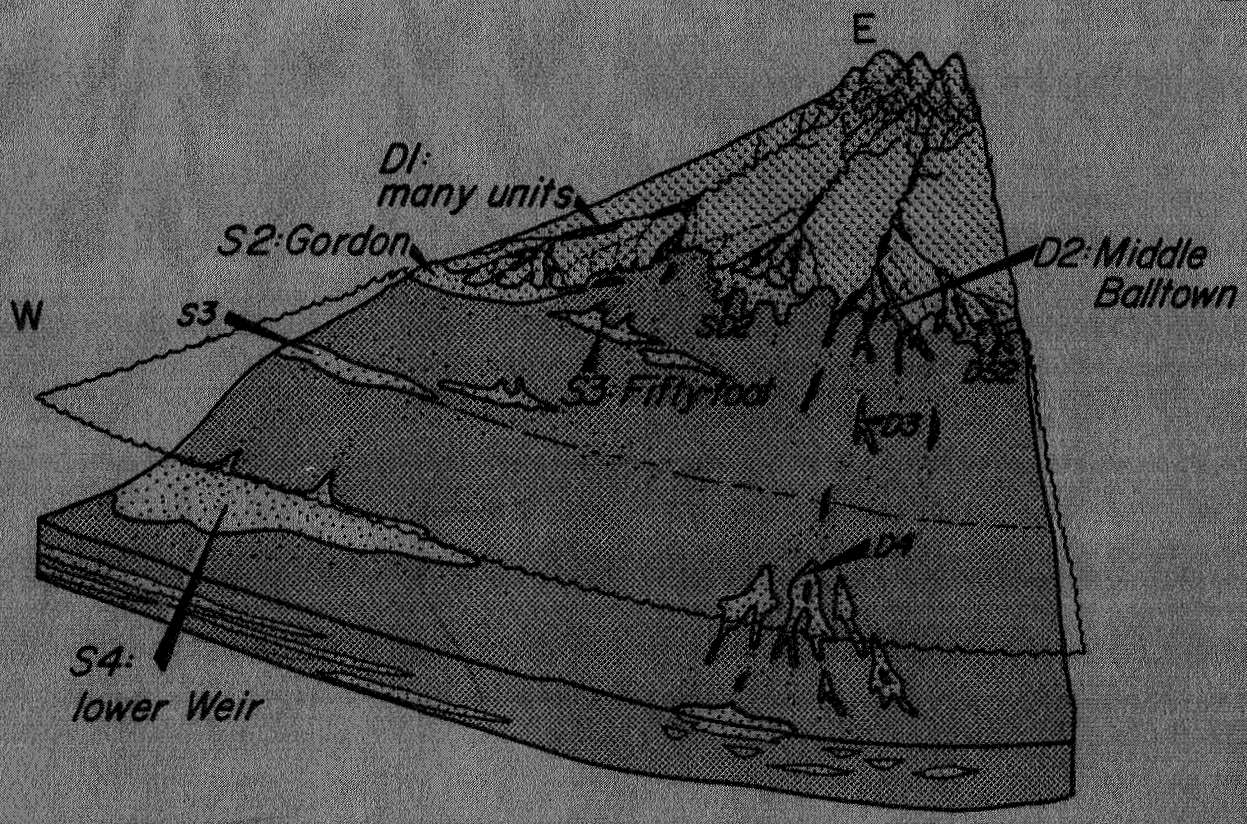
ATLAS OF UPPER DEVONIAN/LOWER MISSISSIPPIAN SANDSTONES IN THE SUBSURFACE OF WEST VIRGINIA



Ray M. Boswell
Gregory A. Jewell

West Virginia Geological and Economic Survey

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ATLAS OF
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Ray M. Boswell
Department of Geology and Geography
West Virginia University

and

Gregory A. Jewell
Kerr-McGee Corporation

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ATLAS OF UPPER DEVONIAN-LOWER MISSISSIPPIAN SANDSTONES IN THE SUBSURFACE OF WEST VIRGINIA

Ray M. Boswell, Dept. of Geology and Geography, West Virginia University, Morgantown, WV 26505; and **Gregory A. Jewell**, Kerr-McGee Corporation, Oklahoma City, OK 73125

ABSTRACT

Upper Devonian and Lower Mississippian sandstones are significant hydrocarbon reservoirs throughout the subsurface of West Virginia. Nonetheless, the regional trends and geometries of these units, as well as their environments of deposition, remain poorly understood. This report presents a series of regional isolith maps and more detailed isopach maps that reveal the distribution patterns of sandstones within the Acadian clastic wedge of northern, central and southeastern West Virginia.

A classification scheme is presented that describes sandstone bodies with respect to: 1) the trend relative to depositional strike (S) and dip (D) as determined through subsurface mapping; and 2) the paleogeographic position of the sandstone (1 for terrestrial; 2 for shoreline; 3 for shelf; and 4 for basinal) as determined through reference to outcrop characteristics of age-equivalent facies.

The dominant depositional trends observed and their classifications are: 1) fluvial-deltaic channel sandstones oriented parallel to paleoslope (east-west, or "dip-trends": TYPE D1) and best developed within eastern equivalents of the "Gordon" sandstone; 2) shoreline sandstones with dip trends (TYPE D2) such as the "Balltown" and "Speechley" sandstones; 3) shoreline sandstones trending parallel to depositional strike ("strike-trends": TYPE S2) such as the "Gordon" sandstones; 4) shoreline sandstones exhibiting a combination of dip- and strike-trends (TYPES SD2 and DS2), including many units within the "Fifth", "Fourth" and "lower Weir" intervals; 5) strike-trending marine sandstones deposited in shallow-water shelf or estuarine environments (TYPE S3), perhaps bridging promontories of highly-embayed shorelines, as in the "Fifty-foot" interval; and 6) strike-trending units deposited in relatively deep-water environments far removed from the paleoshoreline (TYPE S4) represented by the "western Lower Weir" sandstones.

INTRODUCTION

Complex plate interactions along the eastern margin of the North American continent during the Middle and Late Devonian produced an elongate belt of folded and thrusted mountains that extended from Maritime Canada to Alabama (Williams and Hatcher, 1982). Tectonic loading associated with the periodic emplacement of thrust sheets within the orogenic belt accelerated rates of subsidence within the adjacent craton, creating a linear depositional trough within the easternmost areas of the Appalachian Basin (Quinlan and Beaumont, 1985). Throughout the Upper Devonian, sediment eroded from the western flanks of the Acadian Mountains was delivered westward to a shoreline with roughly north-south trend by a small number of positionally-stable and evenly-spaced fluvial-deltaic systems (Barrell, 1913; Boswell and Donaldson, in press).

Appalachian marginal marine strata became progressively more sandstone-rich throughout the Upper Devonian. A gradual increase in the strength of marine processes relative to the rate of sediment influx during the Famennian Stage increased the degree to which this sand was reworked into continuous belts (Boswell and Donaldson, in press). Maximum progradation was achieved in the Late Devonian. Subsequently, two regional transgressions, one in the latest Devonian and a second in the earliest Mississippian, drove shorelines far to the east before progradation resumed in the Lower Mississippian (Figure 1; Bjerstedt and Kammer, 1988). Sandstones deposited along these shorelines, as well as the equivalent basinal, shelf, and terrestrial units, comprise the Acadian clastic wedge.

Acadian clastic wedge rocks have been the focus of extensive academic and economic exploration for more than a century. However, because the majority of these studies have been conducted within the outcrop belts that rim the basin, little is known concerning the nature or regional distribution of the sandstone-rich strata within the basin interior. Moreover, the progradation of the Catskill shoreline westward of the present outcrops during the Famennian Stage has largely precluded study of Famennian and Lower Mississippian near-shore sedimentation on outcrop. Consequently, current views of Acadian clastic wedge depositional environments may be flawed by an inappropriate emphasis on the older Frasnian rocks of the outcrop areas. For example, generalizations of this type resulted in the the debate over the relative "sandiness" or "muddiness" of Upper Devonian shorelines (see Walker, 1971). However, as the maps presented herein show, and as well drillers long have known, sandstones are a prominent component of Famennian strata in the subsurface of West Virginia.

This report presents the results of five years of

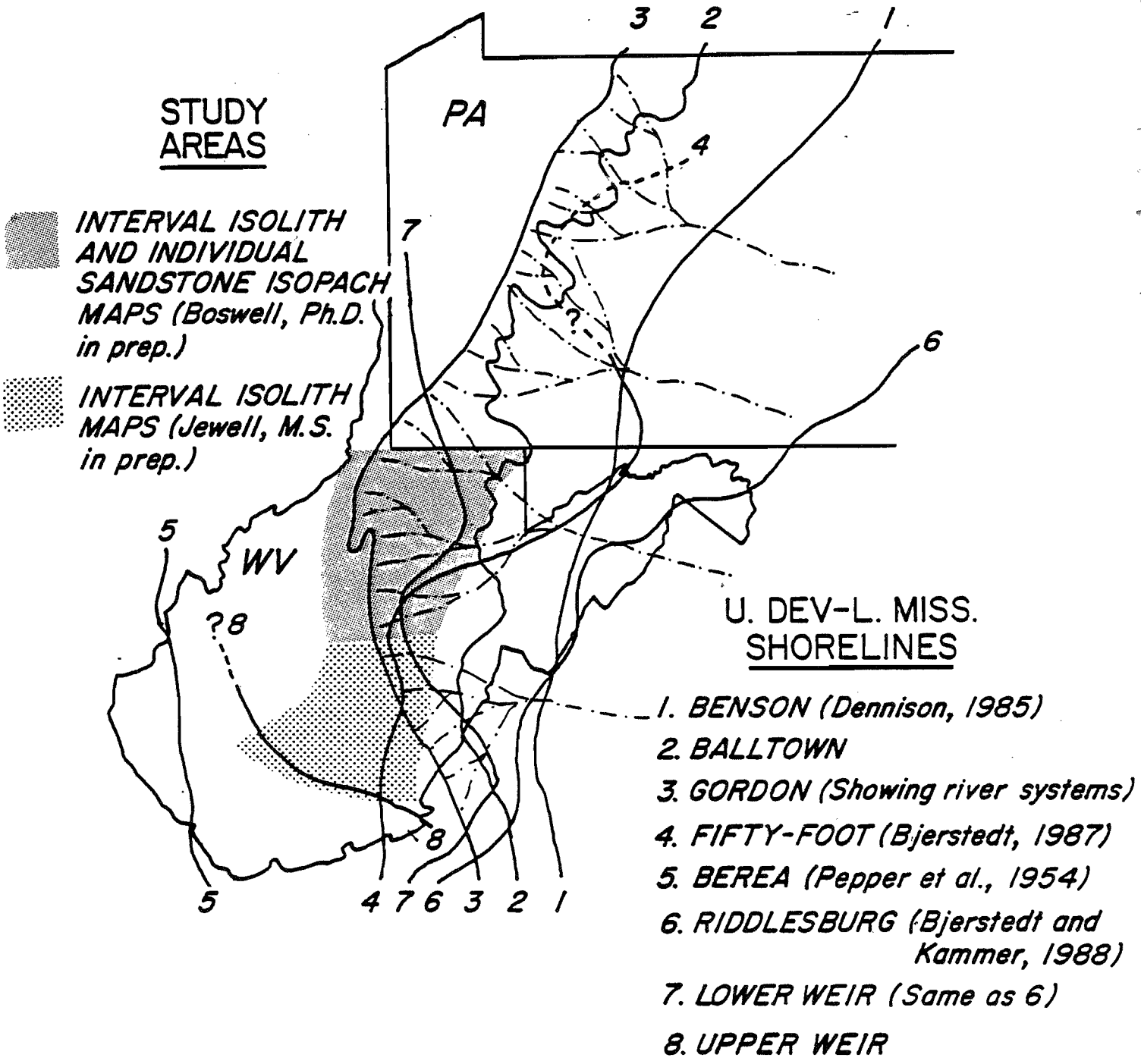

Figure 1: Location of subsurface mapping areas. The figure also illustrates the migration of Acadian clastic wedge shorelines. Dashed lines indicate fluvial–deltaic architecture during the late Upper Devonain (Boswell and Donaldson, in press).

mapping of Upper Devonian and Lower Mississippian sandstones in northern West Virginia (Boswell, 1985, 1988) and southeastern West Virginia (Jewell, M.S. in preparation). These data indicate the trends, geometries, thicknesses, and depositional environments of sandstones that are among the most important hydrocarbon reservoirs in the central Appalachian basin.

STUDY AREA AND DATA

Mapping of subsurface sandstones is presented on two levels. First, isolith maps of total sandstone thickness are presented for 11 informal subsurface intervals. This mapping is based on the correlation of more than 700 gamma-ray well logs from 18 counties in northern, central, and southeastern West Virginia (Figure 2). Second, over 450 gamma-ray well logs from central and northern West Virginia were used in the construction of 47 individual sandstone isopach maps (Figures 1 and 2).

All Upper Devonian and Lower Mississippian sandstones of significant thickness and extent, with the exception of the Berea Sandstone of southwestern West Virginia, are described in this study. The formal lithostratigraphic terminology of these sandstones is currently under revision (Kammer and Bjerstedt, 1986; Boswell and others, 1987); however, the units probably are best known by a series of informal names developed by well driller's (Plate 1). Sandstones mapped in this report range from the "lower Balltown" sandstones to the "Upper Weir" sandstone of southern West Virginia. The "Upper Weir" is correlative with units referred to as "Big Injun" in northern West Virginia.

Correlations in this study are based in part on the work of Cardwell (1981, 1982), and Lewis (1983). These workers pioneered the study of the correlation and distribution of Upper Devonian-Lower Mississippian sandstones in the subsurface of West Virginia.

REGIONAL STRATIGRAPHY OF SUBSURFACE SANDSTONES

The Acadian clastic wedge records a large cycle of regression and transgression corresponding to the initial uplift and ultimate erosional lowering of the Acadian Mountains. This wedge is divided by a latest Devonian transgressive event that terminated red bed deposition across most of West Virginia. This transgression, marked by deposition of the Cleveland Shale of Ohio and the Oswayo Member of the Price Formation on outcrop in northern West Virginia (Kammer and Bjerstedt, 1986), marks the boundary between the Upper Devonian Catskill delta

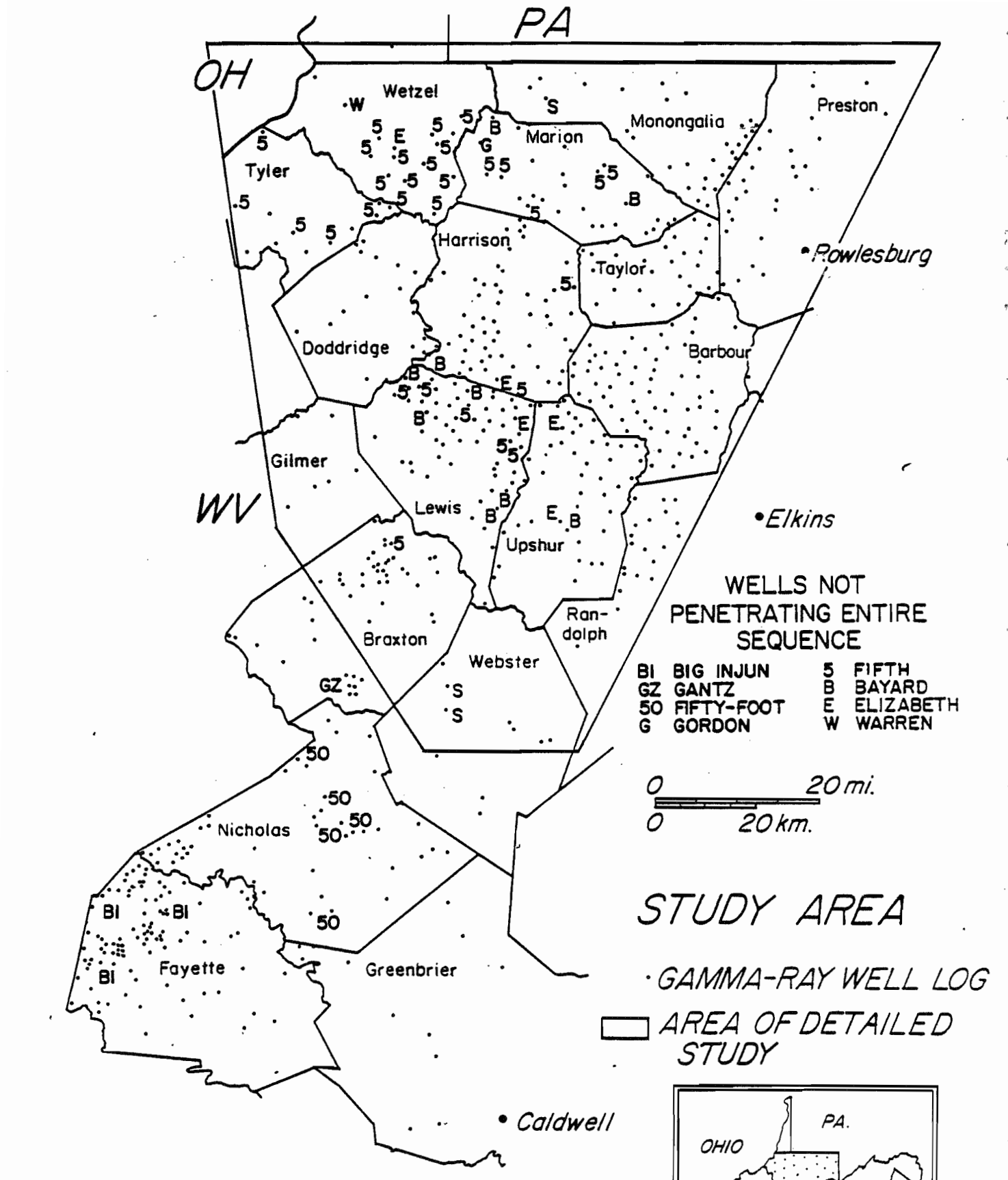

Figure 2: Distribution of well log data in the study area .

complex and the predominantly Lower Mississippian Price-Rockwell delta complex.

The Catskill and Price-Rockwell delta complexes are further subdivided into bundles of sandstone approximately 200 feet in thickness by smaller cycles of transgression and regression. These sandstone packages are well known to well drillers, and have acquired an informal terminology that will be extensively used in this report (Plate 1). Isolith maps of total sandstone thicknesses within the "Balltown", "Warren", "Elizabeth", "Bayard", "Fifth", "Fourth", "Gordon", "Thirty-foot", "Fifty-foot", "Gantz", "Berea-Riddlesburg", "lower Weir", "middle Weir", and "upper Weir" sandstones, as well as the position of each within the Acadian clastic wedge, are presented as Plates 1 through 28.

Each informal subsurface interval is comprised of from three to eight individual sandstones that are identified by letters of the alphabet, with the youngest sandstone labelled "A", the subjacent sandstone labelled "B", et cetera (Plate 1). Assignment of certain sandstones that occur at the transition from one interval to another such as "Fifth A" or "Bayard A" is arbitrary, and many of these units could be just as satisfactorily placed within the adjacent interval. An isopach map of each sandstone is presented in Plates 29 through 77.

THE SANDSTONE MAPS

Isopach maps of subsurface sandstones indicate the sand dispersal pattern. These patterns are suggestive of specific depositional environments based on the understanding of the fluvial-deltaic nature of Catskill and Price-Rockwell deposition, and a general knowledge of common deltaic sandstone geometries (Coleman and Prior, 1980). Correlation of subsurface intervals with outcrops at Rowlesburg, Preston County; Caldwell, Greenbrier County; and Elkins, Randolph County, West Virginia, (Figure 2; and labelled on the plates as "R", "E", and "C" respectively), contribute greatly to the environmental interpretation of subsurface sandstones by indicating the depositional environments that are associated with specific sandstone geometries, and by revealing the nature of laterally-equivalent facies of units that are not exposed in outcrop.

Subsurface sandstones are interpreted based on the trend of thickest sandstone occurrence and the paleogeographic position of that trend (Figure 3). Sandstone trend is described as TYPE S ("strike-trending) when thickest sandstones are aligned with the depositional strike of the basin (commonly north-south), or as TYPE D ("dip-trending") where sandstones parallel the paleoslope (roughly east-west). These classifications are suffixed

by "1" if the dominant trends are interpreted to have formed in terrestrial environments, "2" if along the shoreline, "3" if in shallow shelf environments, and "4" if in deeper-water submarine fans.

Sandstone isopach patterns S2 (strike-trending shoreline sandstones) and D2 (dip-trending shoreline sandstones) represent end members of a spectrum of shoreline morphologies ranging from straight (TYPE S2) to digitate (TYPE D2). Isopach maps that show a combination of both strike- and dip-trends (lobate shorelines) are called TYPE SD2 where the strike-trending element is judged to be dominant or DS2 where the dip-trending style dominates. This spectrum of shoreline shapes is interpreted to correspond to different ratios of rates of sediment supply to the shoreline versus rates of sediment redistribution by marine processes (Wright and Coleman, 1973): TYPE S2 patterns suggest wave-dominant deltaic deposition; whereas TYPE D2 patterns are associated with fluvially-dominated conditions. TYPE SD2 and DS2 isopachs represent intermediates between these two end members.

TYPE D2 Sandstones

TYPE D2 sandstones are common in the "Balltown" and "Speechley" intervals of the Catskill delta complex (Plates 70-75 and Figure 3). Study of these units in outcrop at Elkins (Lewis, 1983; McDowell, M.S. in preparation) revealed a variety of near-shore marine, shoreline, and non-marine environments indicating the repeated passage of the shoreline both eastward and westward through the outcrop. The proximity of the shoreline to the dip-trending sandstones mapped in the subsurface indicates that the mapped units were formed in close association with the shoreline, most likely as extended distributary channels producing a digitate shoreline configuration. However, the extent to which the western ends of these dip-trends may represent subaqueous deposition on the shelf (TYPE D3 trends) is not clear.

TYPE DS2 and SD2 Sandstones

TYPE DS2 and SD2 trends dominate the sandstones in the interval from the "Warren" through the "Fourth". Outcrop study of "Elizabeth" and "Bayard" sandstones at Rowlesburg (Boswell, 1985; Boswell and others, 1987) and Elkins (Lewis, 1983; McDowell, M.S. in preparation) indicate interbedded brackish-marine and non-marine sandstones encased in red, green and grey shales. Equivalents of still younger and more prograded units, such as the "Fifth" and "Fourth" sandstones, reveal

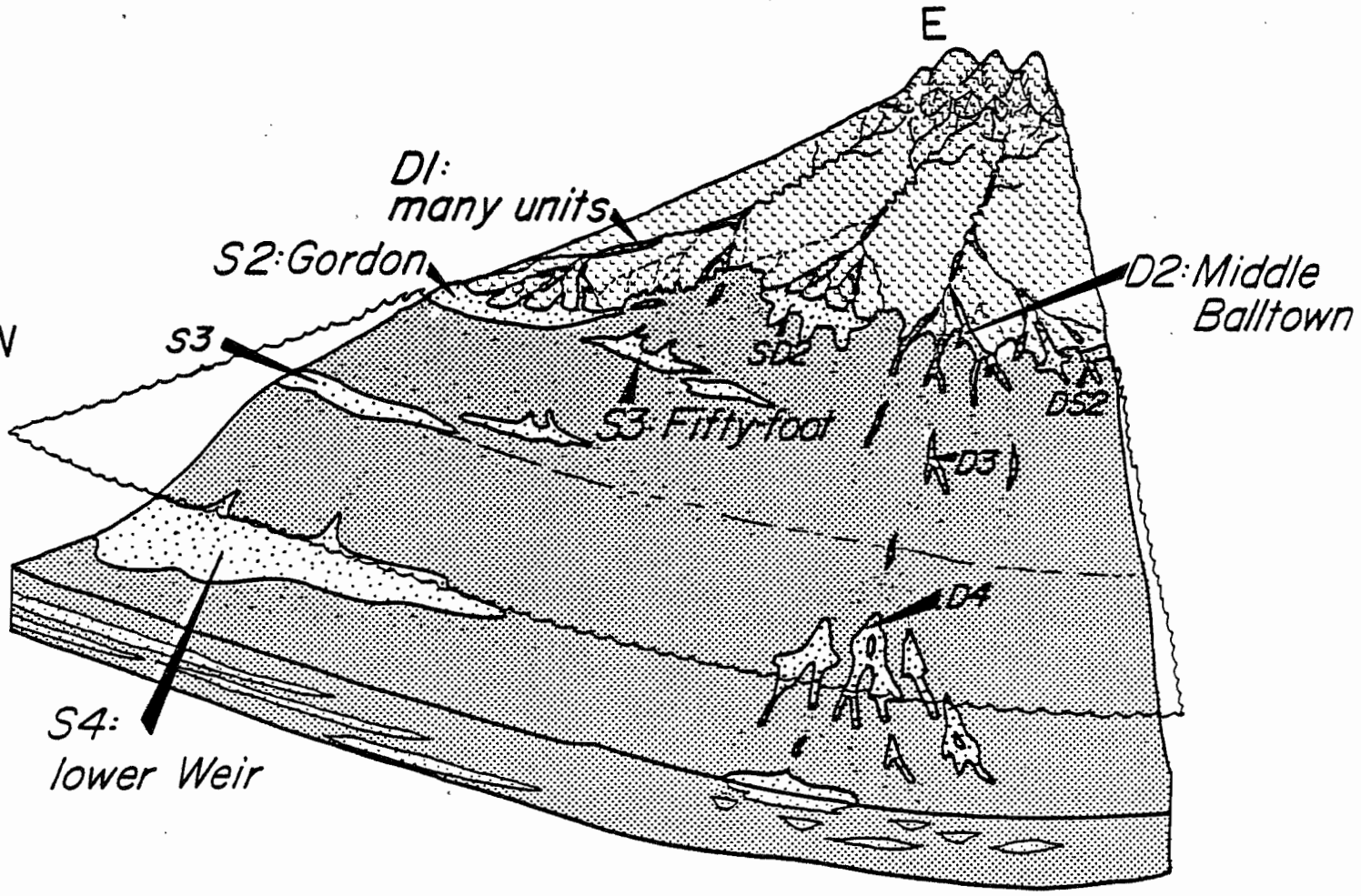

Figure 3 Classification of Acadian clastic wedge sandstones by trend relative to depositional strike (S,D) and paleogeographic position (1–4). Types S2, SD2, DS2, D2, D1, S3 and S4 are common depositional trends in the interval from "Balltown" to "upper Weir" in the subsurface of West Virginia.

uninterruped flood plain deposition characterized by root mottled red shale, channel sandstones, and evidence of paleosoil development (pseudoanticlines). The dominant sandstone trends in these intervals are interpreted to have formed along shorelines with lobate morphologies (Plates 22,24,56-62,64-67).

TYPE SD2 also characterizes the distribution of "Weir" sandstones within the eastern part of the study area (Plates 31-35). In outcrop at Rowlesburg, these units display features suggestive of distributary mouth bar and lower fluvial-deltaic plain deposition (Boswell, 1985; Bjerstedt and Kammer, 1988).

TYPE S2 Sandstones

TYPE S2 trends are most common in the "Gordon" sandstones. Because these units are not exposed in outcrop, the character of S2 trends is based partly on study of the strike-trending "Warren B" sandstone (Plate 69) as it occurs at Rowlesburg. The "Warren B" sandstone overlies fossiliferous grey shale, is massive, quartz-rich and medium-grained, contains abundant horizontal and low-angle planar cross-stratification, and is abundant in heavy minerals. These features indicate deposition in paralic environments such as beach and barrier bar (Boswell, 1985).

Outcrops of eastern equivalents of the "Gordon" S2 sandstones (Plates 16,50-54) reveal flood plain and fluvial channel facies similar to those of the "Fifth" and "Fourth". "Gordon" sandstones are interpreted to represent deposition along straight, wave-dominant, shorelines. An isolith map of the "Gordon" sandstone interval published by Piotrowski and Harper (1979; "D2 sands") shows this strike-trending belt extending throughout the subsurface of southwestern and west-central Pennsylvania.

TYPE S3 Sandstones

The "Fifty-foot" sandstones (Plates 12,43-46) show strike-trends similar to those of the "Warren B" and "Gordon". However, eastern equivalents of these units, as observed at Rowlesburg, are grey siltstones and shales containing a brackish-marine fauna (Boswell and others, 1987; Bjerstedt, 1988). Consequently, these units can not be interpreted as shoreline in origin; instead, an offshore sand bar setting is indicated. However, as traced southward to Elkins, these back-bar deposits grade into non-marine red shale (Boswell and others, 1987),

indicating that "Fifty-foot" sandstones may be of shoreline origin in central West Virginia. Further south at the Caldwell outcrop, the interval of the uppermost "Fifty-foot" sandstones is occupied by the Cloyd Conglomerate Member of the Price Formation (Bjerstedt and Kammer, 1988; Jewell, M.S. in preparation). The Cloyd Conglomerate is interpreted to represent fluvial and near-shore marine deposition (Bjerstedt and Kammer, 1988).

TYPE S4 Sandstones

Isopach maps of "Weir" sandstones in the western part of the study area (Plates 6,30-35) exhibit strike-trends positioned to the west of, and separated from, age-equivalent shoreline sandstones to the east. Outcrop study of these "western Weir" sandstones as they occur at Caldwell, reveals features suggestive of relatively deep-water submarine fan deposition (Bjerstedt and Kammer, 1988; Jewell, M.S. thesis in preparation). Although S4 trends are not common in the Upper Devonian, strike-trending belts of siltstone do occur in offshore positions within the "Balltown" through "Warren" intervals (Boswell, 1988). It is not clear, however, if these trends represent deposition along the shelf edge (S3) or turbidites in deeper-water offshore (S4; see Figure 3). Minor sandstones within these belts allow the recognition of poorly-developed offshore strike-trends on isopachs of the "Middle Balltown" B and C sandstones, and the "Lower Balltown" sandstone (Plates 75-77).

TYPE D1 Sandstones

TYPE D1 (distributary and fluvial channel) geometry is present on every map where shoreline position is sufficiently westward to allow mapping of a significant portion of the fluvial-deltaic plain. However, these trends are thin, discontinuous, and narrow, and as such are considered subordinant to the equivalent shoreline trends.

The Berea Sandstone of northern West Virginia, also known as the "Gay-Fink trend", is commonly considered to have formed in non-marine environments (Pepper and others, 1954) and is correspondingly labelled as a D1 sandstone (Plate 38).

TYPE D3 and D4 Sandstones

Dip-trending marine sandstones are not well-developed in the study area. However, D3 sandstones probably do occur as the nearshore equivalents of elongate distributary sandstones in units with dominant D2 trends. Examples include the "Elizabeth A" (Plate 66), "Bayard B" (Plate 63), "Upper Balltown B" (Plate 73) and "Speechley B" (Plate 71) sandstones. D4 sandstone trends are not observed in the study area; however, isopach maps of the basal Famennian/upper Frasnian "Benson" sandstone in the subsurface of central West Virginia (Cheema, 1977) appear to exhibit a D4 pattern.

PROBLEMATIC UNITS

Several sandstones within the study area exhibit trends that can not be easily interpreted. The classifications of such units are noted with question marks on the maps. Middle and upper "Weir" sandstones mapped in southern West Virginia are problematic in the northern part of the state because their equivalents are not present at the Rowlesburg outcrop, making it difficult to place the subsurface sandstone trends within a paleogeographic perspective. Consequently, tentative classifications based solely on subsurface trends are provided. Also, sandstones stratigraphically above the "Weir" sandstones, including the "Squaw" and "Big Injun", are extensively eroded throughout the study area and have not been included within this report. The thickness of this unmapped interval ranges from 0 to more than 200 feet and contains up to 150 feet of shoreline and non-marine sandstones (Jewell, M.S. in preparation).

Secondly, equivalents of the "Fifty-foot" and "Gantz" sandstones at Rowlesburg record continuous near-shore marine deposition with no non-marine facies present (Bjerstedt and Kammer, 1988). However, just to the south at Elkins, very little latest Late Devonian marine strata occurs. Consequently, strike-trending sandstones within the "Fifty-foot" and "Gantz" intervals are interpreted to change along strike from S3 (shelf) to S2 (shoreline) types. The exact location and nature of this change (and, correspondingly, the change from D3 to D1 patterns in the dip-trending units to the east of the strike trends) is poorly understood. Furthermore, it remains unclear whether dip-trending units to the east of the S3 trends represent the western edges of elongate distributaries (D2) or subaqueous channels within bay environments (D3).

The paucity of marine units at Elkins suggests that a positive area existed in central West Virginia during deposition of the "Fifty-foot" and "Gantz" sandstones.

This area, related to either very strong rates of sedimentation or to low rates of subsidence above the West Virginia Dome (see Plate 6 for location of the dome), most likely produced a subaerial promontory that formed the southern edge of a large estuarine embayment in northern West Virginia. "Fifty-foot" and "Gantz" strike-trends are interpreted to have formed across the mouth of this estuary, perhaps fed by longshore currents from a similar promontory in western Pennsylvania.

EVOLUTION OF ACADIAN CLASTIC WEDGE SHORELINE SANDSTONES

The stratigraphic distribution of sandstone geometries and the corresponding change in ratio of marine- to fluvial-dominance of the shoreline is illustrated by the plot along the right margin of Plate 1. The close correspondence between this curve and the shifting of the clastic wedge indicates that prograding shorelines are characterized by TYPE D2, DS2 and SD2 morphologies. TYPE S2 trends are characteristic of stillstands marking points of regressive maxima. The transgressive "Fifty-foot" sandstone is marked by TYPE S3 sandstones, whereas sandstones are poorly-developed in the transgressive Riddlesburg interval.

Assuming that marine energies remained relatively unchanged, two episodes of gradually decreasing fluvial supply are recognized; the first culminating in the "Gordon" sandstones, and second during progradation of the "Weir" sandstones. These two "cycles" may be related to the waning of discrete tectonic episodes of the Acadian orogeny in the central Appalachian basin.

SUMMARY

Mapping of Upper Devonian-Lower Mississippian sandstones in the subsurface of West Virginia reveals a variety of distribution patterns typical of fluvial-deltaic deposition. Reference to outcrop characteristics of lateral equivalents of mapped intervals allows deposystem interpretation of these trends. Five styles of sandstone deposition are found to be most common: 1) elongate strike-trending belts associated with deposition along wave-dominant shorelines (S2); 2) a pattern of dip-trending sandstones deposited along the shorelines of fluvially-dominated delta systems (D2); 3) mixed patterns of strike- and dip-trending units formed along lobate shorelines under environmental conditions intermediate between those indicated by S2 and D2 trends (SD2 and DS2); 4) strike-trending belts associated with estuary development representing shallow-water shelf

deposition (S3); 5) strike-trending belts well removed from the paleoshoreline and deposited in relatively deep-water submarine fan environments (S4); and 6) dip-trending sandstones in areas landward of the paleoshoreline representing fluvial-deltaic channels (D1).

The style of deposition of Upper Devonian-Lower Mississippian sandstones appears to be a response to the transgression and regression of the clastic wedge, with regressive units tending to have D2, SD2, and DS2 morphologies, whereas S2 is characteristic of stillstand at points of maximum regression. Sandstones are either not developed, or exhibit S3 trends during periods of major transgression.

ACKNOWLEDGEMENTS

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PLATES

Plates 1-28: Interval isolith maps for the larger study area with a cross section on the facing page indicating the stratigraphic occurrence of the mapped interval.

Plates 29-77: Sandstone isopach maps for northern West Virginia. These units are identified by letters of the alphabet on each of the cross-sections presented in plates 1-28.

NOTE

PALEOGEOGRAPHIC INTERPRETATION OF SANDSTONE MAPS

The sandstone distribution patterns recognized for each mapped interval are provided in the lower left-hand corner of each map. The dominant trend is shown in bold lettering. Inferred or less obvious trends are noted with question marks. These classifications for sandstone trend can be related to broadly-defined paleoenvironments through reference to Figure 3.

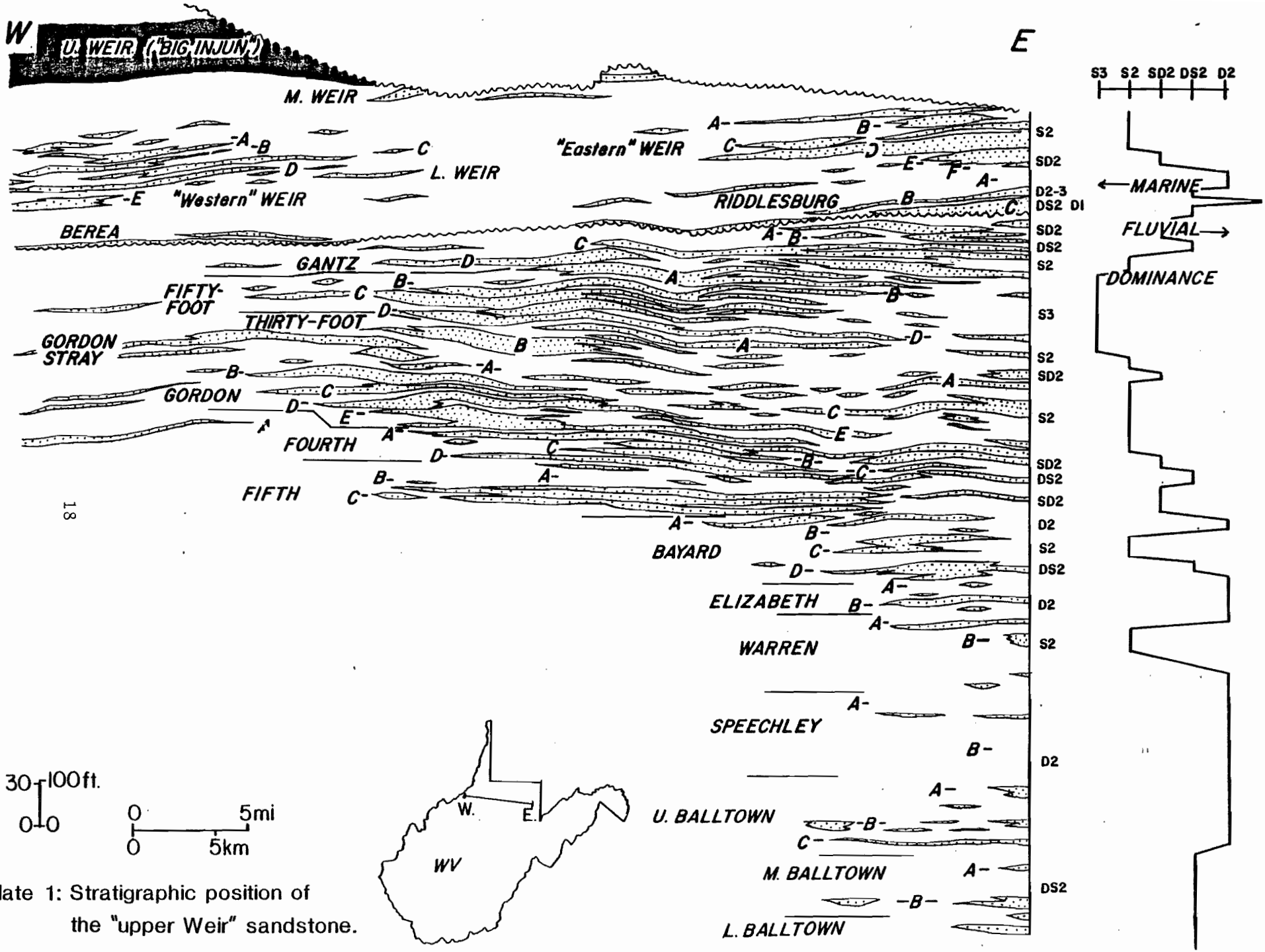


Plate 1: Stratigraphic position of the "upper Weir" sandstone.

