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Thermal maturity patterns (CAI and $\%R_o$) in the Ordovician and Devonian rocks of the Appalachian basin in West Virginia

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[Note: Image quality may have been affected by the addition of Section 508-compliant tags.]

TABLES

Introduction

This report presents a series of new thermal maturation maps for West Virginia, based on conodont color alteration index (CAI) and vitrinite reflectance (%R_o). Also, RockEval and total organic carbon (TOC) data are included in the report. Three Paleozoic intervals were studied: Middle Ordovician carbonate rocks, Lower and Middle Devonian carbonate rocks, and Middle and Upper Devonian black shale. These intervals were chosen for several reasons: A) they represent target reservoir zones for most of the oil and gas exploration and drilling in West Virginia; B) they are stratigraphically near probable source rocks for the oil and gas; C) they include contiguous geologic formations that extend across most of West Virginia; D) they contain carbonate grainstone/packstone which give a reasonable to good probability of recovery of conodont elements from small samples of drill cuttings; and E) the Middle and Upper Devonian black shale contains large amounts of organic matter for geochemical analysis.

The maps presented herein complement, and in some areas replace, the West Virginia part of the CAI-based thermal maturation maps for the Appalachian basin of Harris and others (1978). The maps of Harris and others (1978) were pioneering efforts in applying the concepts and techniques of CAI analysis developed by Epstein and others (1977). Our maps differ in that the CAI data used are derived almost entirely from subsurface samples whereas the CAI data used by Harris and others (1978) are almost entirely from outcrop samples. Because of the sampling methods, there is little geographic overlap in the two data sets, with the new data presented herein mostly from the Appalachian Plateau province and most of the data of Harris and others (1978) being from the Valley and Ridge province.

Several vitrinite reflectance ($\%R_o$) maps are available for evaluating thermal maturity patterns in the Appalachian basin but they are limited to smaller areas than the CAI-based maps. Examples of vitrinite reflectance maps that apply to West Virginia are those for Upper Devonian black shale by Streib (1981), Hamilton-Smith (1996), and Curtis and Faure (1997) and for Pennsylvanian coal beds by Trinkle and others (1978), Cole and others (1979), Chyi and others (1987), and Hower and Rimmer (1991). RockEval/TOC-derived maps for Appalachian Ordovician black shale are available in Wallace and Roen (1989).

Thermal maturity patterns of the Middle Ordovician Trenton Limestone are evaluated here because they are expected to closely approximate those of the overlying Ordovician Utica (Antes) Shale that is the probable source rock for oil and gas in Upper Cambrian sandstone, Lower Ordovician carbonate rocks, and Lower Silurian sandstone (Ryder and others, 1998) and possibly for new gas discoveries in the Trenton and Black River Limestones (Schwochow, 2000; Avary, 2001). Thus, improved CAI-based thermal maturity maps are important to identify areas of optimum gas generation from the Utica (Antes) Shale and to constrain the origin, distribution, and quality of natural gas in the Lower Silurian regional oil and gas accumulation (Ryder and Zagorski, 2003). Also, thermal maturity maps of the Ordovician may contribute to understanding the origin and distribution of gas in Trenton and Black River carbonate reservoirs. Moreover, thermal maturity maps of selected Devonian carbonate rock and black shale intervals will constrain burial history - petroleum generation models of the Ordovician Utica (Antes)

Shale, as well as provide a better understanding of the origin and distribution of regional oil and gas accumulations in Upper Devonian sandstone, self-sourced gas in Middle to Upper Devonian black shale, and conventional gas in Lower Devonian sandstone.

New CAI and $\%R_o$ maps presented in this report also contain information that relates to the thermal and tectonic evolution of the Appalachian basin. Important in this regard are the character of thermal maturity patterns across specific tectonic features, comparison of thermal maturity and overburden patterns, changes in paleogeothermal gradient with time for a given area, and proposed geological/geophysical causes of regional thermal maturity anomalies.

New York State and Pennsylvania were the first areas in the Appalachian basin where the collection, processing, and analysis of subsurface drill-hole cuttings and core samples have resulted in new CAI and $\%R_o$ maps (Weary and others, 2000, 2001; Repetski and others, 2002). The present study is a cooperative effort between the U.S. Geological Survey (USGS) and the West Virginia Geological and Economic Survey. Additional investigations in Ohio (USGS-Ohio Division of Geological Survey), Kentucky (USGS-Kentucky Geological Survey), and Virginia (USGS-Virginia Division of Mineral Resources) are at various stages of completion.

Methods

Seventy-one drill-hole samples were collected, processed, and analyzed for conodont color alteration index (CAI) specifically for this study. Of these, 55 were Devonian and 16 were Ordovician. The Devonian samples used herein were from 46 drill holes and all of them consisted of cuttings. Two of these drill holes were sampled previously (A.G. Harris, unpub. USGS data; 5 samples, 3 having conodonts). These samples yielded 53 new Devonian CAI points for West Virginia. The Ordovician samples were obtained from 17 drill holes; 14 samples were cuttings, 5 were cores. Fourteen of these drill holes were sampled specifically for this study; 3 were sampled previously, for other USGS studies (A.G. Harris, unpub. USGS data; Ryder and others, 1996)(Table 1) In all, these resulted in 16 new Ordovician CAI points.

An additional 40 samples were collected from Devonian black shales. These black shales were sent to Humble Geochemical Services,[1] Humble, Texas, for processing and analysis for total organic carbon (TOC), RockEval parameters, and vitrinite reflectance. Additional vitrinite reflectance values (n = 22) from Devonian black shale in 3 West Virginia core holes (Streib, 1981) supplement our data set (Table 3).

Samples for this study were collected by one of us (KLA) and Melissa Packer from drill core and cuttings in the repository holdings of the West Virginia Geological and Economic Survey, at Morgantown, Monongalia County, West Virginia. Conodonts from 7 additional wells and 2 outcrops (8 Devonian and 4 Ordovician samples), already on file at the USGS (A. G. Harris, unpublished data; Ryder and others, 1996), were re-analyzed for this study. In all, 58 drill holes and 2 outcrops in 36 counties were sampled (Fig. 1; Table 3).

