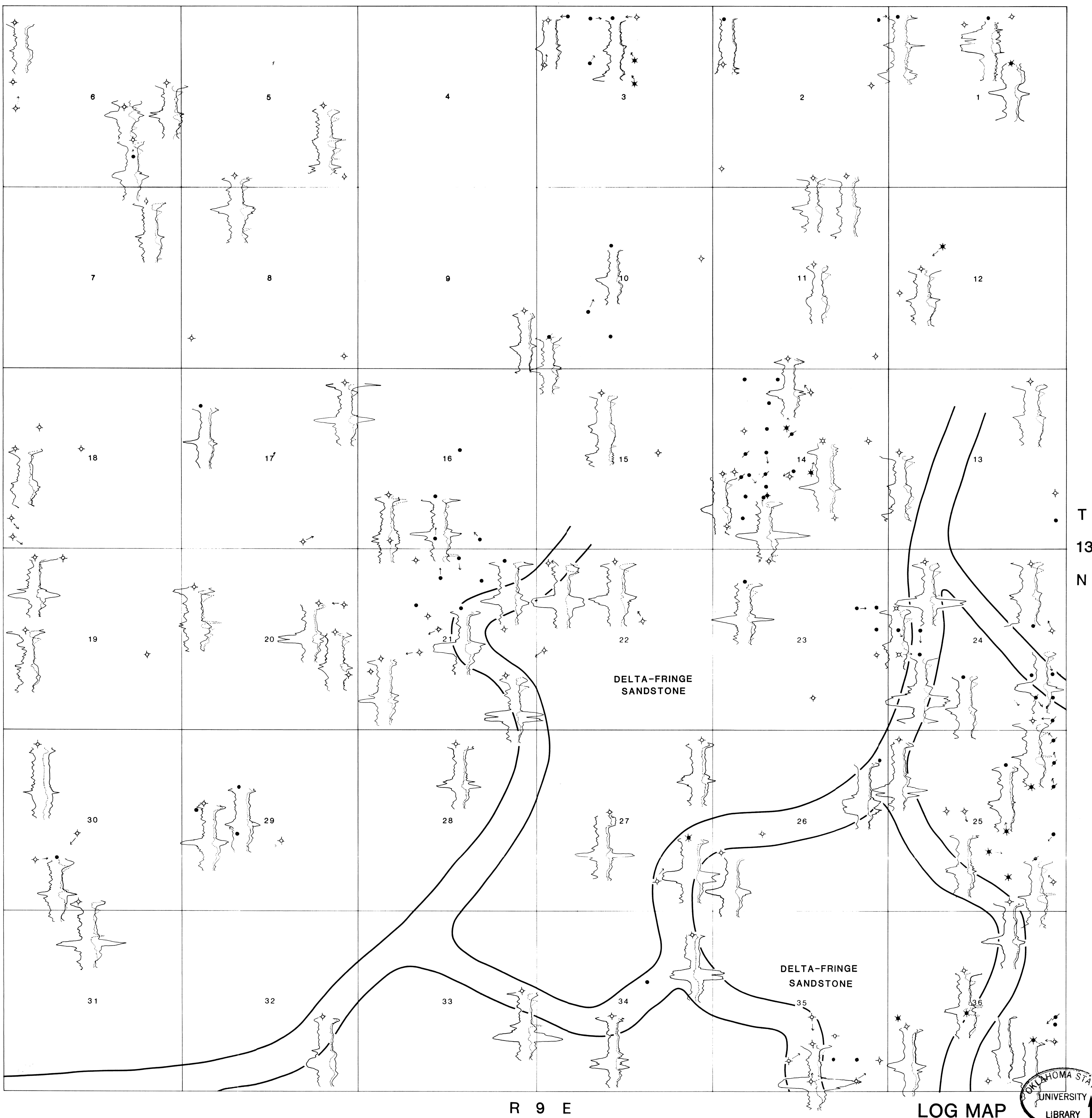
100'
Vertical
Scale
0'

1: 15,840
0 1/2 1 mile

EXPLANATION

P: PHANTOM MARKER
?: SIMILAR LOG CHARACTER
UPPER SANDSTONE UNIT
MIDDLE SANDSTONE UNIT
LOWER SANDSTONE UNIT
UNDIFFERENTIATED SANDSTONE

Dale Reed Cockrell, 1985
Plate 13 a



LOG MAP

RED FORK SANDSTONE

DATUM: Base of Pink Limestone

100'
Vertical
Scale
0'