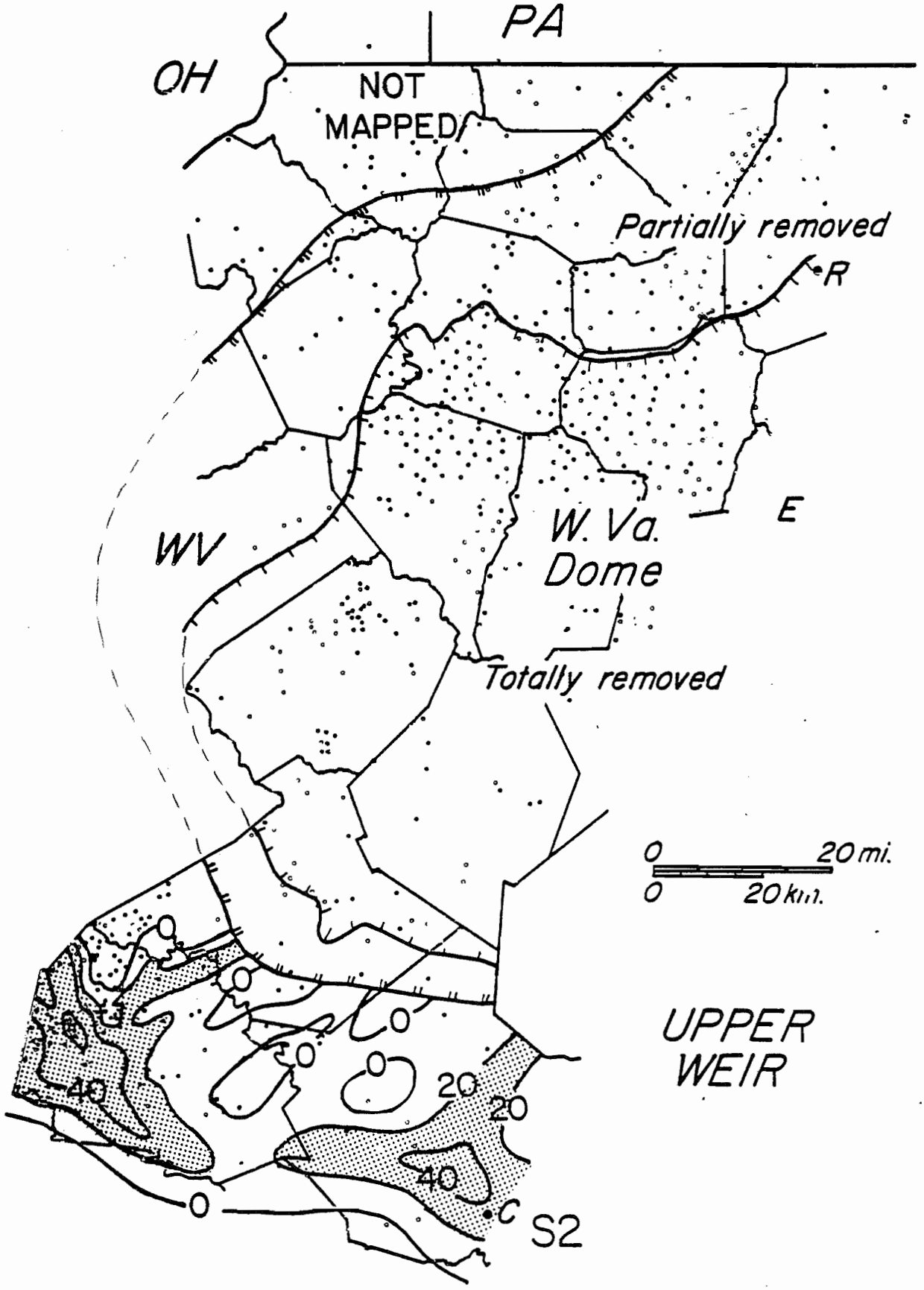


Plate 2: Isolith map of the "upper Weir" sandstone

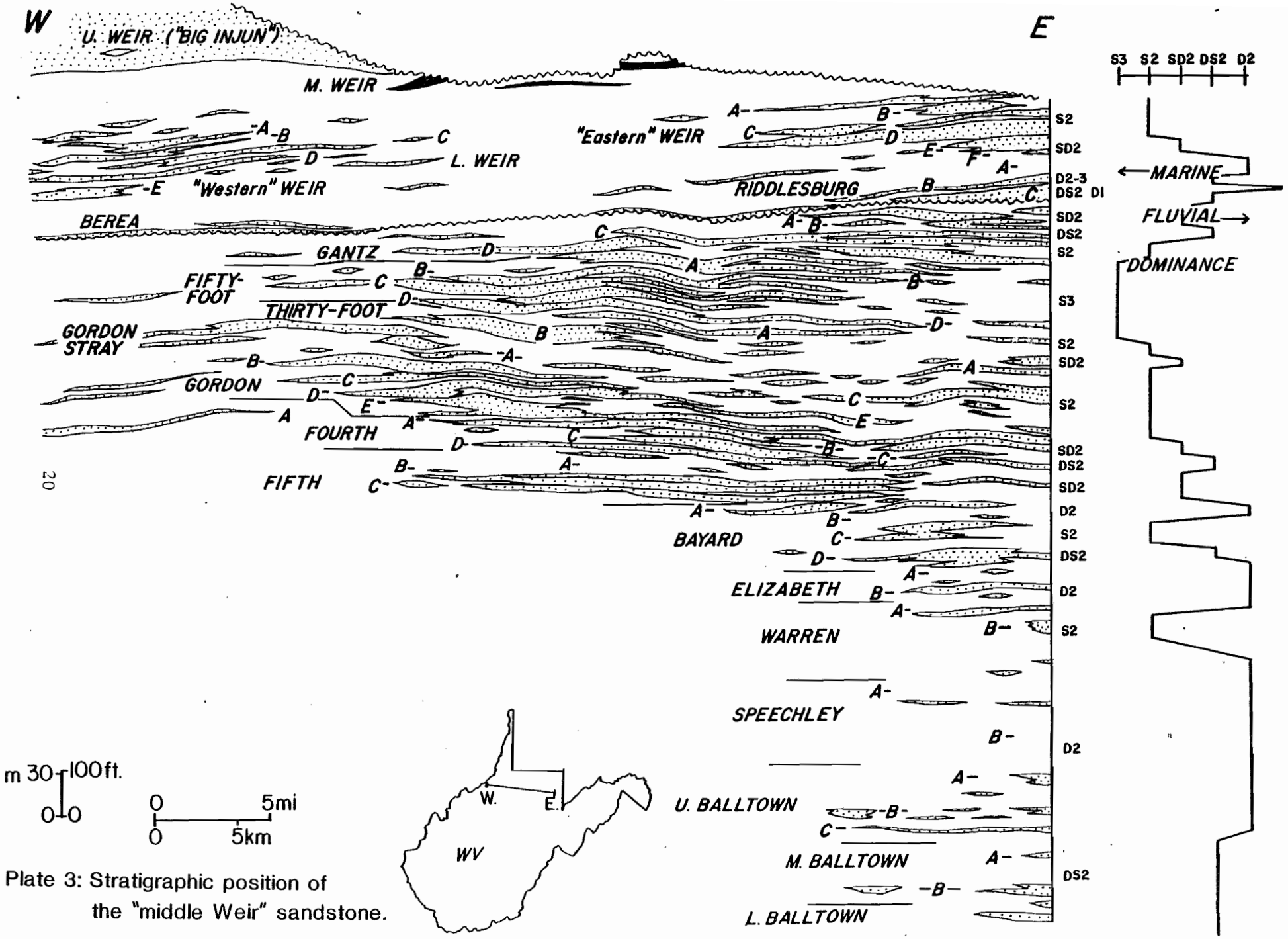


Plate 3: Stratigraphic position of the "middle Weir" sandstone.

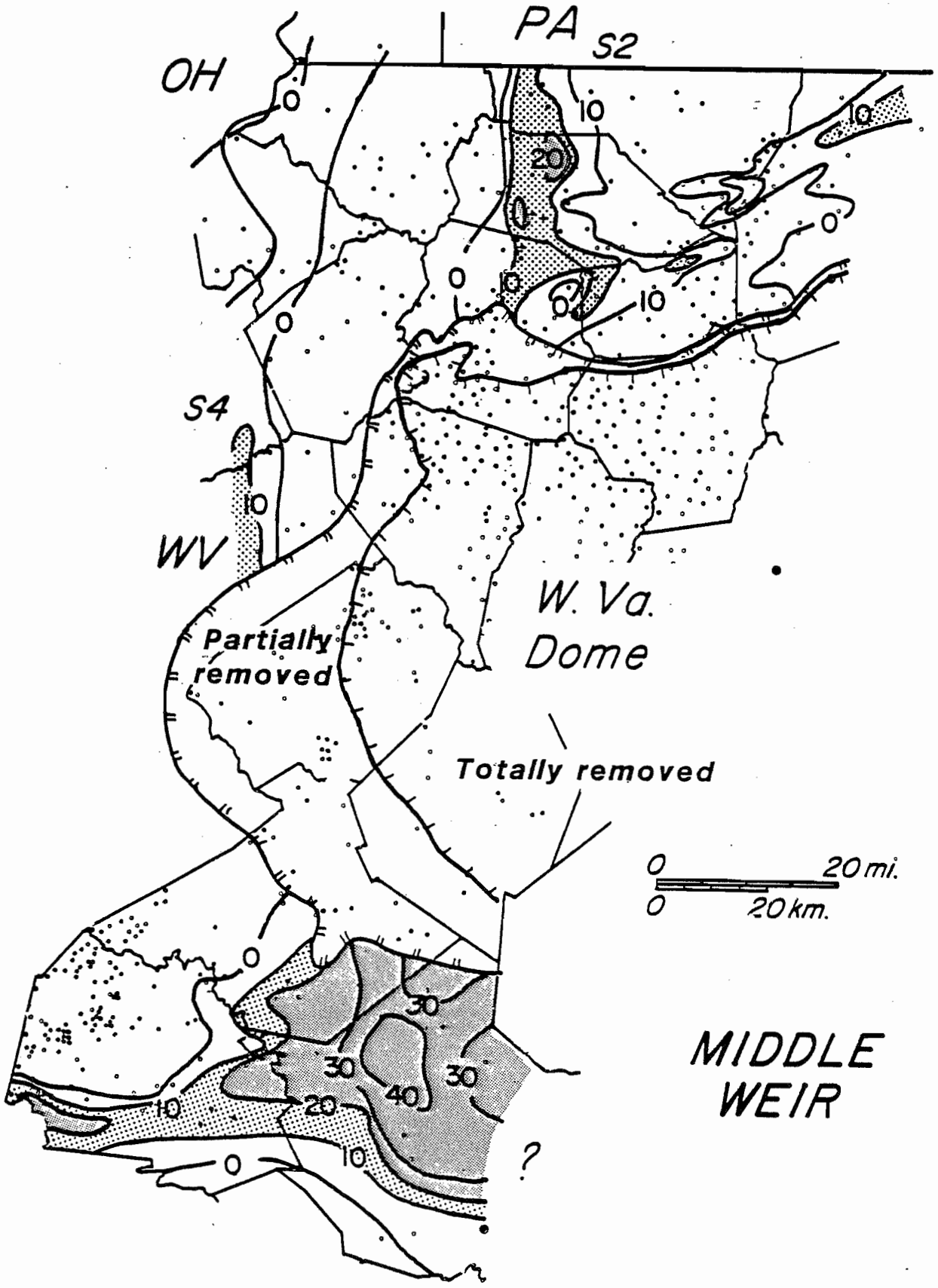


Plate 4: Isolith map of the "middle Weir" sandstone.

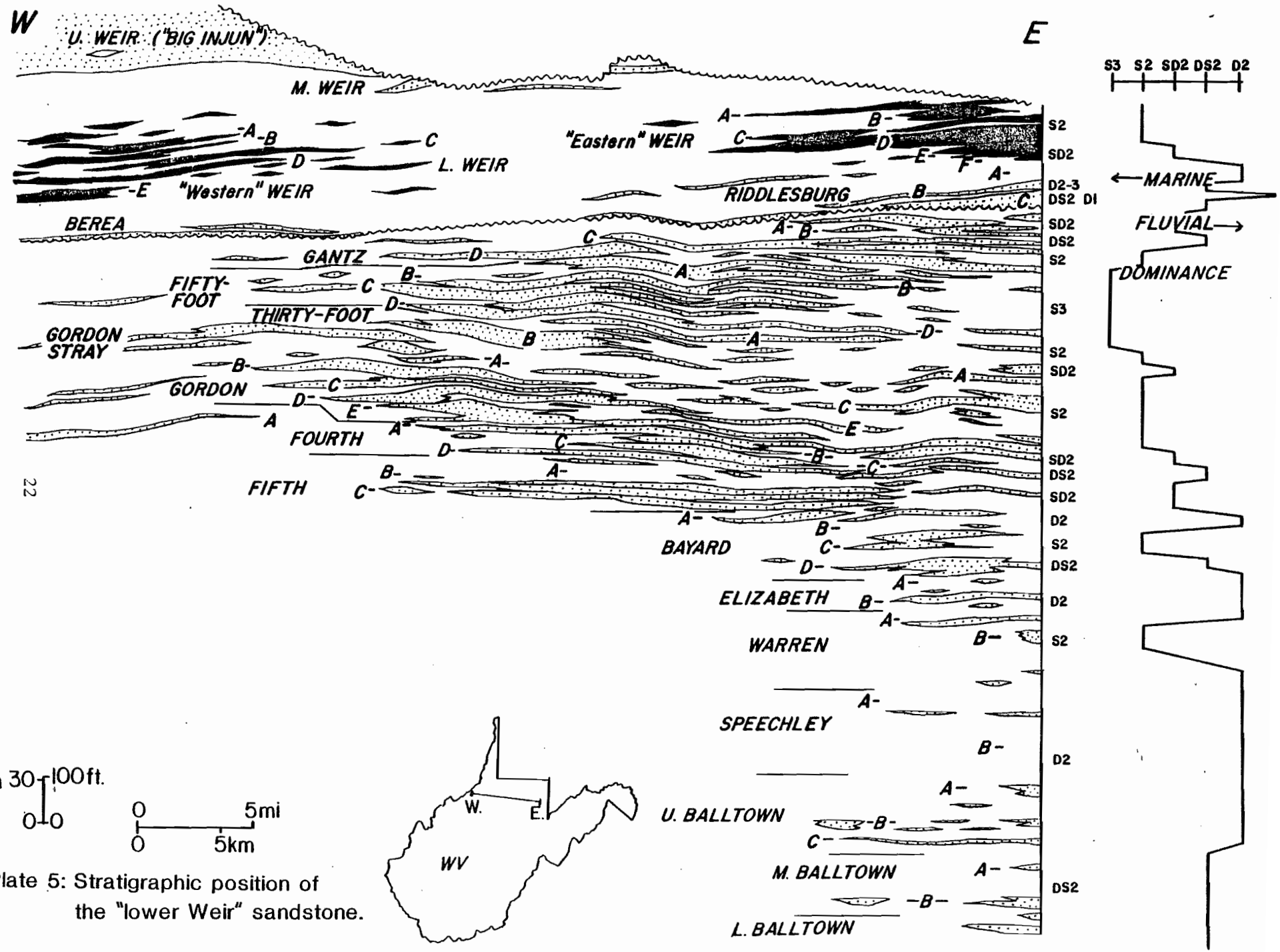


Plate 5: Stratigraphic position of the "lower Weir" sandstone.

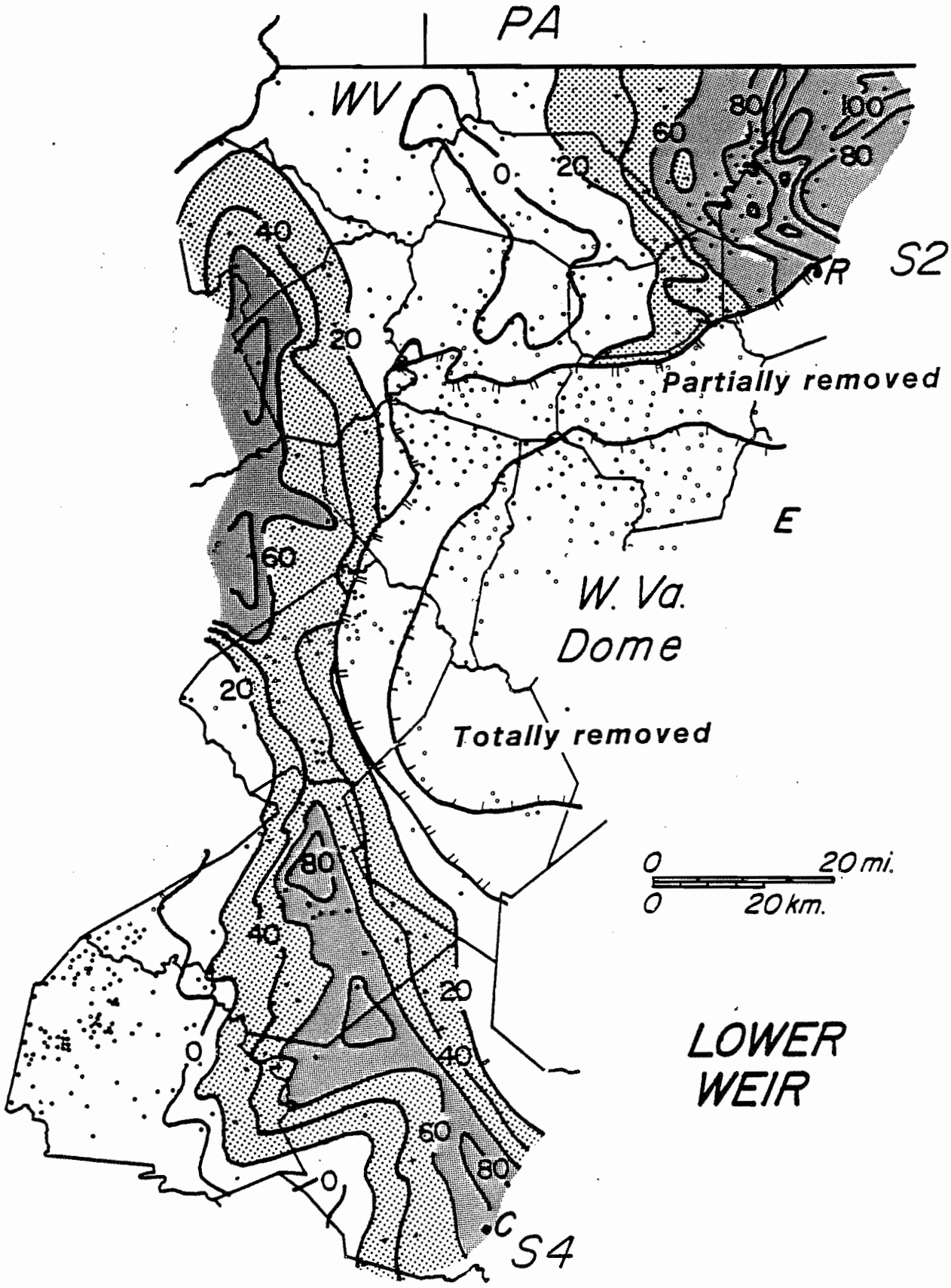


Plate 6: Isolith map of the "lower Weir" sandstone.

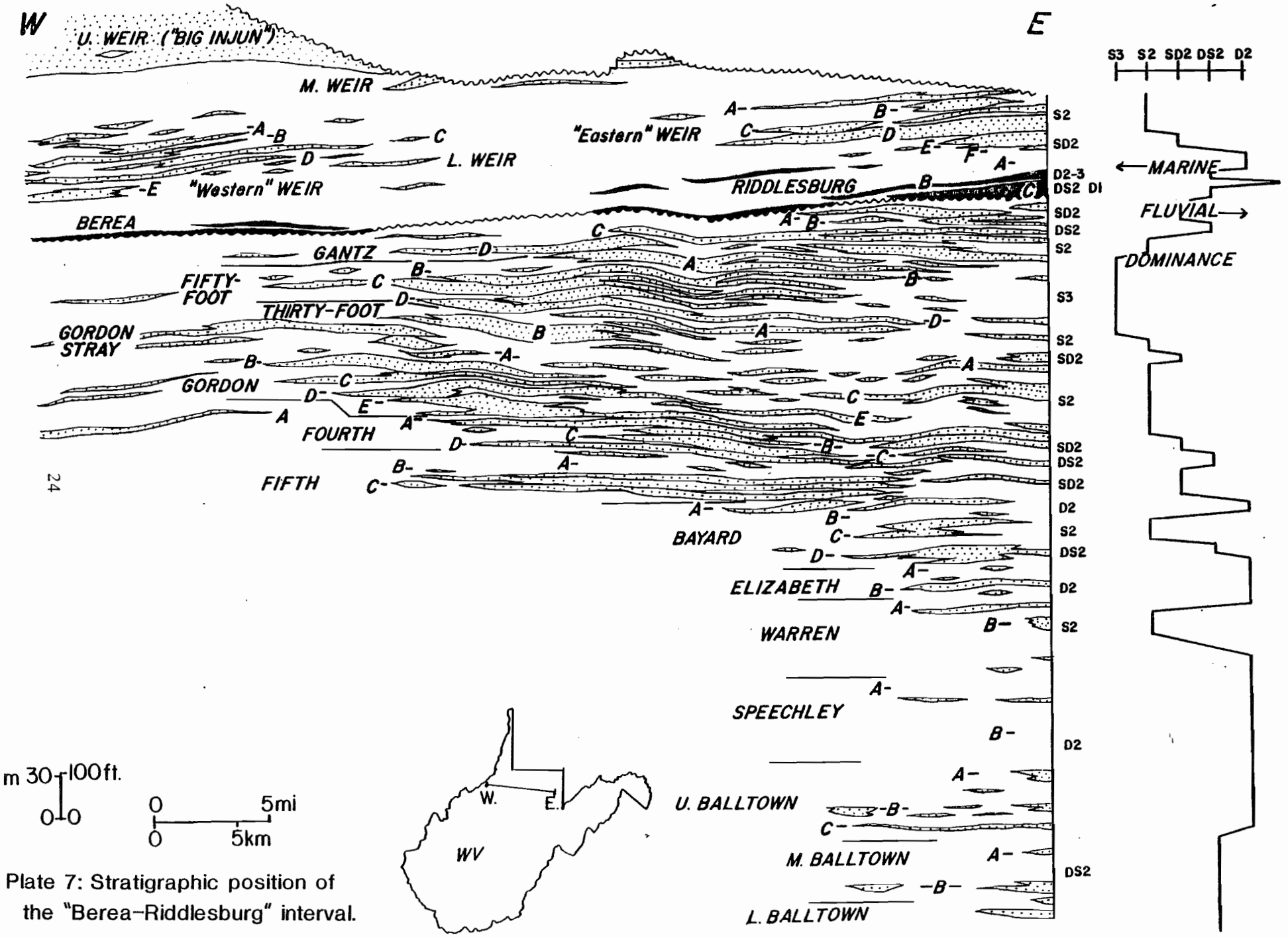
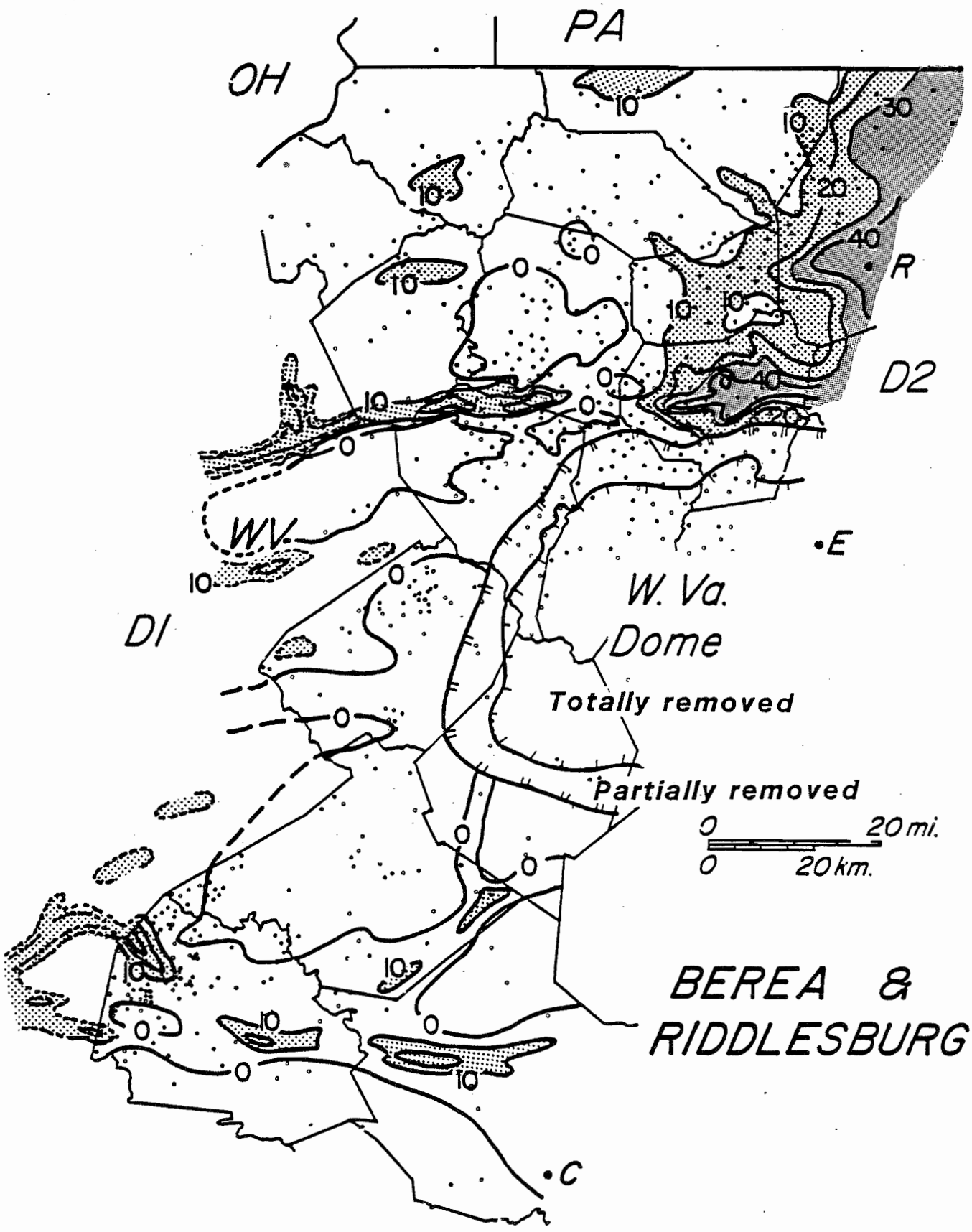


Plate 7: Stratigraphic position of the "Berea–Riddlesburg" interval.



-------CONTOURS MODIFIED AFTER *PEPPER and others (1954)*

Plate 8: Isolith map of sandstones in the "Berea-Riddlesburg" interval.

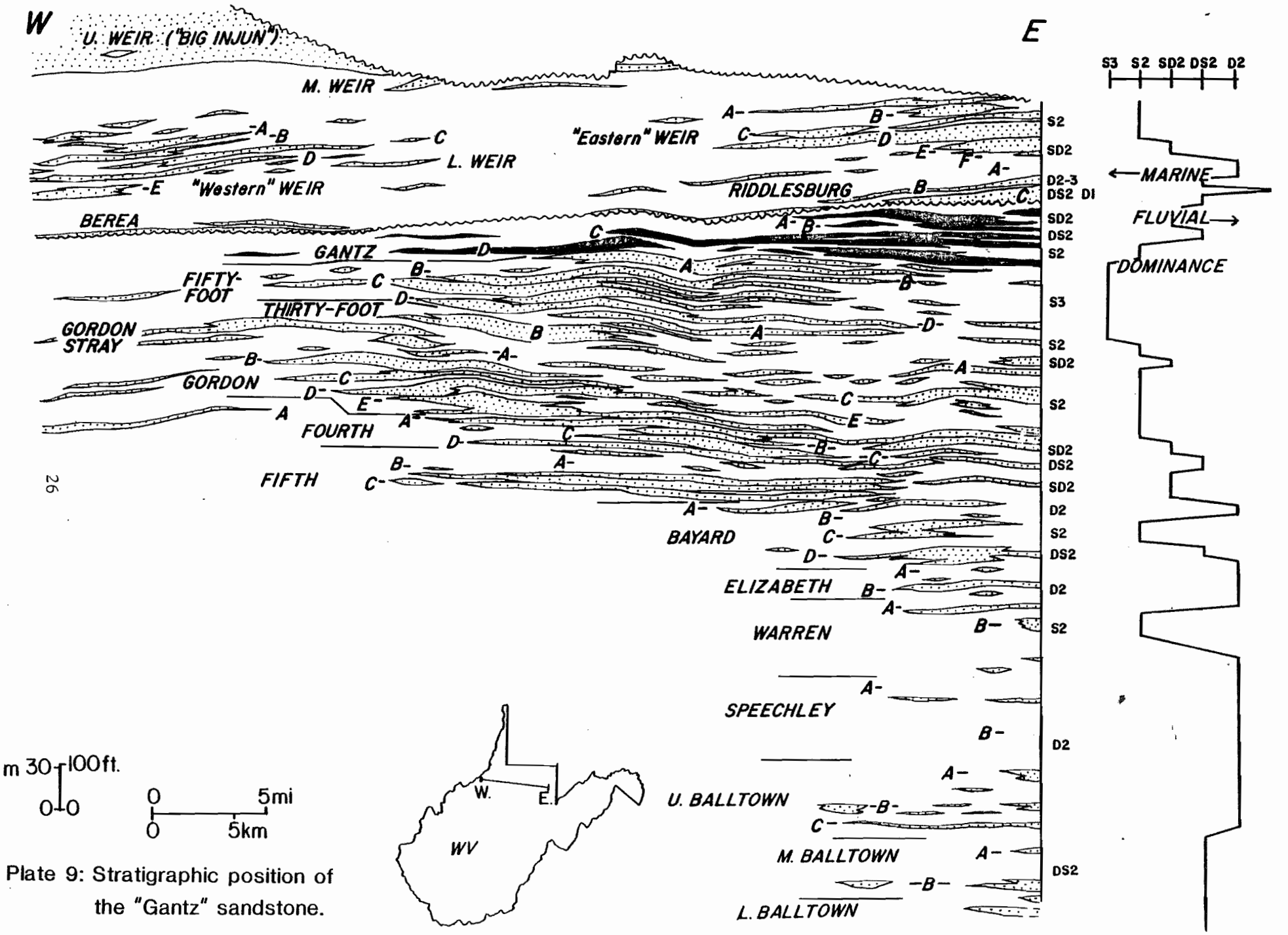


Plate 9: Stratigraphic position of the "Gantz" sandstone.

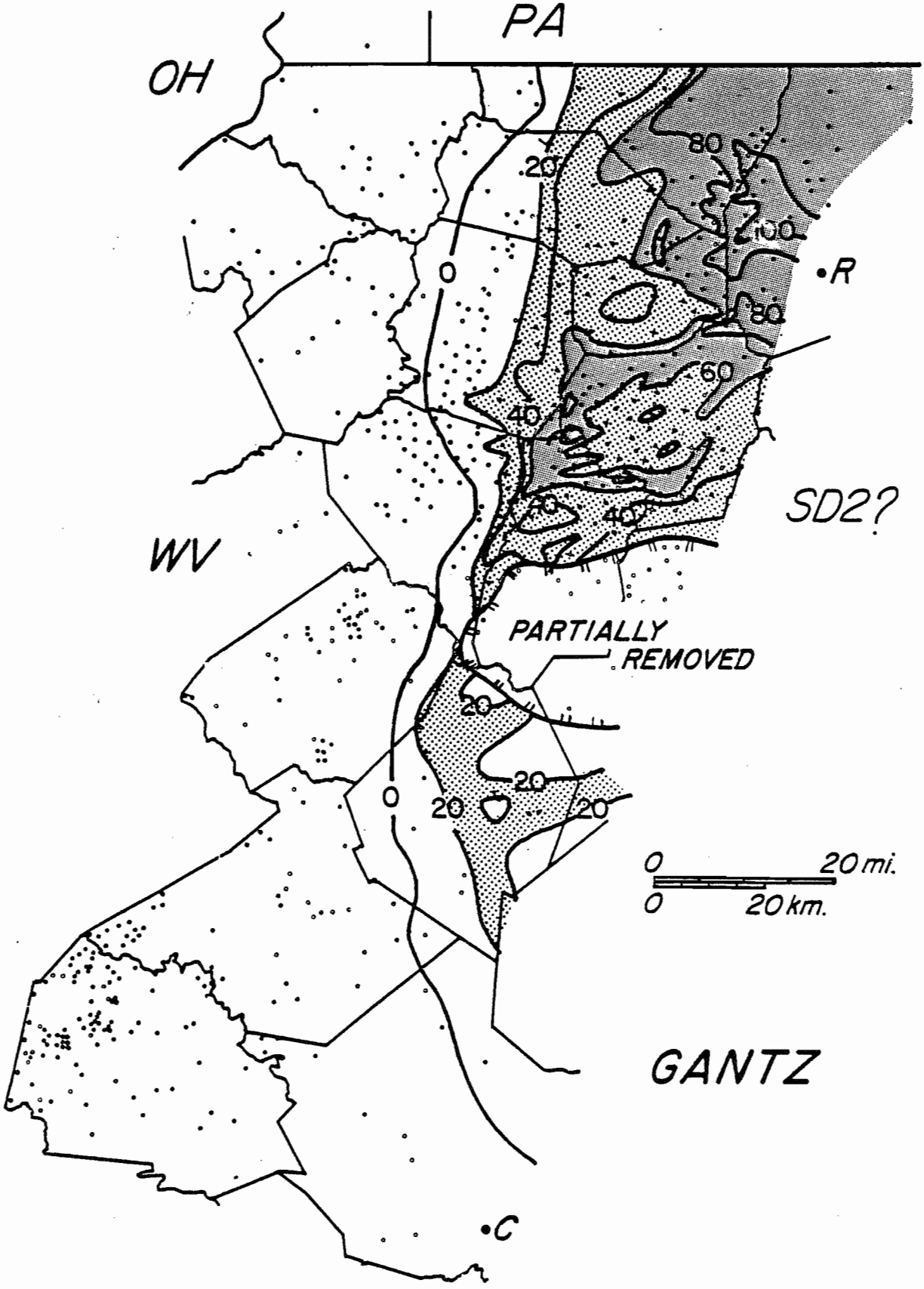


Plate 10: Isolith map of the "Gantz" sandstone.

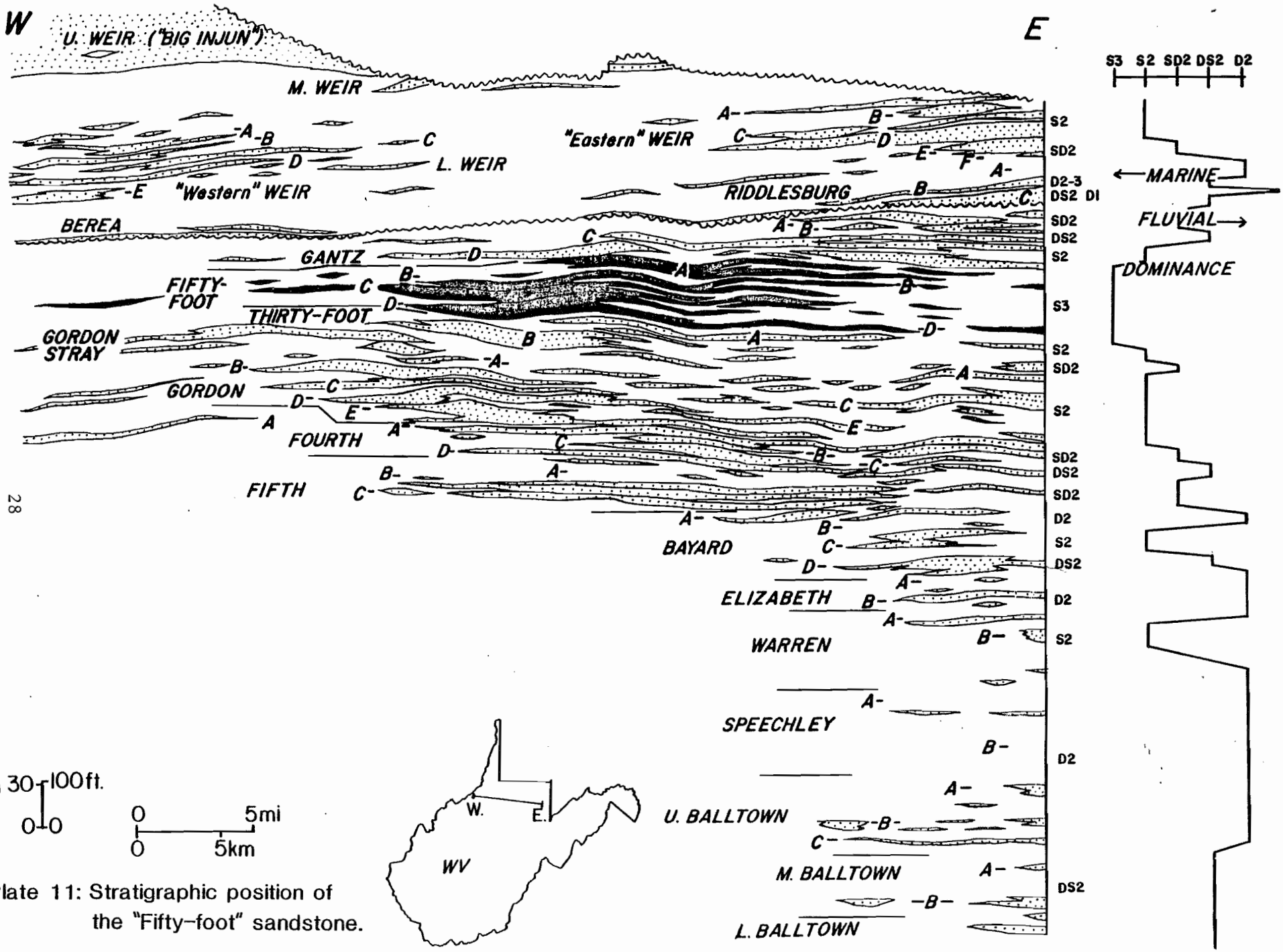


Plate 11: Stratigraphic position of the "Fifty-foot" sandstone.

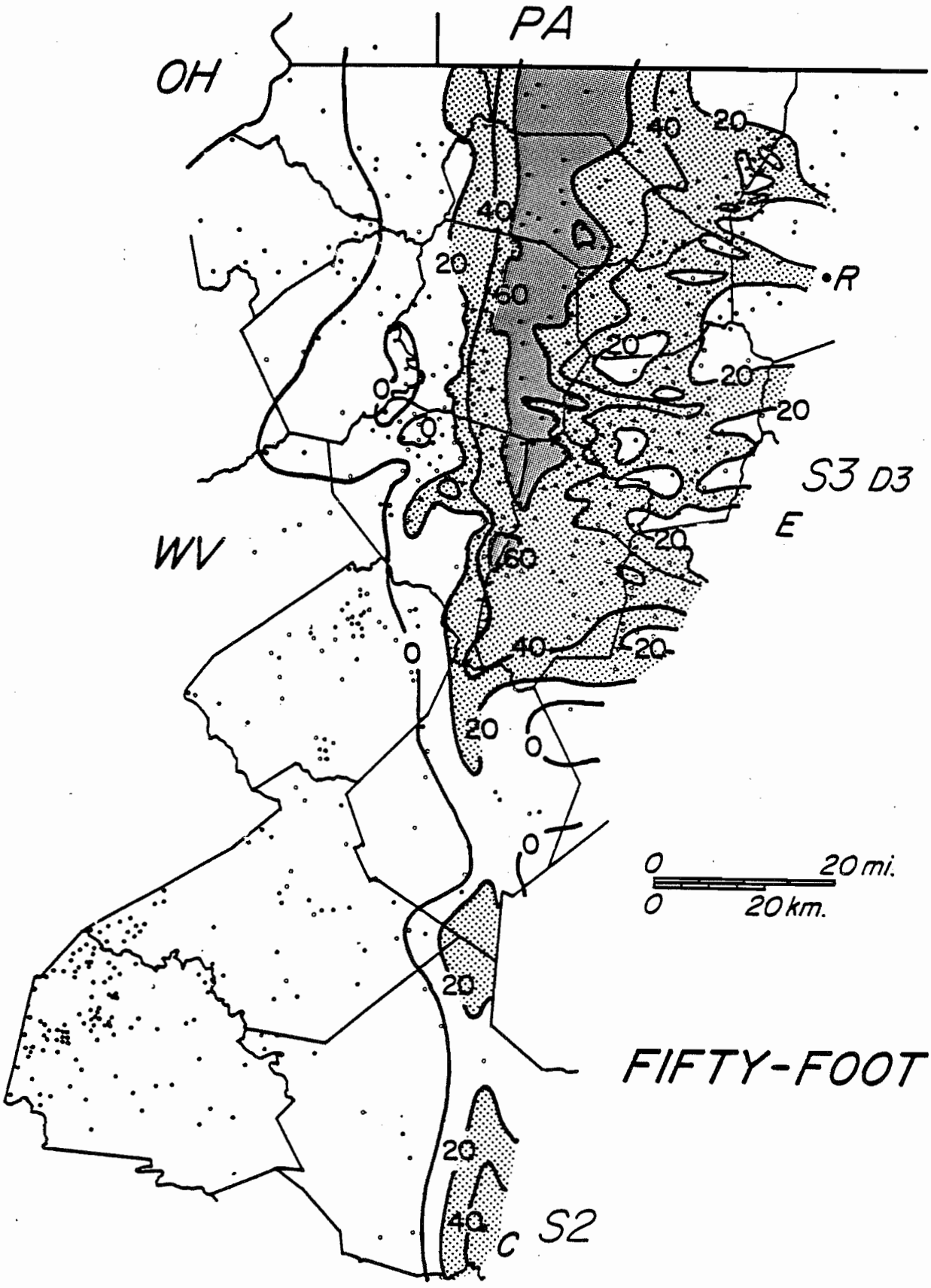


Plate 12: Isolith map of the "Fifty-foot" sandstone.