Where possible (n=41 holes), we sampled the different target intervals from the same drill hole (well). In most of these cases, the sampled pair was the Devonian black shale and Devonian carbonate rocks. The total collection consists of: 1) carbonate

[1] Any use of trade, product, or firm names is for descriptive purposes only and does not imply endorsement by the U.S. Government.

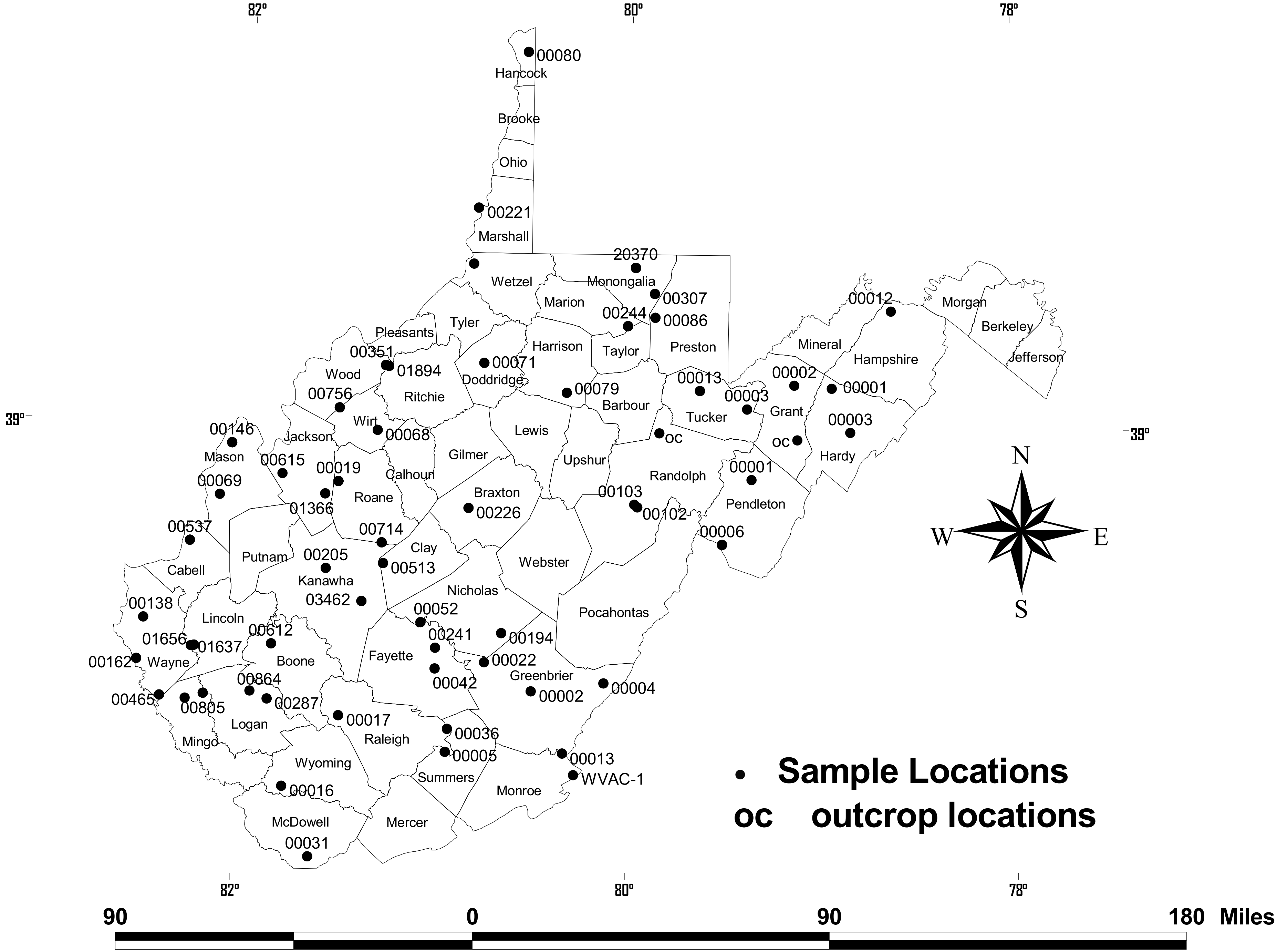

Figure 1. Location of wells and surface localities sampled for conodonts and (or) vitrinite in this study.

(limestone) samples from the Upper Cambrian-Lower Ordovician Beekmantown Group (or Formation, as used by the West Virginia Geological Survey), Middle-Upper Ordovician Black River and Trenton Limestones, and Middle Ordovician Chazy Limestone (n=19, including 3 barren samples and 3 from Harris, unpub. USGS data, and Ryder and others, 1996) (Fig. 2; Table 1); 2) carbonate (chiefly limestone, with minor dolostone) samples from selected Devonian formations (n=60, including 7 barren samples and 3 from A.G. Harris, unpub. USGS data) (Fig. 3; Table 2); and 3) black shale samples from the Middle Devonian Marcellus Shale or Upper Devonian Rhinestreet and Huron Shales (n=62, including 22 from Streib, 1981) (Table 3). The samples averaged about 120 g, with a range from 2.1 to several hundred g, and consisted of rock fragments >20-mesh. Most samples were composites representing from about 100 to several hundred feet of stratigraphic section. The carbonate samples were shipped to the USGS in Reston, Virginia, where they were processed for conodonts using standard chemical and physical extraction procedures (Harris and Sweet, 1989).