1: 15,840

0 1/2 1 mile

EXPLANATION

P: PHANTOM MARKER

?: SIMILAR LOG CHARACTER

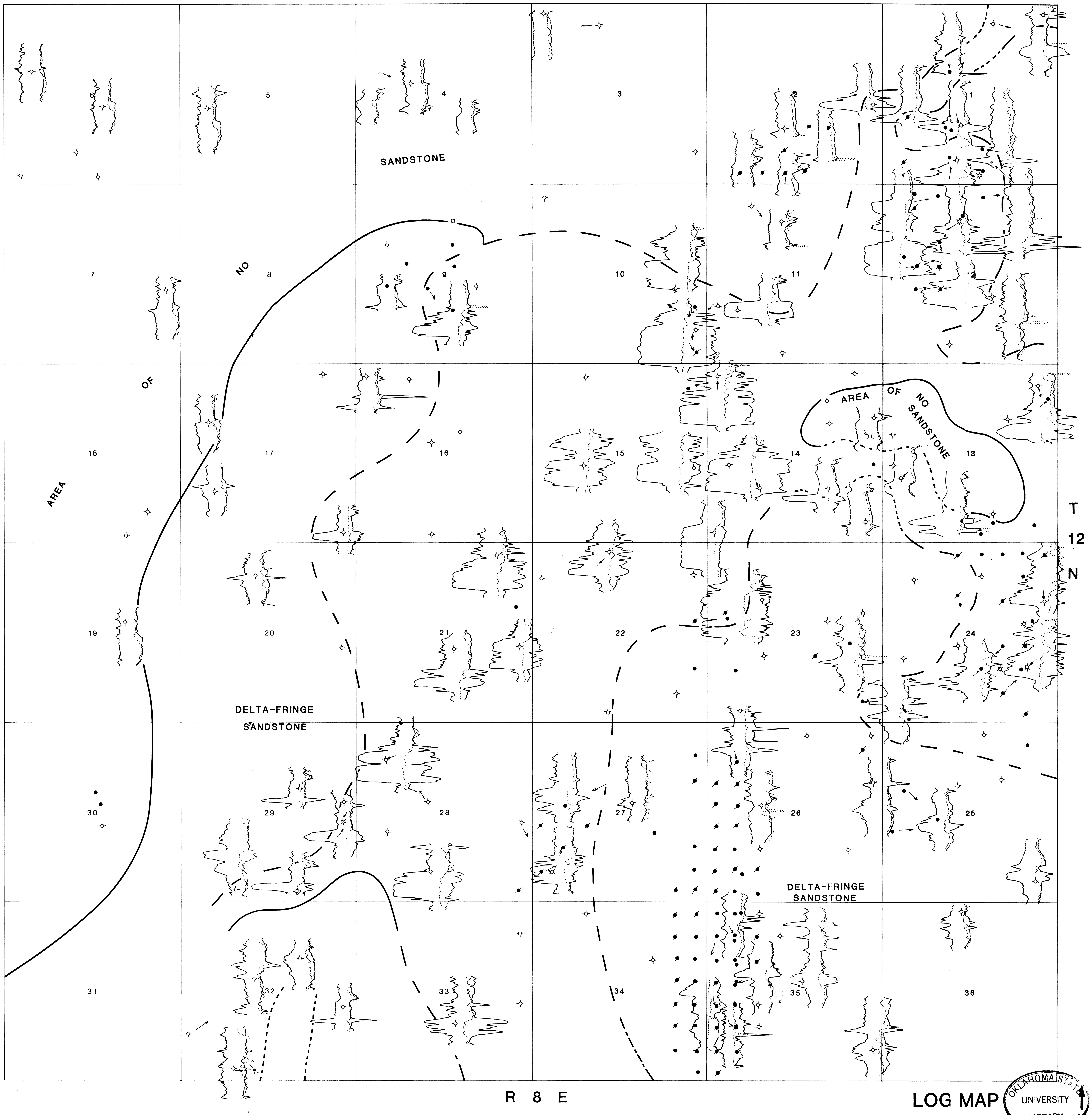
UPPER SANDSTONE UNIT — MIDDLE SANDSTONE UNIT

LOWER SANDSTONE UNIT — UNDIFFENTIATED SANDSTONE

Dale Reed Cockrell, 1985

Plate 13 b

N



LOG MAP