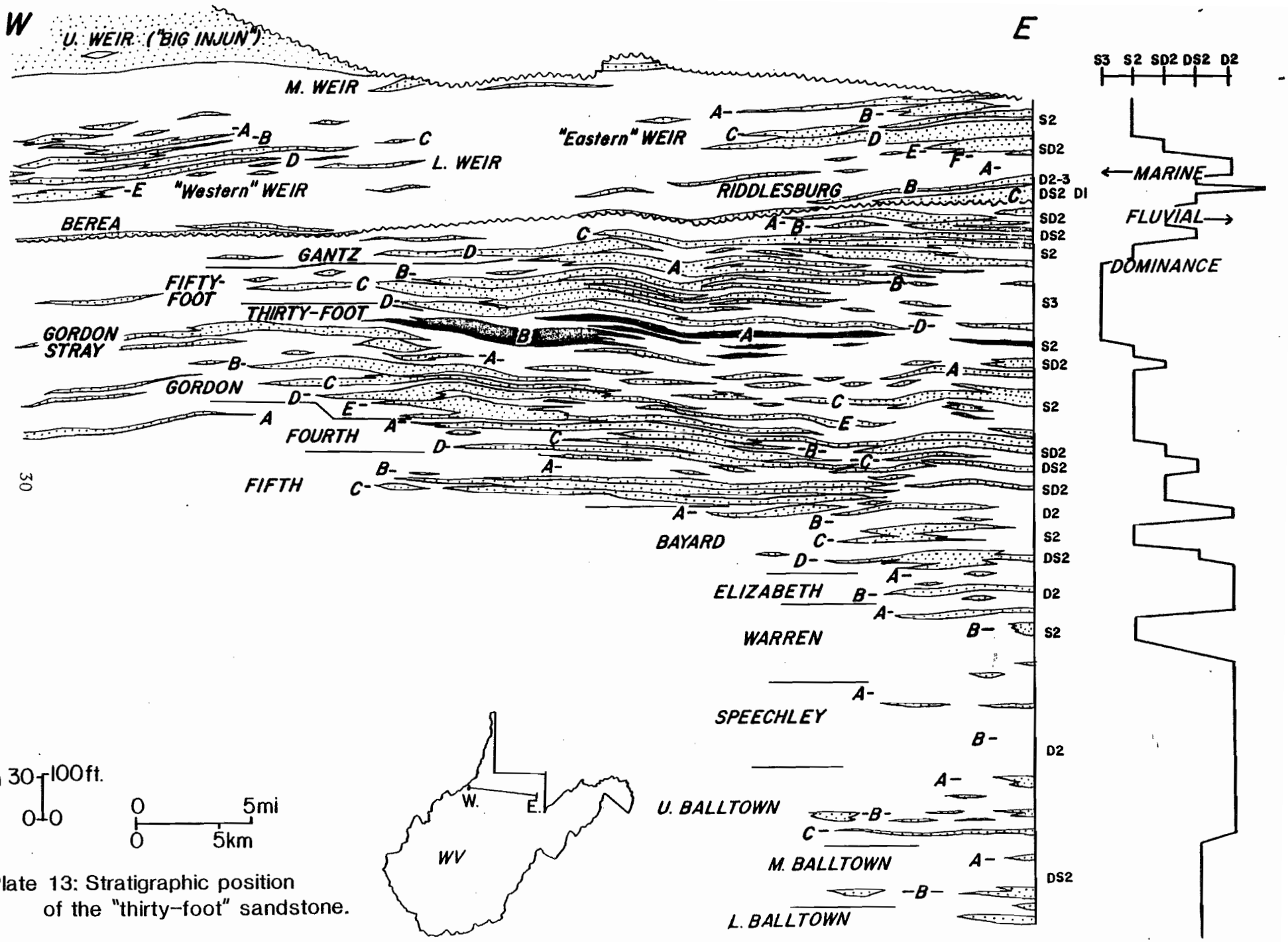


Plate 13: Stratigraphic position of the "thirty-foot" sandstone.

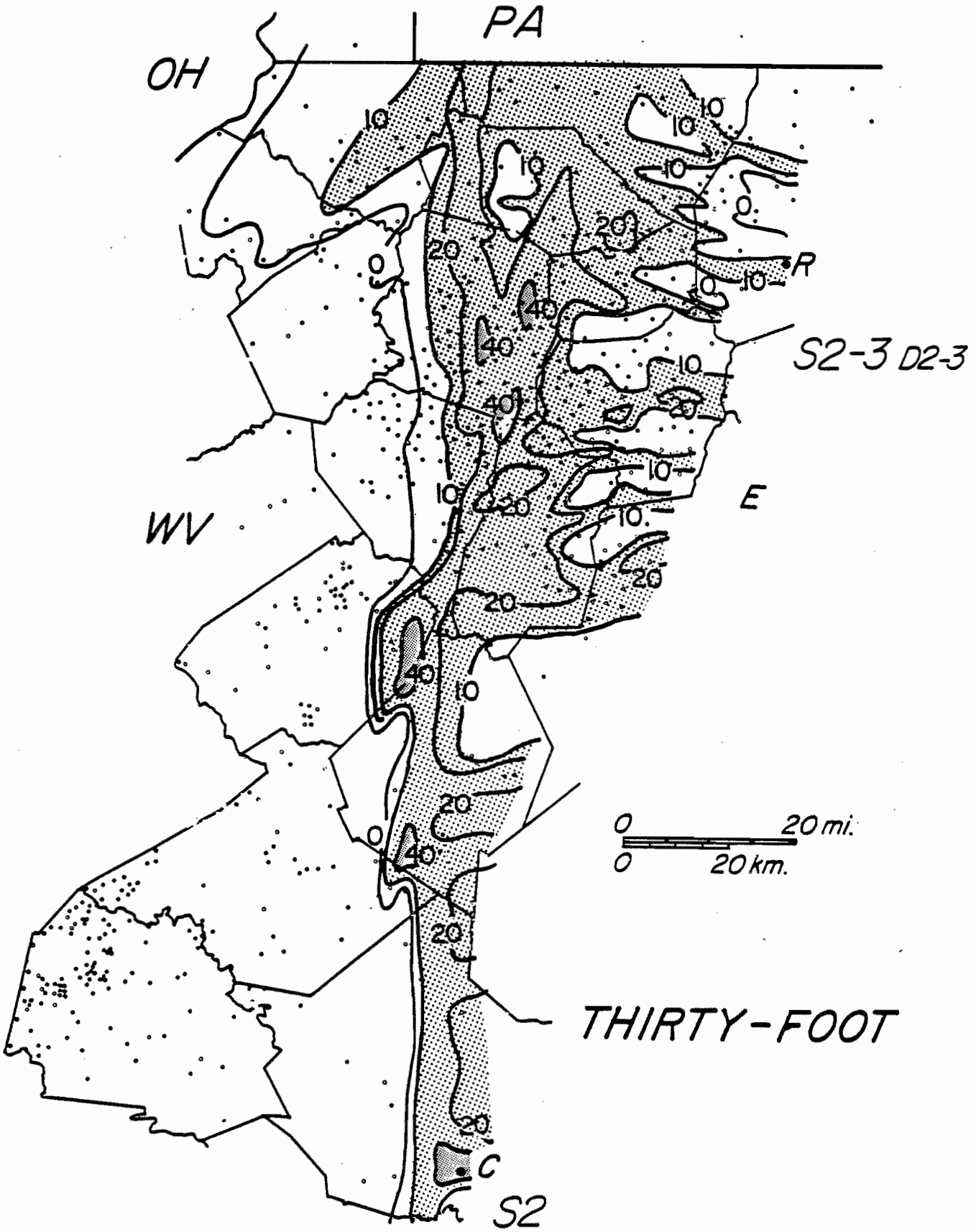


Plate 14: Isolith map of the "Thirty-foot" sandstone.

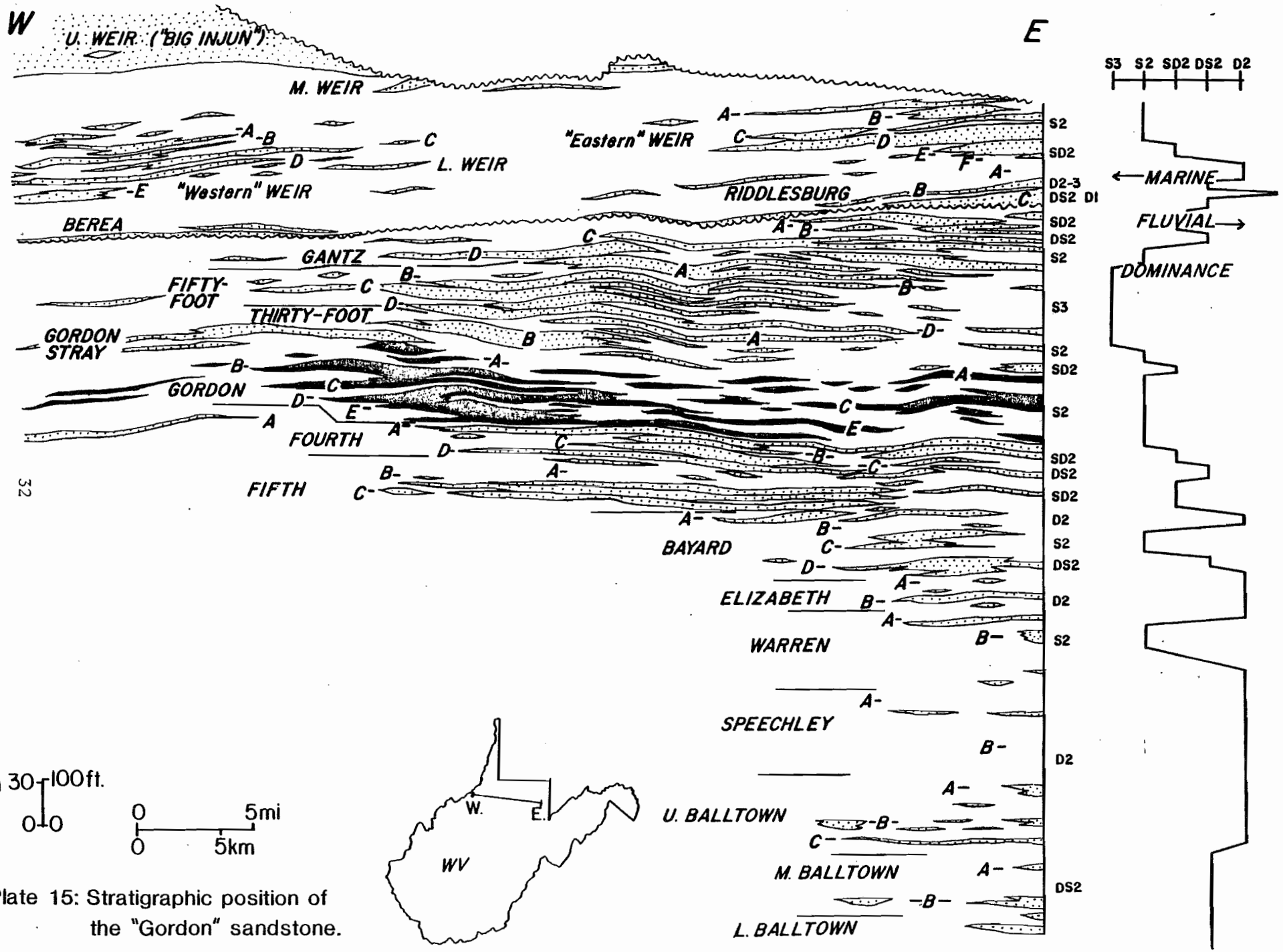


Plate 15: Stratigraphic position of the "Gordon" sandstone.

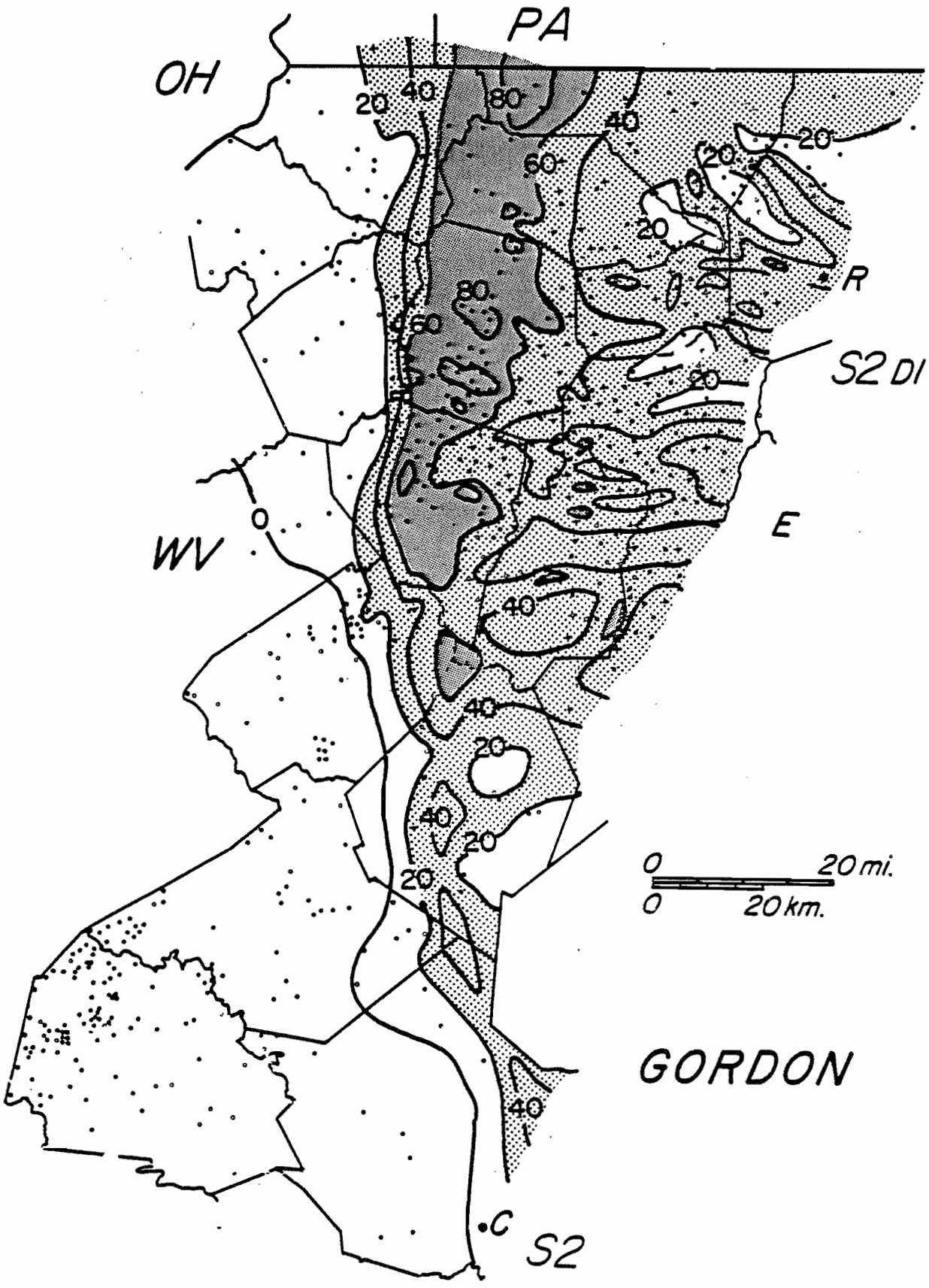


Plate 16: Isolith map of the "Gordon" sandstone.

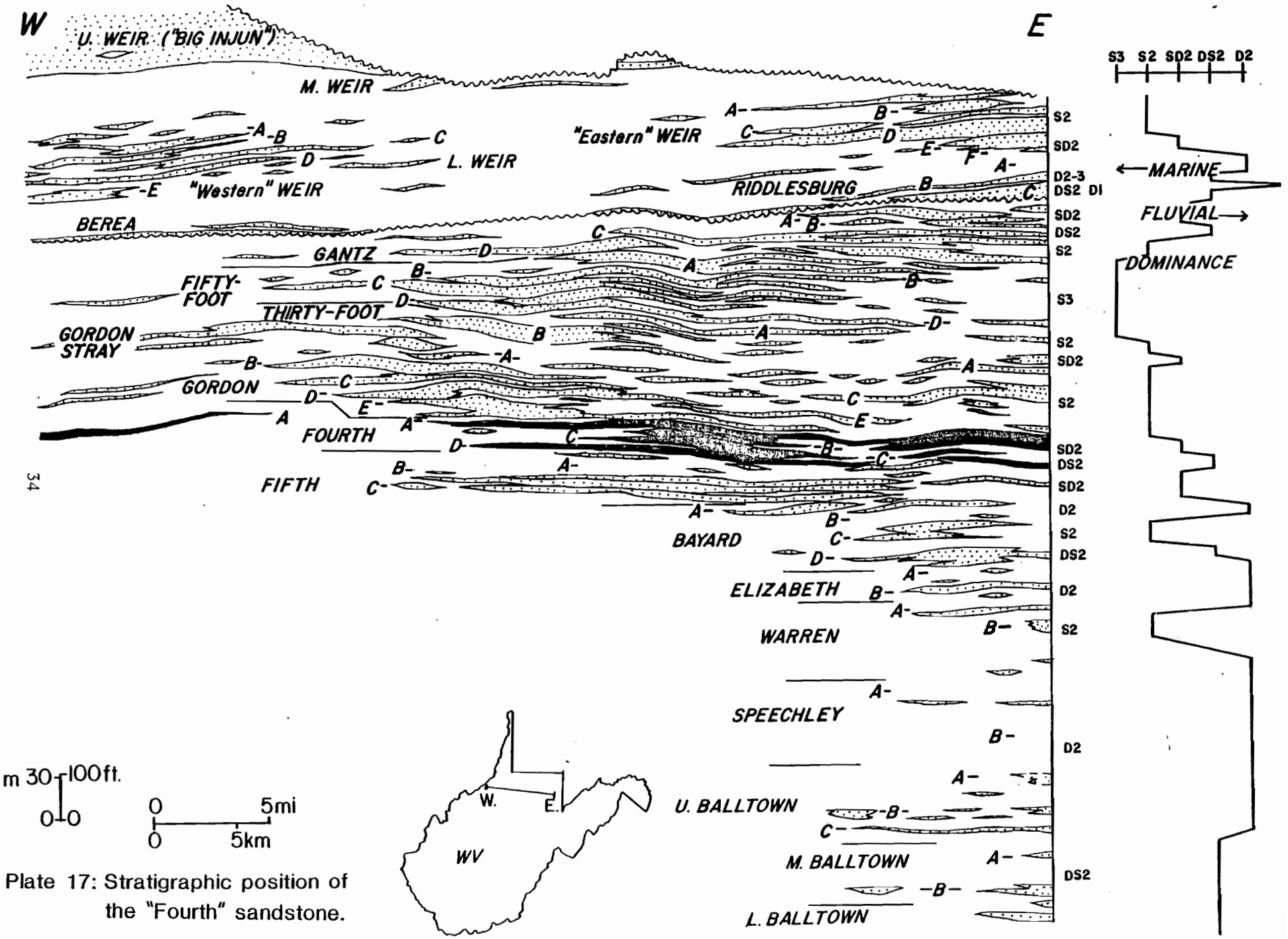


Plate 17: Stratigraphic position of the "Fourth" sandstone.

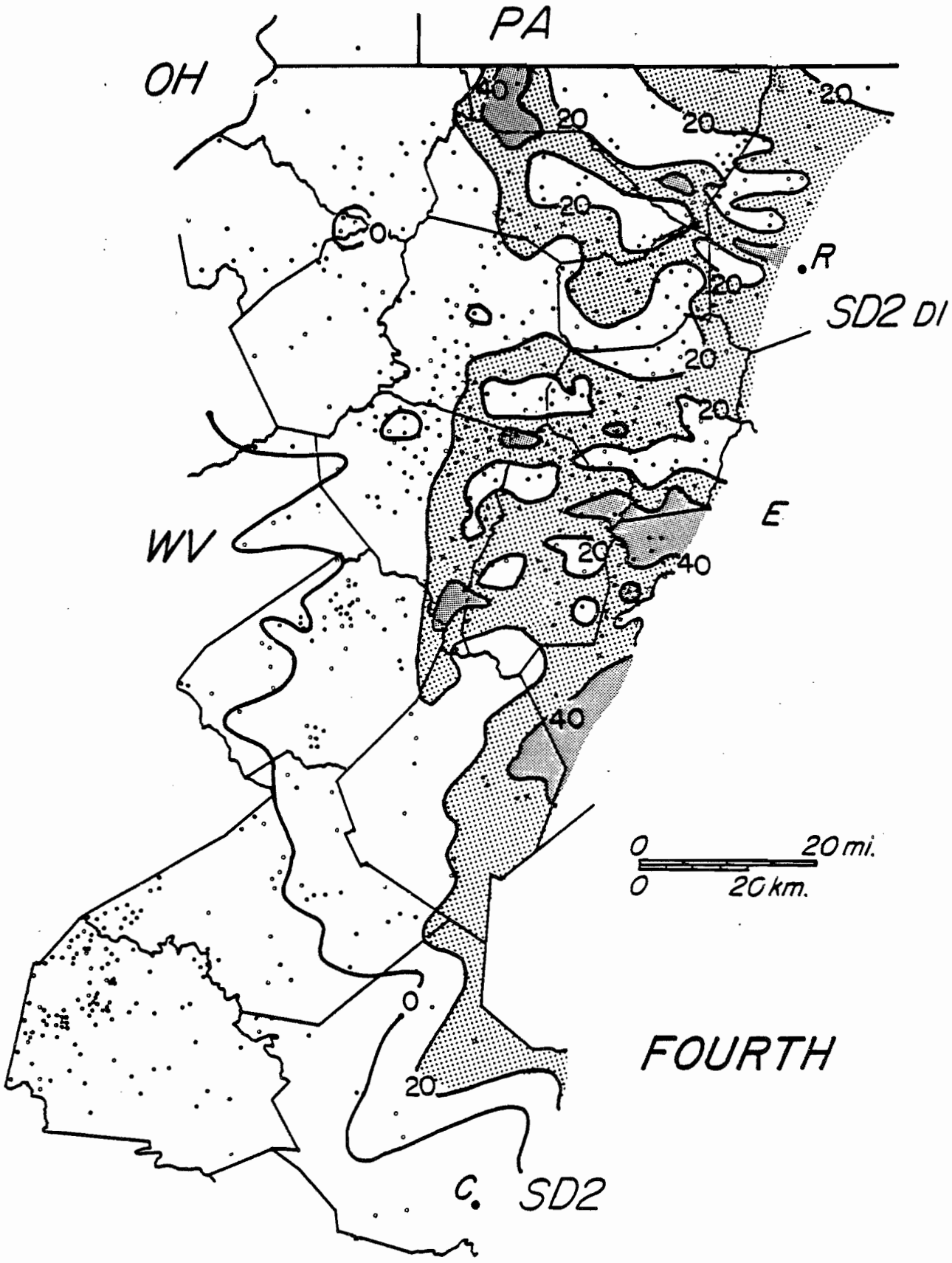


Plate 18: Isolith map of the "Fourth" sandstone.

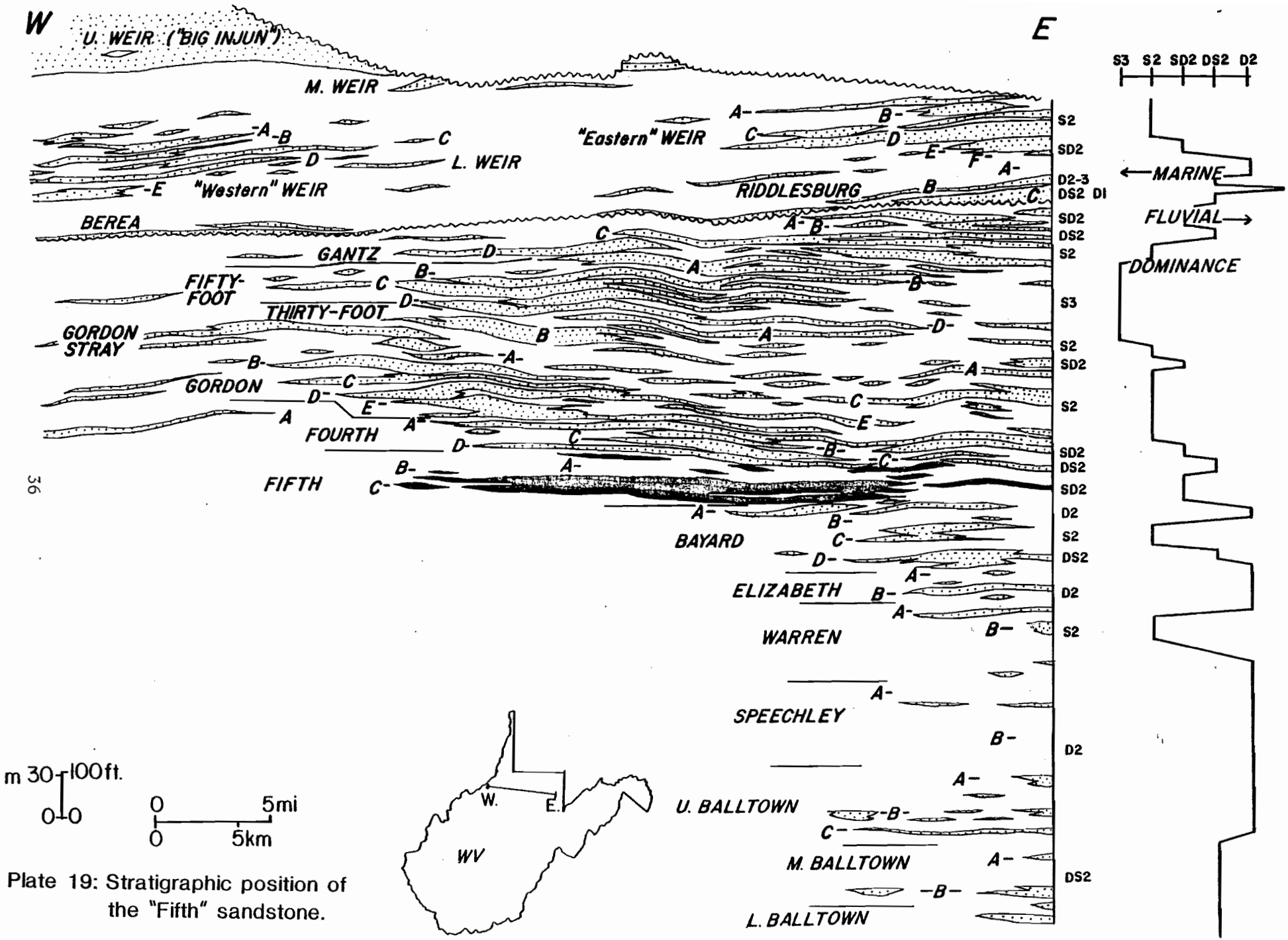


Plate 19: Stratigraphic position of the "Fifth" sandstone.

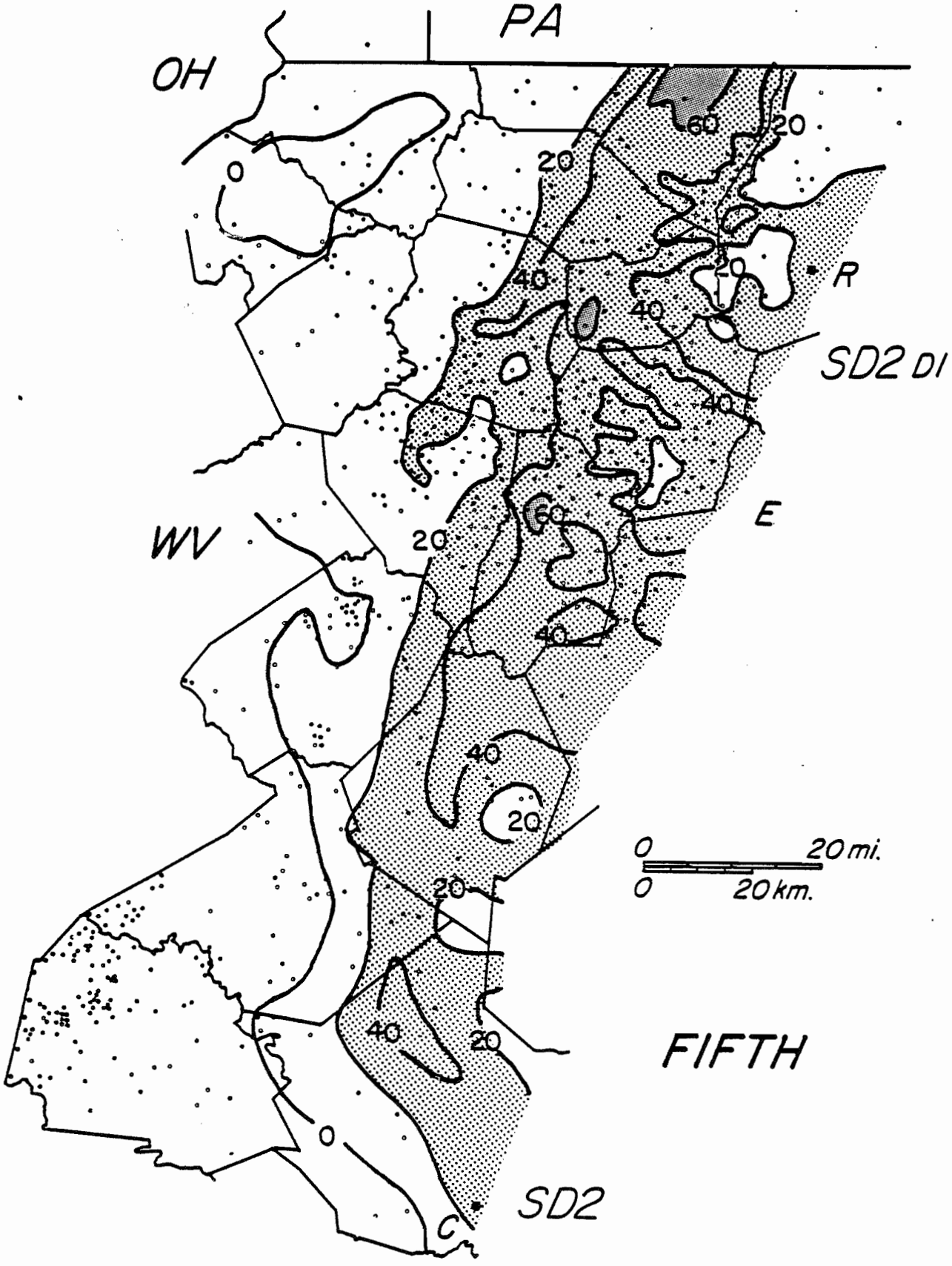


Plate 20: Isolith map of the "Fifth" sandstone.

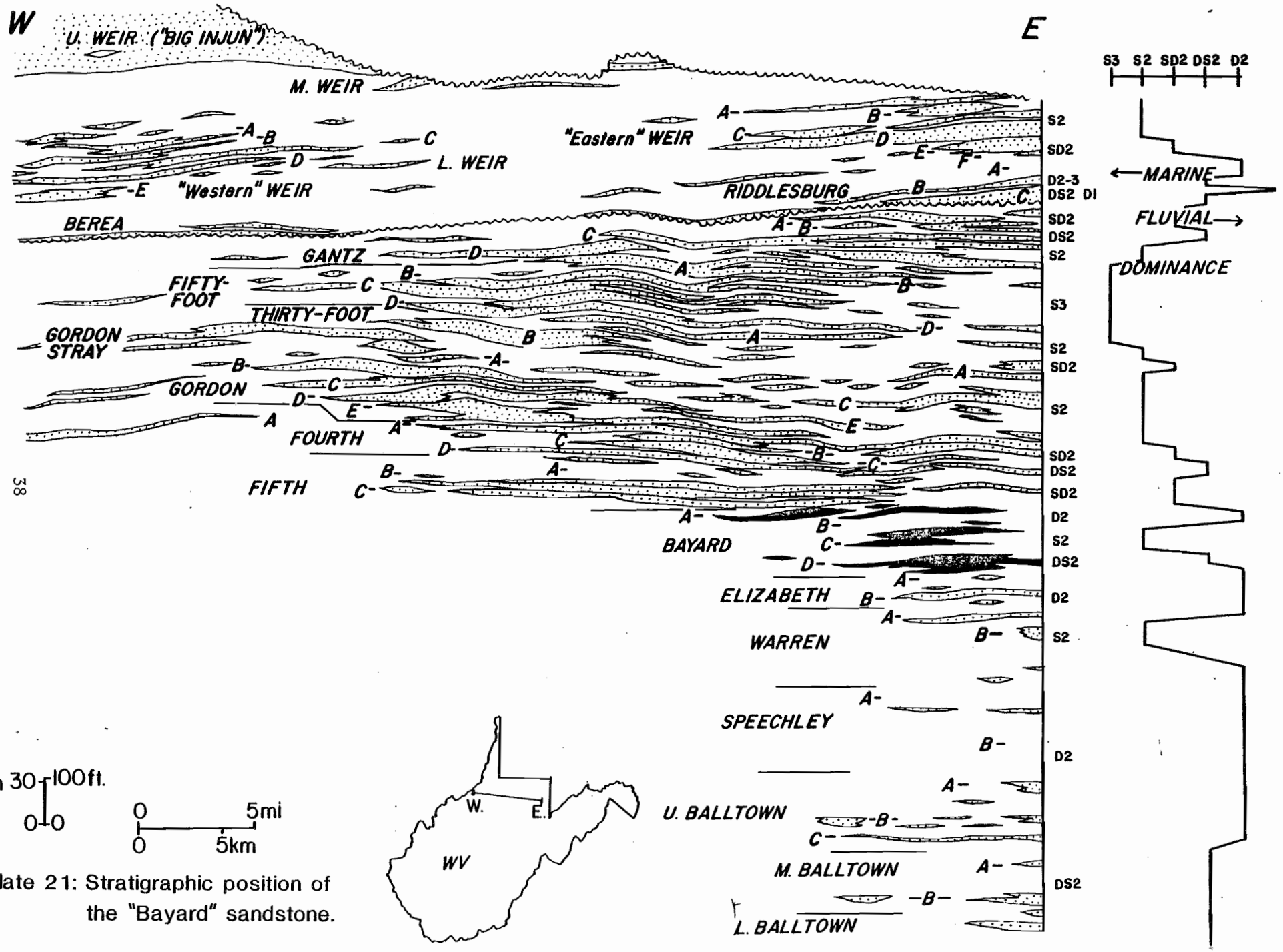


Plate 21: Stratigraphic position of the "Bayard" sandstone.

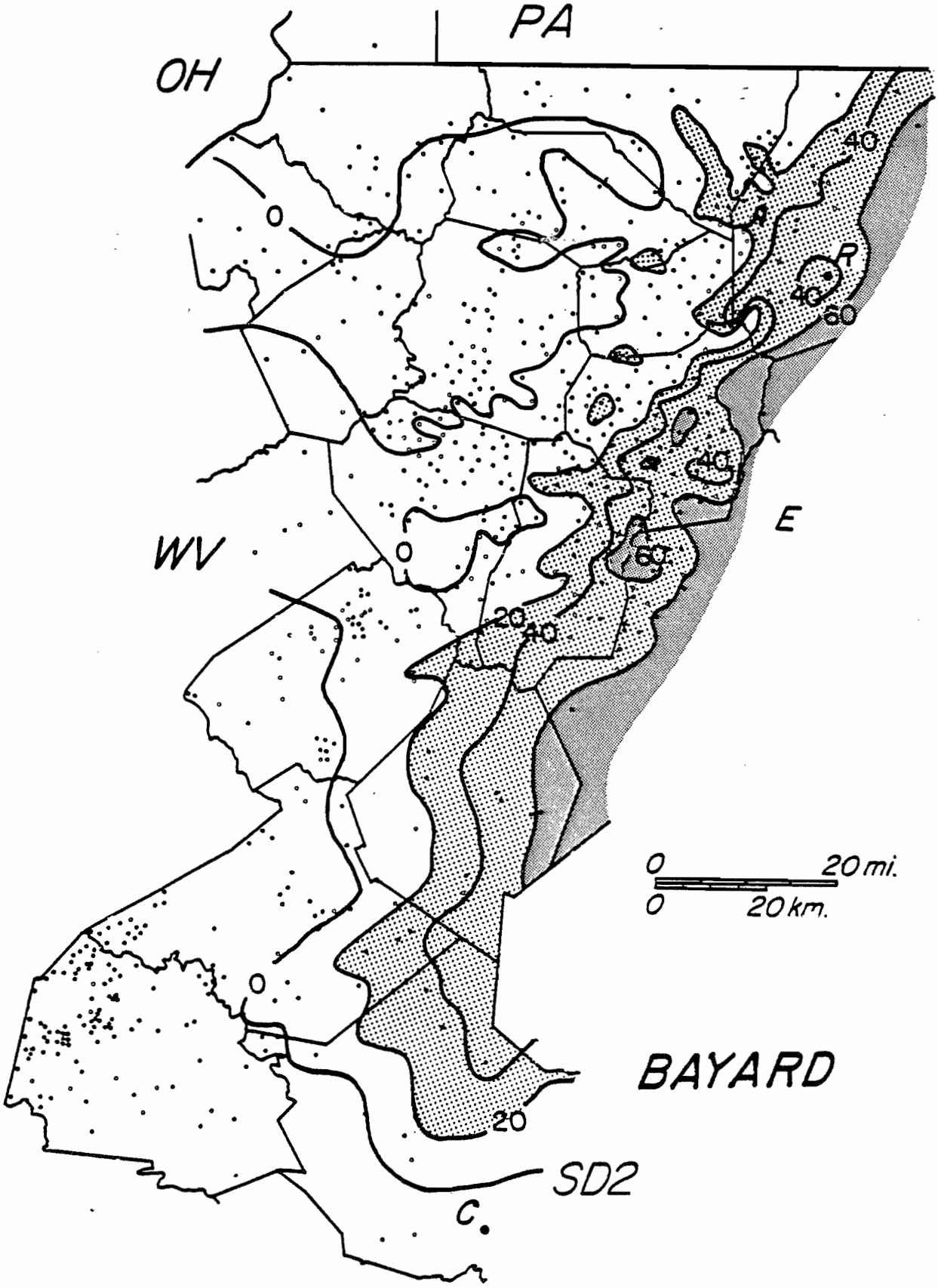


Plate 22: Isolith map of the "Bayard" sandstone.

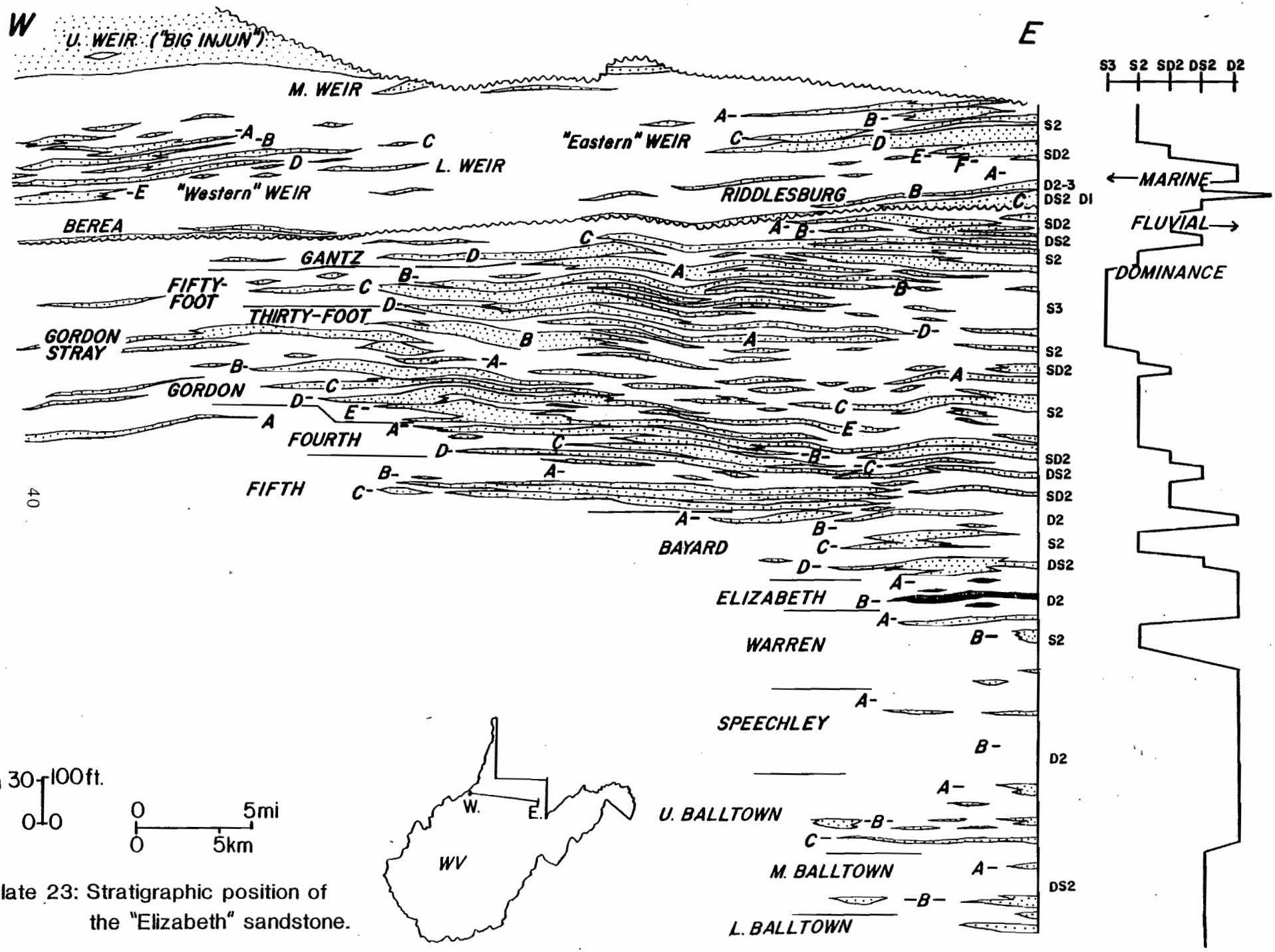


Plate 23: Stratigraphic position of the "Elizabeth" sandstone.