Conodonts recovered were visually compared with a set of conodont color standards of approximately the same age (to Period), provided by A.G. Harris (USGS-Emeritus), and assigned a conodont alteration index (CAI) value. Samples exhibiting a range in CAI values and samples with very few individual conodont elements or only a few element fragments were assigned a minimum and maximum value. We chose to use the maximum CAI value for plotting the isograds on the accompanying maps (Figs. 4-6, 8-10) to maintain consistency with the procedures used by Harris and others (1978), for their Appalachian CAI maps. In effect, if a host rock experienced at least the magnitude and duration of heating to raise any of the contained conodont elements to the higher CAI value in an observed range of values, then any associated hydrocarbons also would have experienced those temperatures as well. The conodonts used in this study are reposited in the collections of the U.S. Geological Survey in Reston, Virginia, and are curated using the USGS Cambrian-Ordovician (CO) and Silurian-Devonian (SD) fossil collection/locality numbers. (Tables 1 and 2). Tables 1 and 2 also provide faunal lists, biostratigraphic ages or age ranges for the recovered conodonts from each productive sample, and details of the processed residues for the Ordovician and Devonian carbonate sample sets, respectively. Summaries of the location, age, and depth of the samples, as well as their measured TOC, RockEval, vitrinite reflectance, and CAI values are given in Table 3. Also given in Table 3 are notable minerals and fossils seen in the heavy fraction (sp. gr. >2.87) of the picked insoluble residues.

All of the maps were constructed by plotting points in ARC/VIEW over a digital base map, using latitude/longitude coordinates from the West Virginia Geological and Economic Survey oil and gas well database. The points were then attributed with American Petroleum Institute (API) numbers, minimum and maximum CAI values, RockEval parameter values, and $\%R_o$ values. Data points and CAI isograd contours from Harris and others (1978) were captured and replotted by tracing and attributing the points and lines in ARC/INFO. The coverages were exported to ARC/VIEW version 3.1 for ease of manipulation and graphic display.

Stratigraphy of Sampled Intervals

All Ordovician samples used in this study were identified from well logs as the Chazy Limestone, Trenton Limestone, Black River Limestone, or Beekmantown

Formation by the West Virginia Geological Survey. All but three of the 19 Ordovician samples were productive of conodonts, yielding from one to 8 elements or fragments identifiable as conodonts. Analysis of the total possible biostratigraphic ranges for each fauna indicates that they all are consistent with the lithostratigraphic determinations, even though most of these possible age ranges extend above or below the range of the identified lithostratigraphic unit. The lithostratigraphy of the studied interval, from Patchen and others (1985), and the biostratigraphic ranges of the conodonts are shown on Figure 2. Because of long-standing usage in North America, we have used the traditional level of the Middle/Upper Ordovician boundary, even though the International Commission on Stratigraphy has recently standardized the base of the Upper Ordovician at a significantly lower level (Webby, 1998). The new usage includes all strata above a level in the middle part of the Chazy Group in the Upper Ordovician, i.e., all of the samples used in this study would be considered to be of Late Ordovician age. Table 1 shows detailed faunal composition, abundance, biostratigraphic range, CAI, and other data from the Ordovician conodont samples analyzed.

Devonian samples were selected where carbonate rocks could be located, identified stratigraphically with reasonable confidence, and sampled in suitable quantity. Where possible, samples comprise a single carbonate lithostratigraphic unit. However, commonly we had to composite cuttings from more than one unit. Fifty of the 55 samples yielded conodonts, with element abundances ranging from a single element to 112 elements or fragments identifiable as conodonts. The sample suite as a whole was limited to the Lower and Middle Devonian, thereby obtaining CAI data reasonably close stratigraphically to the samples from the black shales of the Marcellus Formation that