RED FORK SANDSTONE
DATUM: Base of Pink Limestone

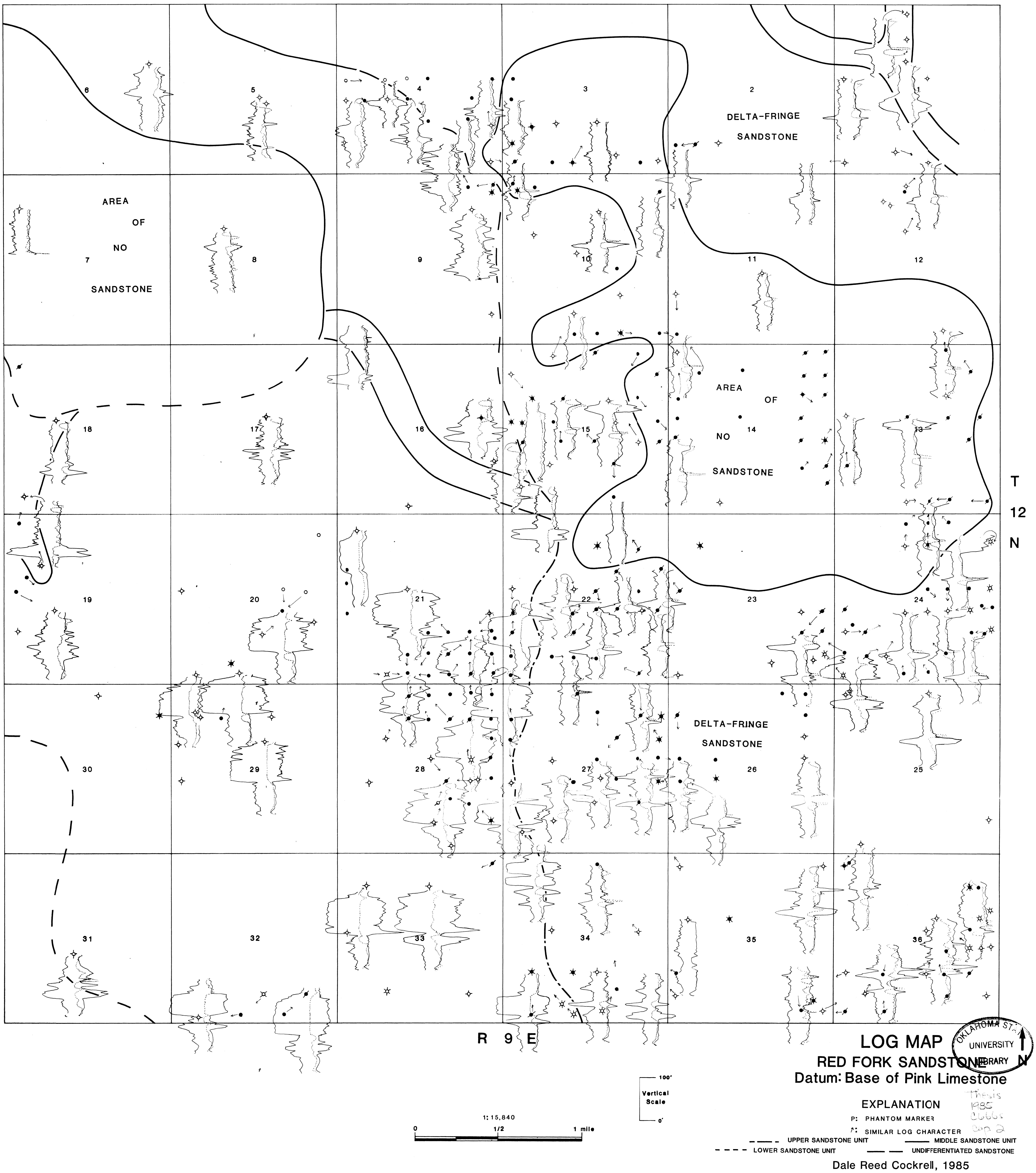
N

100'
Vertical Scale
0'

1: 15,840
0 1/2 1 mile

P: PHANTOM MARKER
?: SIMILAR LOG CHARACTER
UPPER SANDSTONE UNIT
MIDDLE SANDSTONE UNIT
LOWER SANDSTONE UNIT
UNDIFFERENTIATED SANDSTONE