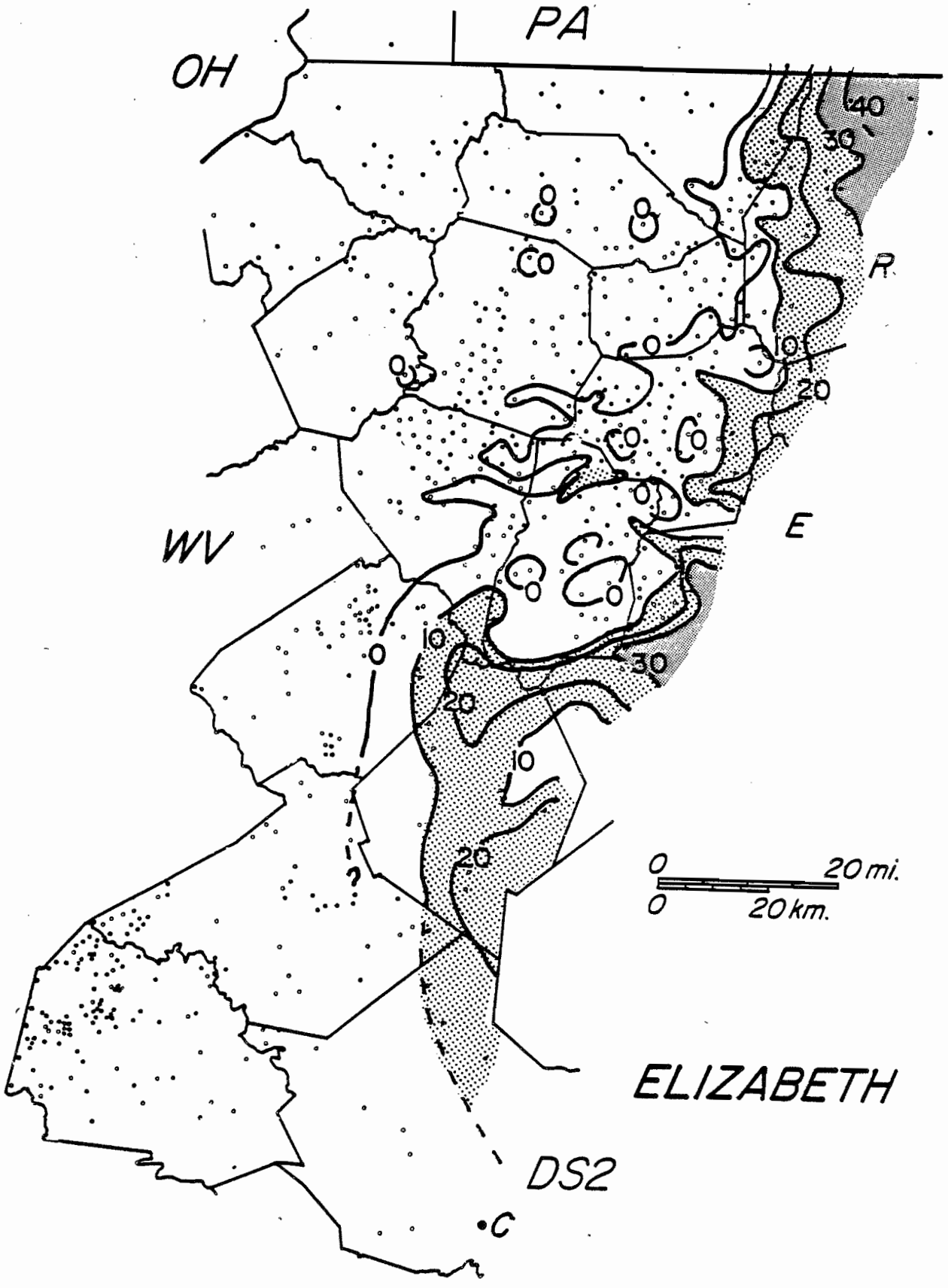


Plate 24: Isolith map of the "Elizabeth" sandstone.

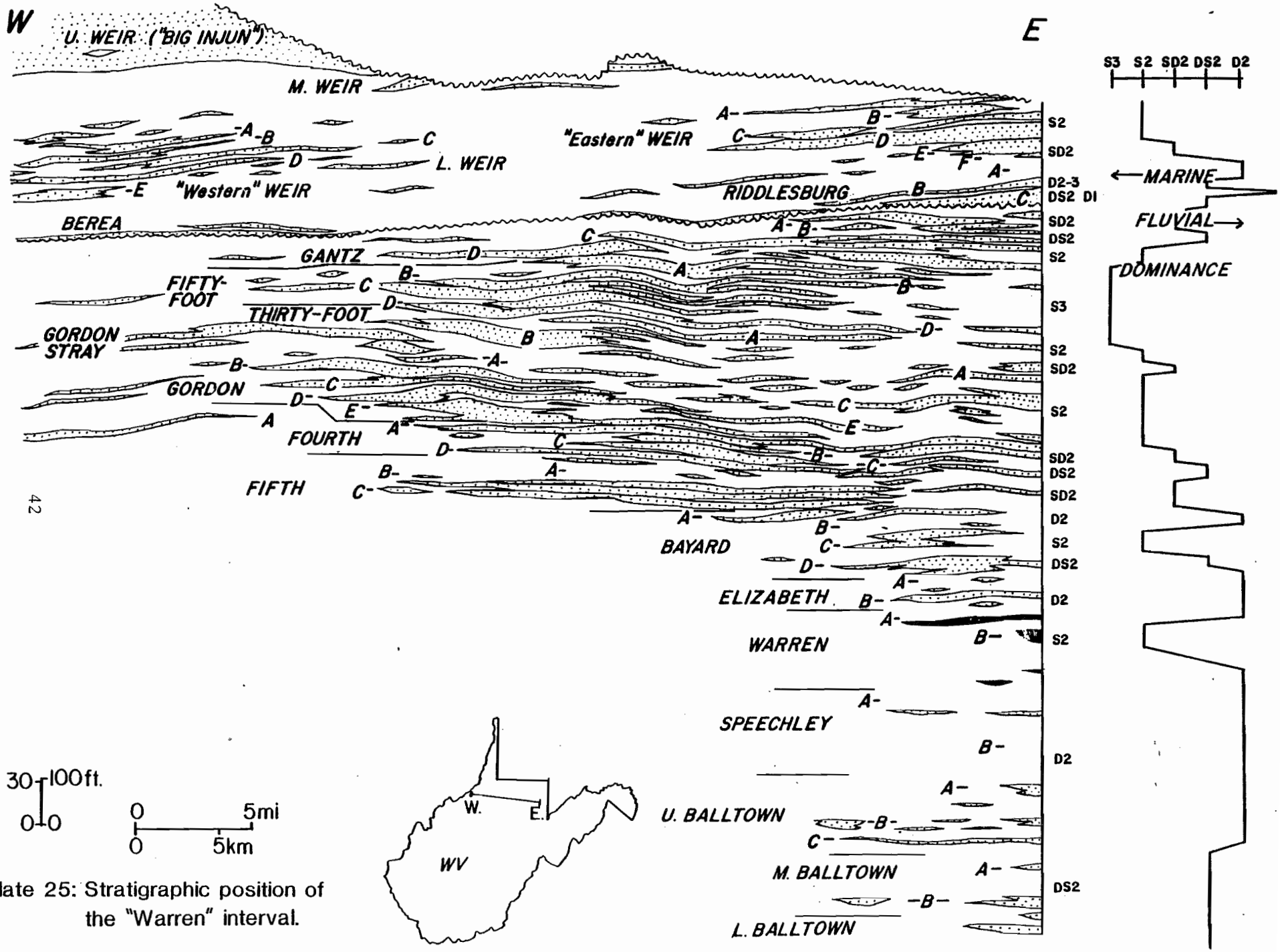


Plate 25: Stratigraphic position of the "Warren" interval.

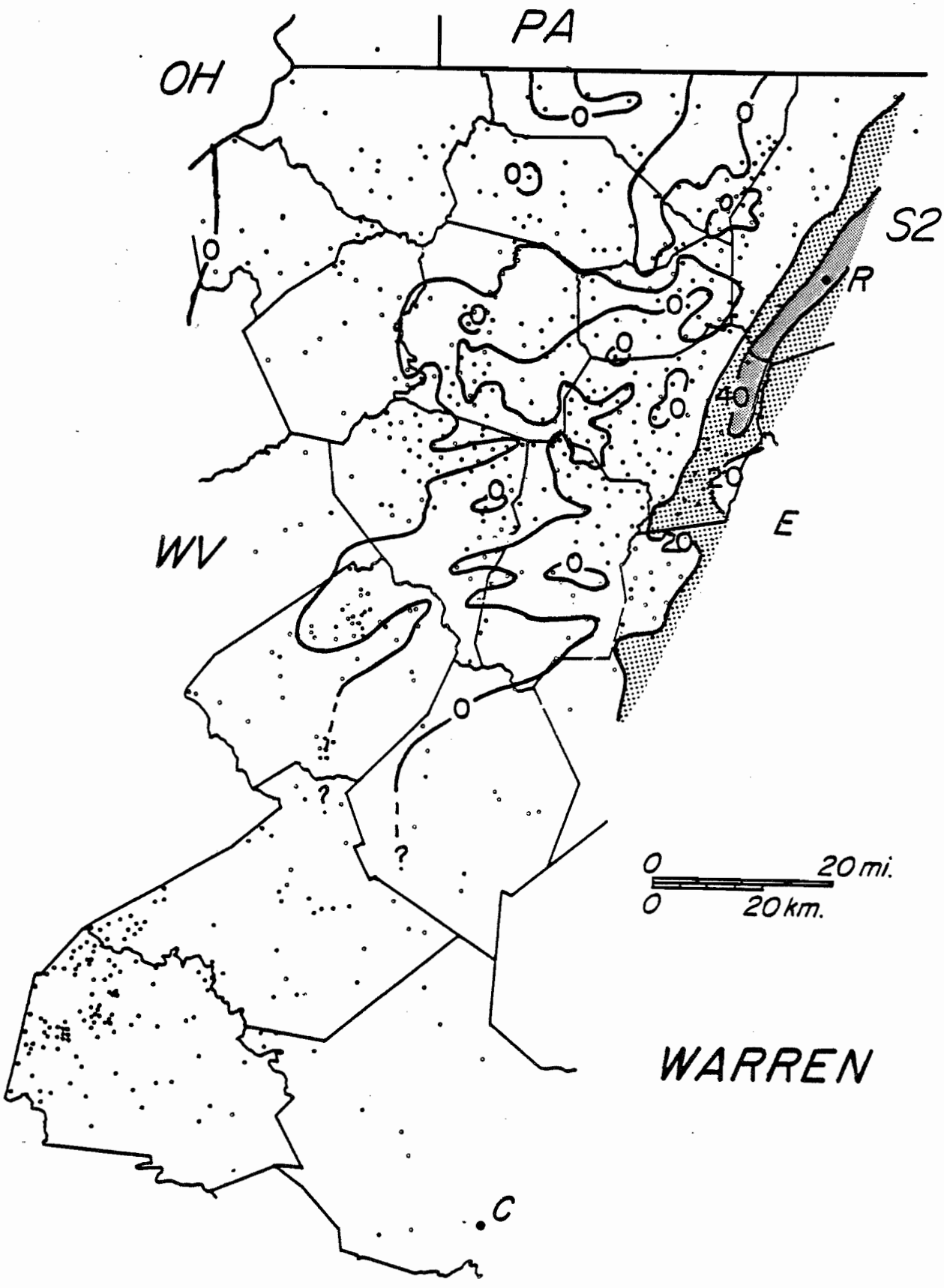


Plate 26: Isolith map of the "Warren" sandstone

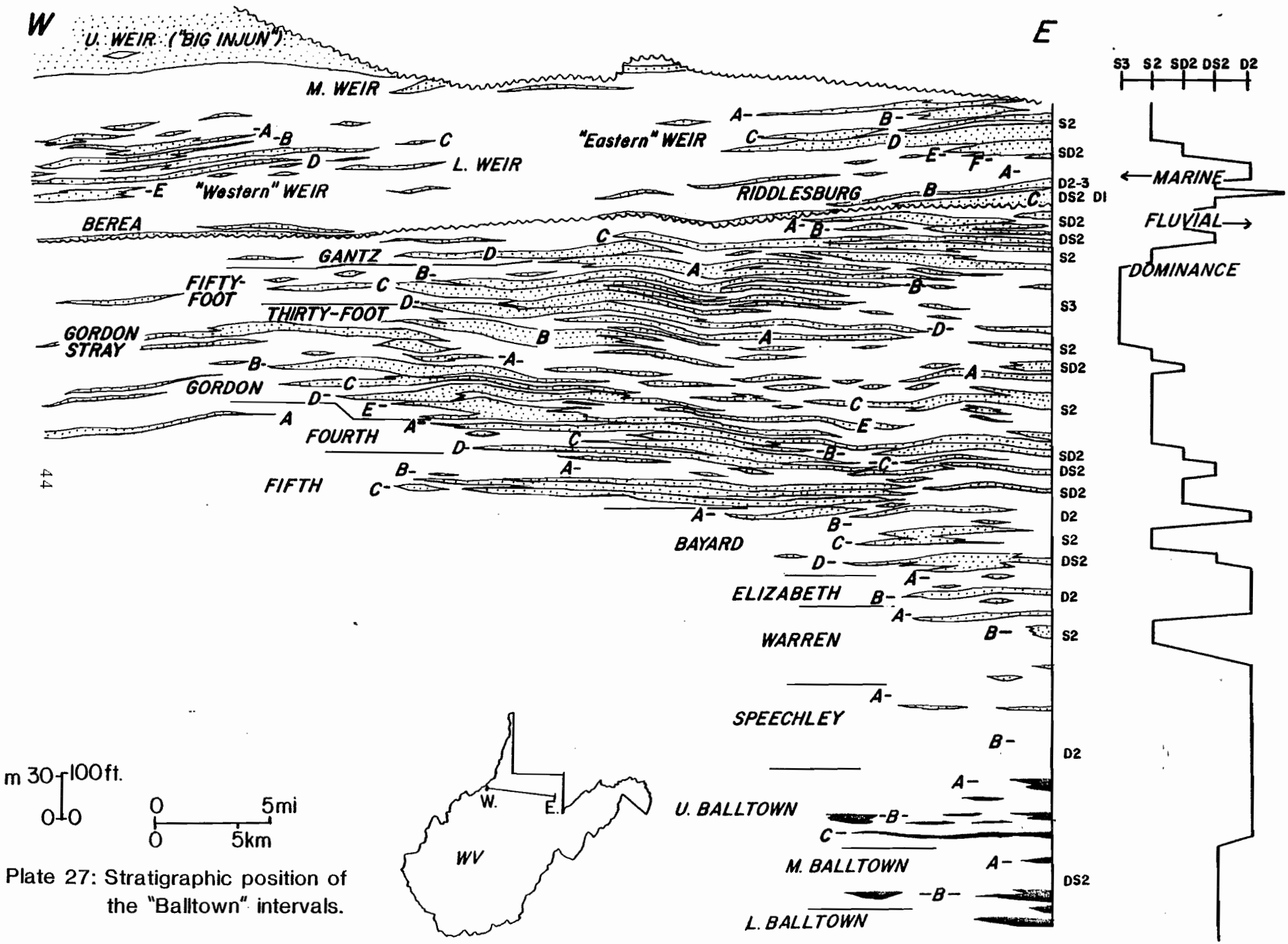


Plate 27: Stratigraphic position of the "Balltown" intervals.

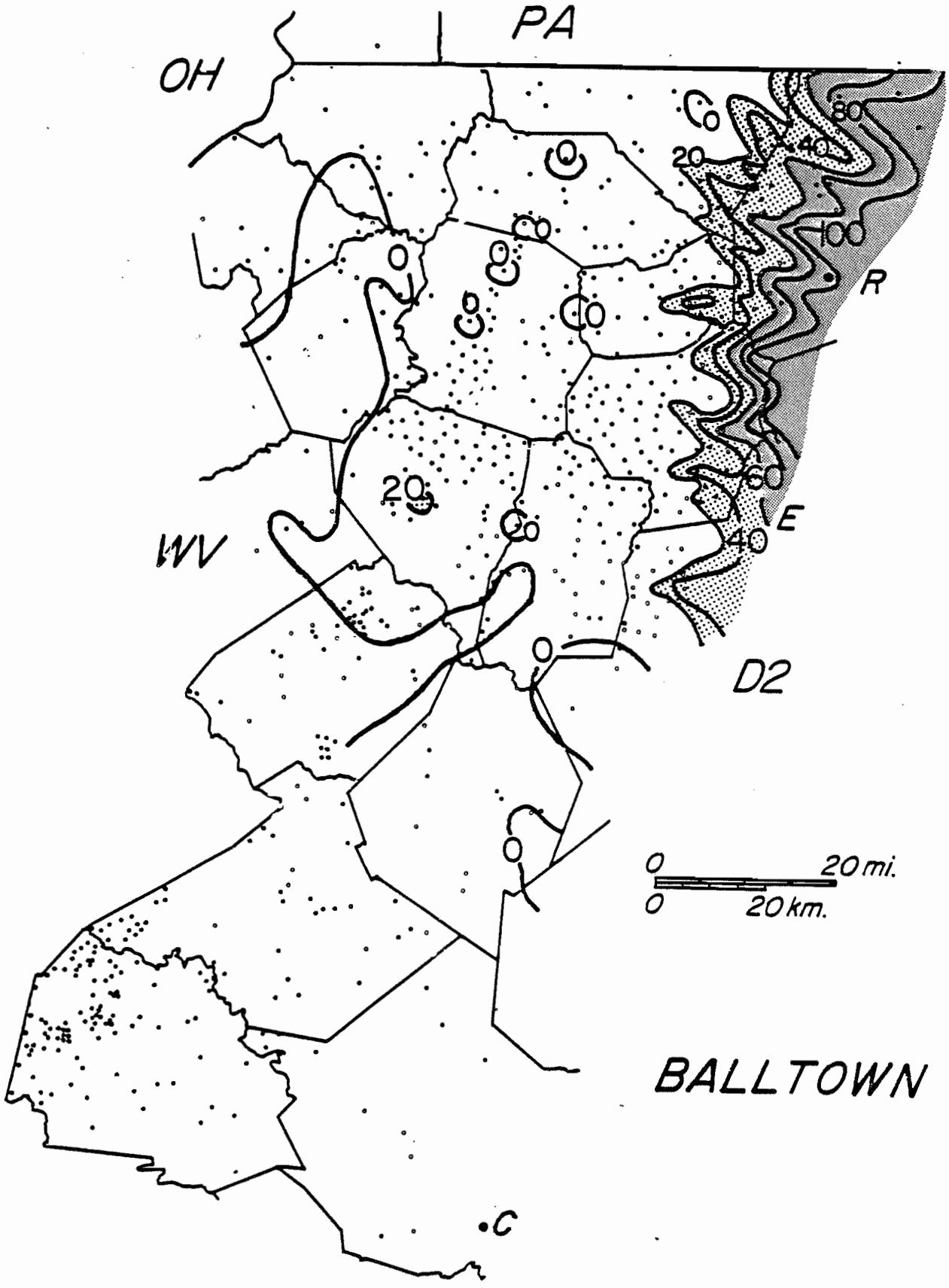


Plate 28: Isolith map of the "Balltown" sandstones.

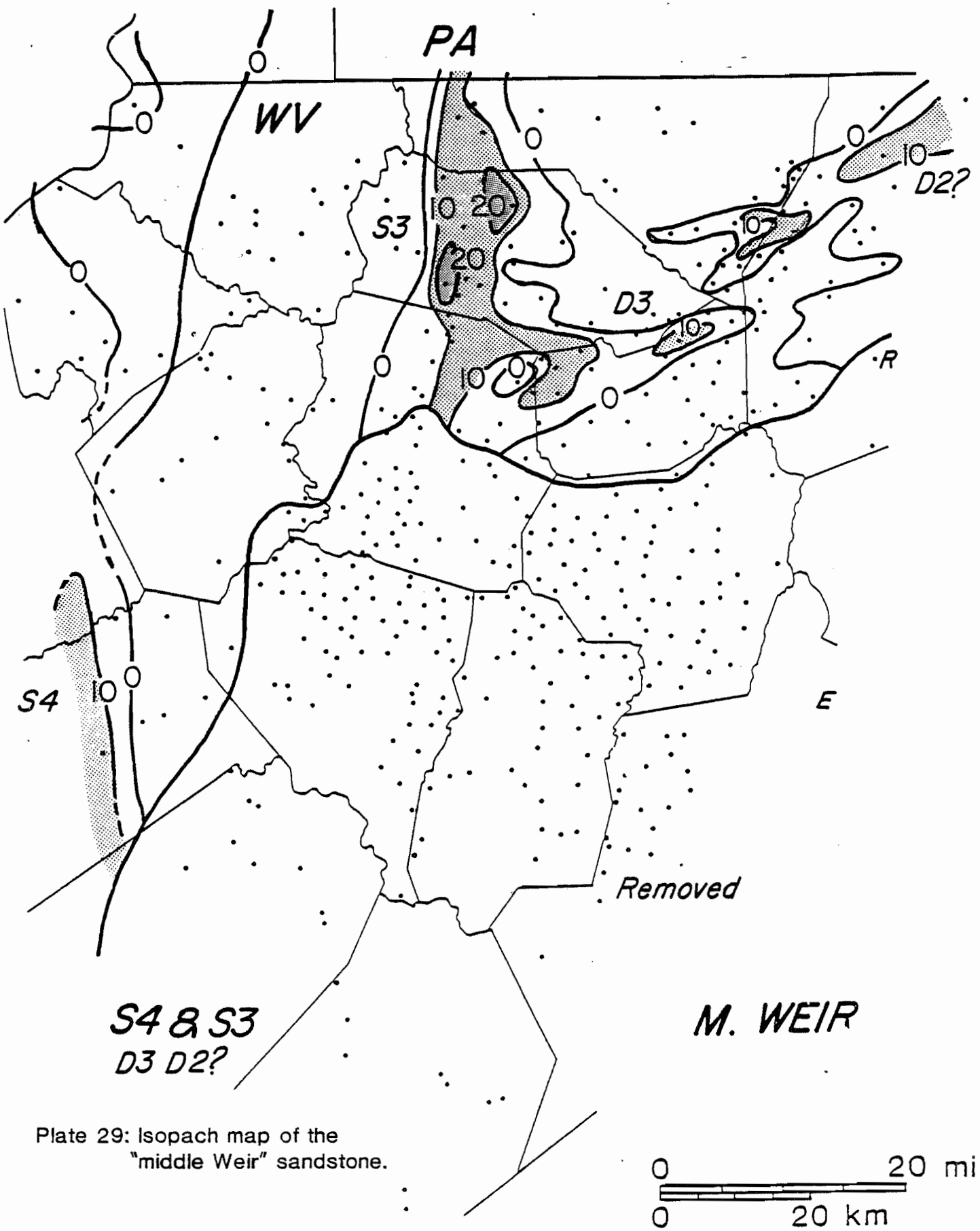


Plate 29: Isopach map of the "middle Weir" sandstone.

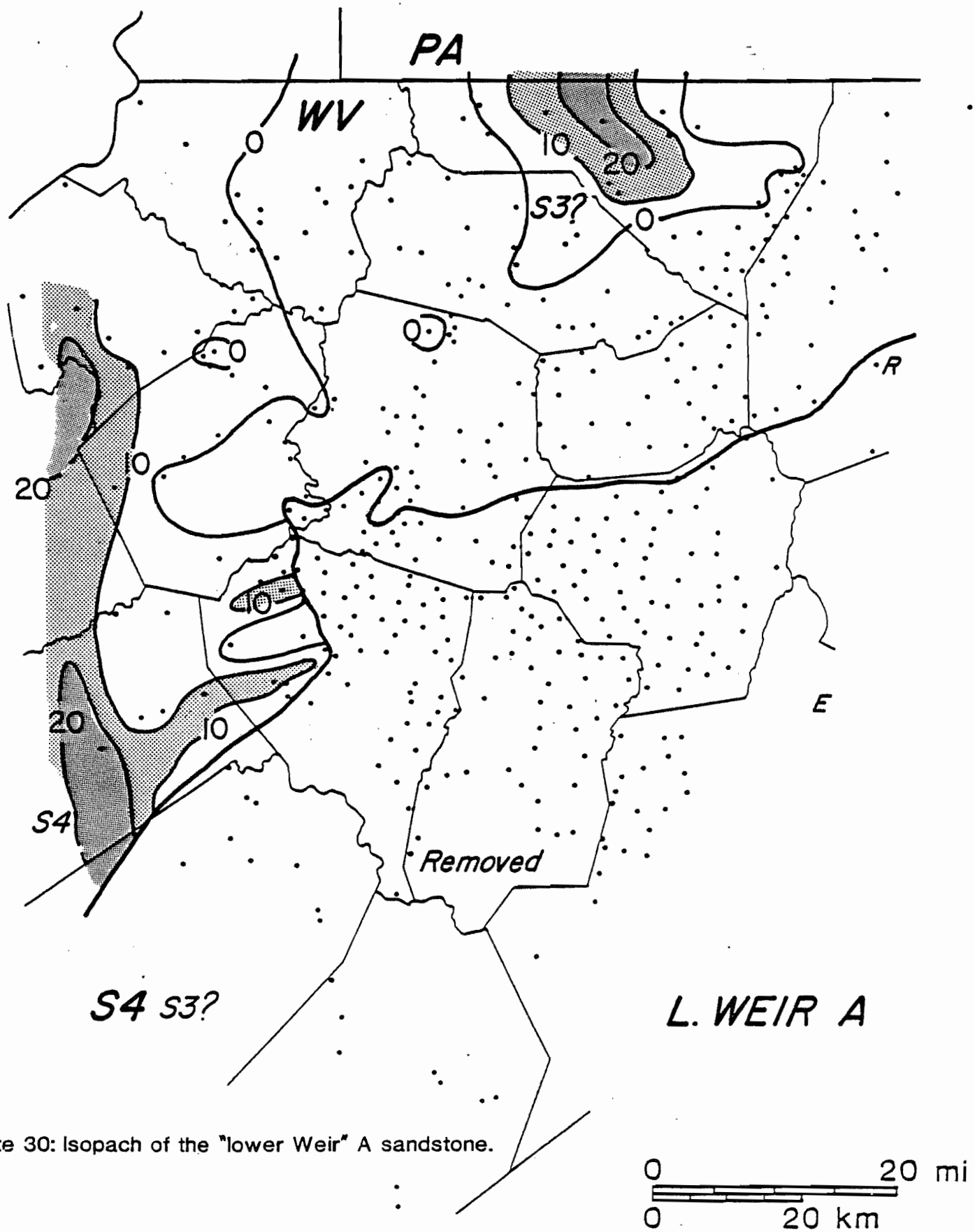


Plate 30: Isopach of the "lower Weir" A sandstone.

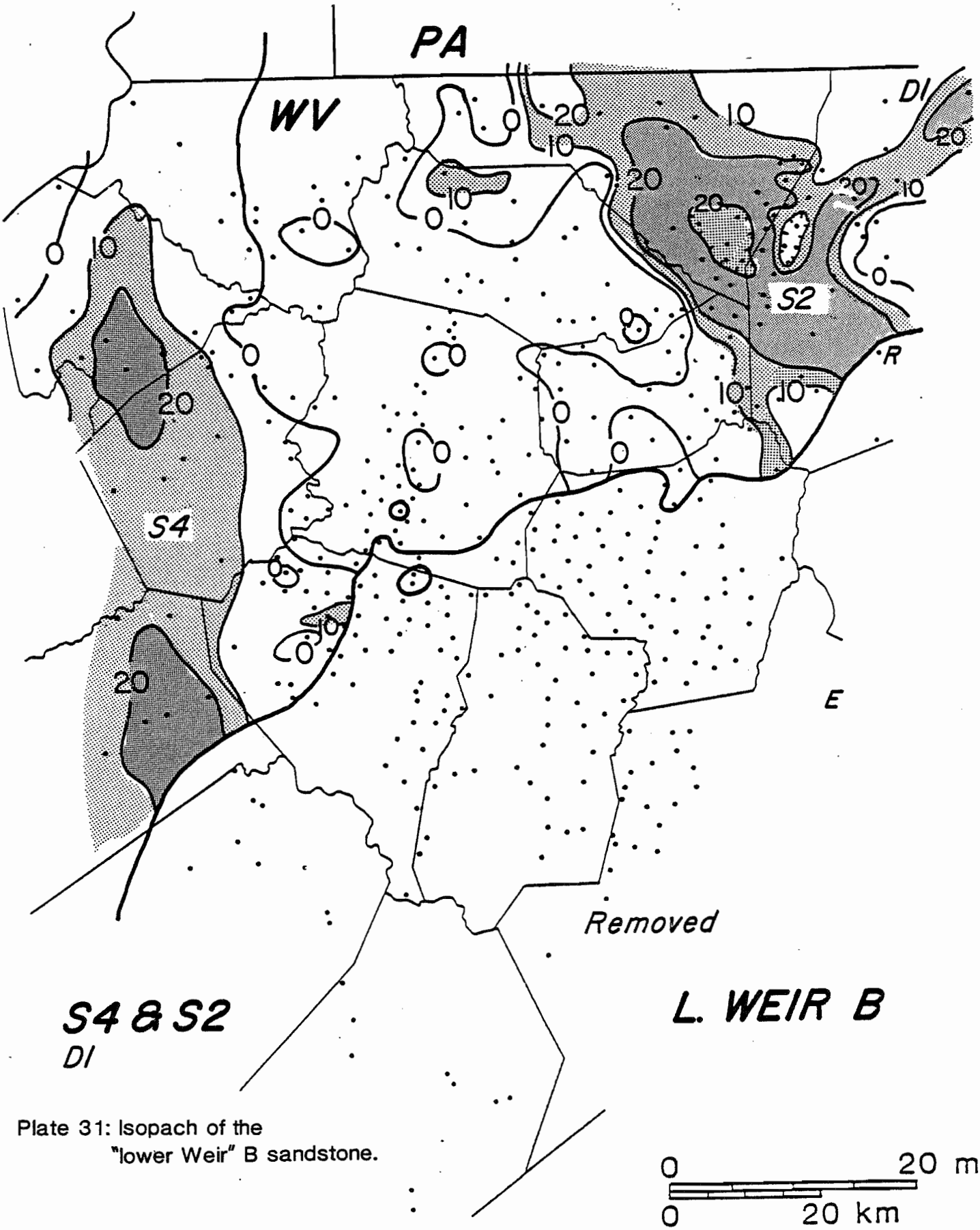


Plate 31: Isopach of the "lower Weir" B sandstone.

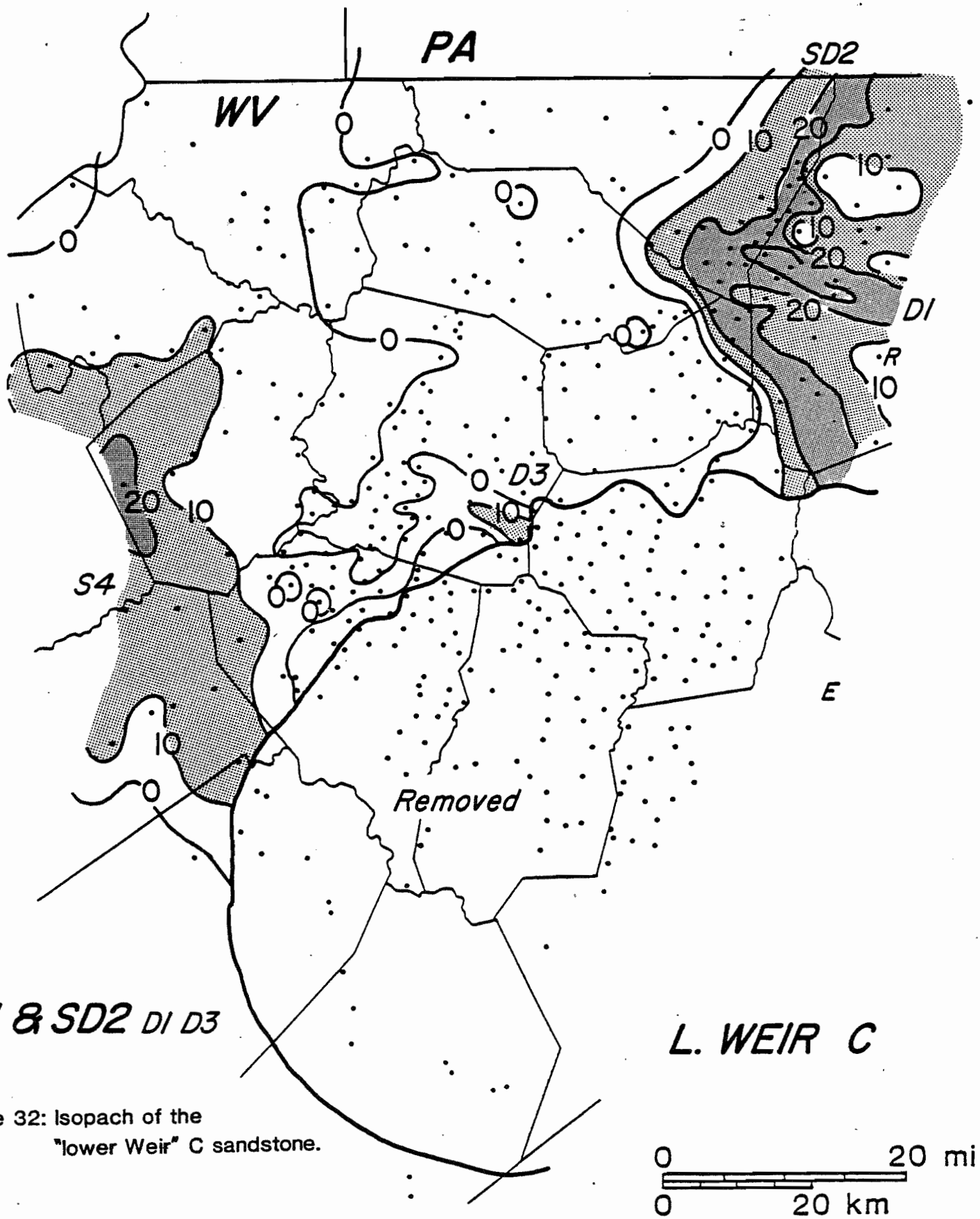


Plate 32: Isopach of the "lower Weir" C sandstone.

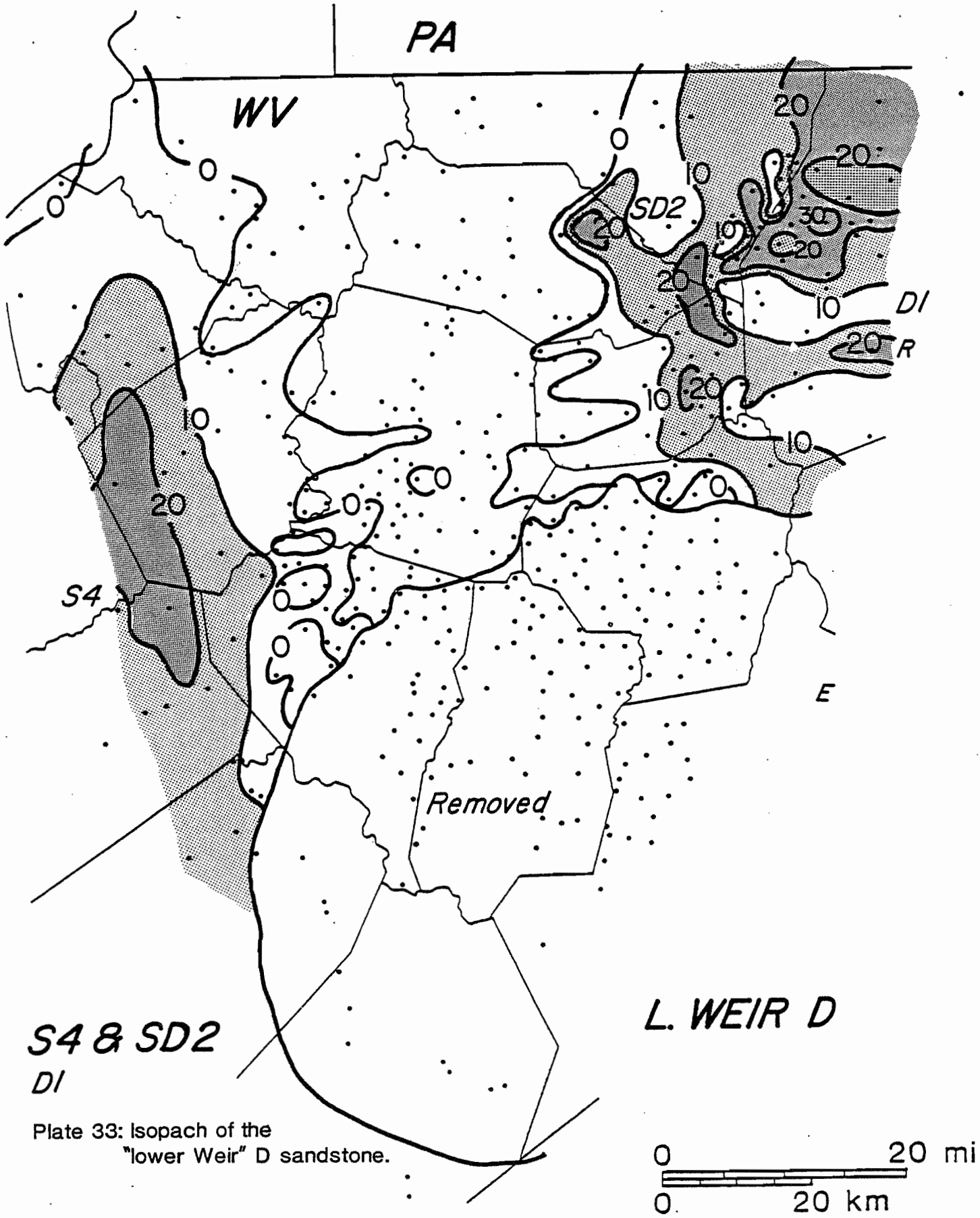


Plate 33: Isopach of the "lower Weir" D sandstone.

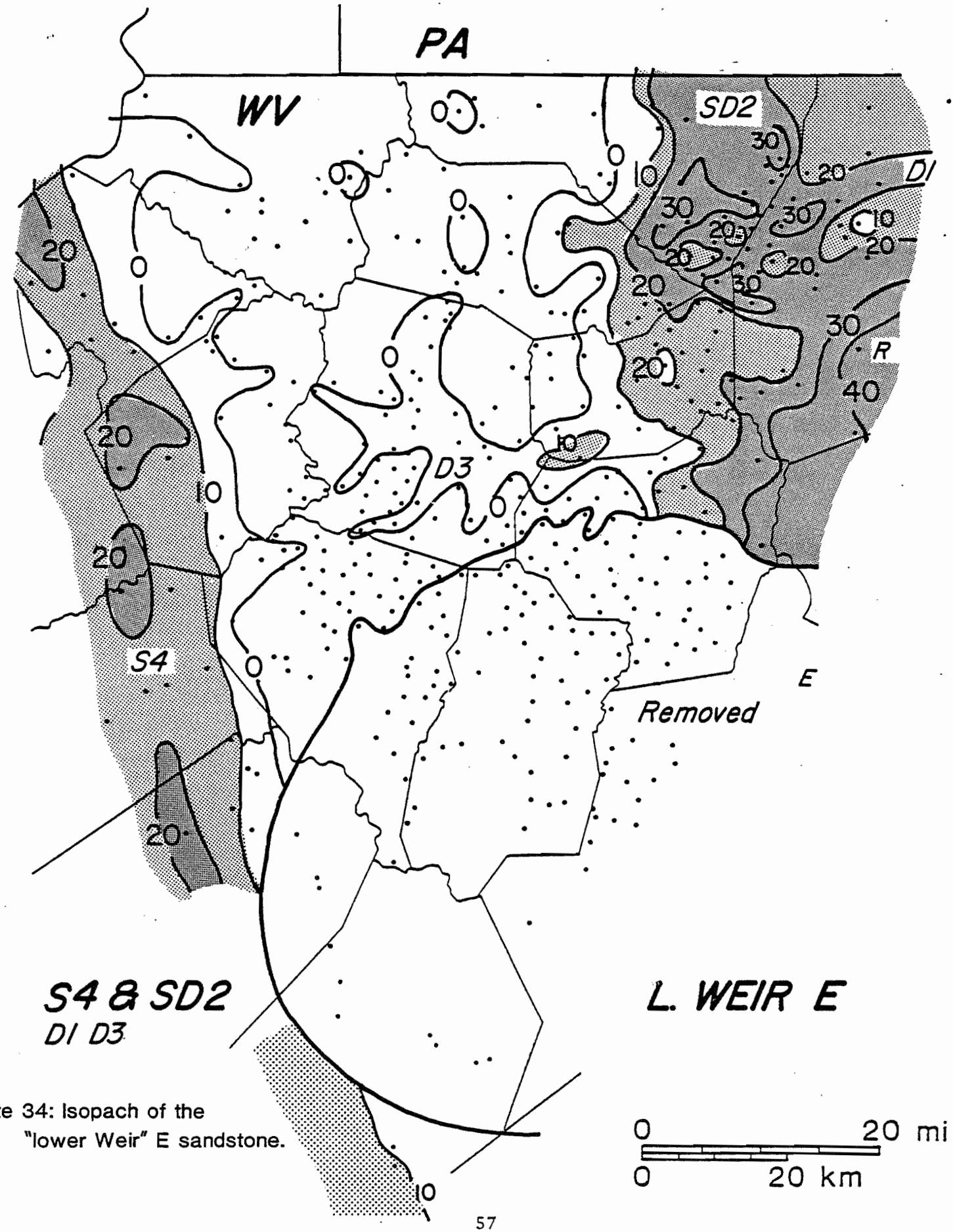


Plate 34: Isopach of the "lower Weir" E sandstone.