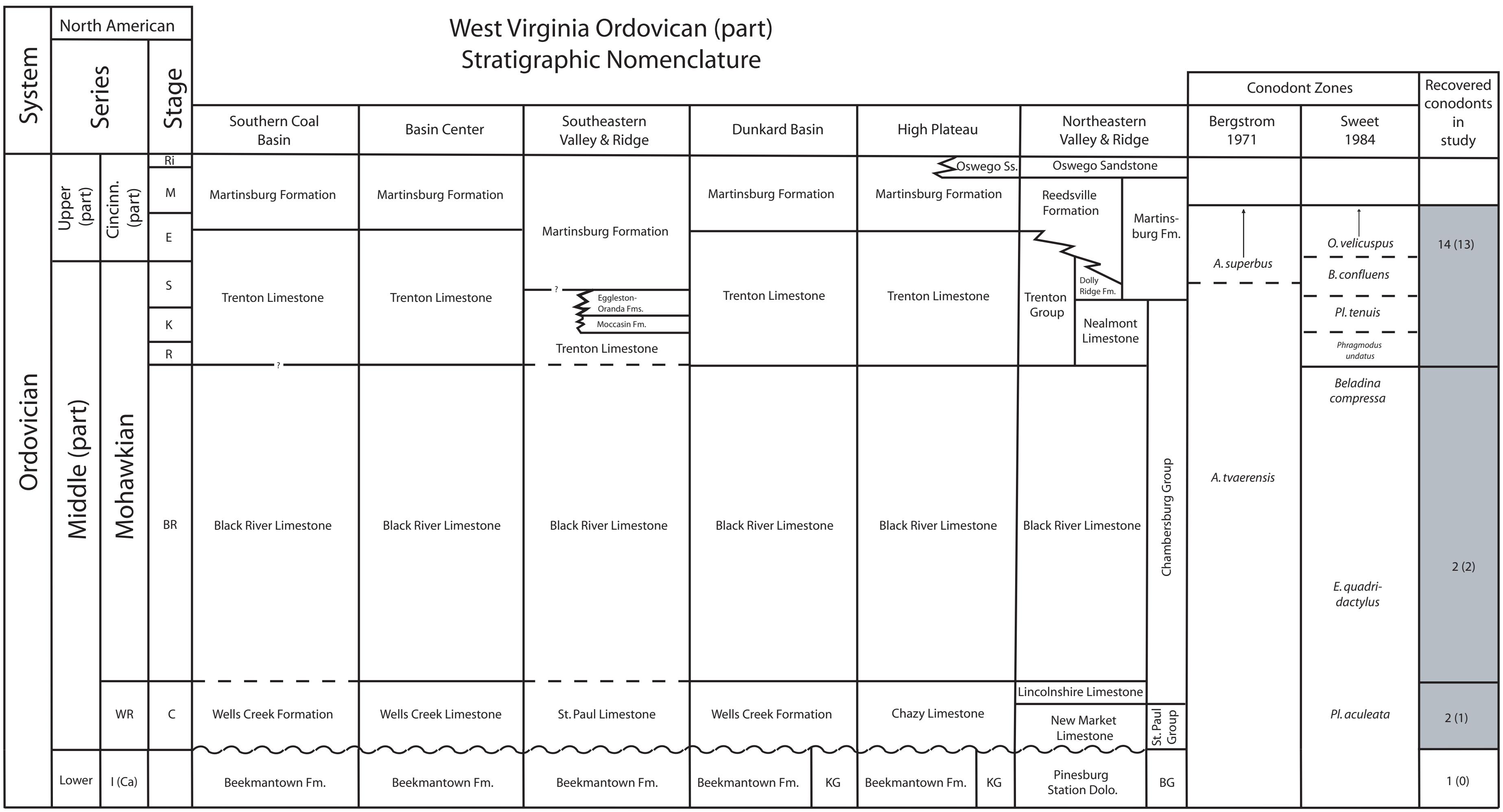

Figure 2. Stratigraphic relations of Ordovician rocks (part) in West Virginia (after Patchen and others, 1985) with conodont sample collections indexed for this study. Number of conodont samples from each unit in plain numerals. Samples yielding conodonts in parentheses. Total-Ordovician samples with recovered conodonts: 16. Ri - Richmondian; M - Maysvillian; E - Edenian; S- Shermanian; K - Kirkfieldian; R - Rocklandian; BR - Blackriveran; C - Chazyan; I - Ibexian; Ca - Canadian; WR - Whiterockian; KG - Knox Group; BG - Beekmantown Group

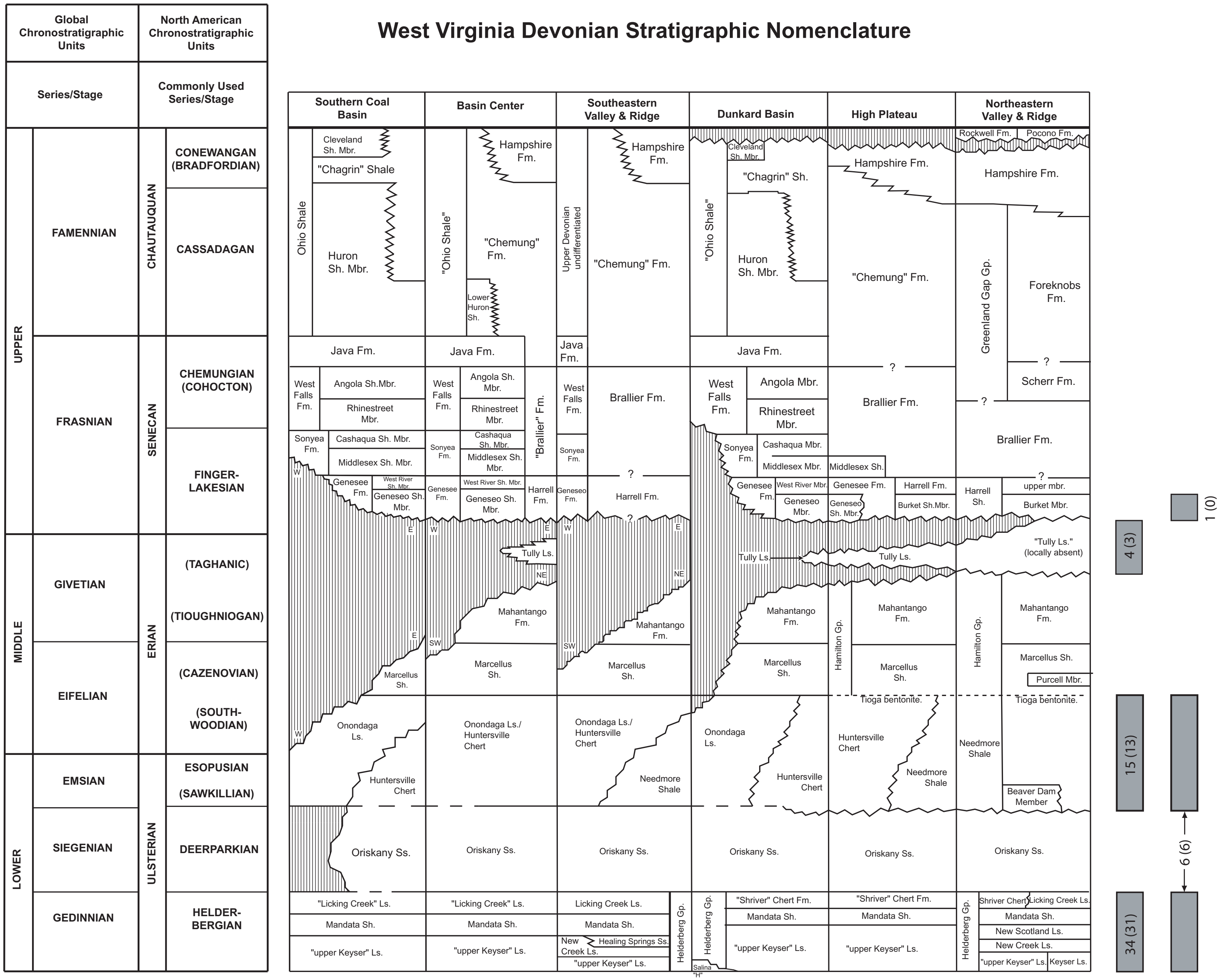

Figure 3. Stratigraphic relations of Lower, Middle, and Upper Devonian rocks in West Virginia (after Patchen and others, 1985) with conodont sample collections used in this study (Table 3). Number of conodont samples from each unit in plain numerals. Samples yielding conodonts in parentheses. Total Devonian samples with recovered conodonts: 53.

were selected and analyzed for vitrinite reflectance and RockEval/TOC data. Figure 3 shows the stratigraphic framework for the studied part of the Devonian in selected structural provinces of West Virginia (from Patchen and others, 1985), as well as the positions of the conodont samples, both productive and barren. Details of the faunal compositions, element counts, biostratigraphic positions, CAI, and other data, for each of the Devonian conodont samples used in this study are shown in Table 2.