Dale Reed Cockrell, 1985
Plate 13c



LOG MAP

RED FORK SANDSTONE

Datum: Base of Pink Limestone

EXPLANATION

P: PHANTOM MARKER

↗: SIMILAR LOG CHARACTER

UPPER SANDSTONE UNIT

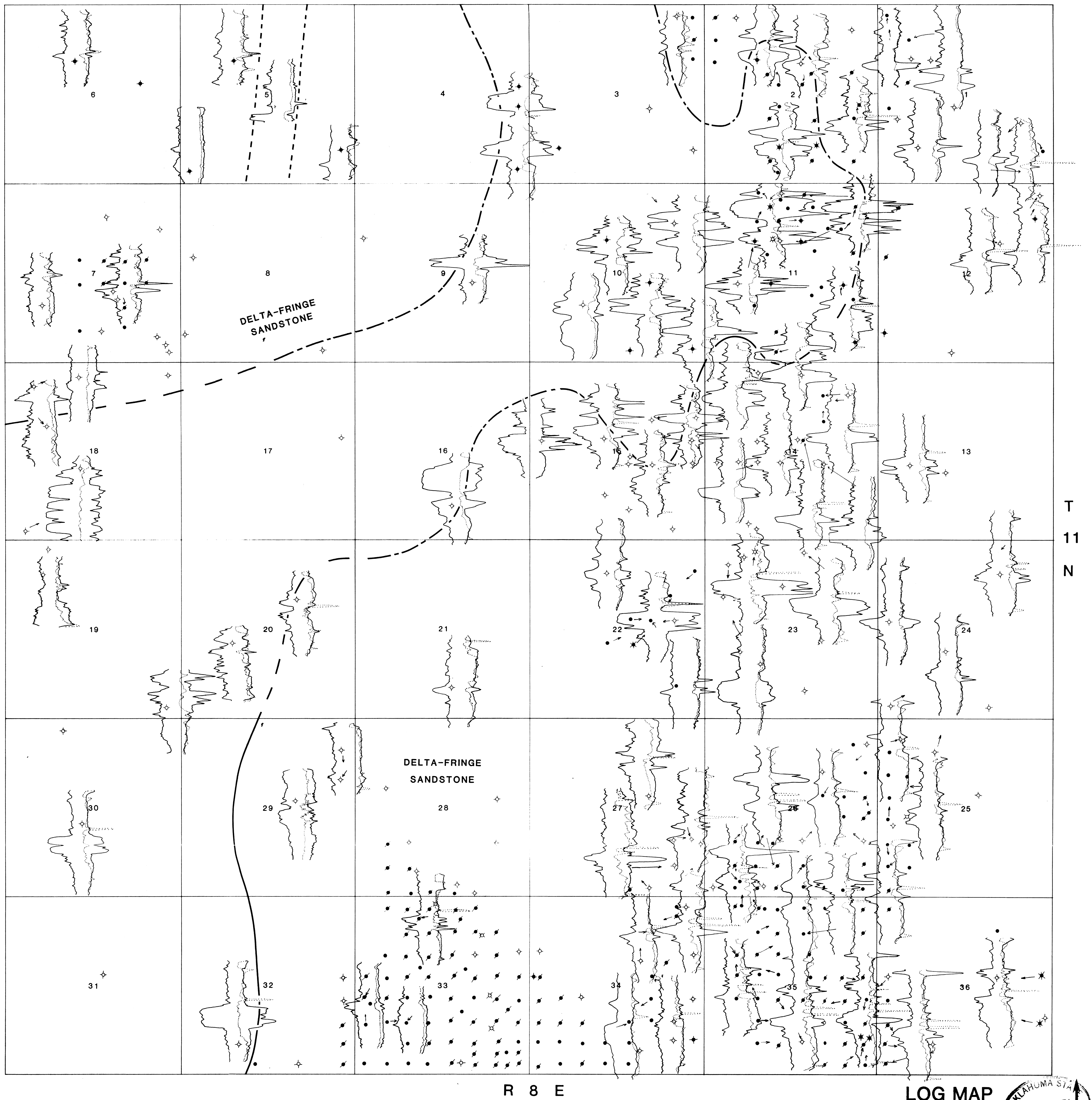
MIDDLE SANDSTONE UNIT

LOWER SANDSTONE UNIT

UNDIFFERENTIATED SANDSTONE

Dale Reed Cockrell, 1985