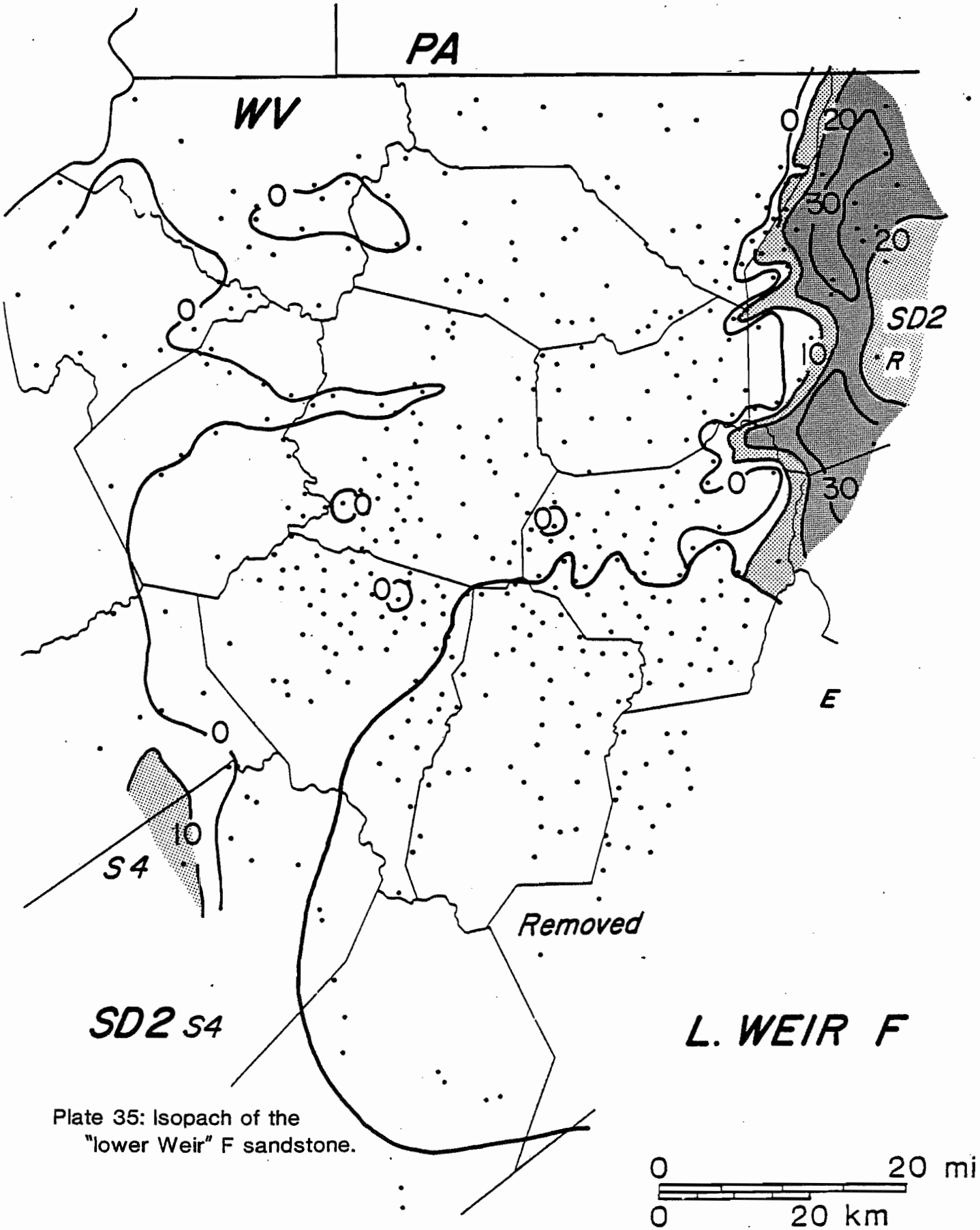


Plate 35: Isopach of the "lower Weir" F sandstone.

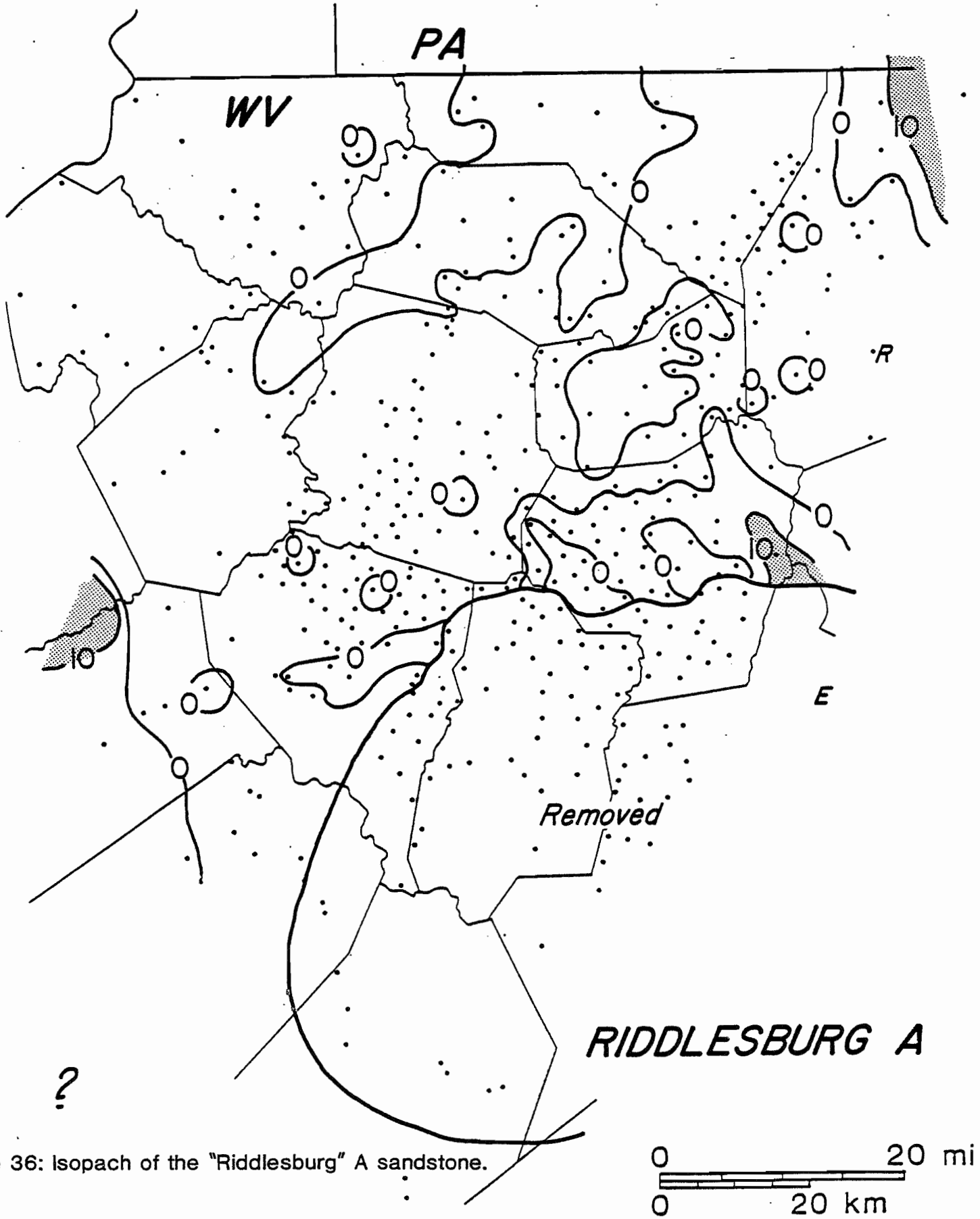


Plate 36: Isopach of the "Riddlesburg" A sandstone.

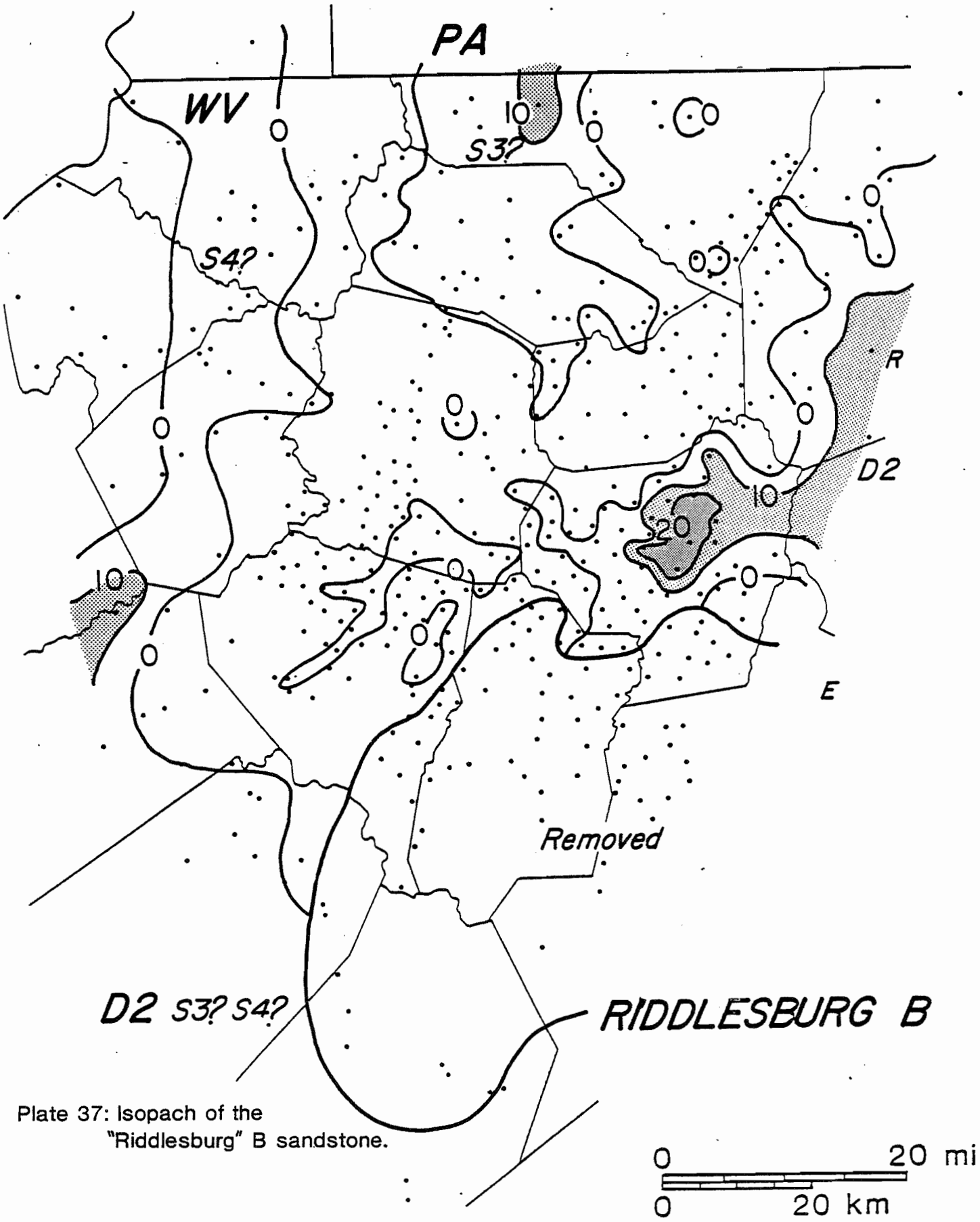


Plate 37: Isopach of the "Riddlesburg" B sandstone.

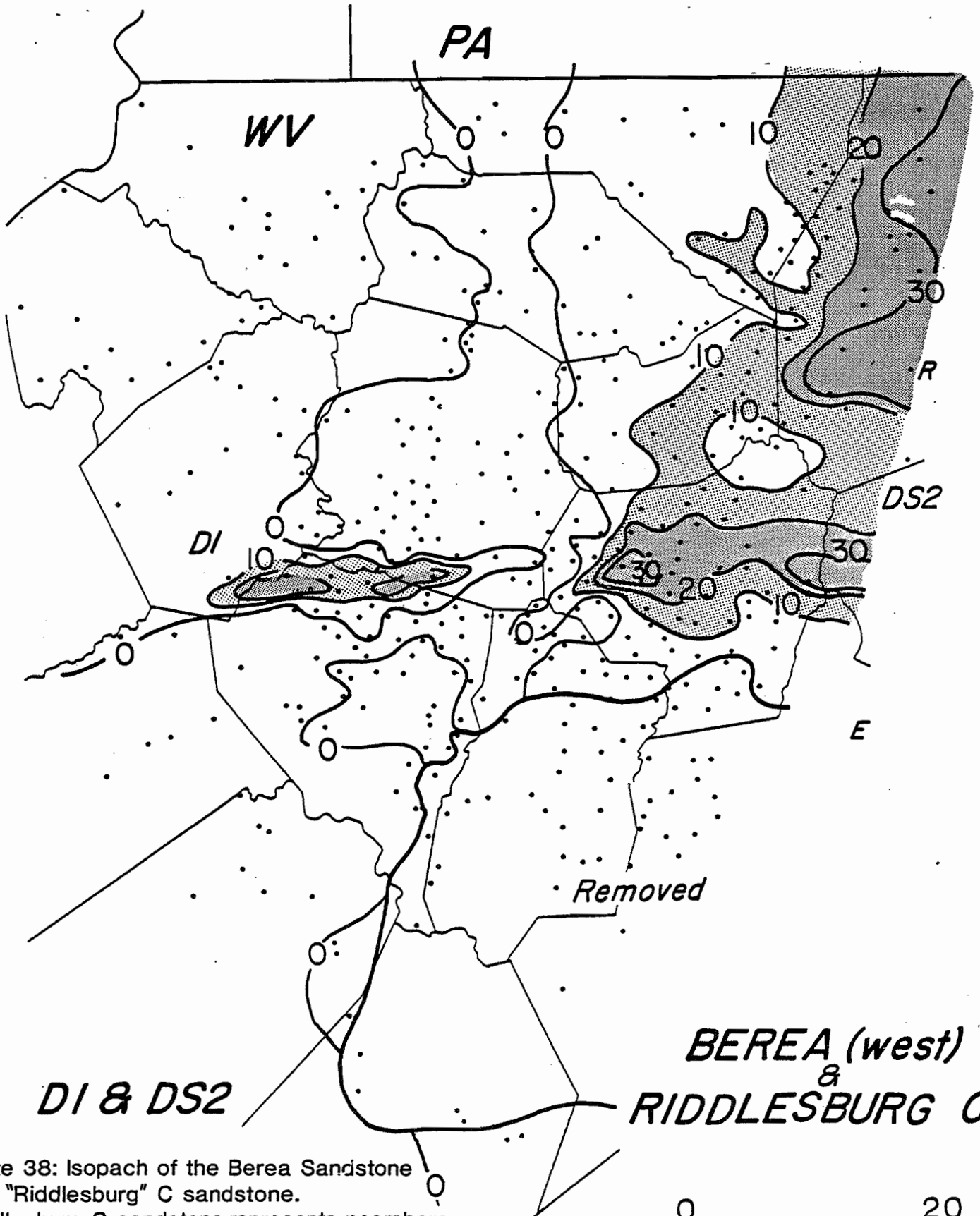


Plate 38: Isopach of the Berea Sandstone and "Riddlesburg" C sandstone.
Riddlesburg C sandstone represents nearshore deposition during transgression immediately following Berea deposition (Boswell and others, 1987).

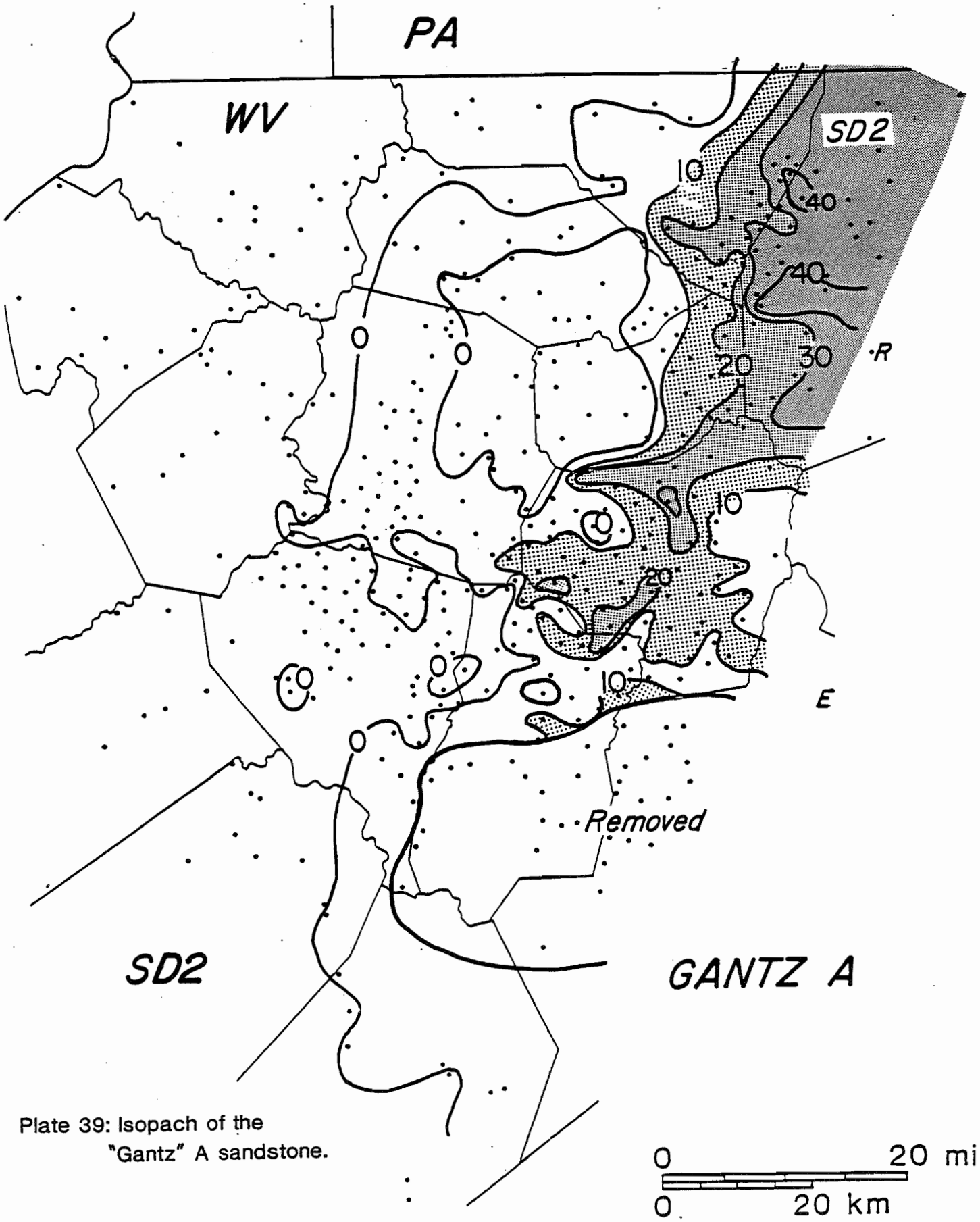


Plate 39: Isopach of the "Gantz" A sandstone.

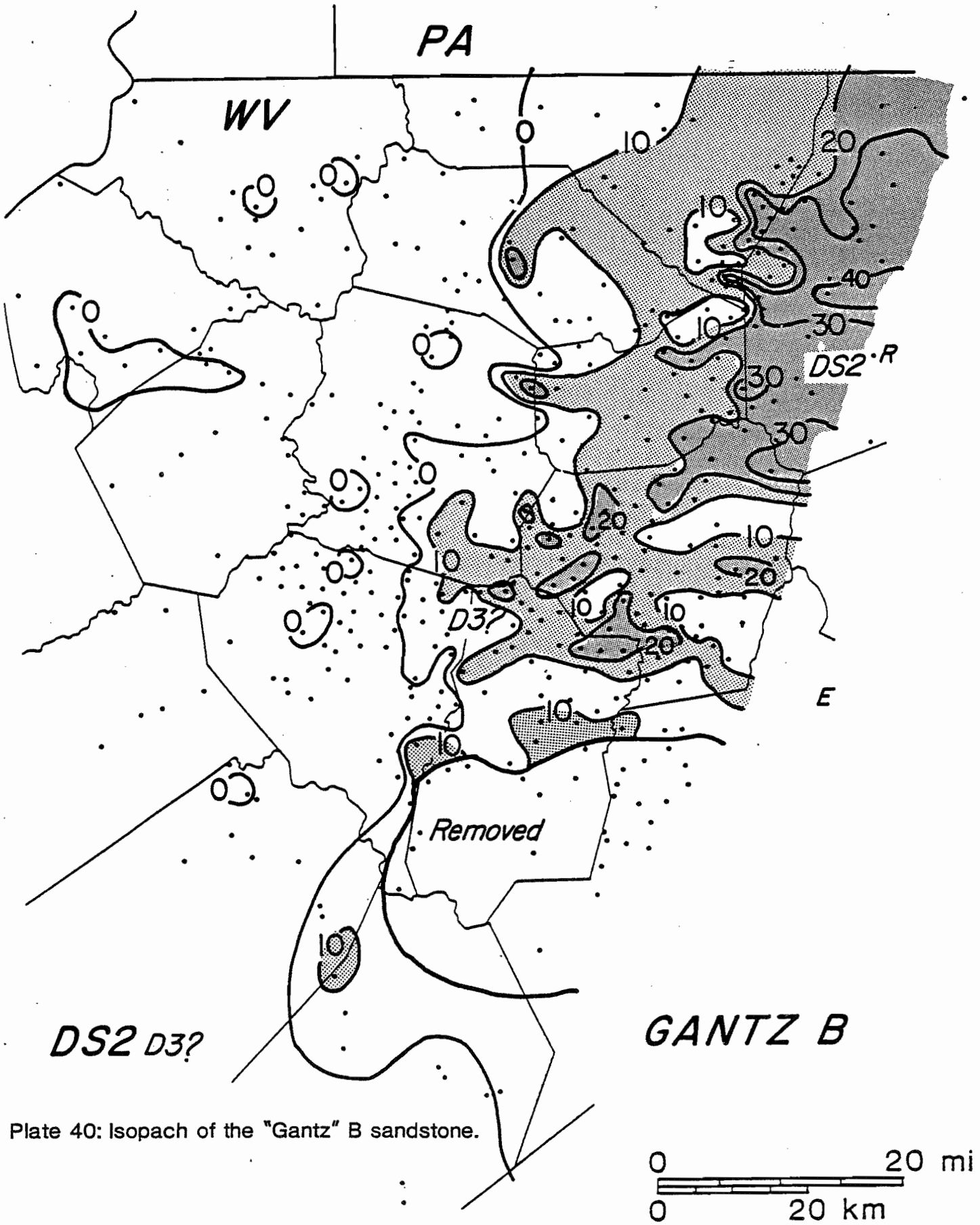


Plate 40: Isopach of the "Gantz" B sandstone.

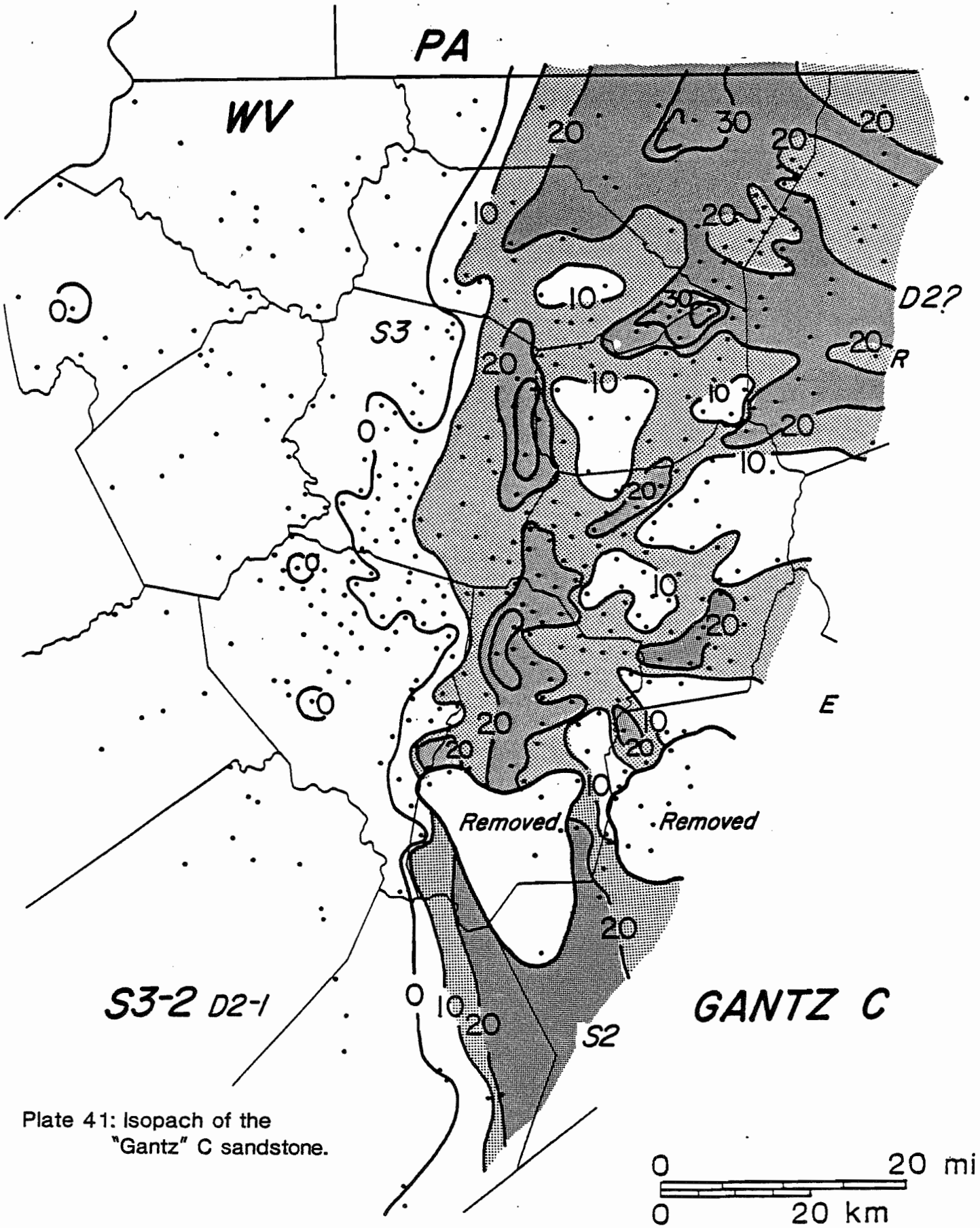


Plate 41: Isopach of the "Gantz" C sandstone.

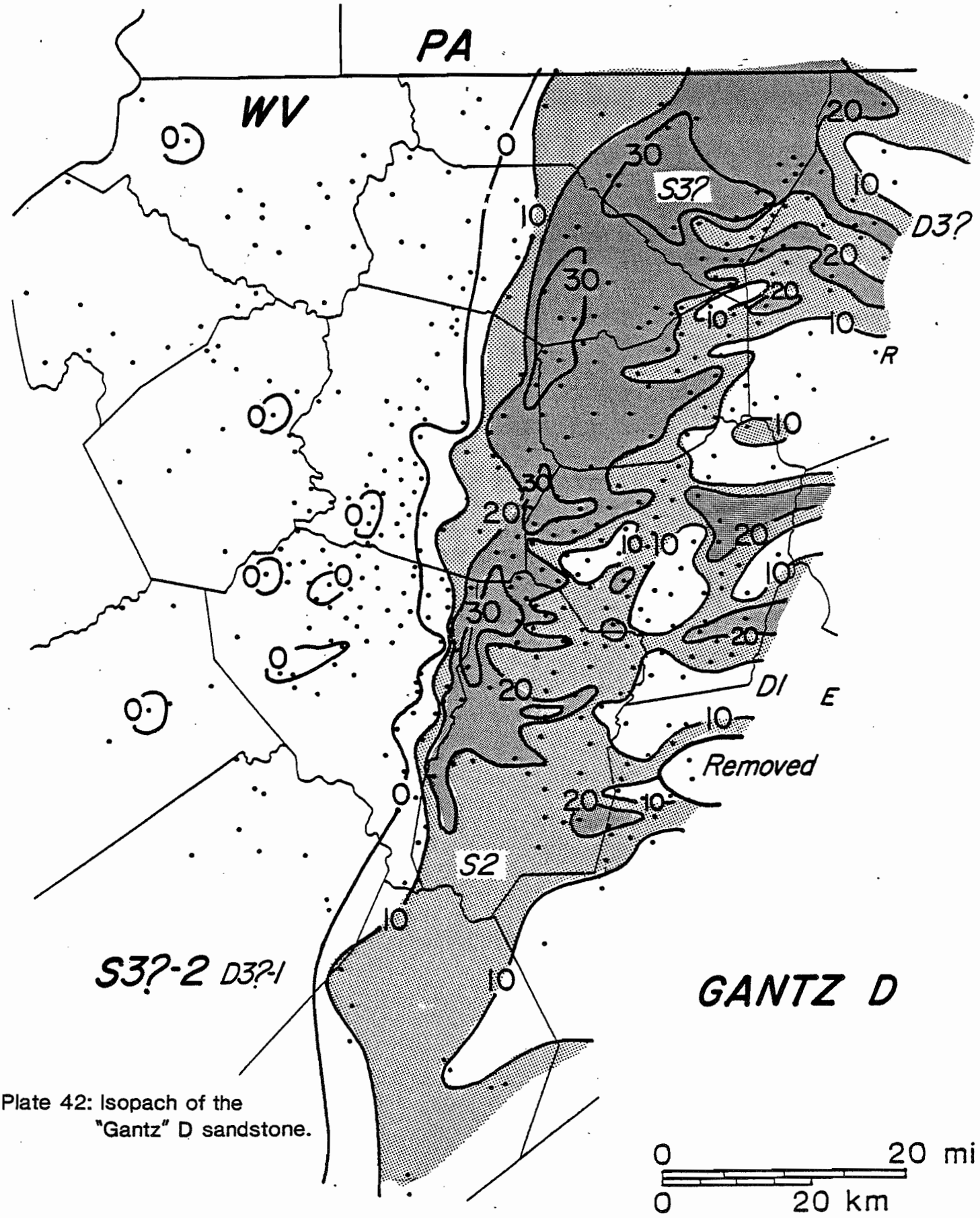


Plate 42: Isopach of the "Gantz" D sandstone.

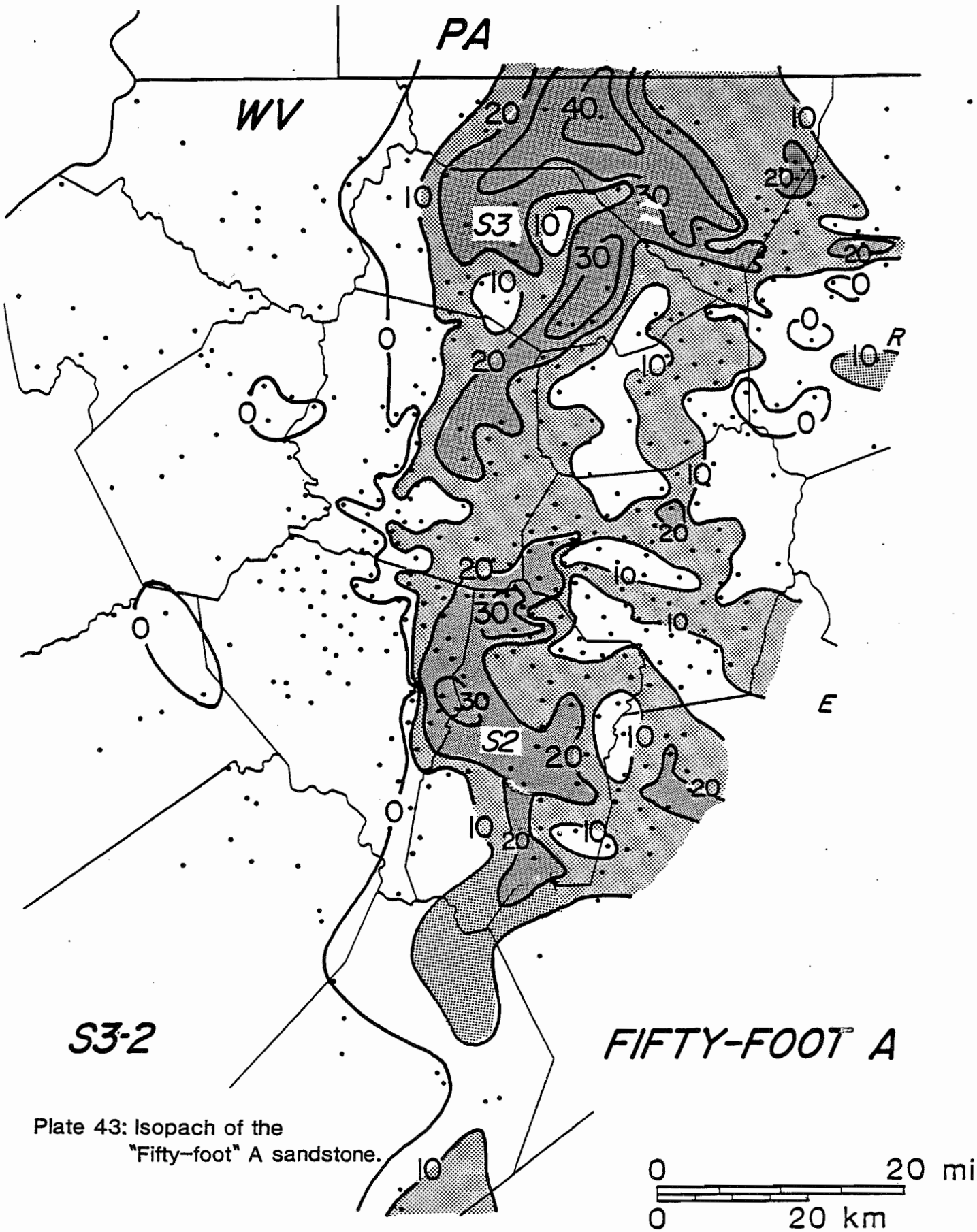


Plate 43: Isopach of the "Fifty-foot" A sandstone.

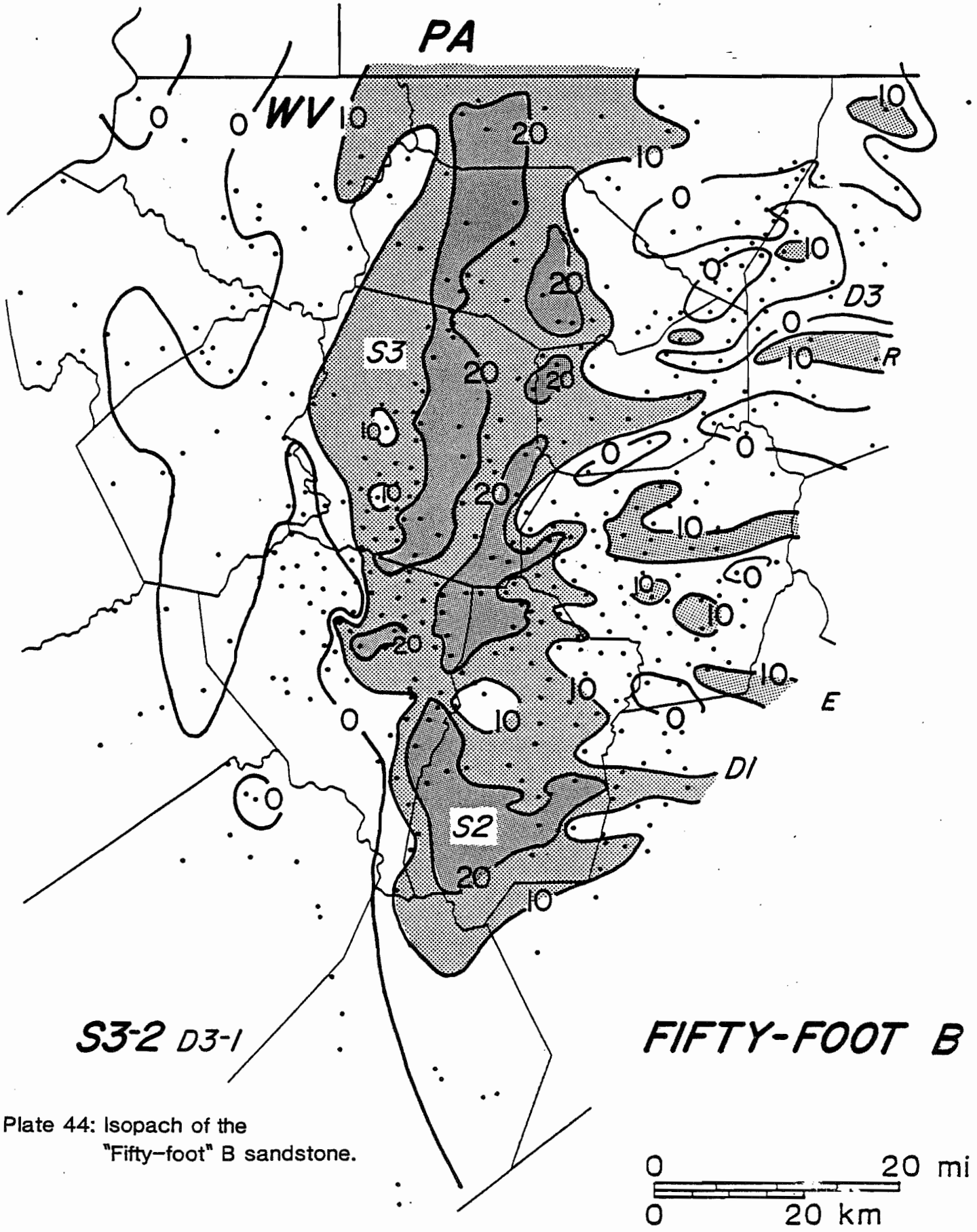


Plate 44: Isopach of the "Fifty-foot" B sandstone.

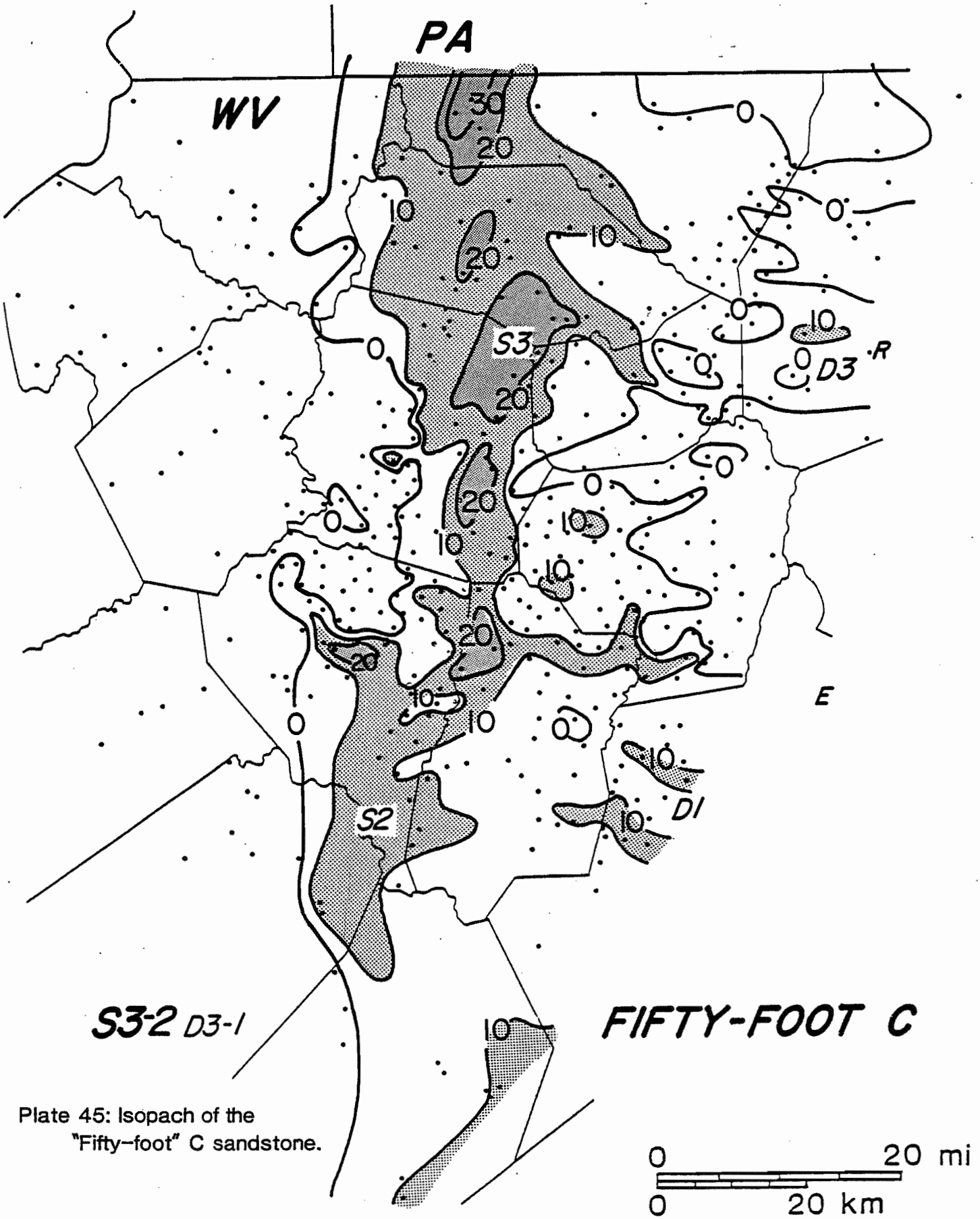


Plate 45: Isopach of the "Fifty-foot" C sandstone.