Thermal Maturity of Ordovician Strata

Distribution of Isograds: The Ordovician CAI data for the new subsurface samples, for one sample reported by Ryder and others (1996), and for several unpublished subsurface samples reported by A. G. Harris (Tables 1 and 3) are plotted in Figures 4 and 5 and contoured as isograds. All Ordovician isograds are based on maximum CAI values for a given control point. The majority of the samples with recoverable conodont elements are located in autochthonous rocks of the Plateau province (11 of 17) with the remainder located in allochthonous rocks of the Valley and Ridge province (Fig. 4). CAI_{max} values in our collection range between 1.5 and 5. The CAI 5 isograd defines a narrow, northeast-trending region of high thermal maturity, approximately 75 mi long, located in northern West Virginia between Lewis and Preston Counties (Fig. 4; see Fig. 1 for county locations). Successively lower CAI isograds, between 4.5 and 3.5, flank both sides of the CAI 5 isograd and close around its southwest end (Fig. 4). The western and southwestern parts of West Virginia are marked by lower isograds that range from CAI 1.5 to CAI 3 and maintain the same dominant northeast trend as the higher isograds (Figs. 4). The

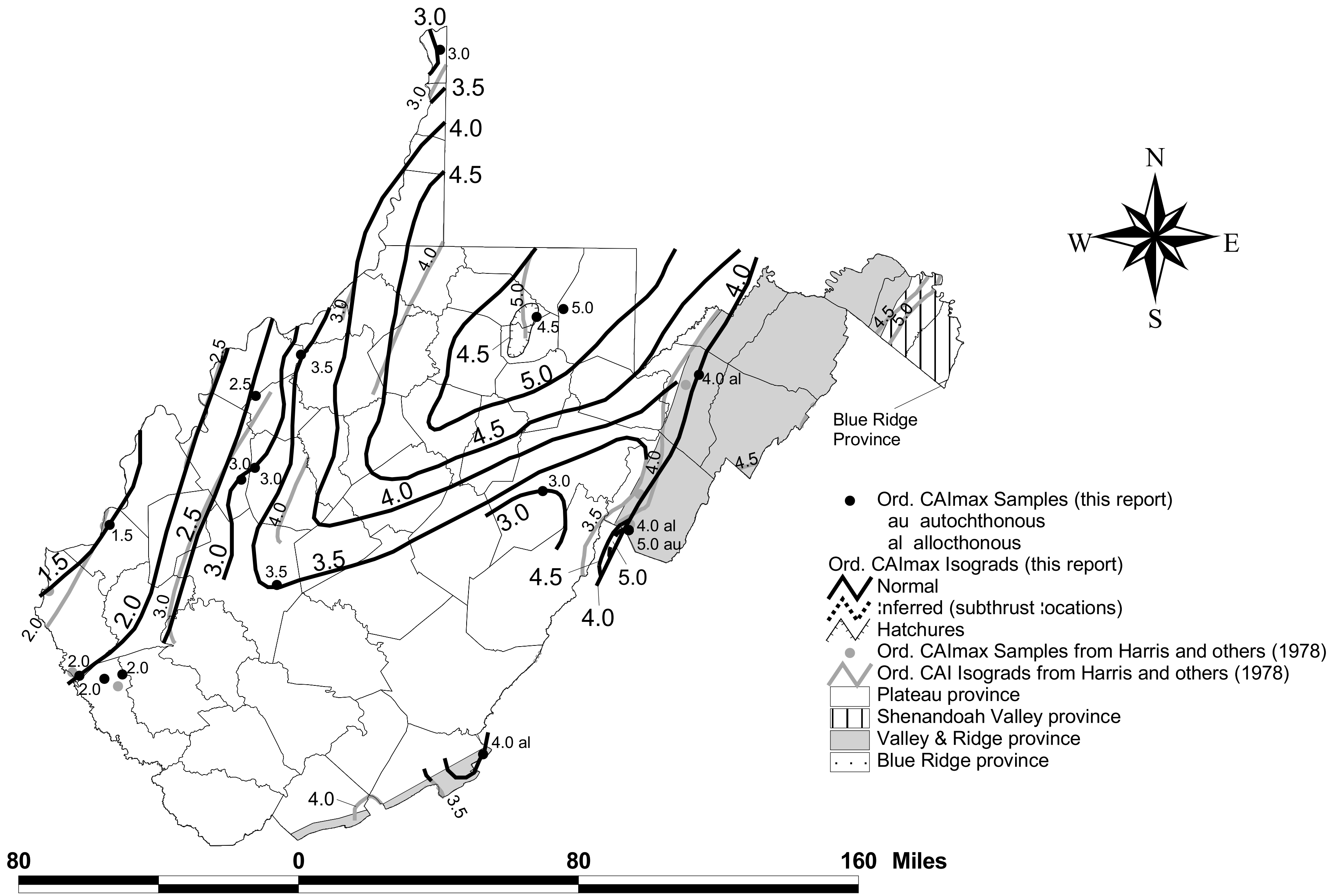

Figure 4. Ordovician conodont alteration index (CAImax) isograds for West Virginia based largely on data collected in this study. Also shown are the structural provinces of West Virginia (Cardwell and others, 1968; Milici, 1980)