Plate 13d



LOG MAP
RED FORK SANDSTONE
DATUM: Base of Pink Limestone

N

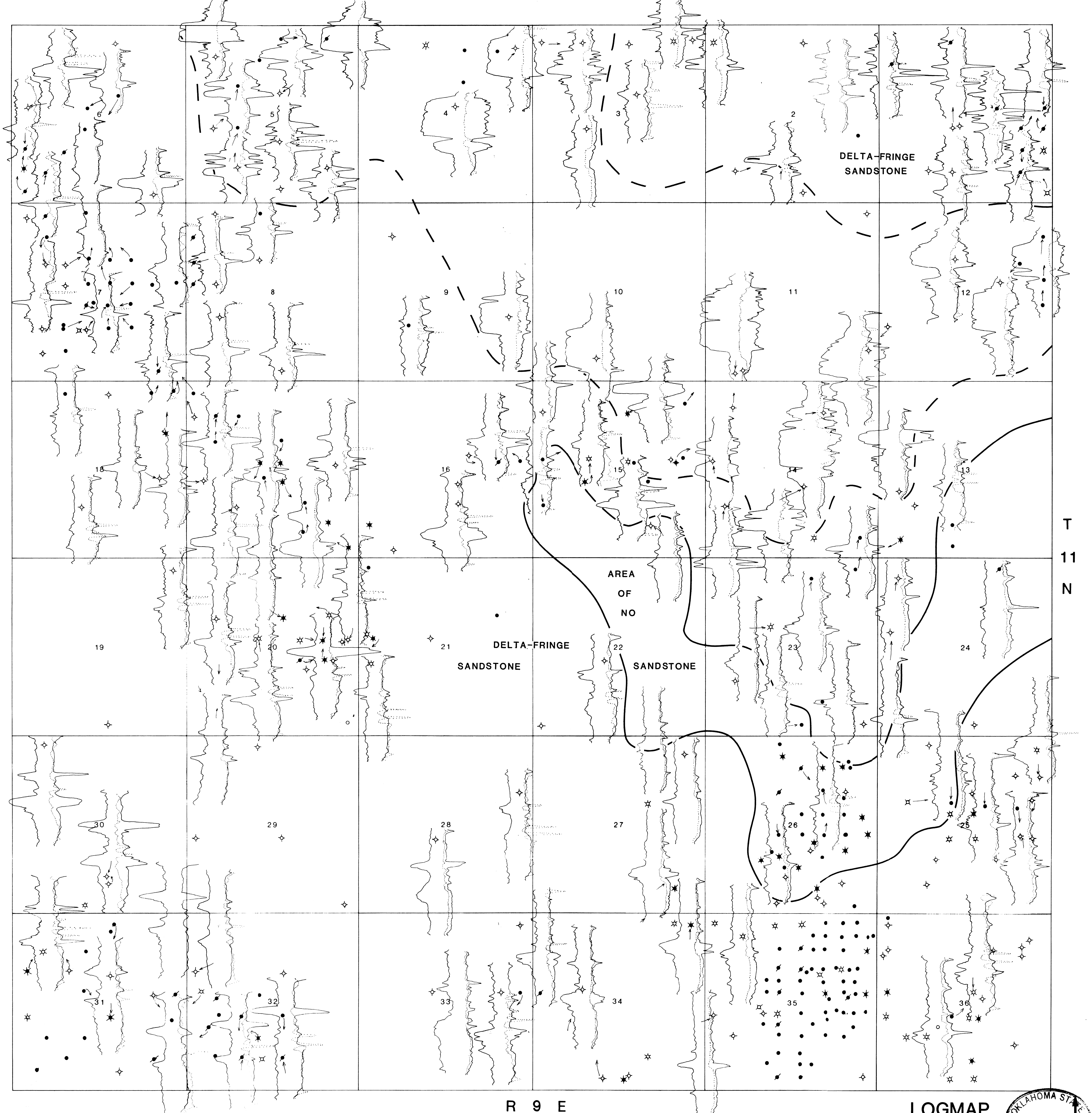
100'
Vertical Scale
0'

1: 15,840
0 1/2 1 mile

EXPLANATION

P: PHANTOM MARKER
↑ SIMILAR LOG CHARACTER
— — UPPER SANDSTONE UNIT
—— MIDDLE SANDSTONE UNIT
- - - LOWER SANDSTONE UNIT
—— — UNDIFFERENTIATED SANDSTONE