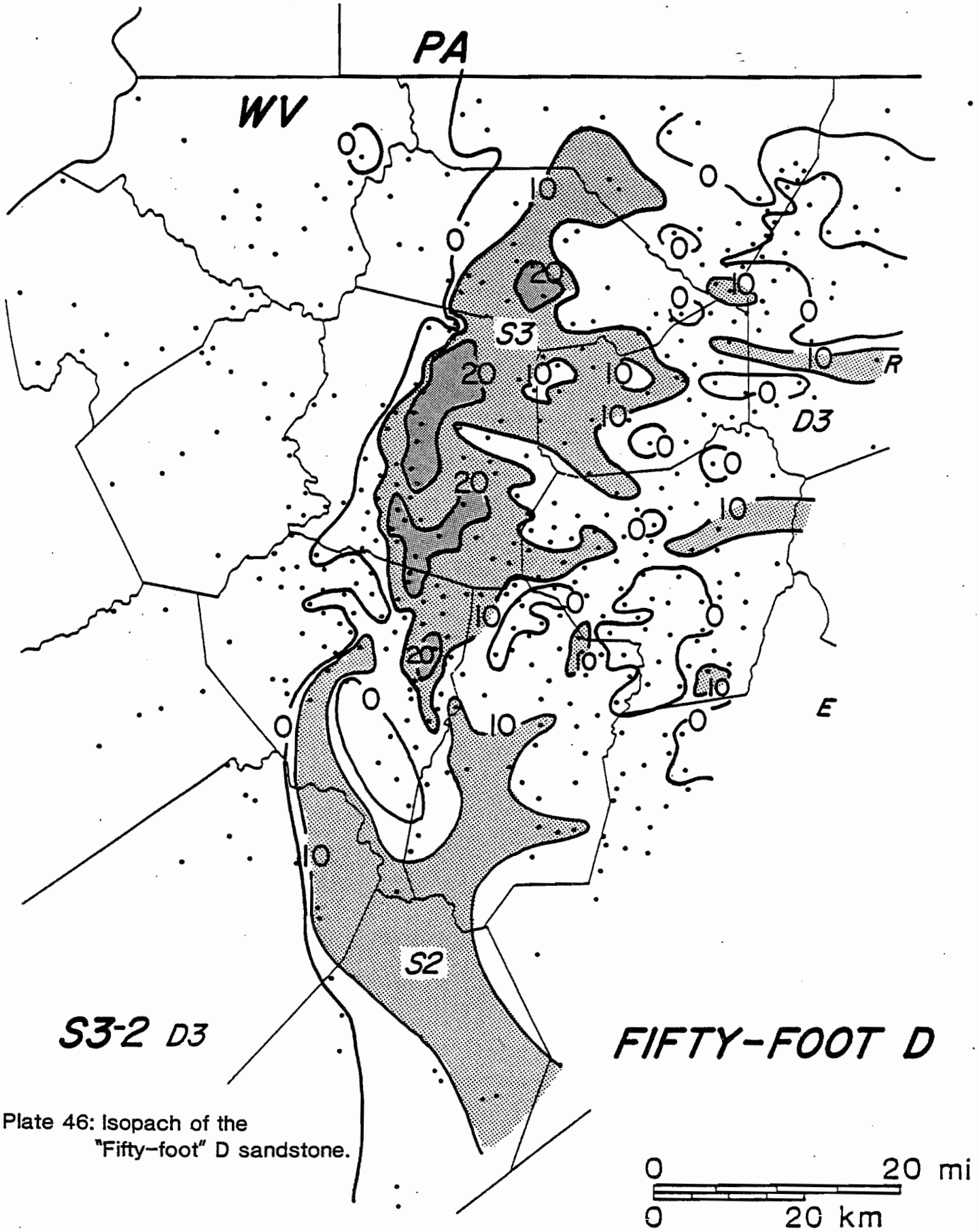


Plate 46: Isopach of the "Fifty-foot" D sandstone.

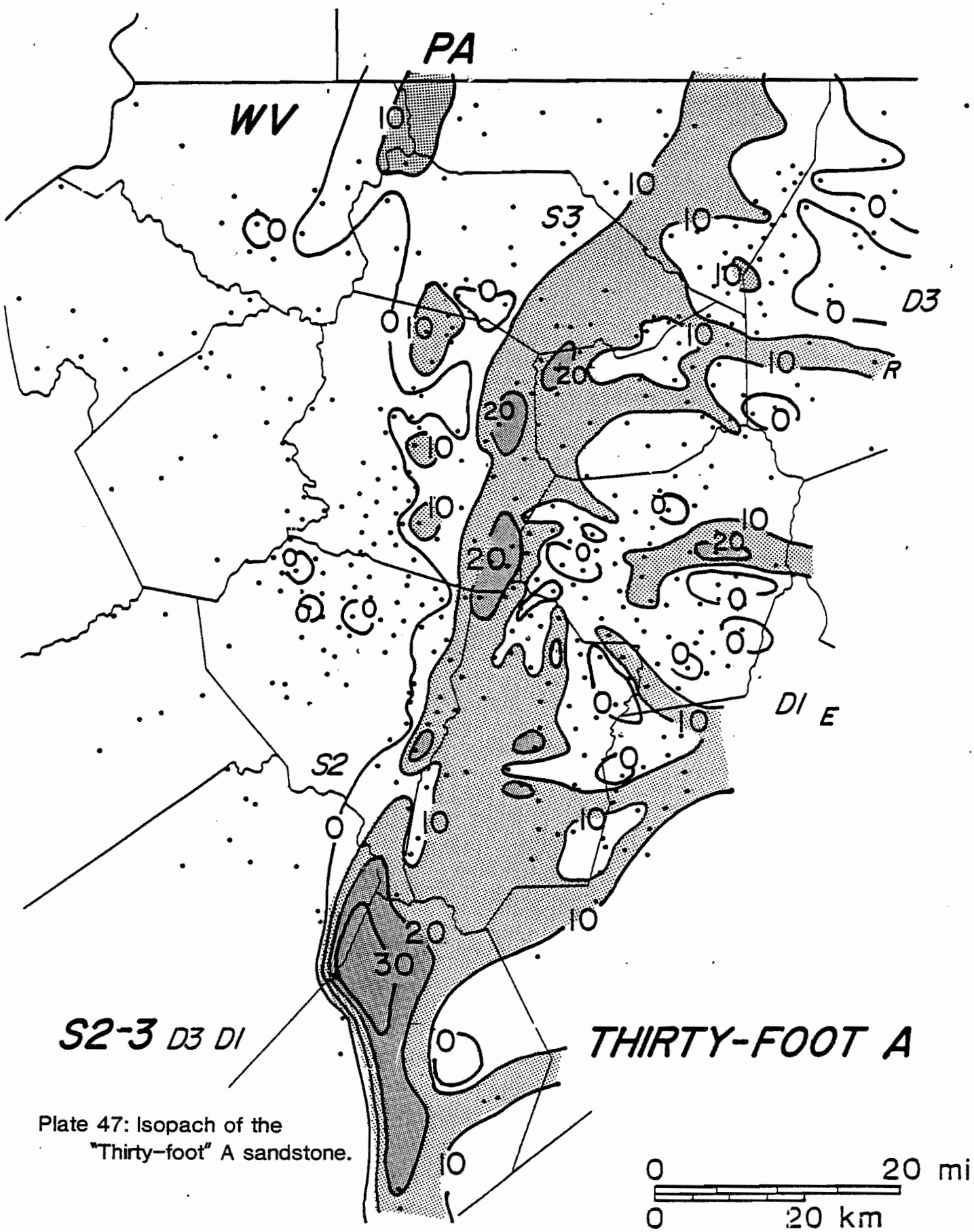


Plate 47: Isopach of the "Thirty-foot" A sandstone.

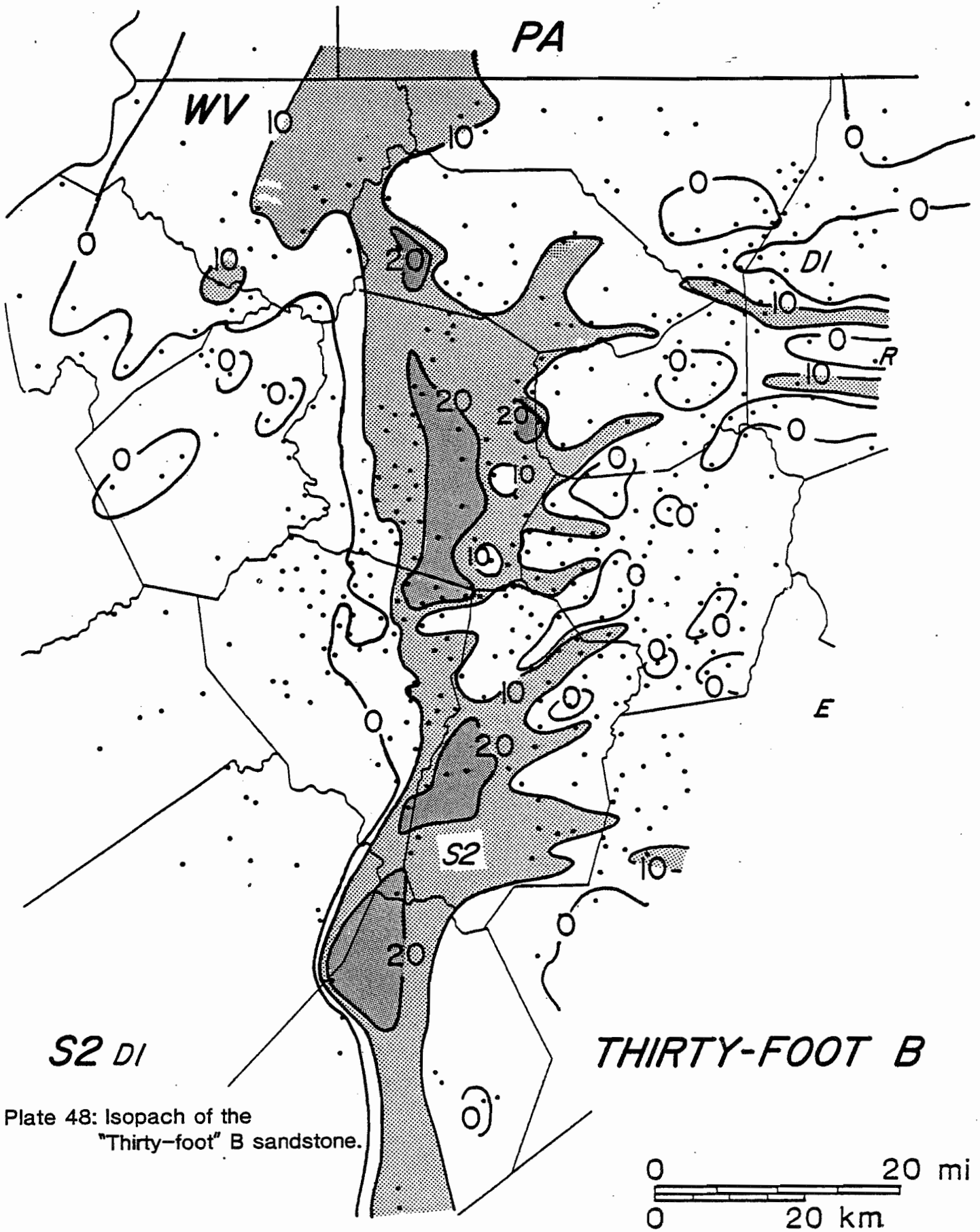


Plate 48: Isopach of the "Thirty-foot" B sandstone.

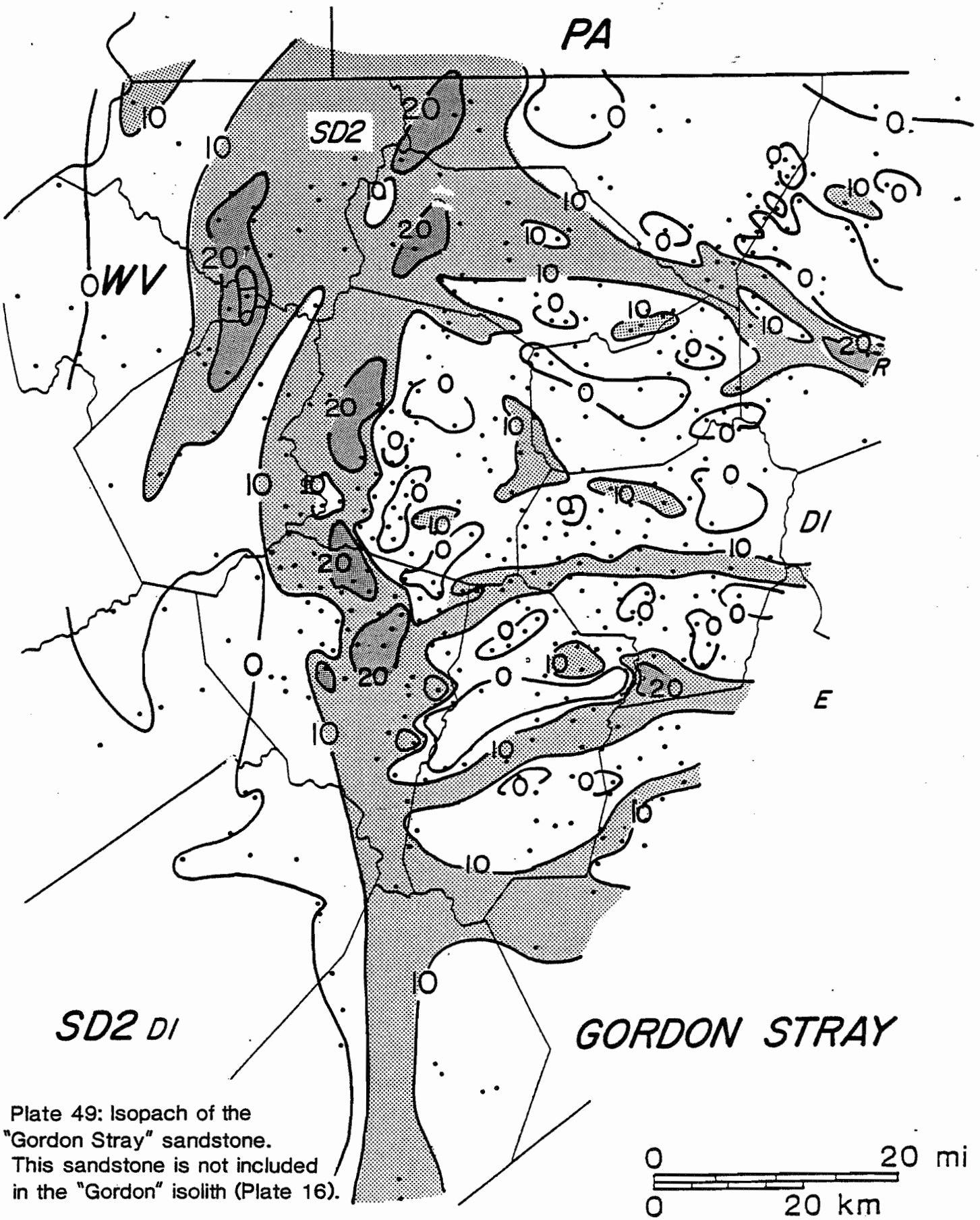


Plate 49: Isopach of the "Gordon Stray" sandstone. This sandstone is not included in the "Gordon" isolith (Plate 16).

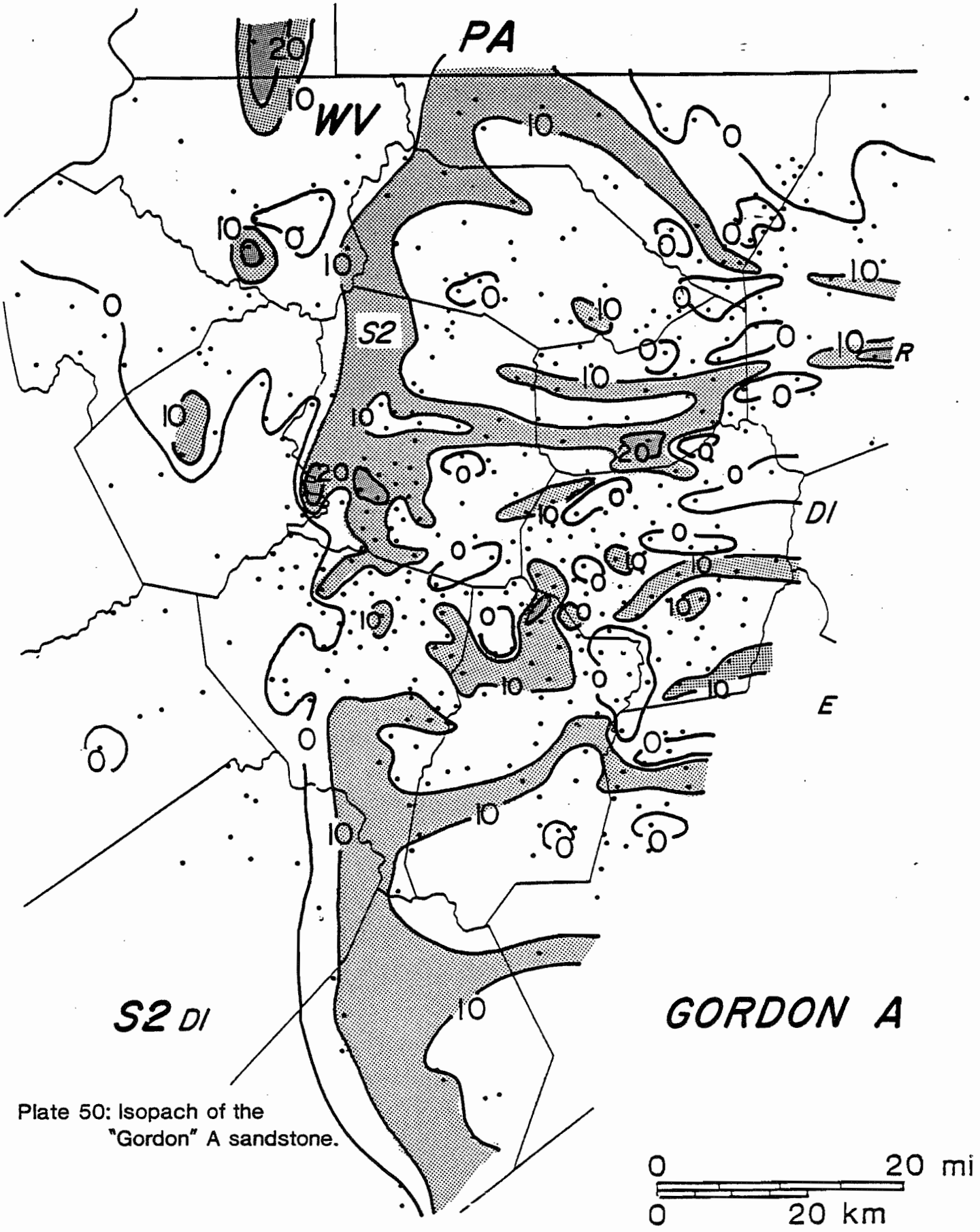


Plate 50: Isopach of the "Gordon" A sandstone.

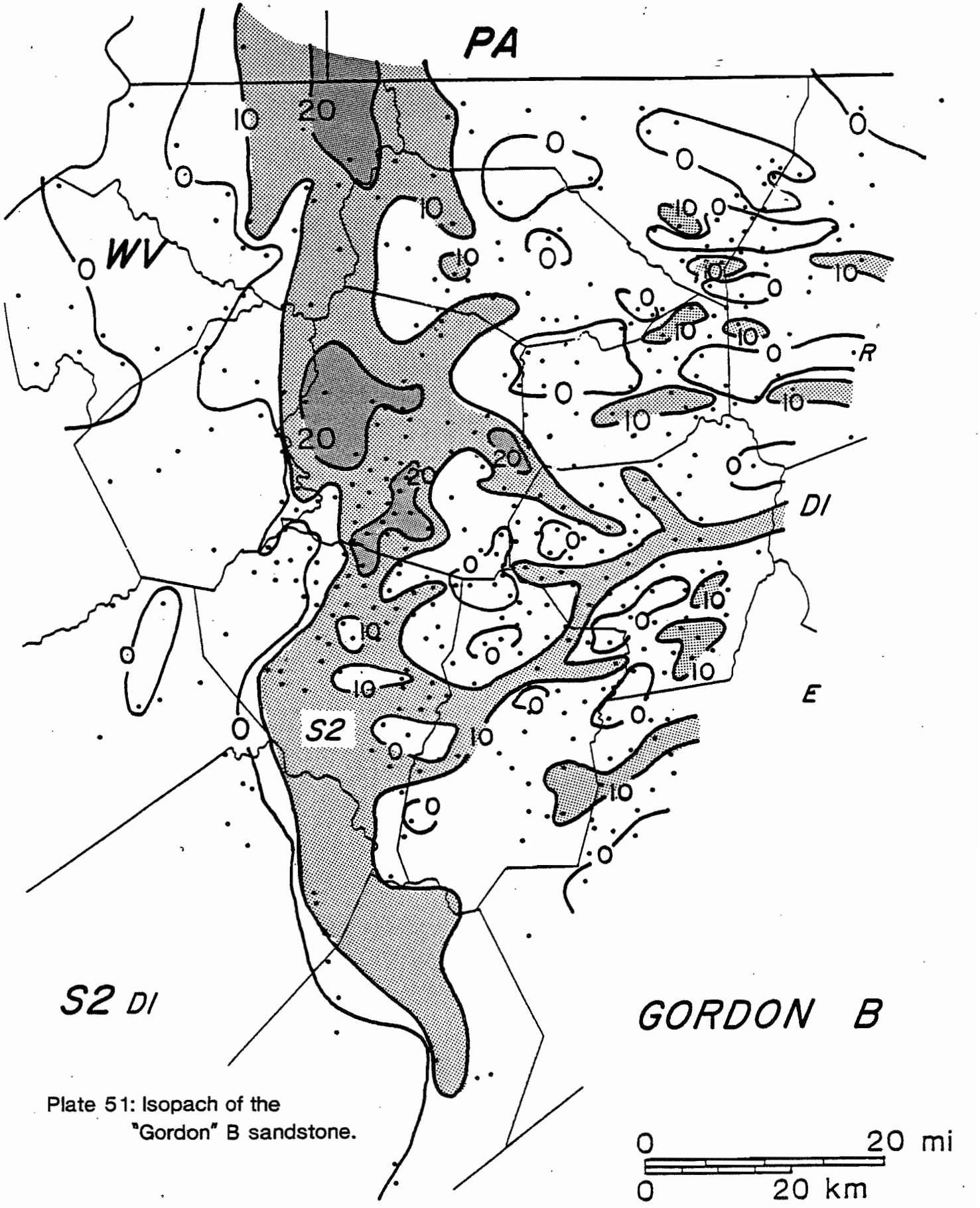


Plate 51: Isopach of the "Gordon" B sandstone.

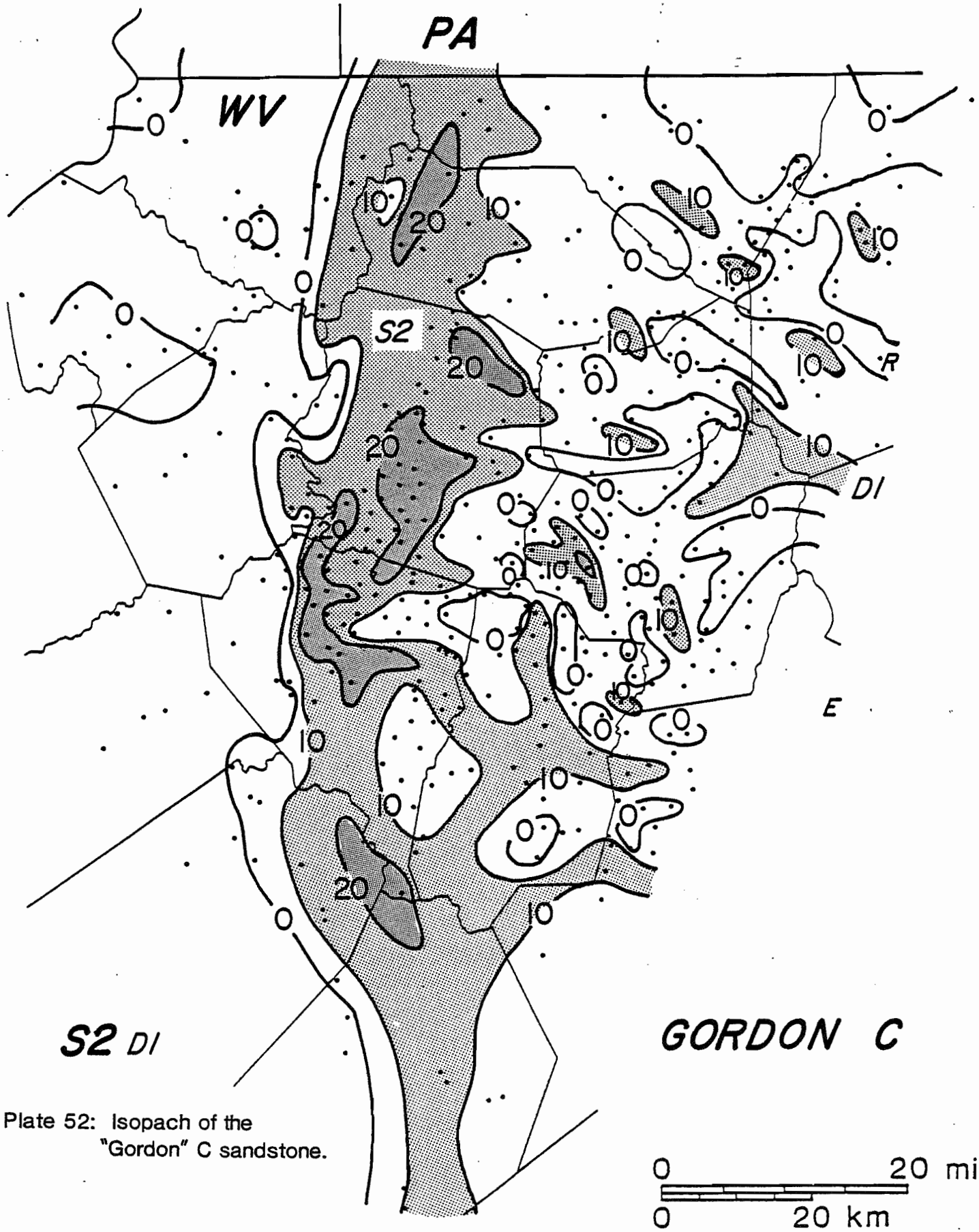


Plate 52: Isopach of the "Gordon" C sandstone.

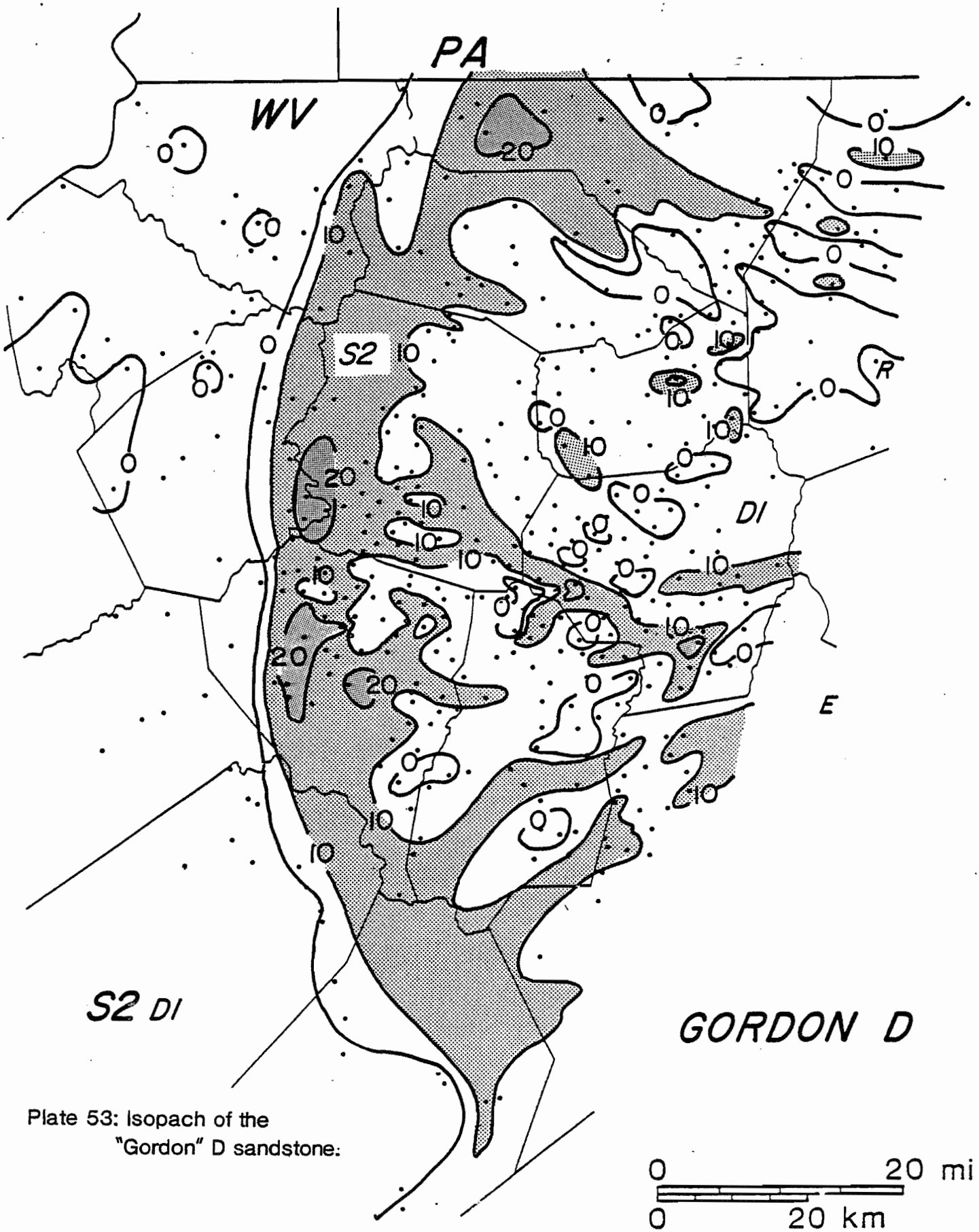


Plate 53: Isopach of the "Gordon" D sandstone.

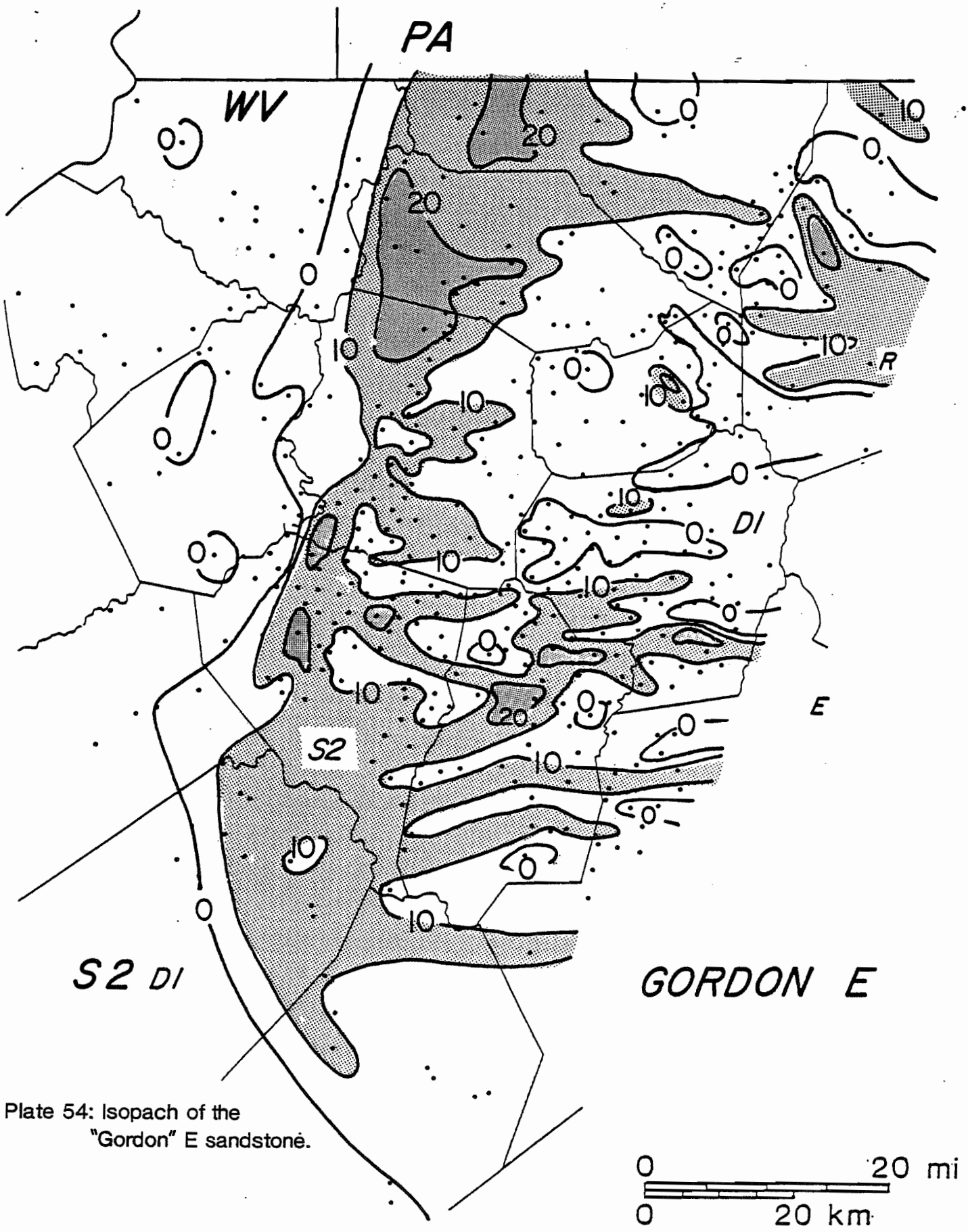


Plate 54: Isopach of the "Gordon" E sandstone.

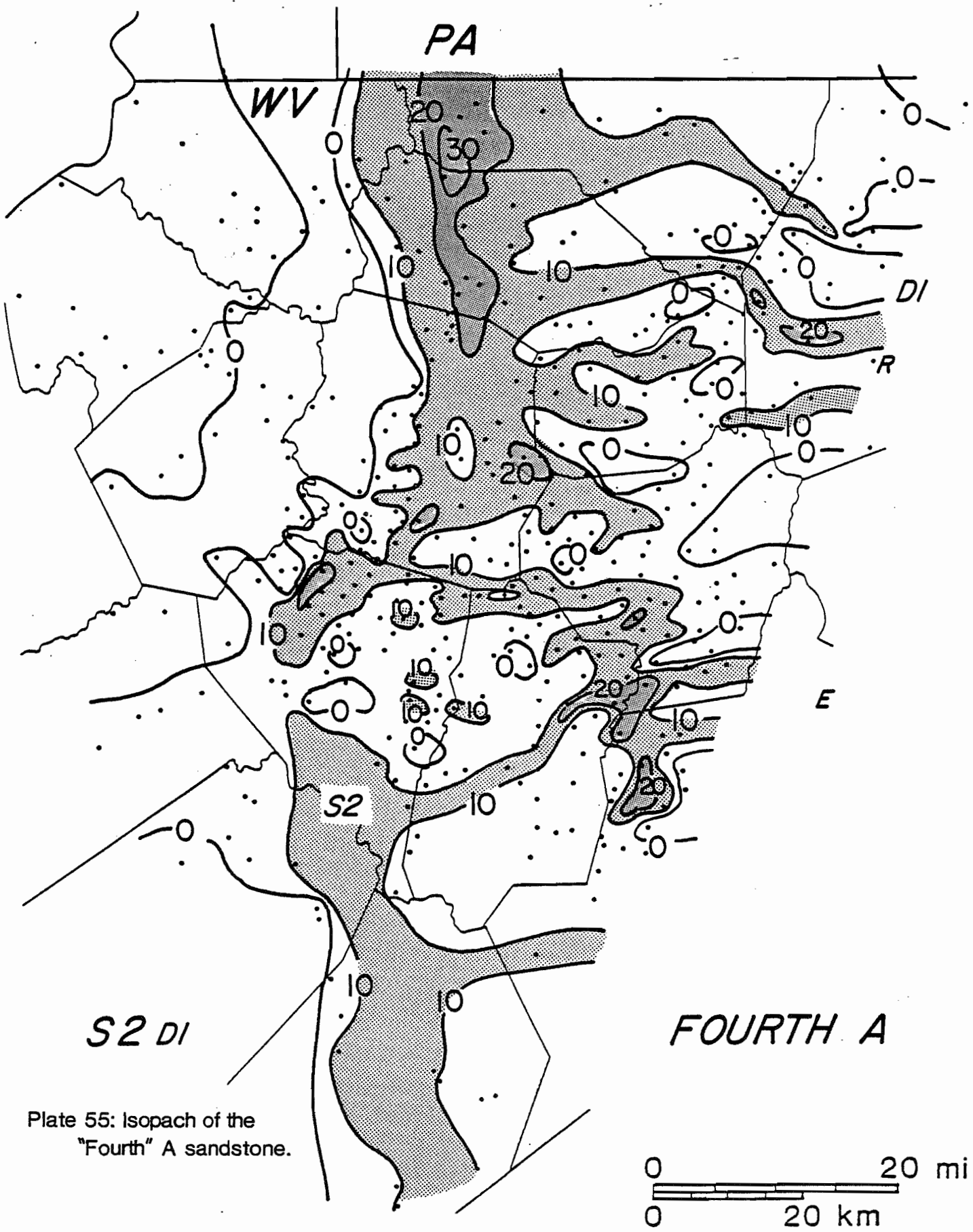


Plate 55: Isopach of the "Fourth" A sandstone.

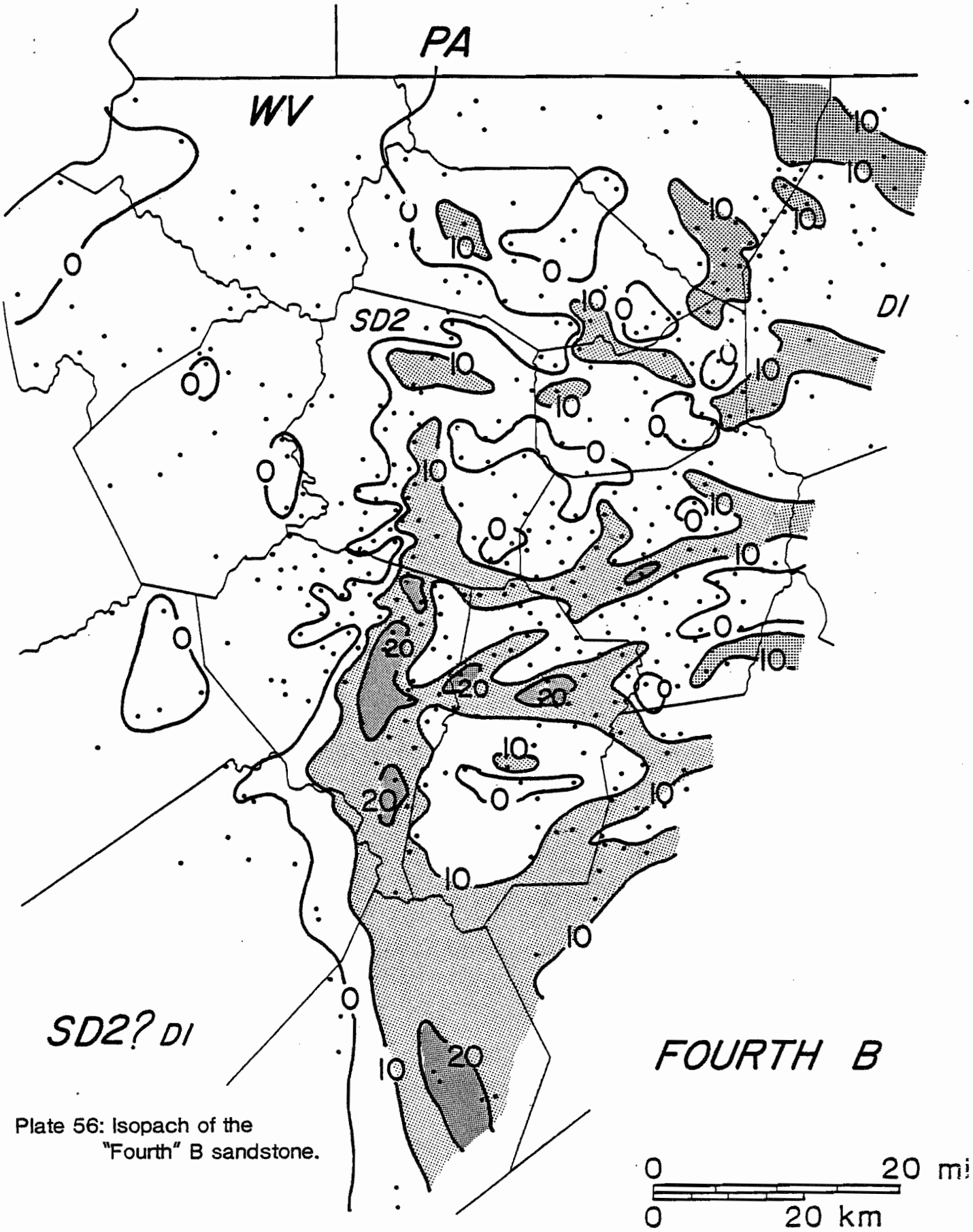


Plate 56: Isopach of the "Fourth" B sandstone.