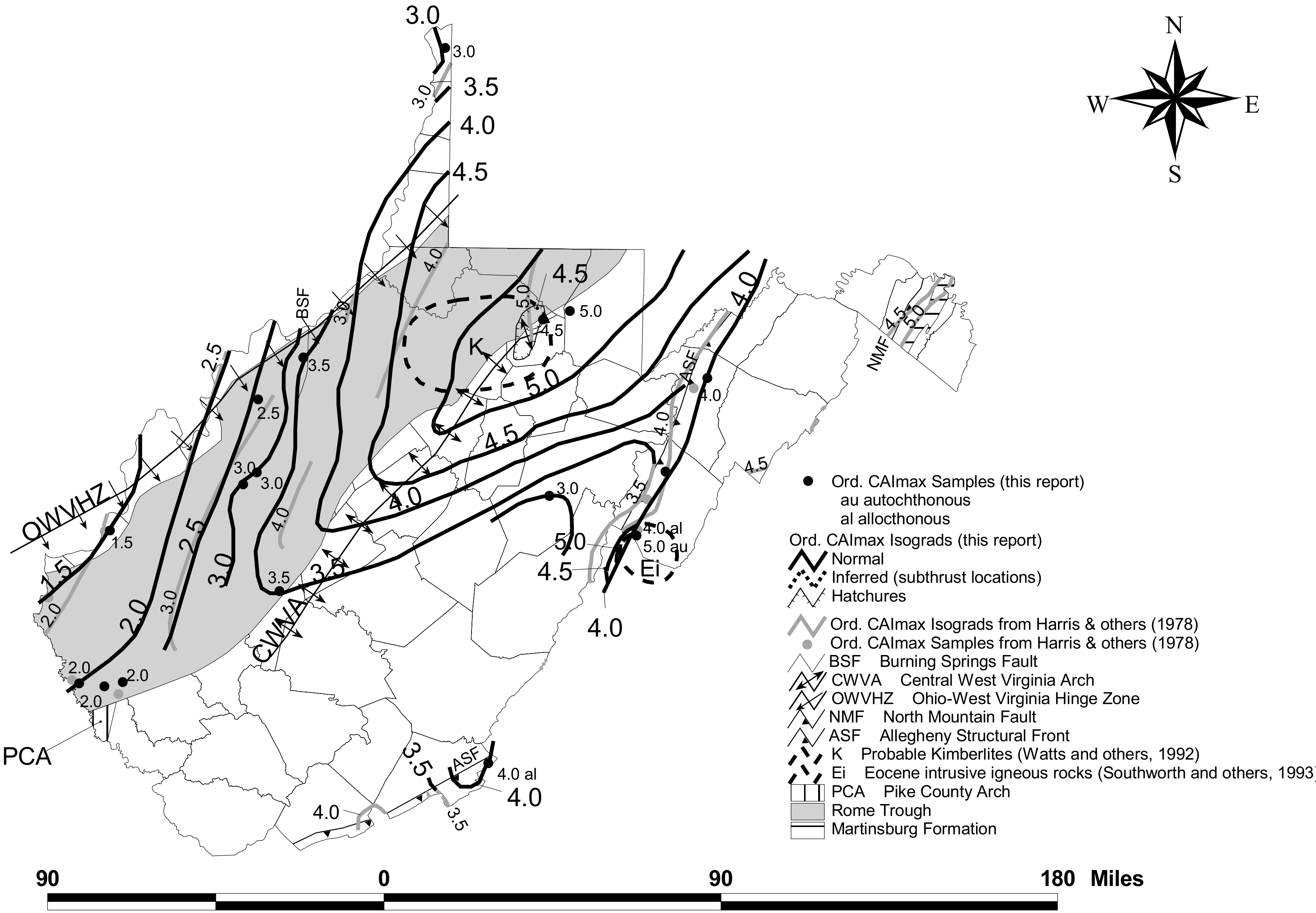

Figure 5. Ordovician conodont alteration index (CAImax) isograds for West Virginia superimposed on selected structural features in West Virginia.

region of highest thermal maturity defined by the CAI 5 through CAI 3.5 isograds coincides with a broad region of extended Proterozoic crust that includes the Rome trough and the adjoining central West Virginia arch (Cardwell, 1977; Kulander and Dean, 1986; Shumaker, 1996; Beardsley and others, 1999) (Fig. 5). Also, CAI 4 - 5 values are recorded along the Allegheny structural front in Pendleton and Monroe Counties (Fig. 5). The CAI 5 isograd extends northeastward along the Rome trough trend an additional 175 mi into southwestern and central Pennsylvania before achieving closure (Repetski and others, 2002).

The configuration of the CAI 2 to 3 isograds in the plateau province of southern West Virginia is largely unknown because Ordovician rocks have not been drilled in this region. However, judging from the CAI 3 value in autochthonous Middle Ordovician rocks in a central Randolph County well [see Gwinn (1964) for structural interpretation] a narrow reentrant of lower maturity rocks (CAI 2.5-3.5) may exist between the east side of the Rome trough and the Allegheny structural front (Fig. 5; Table 3). The Pendleton County well, drilled several miles east of the Allegheny structural front [see Perry (1964) and Shumaker (1985) for structural interpretation], shows that autochthonous Middle Ordovician rocks with CAI 4.5-5 values are overlain by allochthonous Middle Ordovician rocks with CAI 4 values (Figs. 4, 5; Table 3). The CAI 4 values recorded in the Pendleton County well are comparable to values in other subsurface Middle Ordovician rocks in the western part of the Valley and Ridge province as shown in Monroe and Grant Counties (Figs. 4, 5) and in central Pennsylvania (Harris and others, 1978; Repetski and others, 2002). Moreover, these allochthonous rocks commonly have thermal maturity values that are lower than autochthonous rocks of similar age in the adjoining Plateau province as shown in the Pendleton county well (Figs. 4, 5). As yet, CAI control points are insufficient to determine whether Ordovician isograds are discontinuous across the Allegheny structural front, having been offset by Alleghenian-age thrust faults, or whether they are continuous as a result of post-thrusting Alleghenian burial.

Our Ordovician CAI isograd trends, were compared with those from Harris and others (1978) on Figures 4 and 5. Ordovician CAI isograds defined here are consistent with those of Harris and others (1978) who based their isograd map on 6 subsurface and 1 outcrop collections from West Virginia and on numerous outcrop collections from the adjoining states of Maryland, Pennsylvania, and Virginia. Although Harris and others (1978) recognized the strong influence of the Rome trough on regional thermal maturity patterns in West Virginia their map differs slightly from ours. First, the map of Harris and others (1978) shows the Ordovician CAI 3, 4, and 5 isograds to be offset by basement faults in the Rome trough whereas the map in this report shows these isograds to be continuous across the Rome trough (Figs. 4 and 5). Thus, our interpretation suggests that major extensional faulting had largely ceased before the deposition of the Middle Ordovician carbonates. Secondly, the CAI isograds along the western flank of the Rome trough as shown by Harris and others (1978) are about a 0.5 CAI value higher than those shown in this report. The CAI 3.5 value in west-central Pendleton County by Harris and others (1978) is consistent with the reentrant of lower maturity rocks between the Rome trough and the Valley and Ridge province described in the previous paragraph. The CAI 4.5 and 5 isograds interpreted by Harris and others (1978) in the vicinity of the North Mountain fault and in southern Hardy County are consistent with the expected eastward-increasing thermal maturity of Valley and Ridge province rocks and, thus, are adopted in this report (Figs. 4 and 5).