Dale Reed Cockrell, 1985
Plate 13e



LOGMAP

RED FORK SANDSTONE

Datum: Base of Pink Limestone

100'
Vertical Scale
0'

: 15,840

0 1/2 1 mile

EXPLANATION

P: PHANTOM MARKER

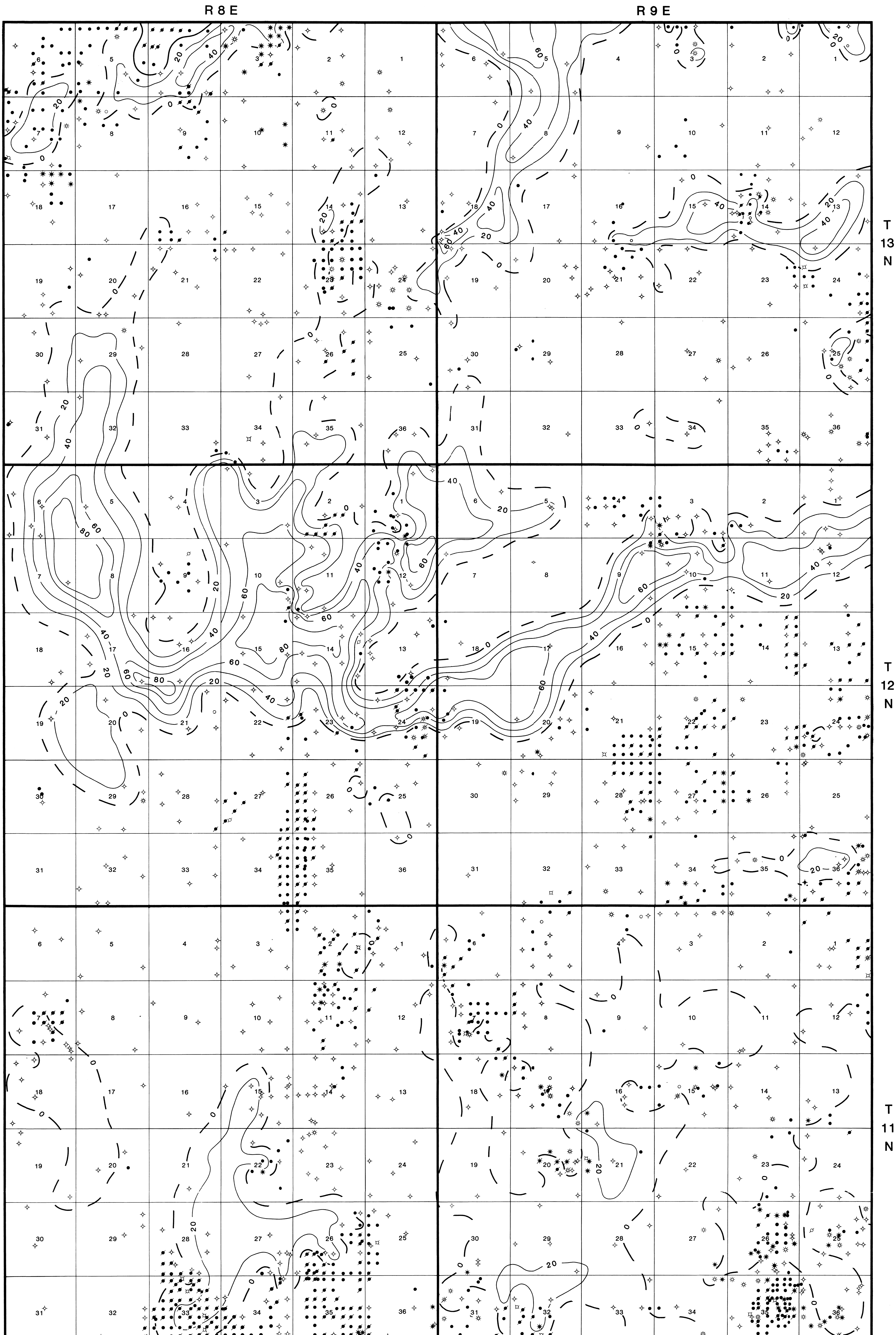
?: SIMILAR LOG CHARACTER

UPPER SANDSTONE UNIT — MIDDLE SANDSTONE UNIT

LOWER SANDSTONE UNIT — UNDIFFERENTIATED SANDSTONE

Dale Reed Cockrell, 1985