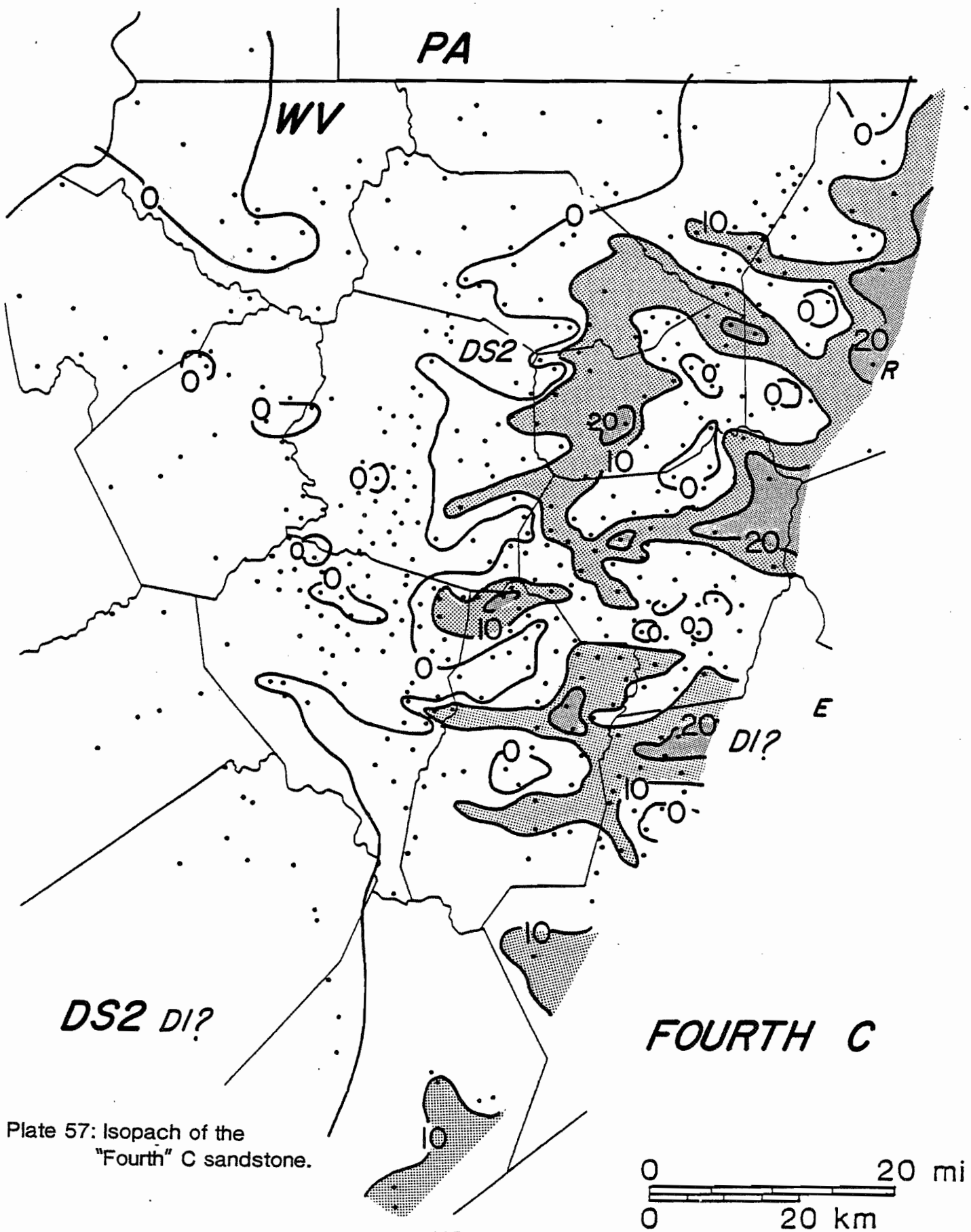


Plate 57: Isopach of the "Fourth" C sandstone.

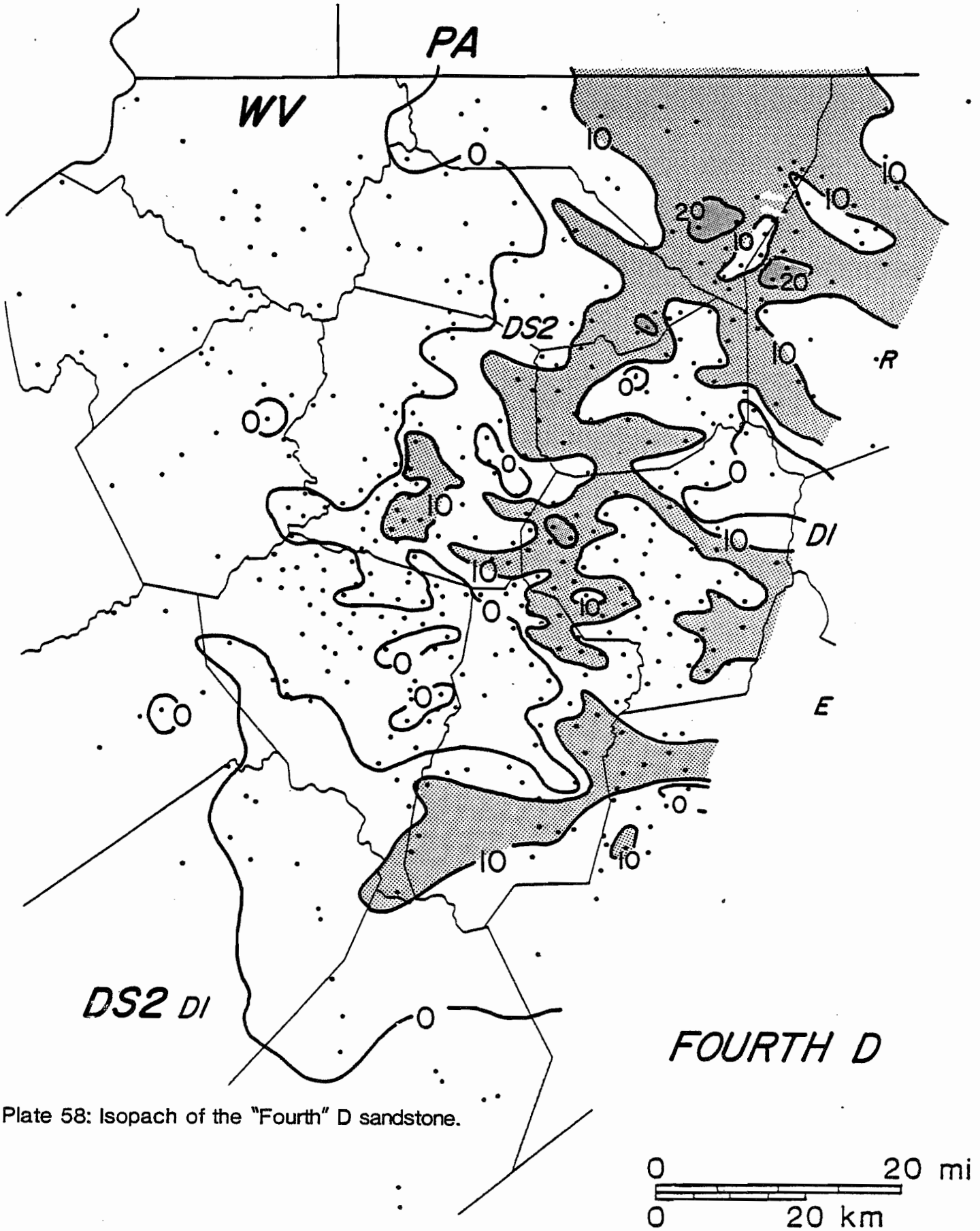


Plate 58: Isopach of the "Fourth" D sandstone.

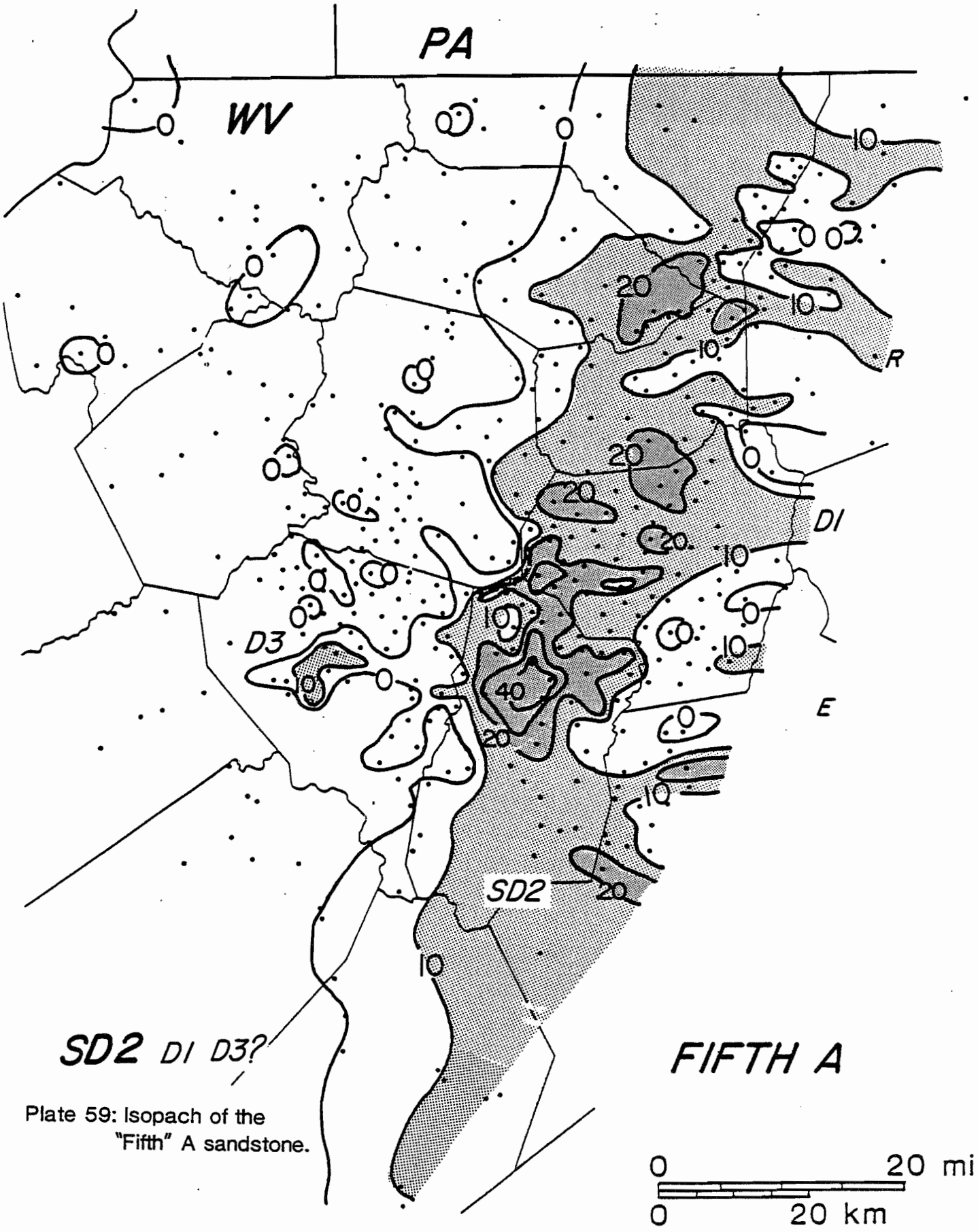


Plate 59: Isopach of the "Fifth" A sandstone.

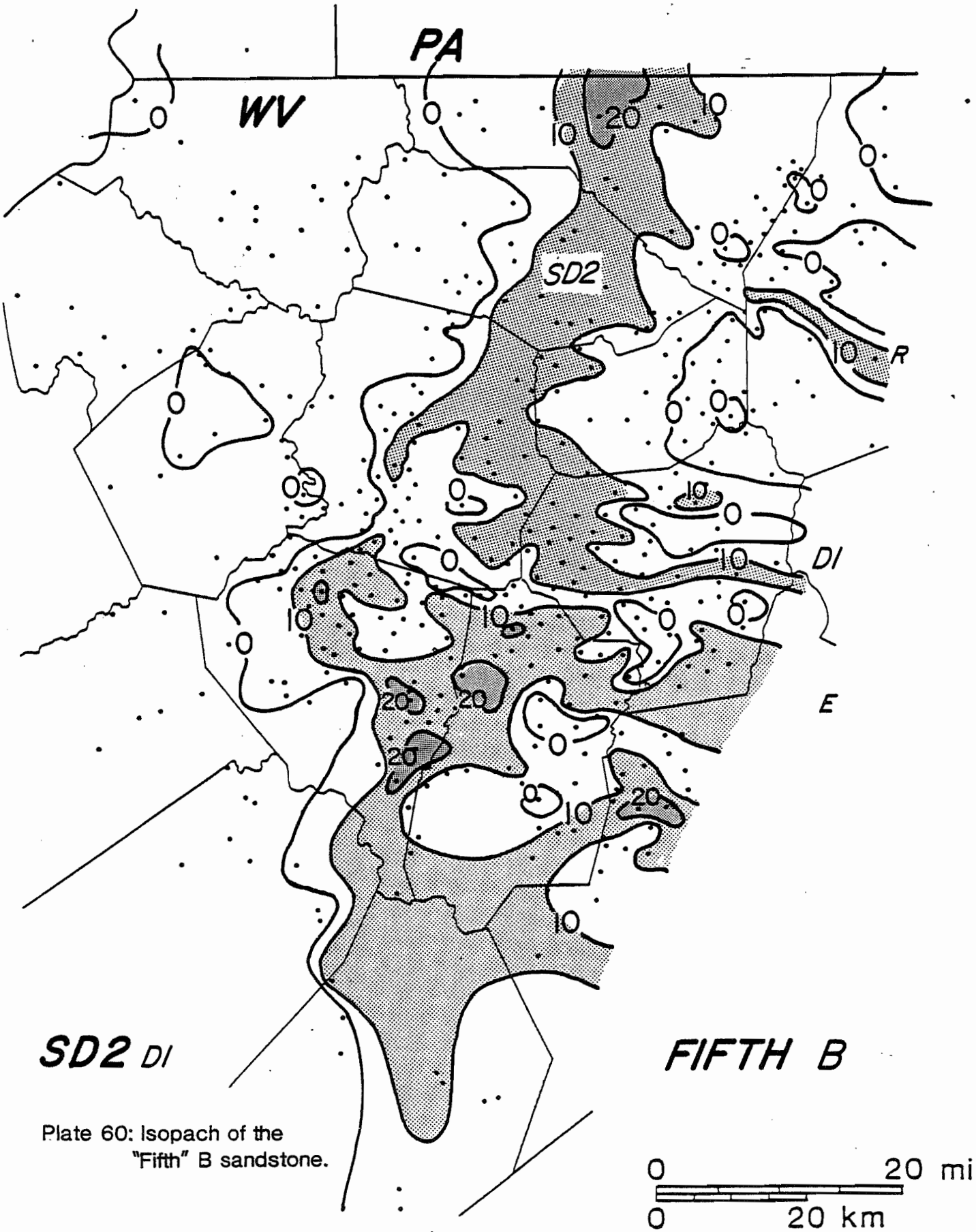


Plate 60: Isopach of the "Fifth" B sandstone.

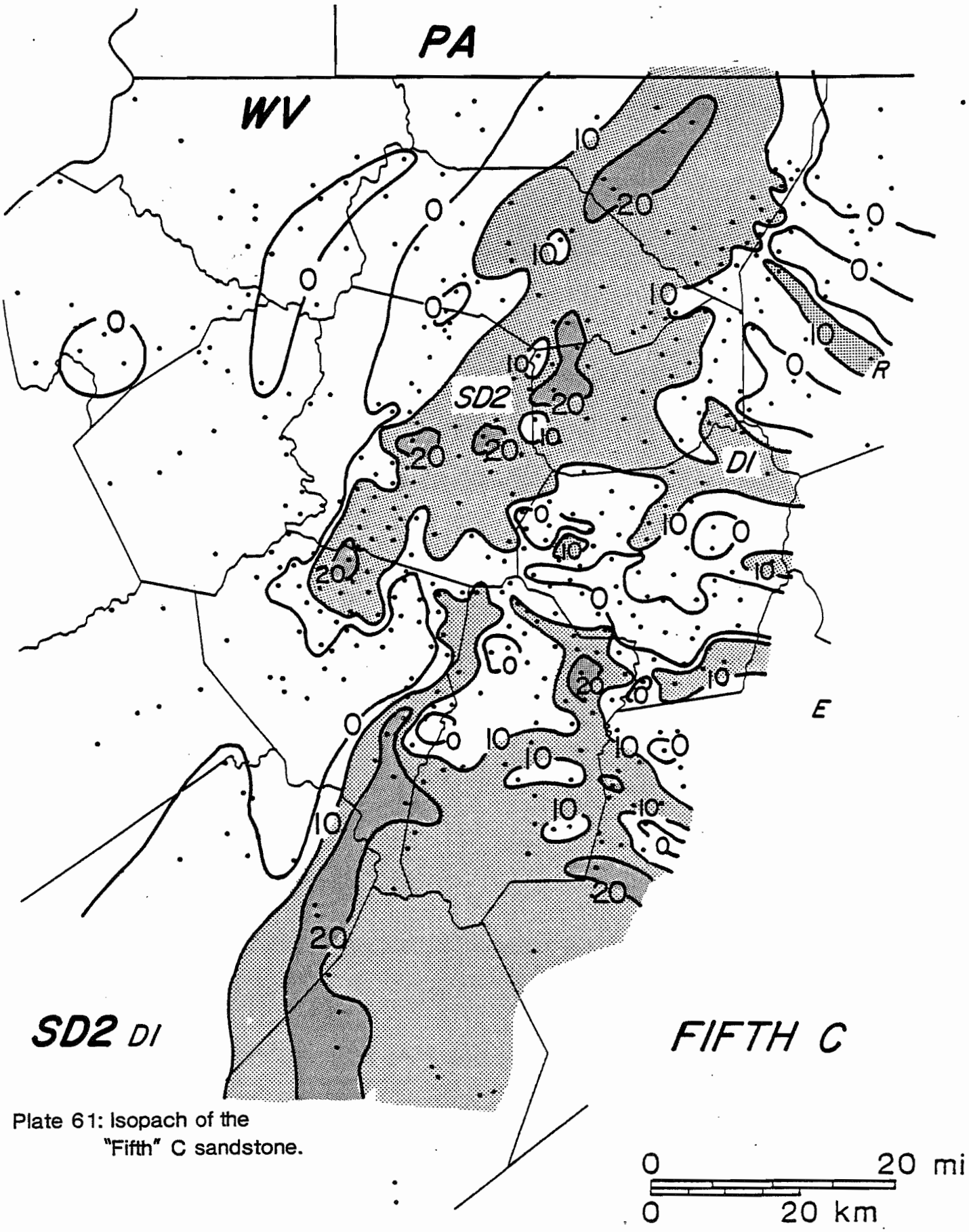


Plate 61: Isopach of the "Fifth" C sandstone.

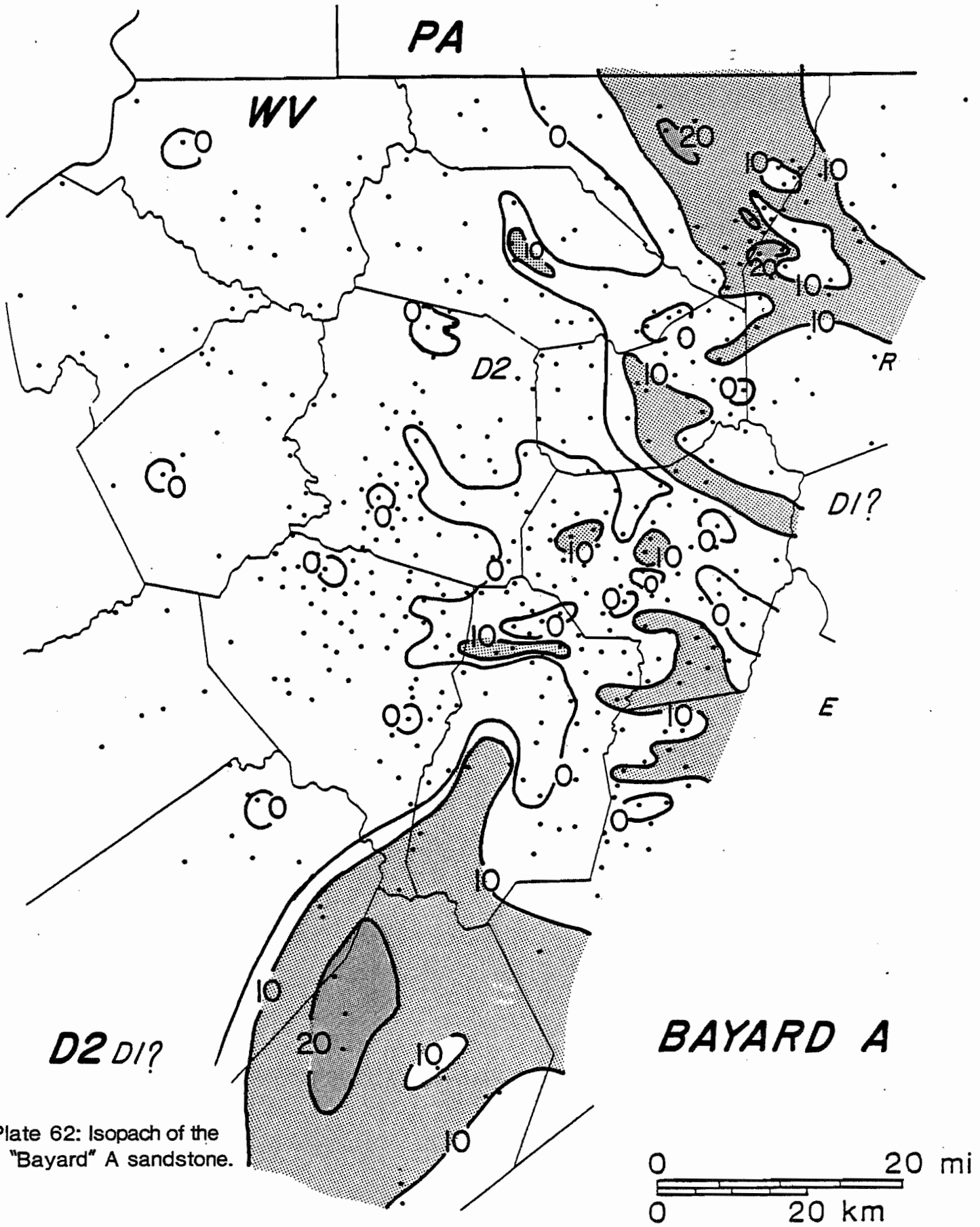


Plate 62: Isopach of the "Bayard" A sandstone.

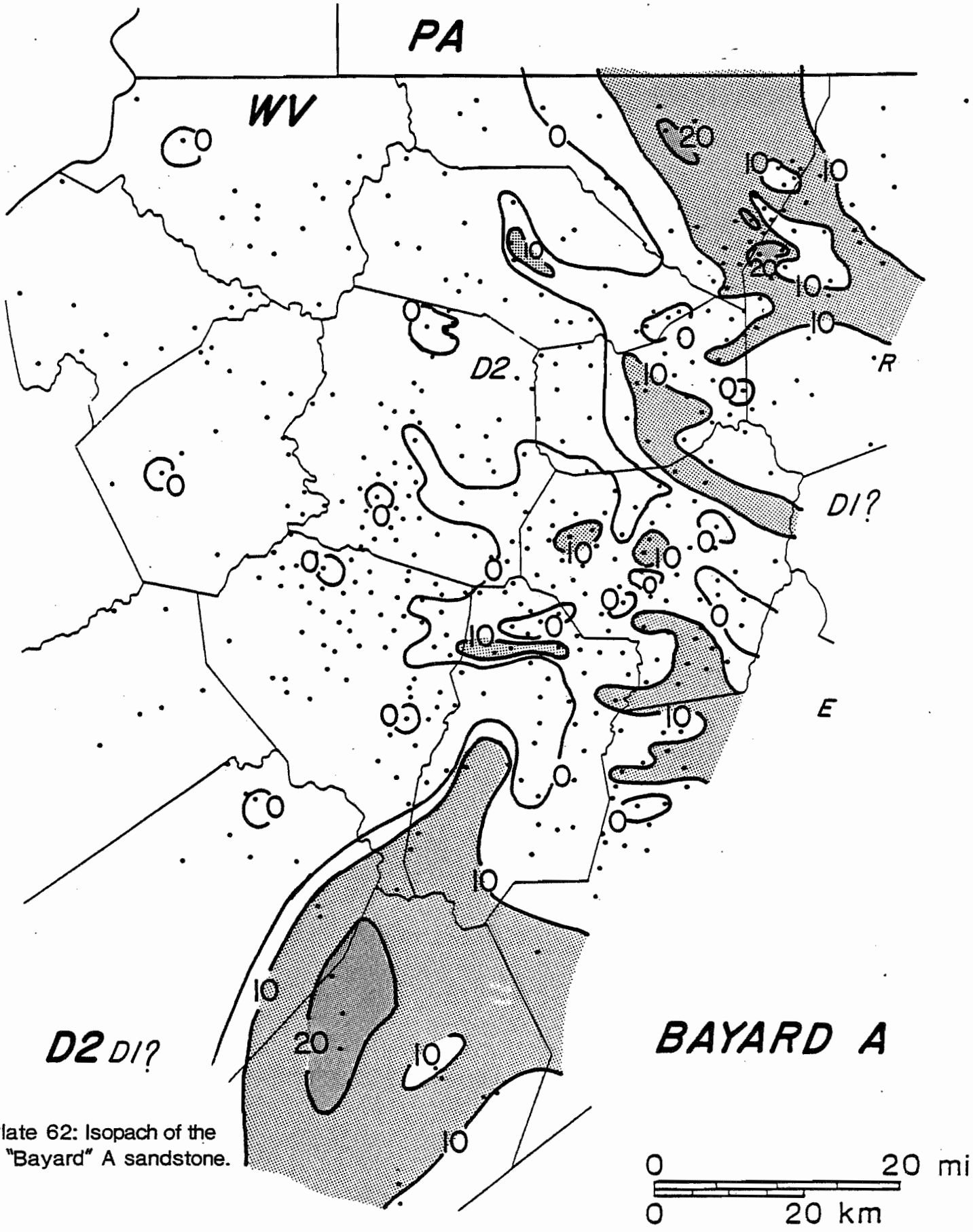


Plate 62: Isopach of the "Bayard" A sandstone.

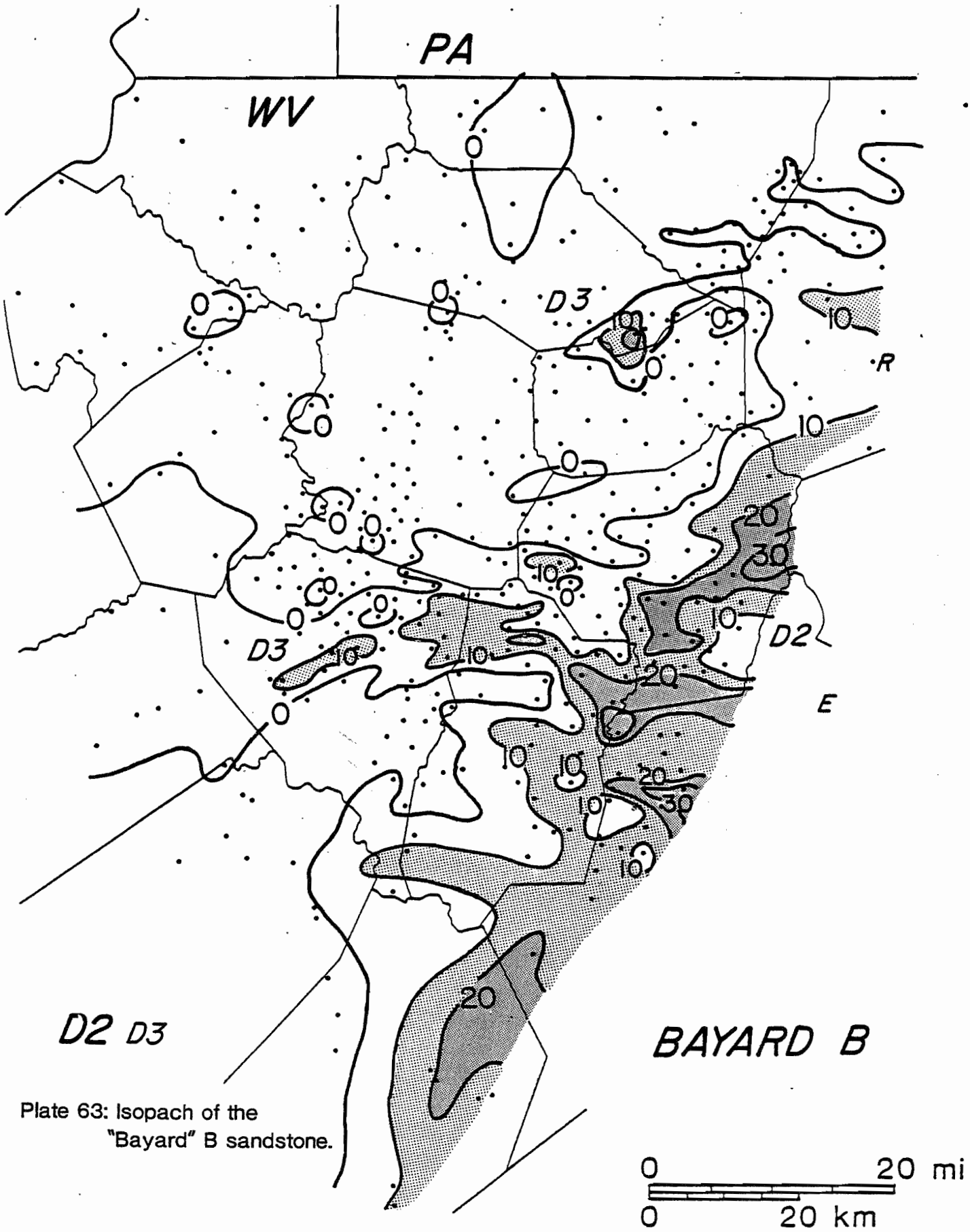


Plate 63: Isopach of the "Bayard" B sandstone.

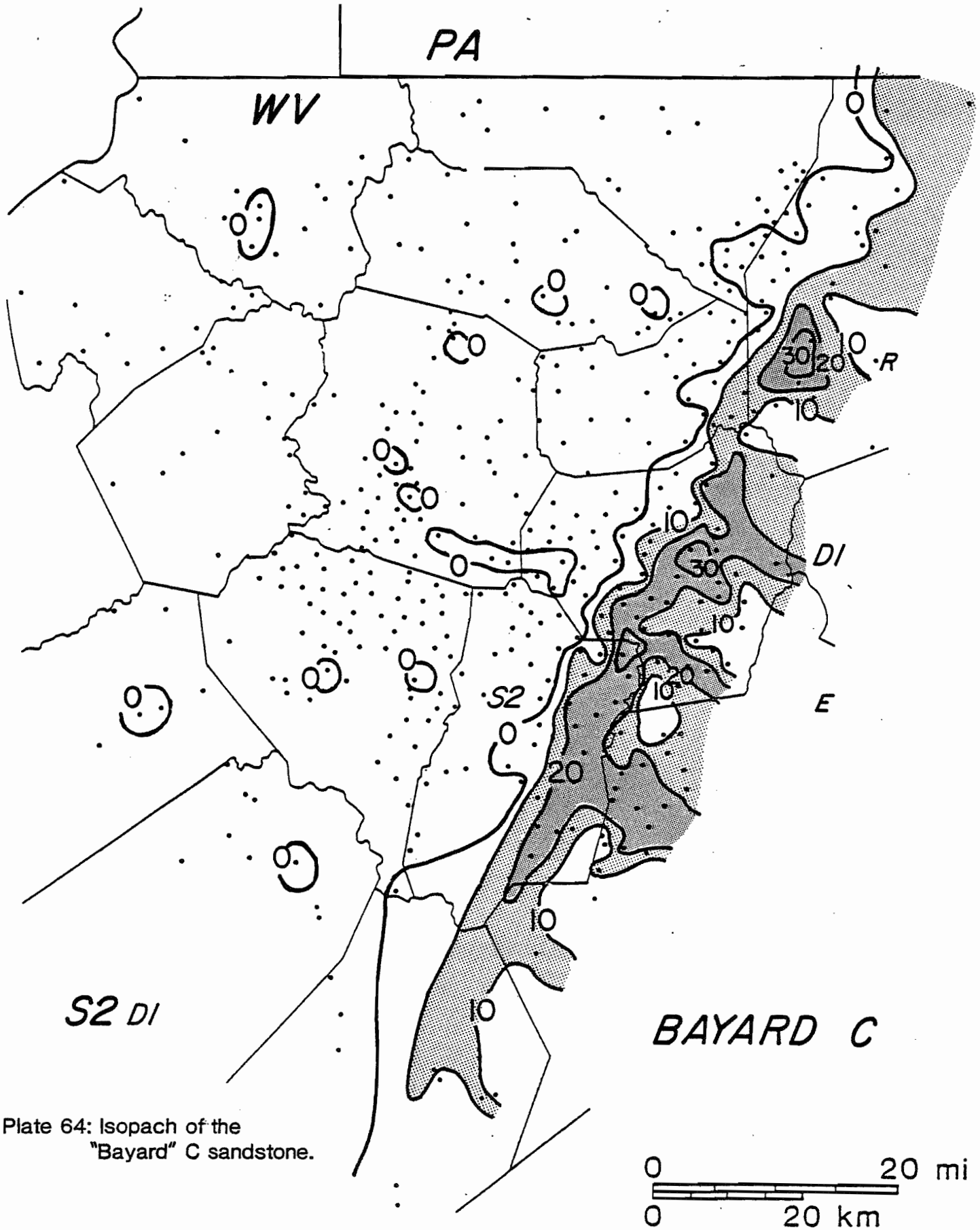


Plate 64: Isopach of the "Bayard" C sandstone.

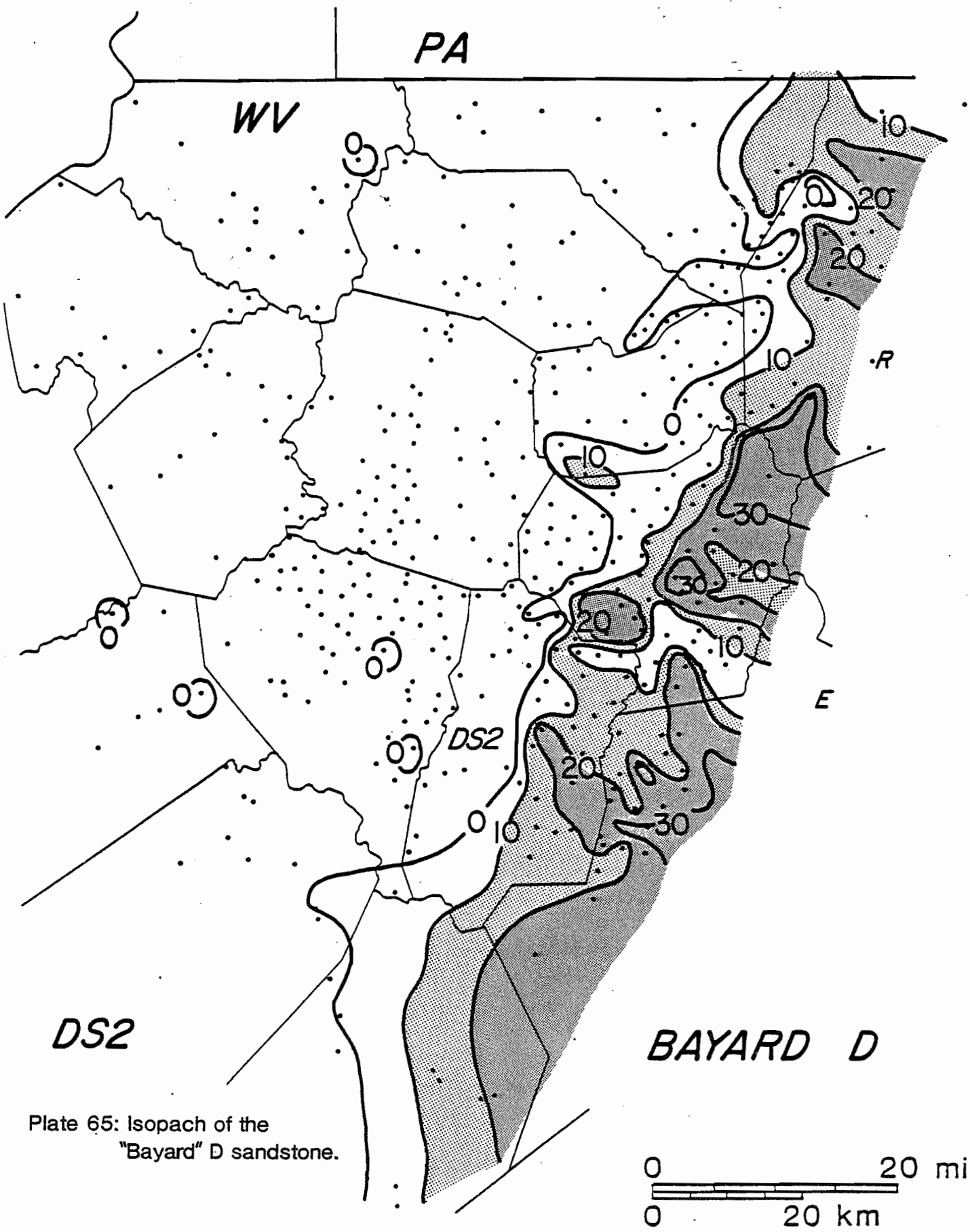


Plate 65: Isopach of the "Bayard" D sandstone.

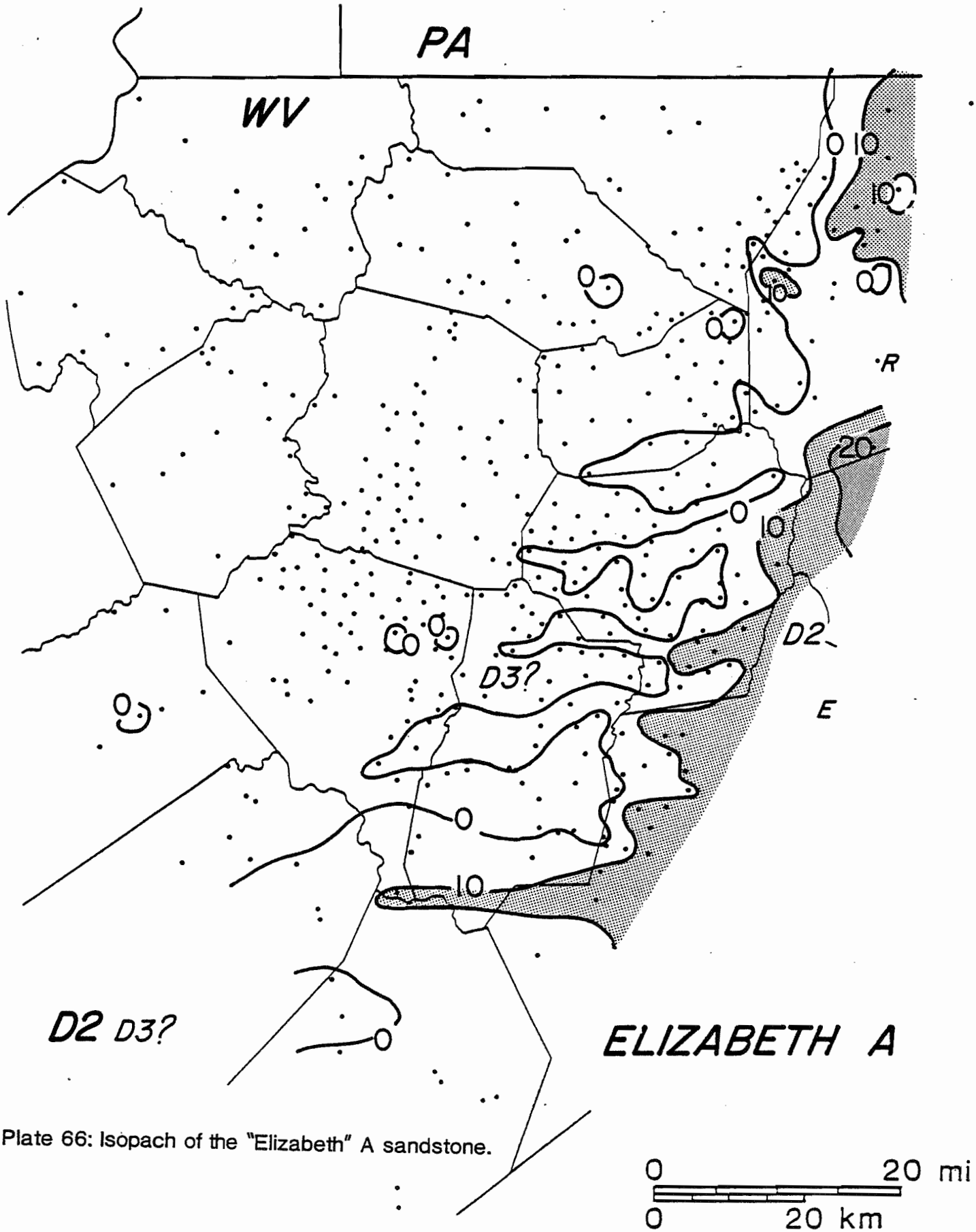


Plate 66: Isopach of the "Elizabeth" A sandstone.