Isograd trends shown in Figures 4 and 5 broadly match the isopach trends in overlying Silurian strata (de Witt and others, 1975) and Devonian through Permian strata (Harris and others, 1978). Silurian isopach patterns shown by de Witt and others (1975) compare most closely with the Ordovician isograds presented here.

Location of Cambrian, Ordovician, and Silurian Oil and Gas Fields with respect to Isograds: In southern Jackson County, a major gas show was reported from the Upper and Middle Cambrian Conasauga Group at a depth of about 14,350 ft (Harris and Baranoski, 1996). Very likely this gas was derived from nearby black shale in the Conasauga Group, whose CAI values are in the 4 to 5 range (%R_o= 3.5 to 4.5) (Ryder and others, 2003). The high methane content of this gas (Harris and Baranoski, 1996) is compatible with these suggested high thermal maturity values.

Recently discovered gas in fractured Middle Ordovician Black River and Trenton carbonate reservoirs (Avary, 2001) is located in Roane County between the CAI 3.5 to 4 isograds and in Putnam/Lincoln Counties between the CAI 2 to 2.5 isograds (Fig. 6). The thermal maturity of each of these Black River-Trenton gas fields is consistent with the produced hydrocarbon phases: 1) the Roane County field produces nonassociated dry gas and 2) the Putnam/Lincoln County field produces dry gas and local condensate. The close proximity of the Ordovician black shale to the Black River-Trenton reservoirs suggest that it is the most likely source of the gas.

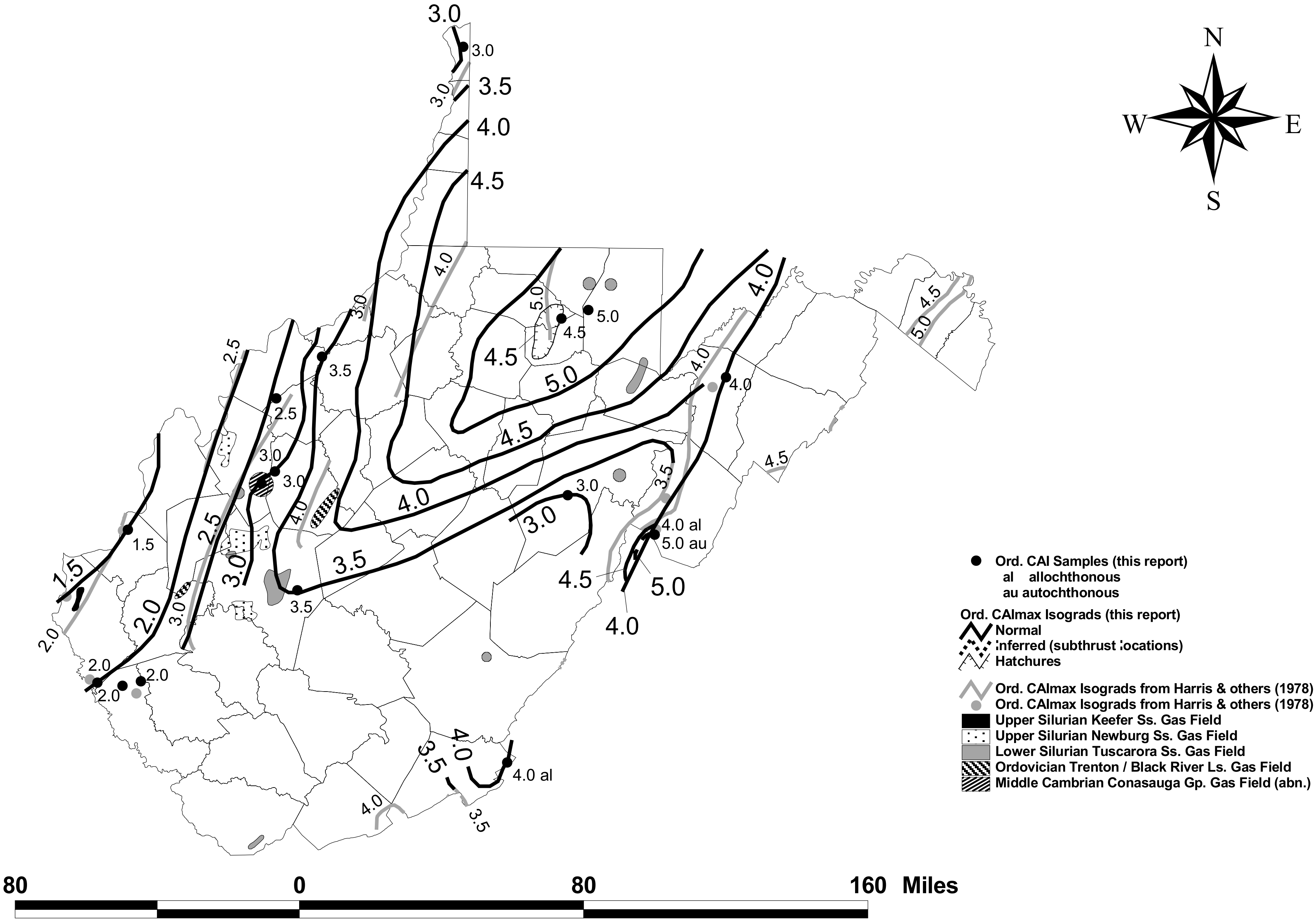

Figure 6. Ordovician conodont alteration index (CAImax) isograds for West Virginia superimposed on Cambrian, Ordovician, and Silurian gas fields (fields from Avary, 2001; Cardwell, 1982; Roen and Walker, 1996)

Central and northern West Virginia gas fields in the Lower Silurian Tuscarora Sandstone (Avary, 1996) are located between the CAI 3 and 5 isograds (%R_o 2 and 4.5) (fig. 6). These high thermal maturity values indicate that the Tuscarora gas is located in the "window" of dry gas generation and preservation. High concentrations of nitrogen and carbon dioxide in the Tuscarora gas (Avary, 1996) are consistent with this high level of thermal maturity. Furthermore, stable isotope distributions reported by Jenden and others (1993) indicate that Tuscarora gas in Kanawha and Raleigh Counties was derived from a source rock having a %R_o= 2 to 2.5. The similarity in thermal maturity of the gas and underlying Ordovician strata is compatible with local derivation of Tuscarora gas from Ordovician black shale (Ryder and others, 1998; Ryder and Zagorski, 2003).