Plate 13f



NET SANDSTONE ISOPACH MAP
Lower Skinner Sandstone Format

C.I. – 20′

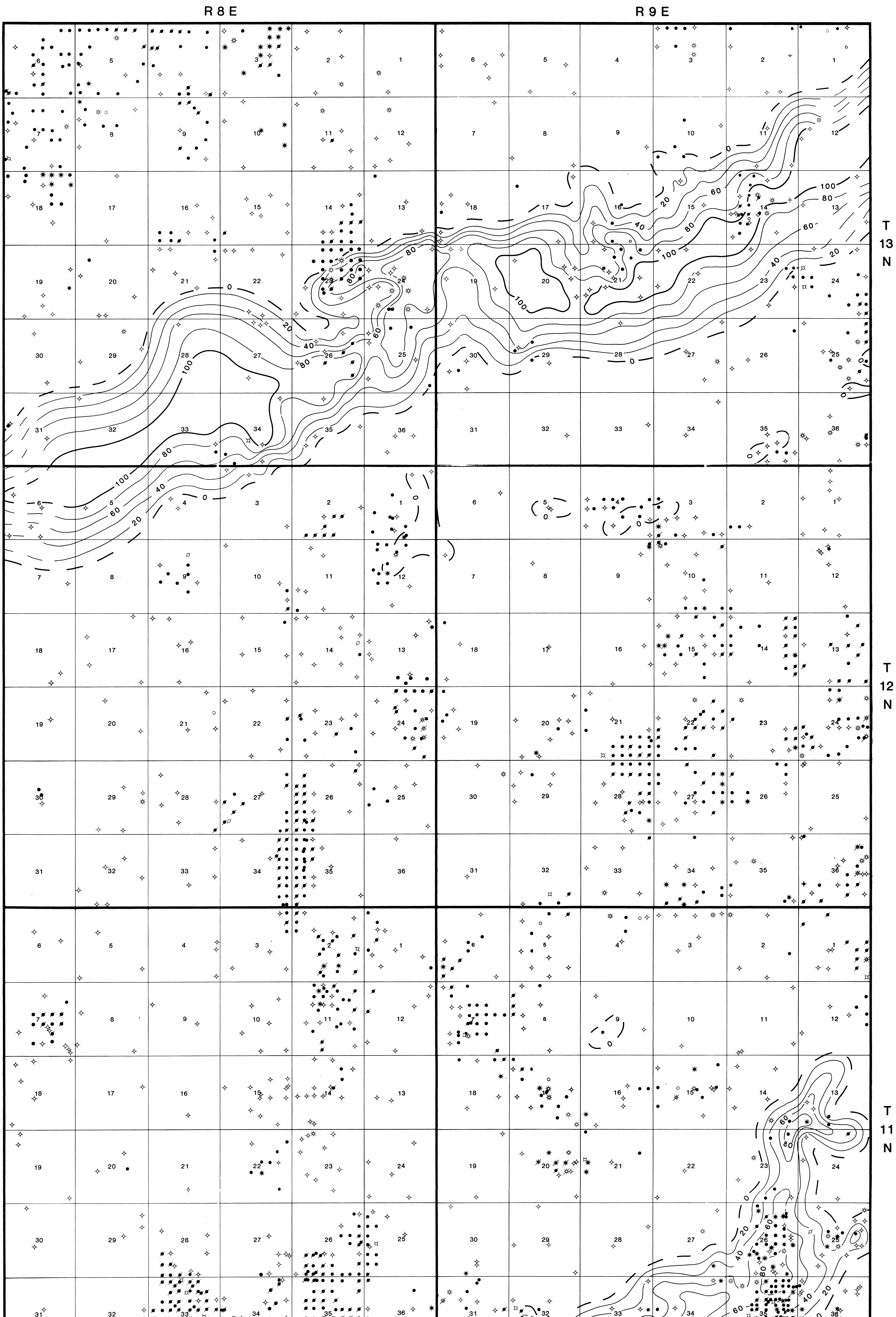
N

1 MILE 0 1 MILE

SCALE: 2″ – 1 MILE

Dale Reed Cockrell, 1985

Plate 14



NET SANDSTONE ISOPACH MAP

Upper Skinner Sandstone Format

C.I. – 20'

N

1 MILE 0 1 MILE

SCALE: 2" – 1 MILE

Dale Reed Cockrell, 1985

Plate 15