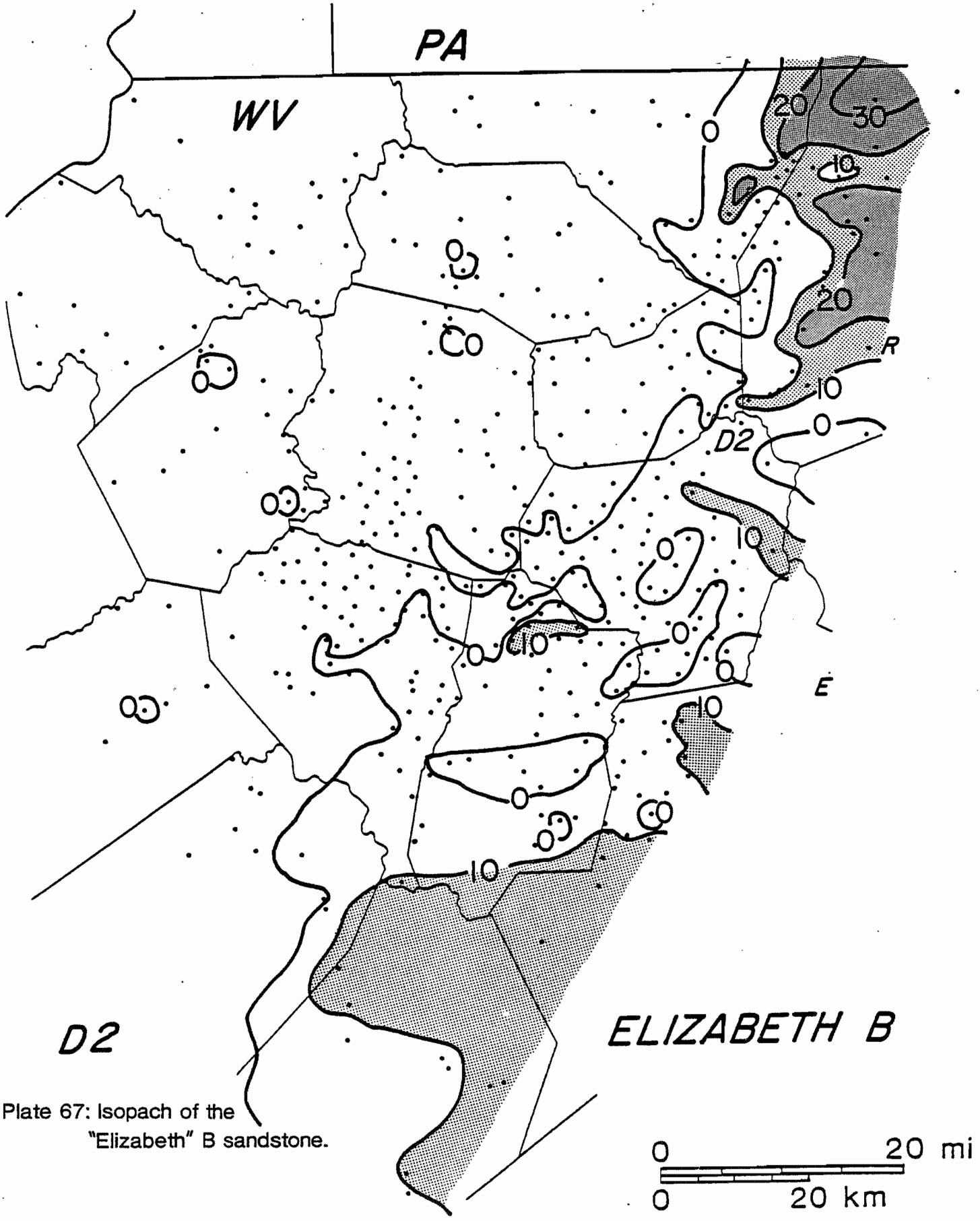


Plate 67: Isopach of the "Elizabeth" B sandstone.

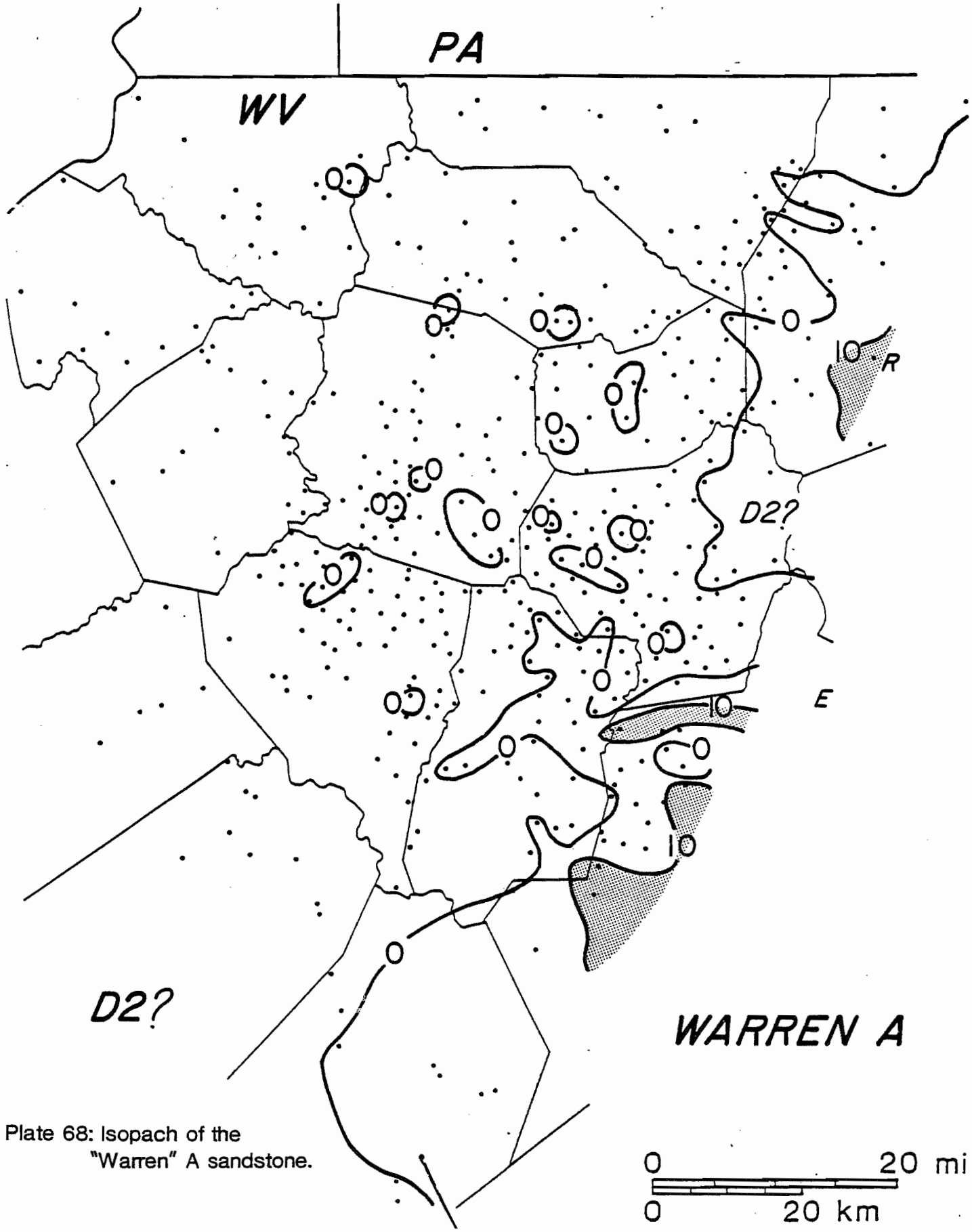


Plate 68: Isopach of the "Warren" A sandstone.

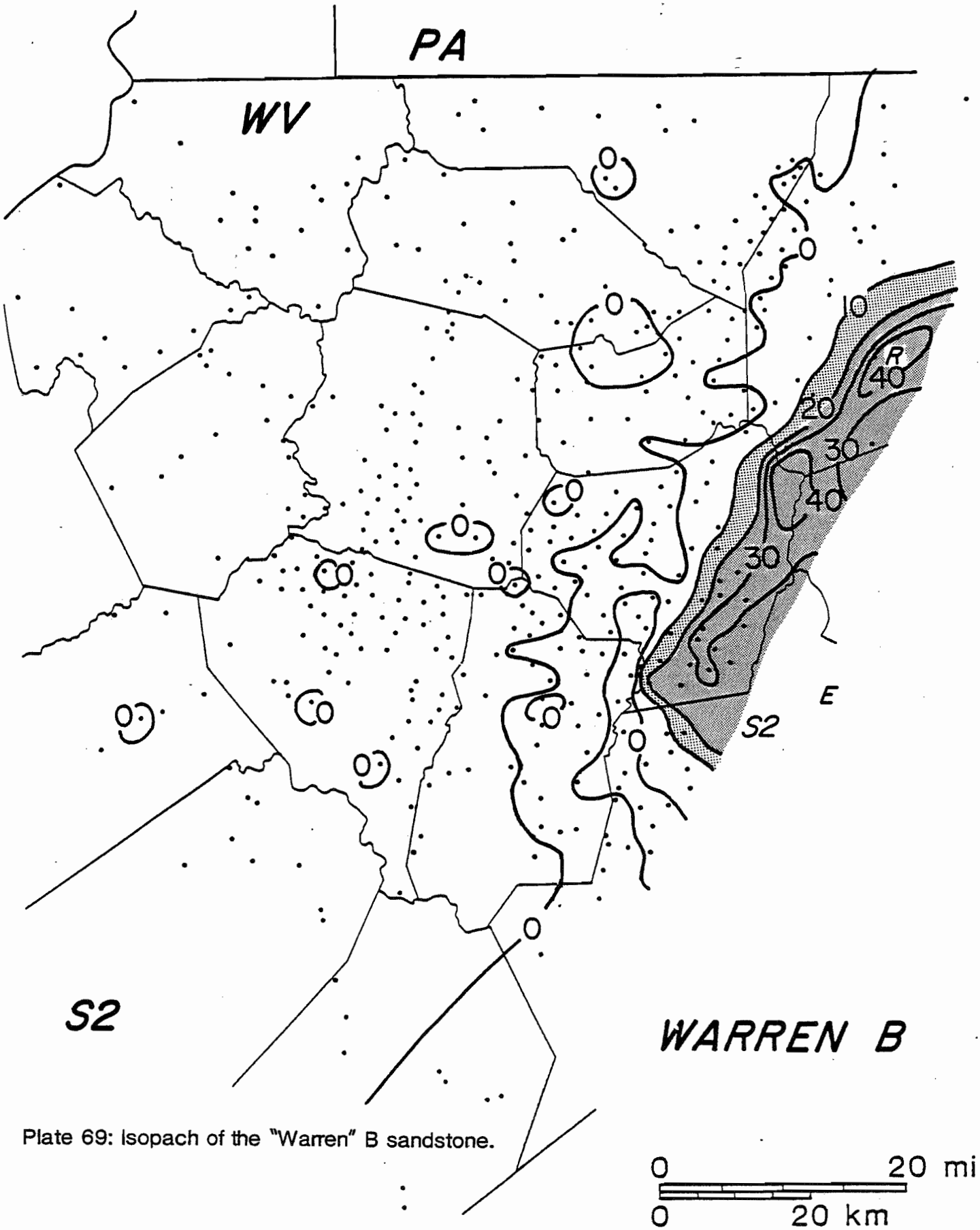


Plate 69: Isopach of the "Warren" B sandstone.

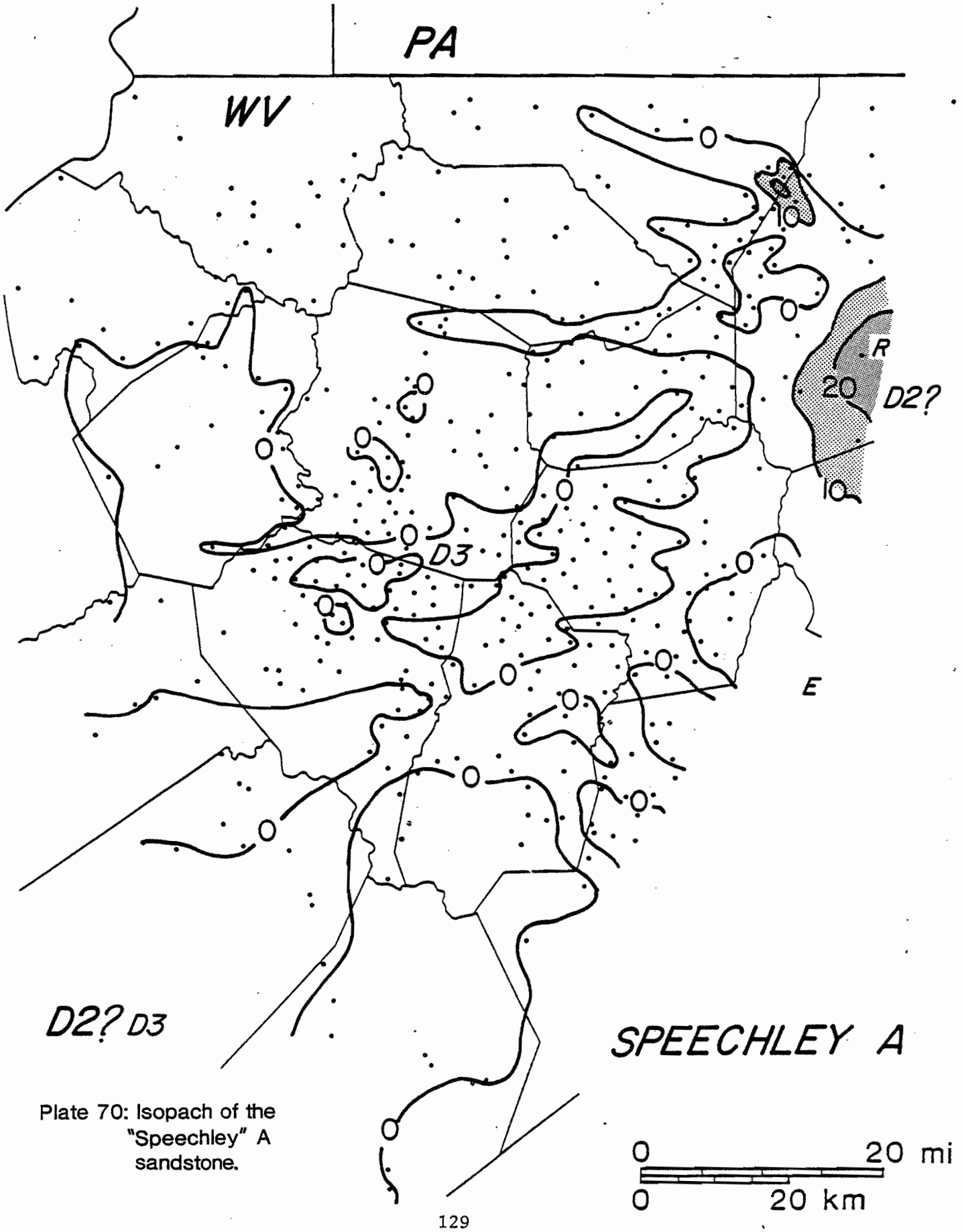


Plate 70: Isopach of the "Speechley" A sandstone.

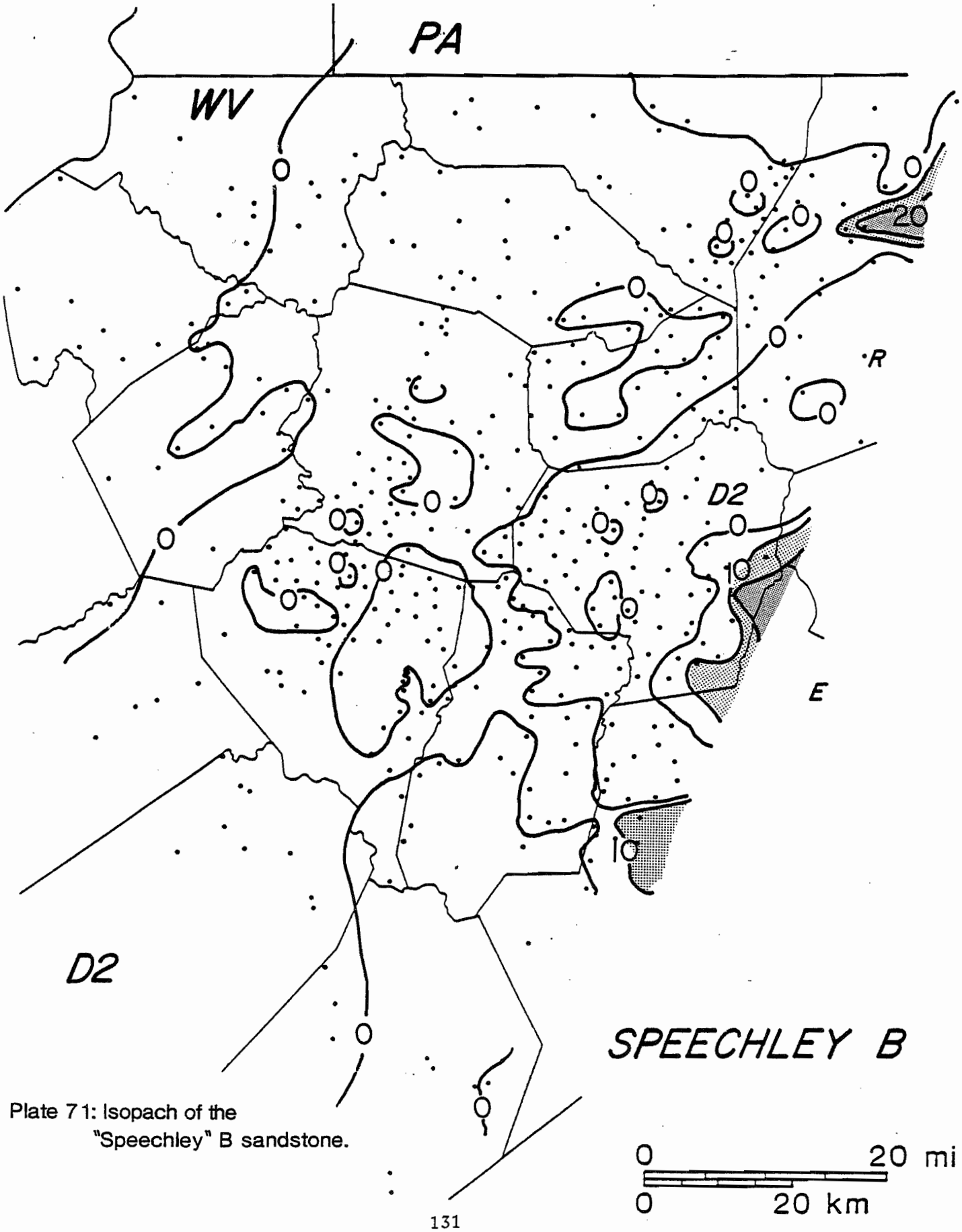


Plate 71: Isopach of the "Speechley" B sandstone.

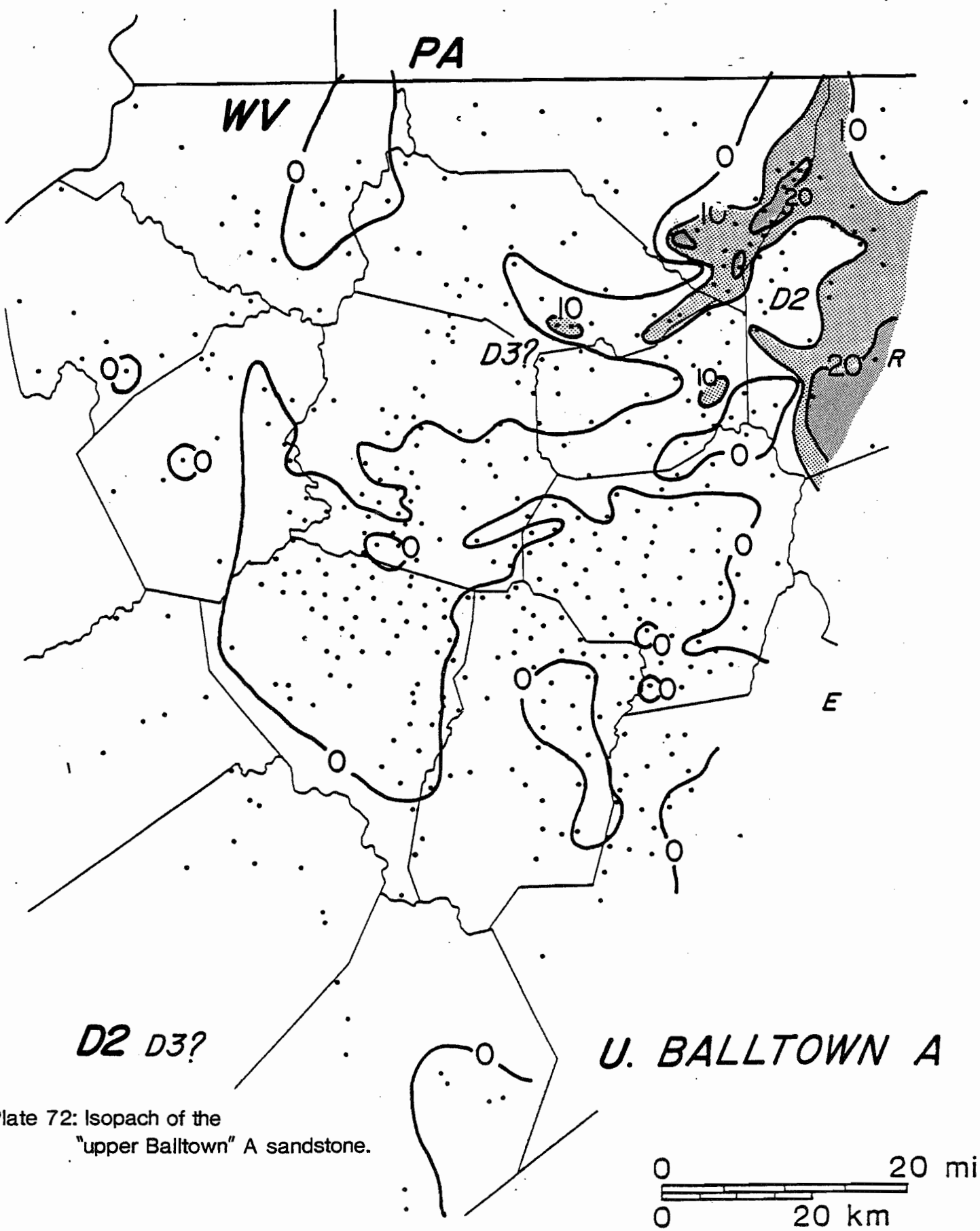


Plate 72: Isopach of the "upper Balltown" A sandstone.

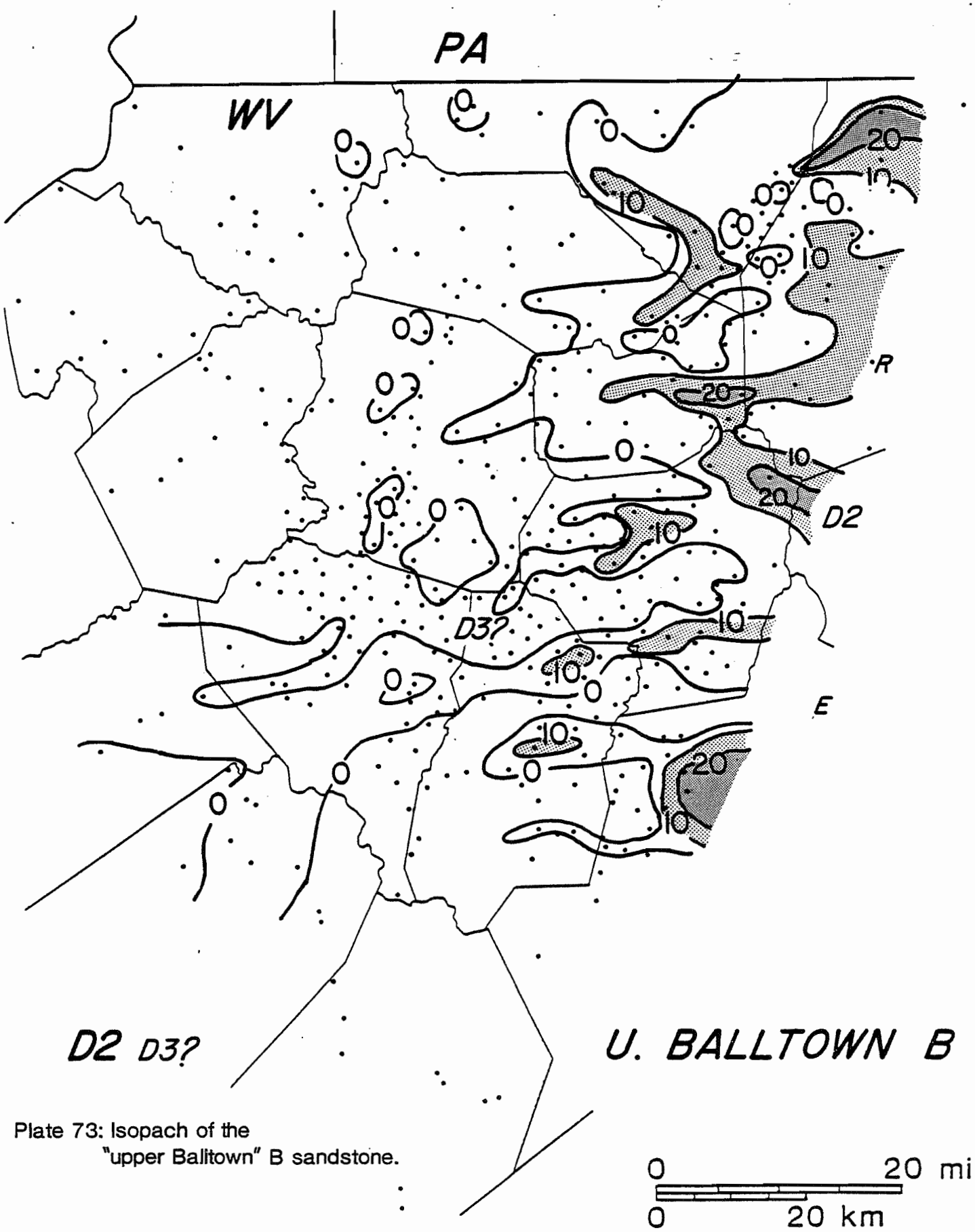


Plate 73: Isopach of the "upper Ballitown" B sandstone.

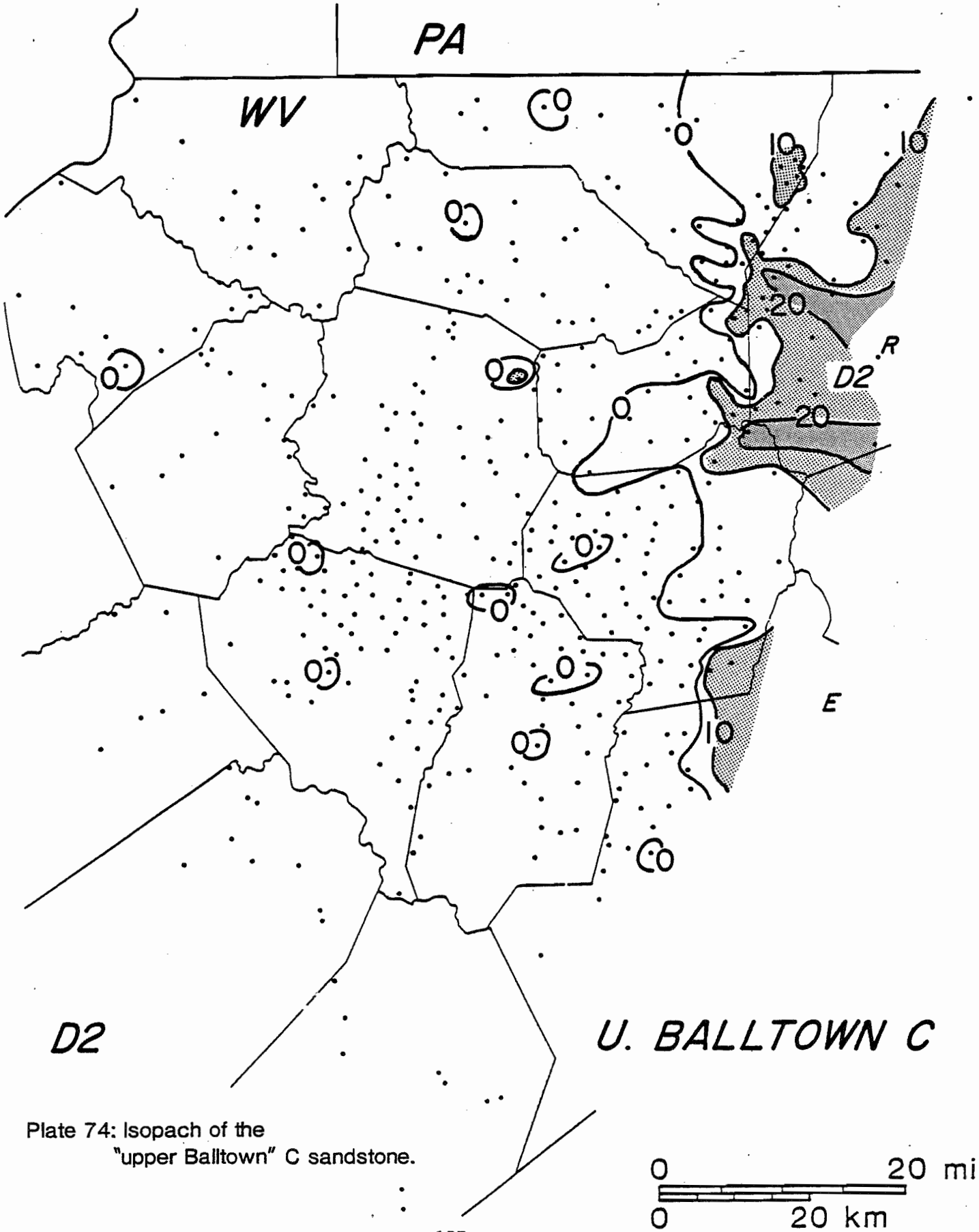


Plate 74: Isopach of the "upper Balltown" C sandstone.

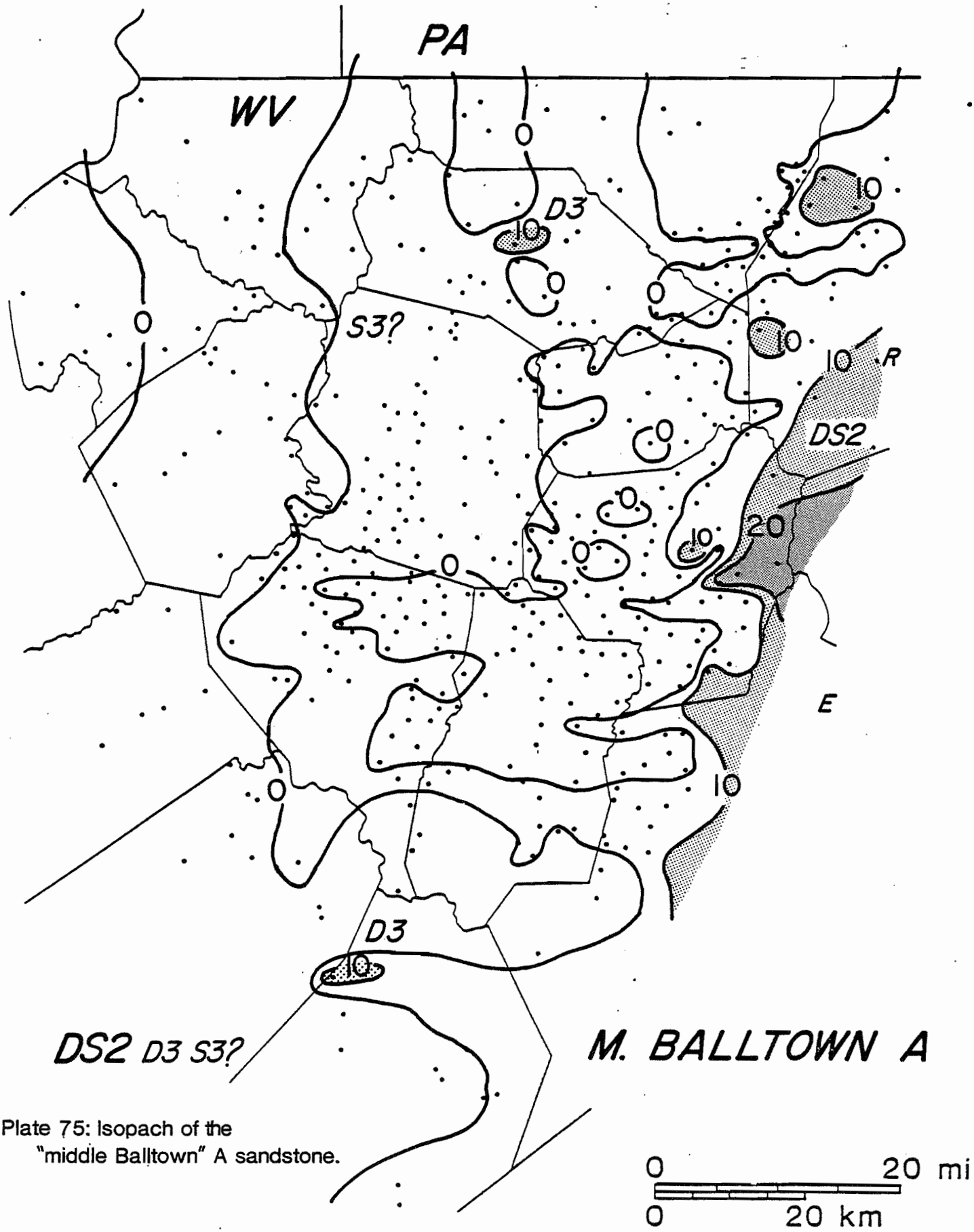


Plate 75: Isopach of the "middle Balltown" A sandstone.

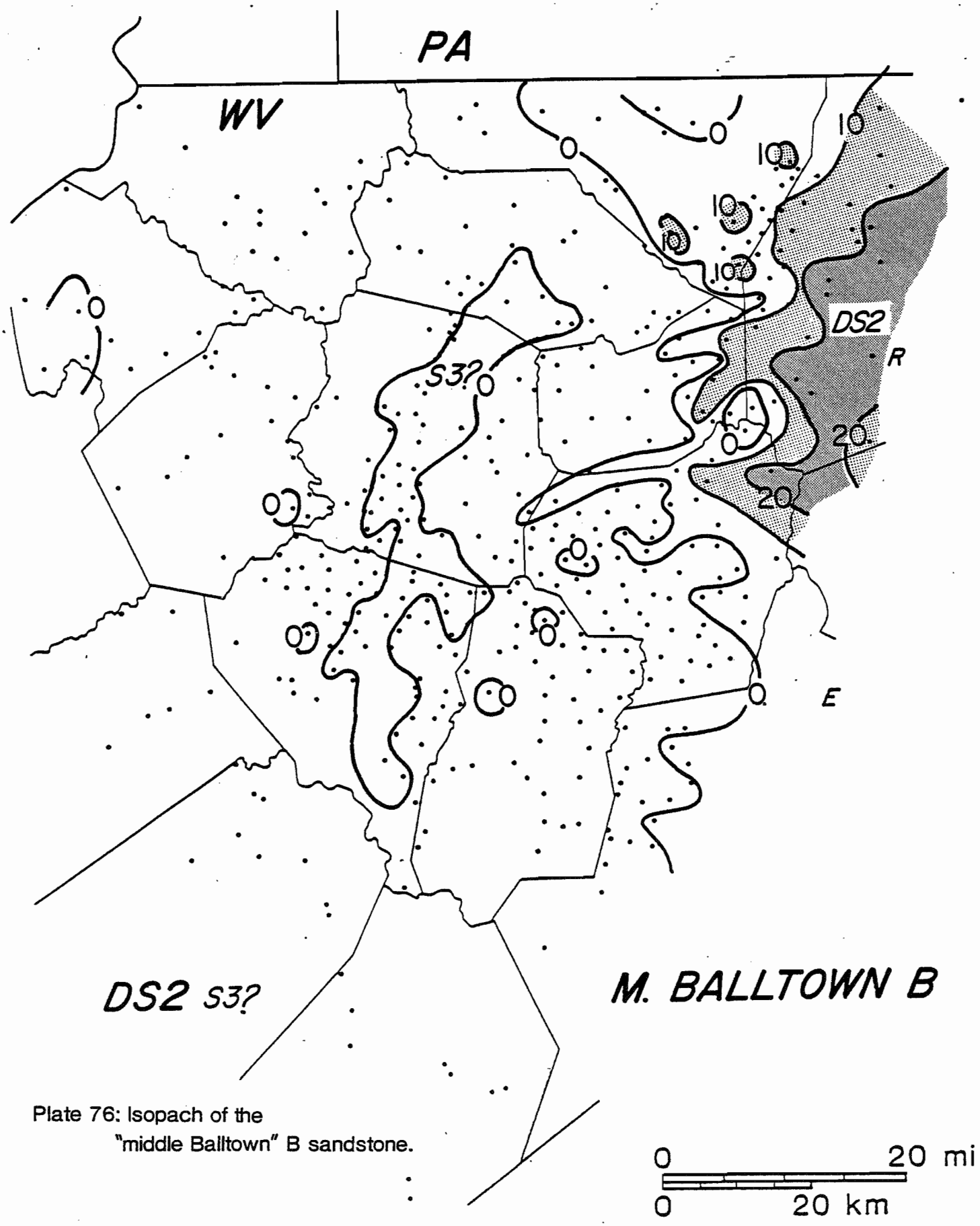


Plate 76: Isopach of the "middle Balltown" B sandstone.

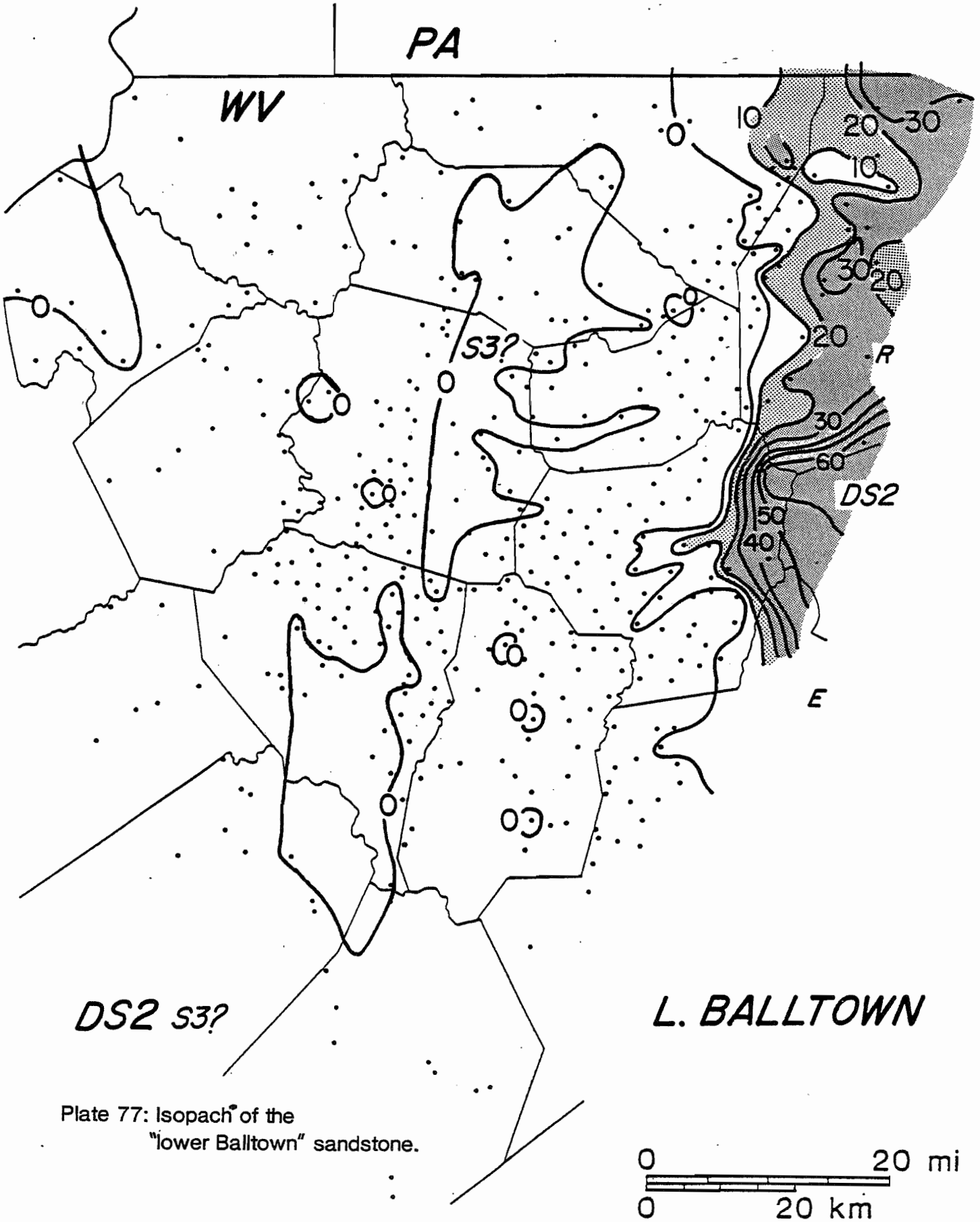


Plate 77: Isopach of the "lower Balltown" sandstone.