Upper Silurian Newburg sandstone gas fields (Patchen, 1996) in west-central West Virginia, with condensate and local associated oil, are located between the CAI 2 and 3 isograds (fig. 6). These CAI values and their corresponding %R_o values of 1 to 2 (Fig. 7) represent thermal maturity values that are indicative of the "window" of wet gas, late oil, and early dry gas generation and preservation (Dow, 1977; Harris and others, 1978; Tissot and Welte, 1984; Hunt, 1996). Thus, the CAI isograds are consistent with the nonassociated gas produced in the Newburg fields. Small Lower Silurian Keefer Sandstone gas fields (Patchen, 1968) in western West Virginia are located near the CAI 1.5 isograd (%R_o values of <1) (Fig. 6). These thermal maturity values are indicative of the oil and wet gas "window" and thus appear to be inconsistent with the nonassociated and local high nitrogen character (Moore, 1982) of the Keefer gas. Of the three possible

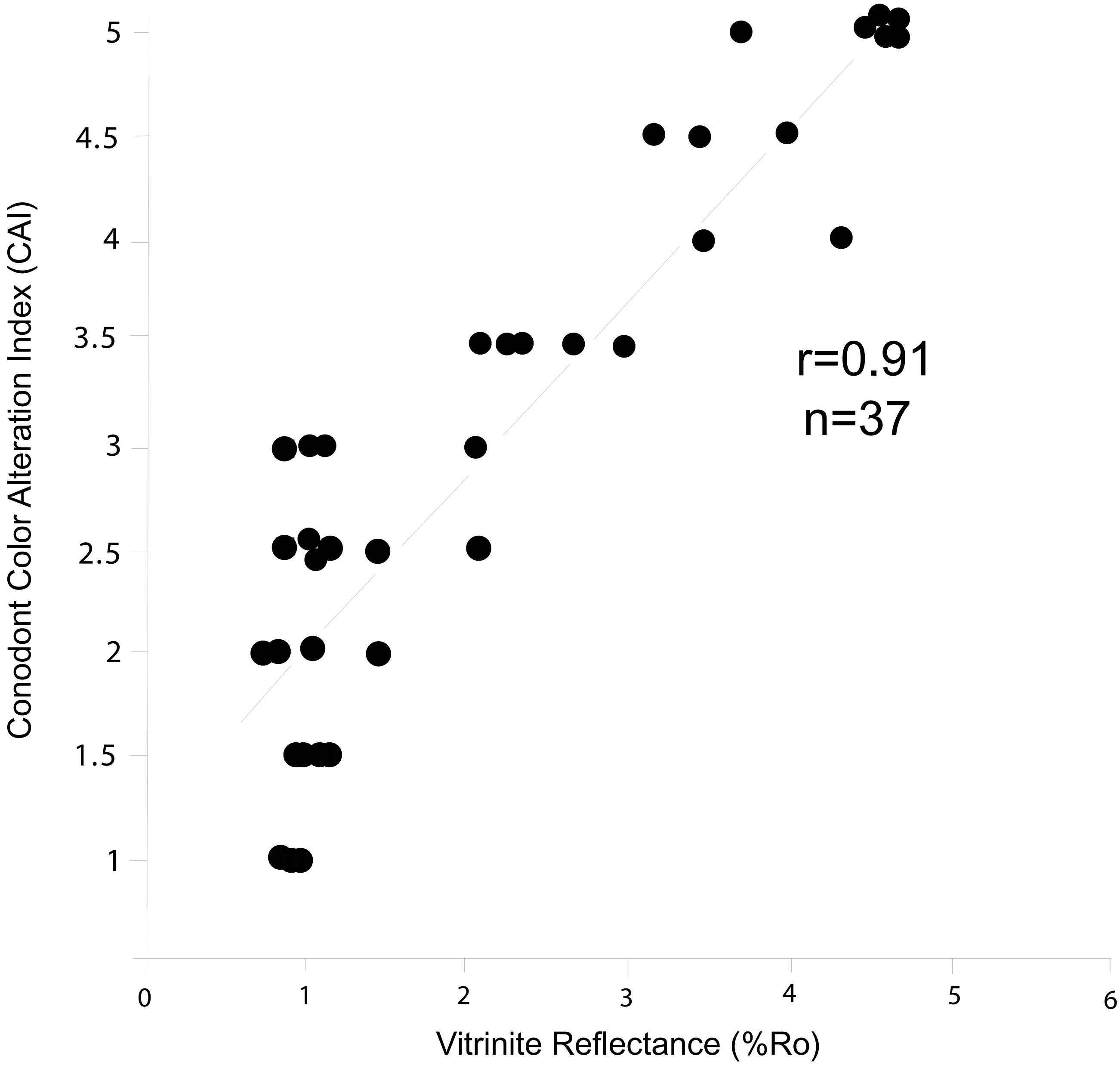

Figure 7. Correlation of vitrinite reflectance and CAI values (after Nöth, 1991)

sources suggested by Ryder (1995) for the Newburg and Keefer gas, an Ordovician black shale source is most consistent with the nonassociated character of the gas.

Thermal Maturity of Devonian Strata

Distribution of Isograds: The Devonian CAI data for the new subsurface samples and for several unpublished subsurface and outcrop samples reported by A. G. Harris (Tables 2 and 3) are plotted in Figures 8 and 9 and contoured as isograds. All Devonian isograds are based on maximum CAI values for a given control point. The majority of the samples with recoverable conodont elements are located in the Plateau province (54 of 58) with 4 samples located in the Valley and Ridge province (Fig. 8). CAI_{max} values in our collection range between 1.0 and 4.0. In northern West Virginia the CAI 4 isograd defines a small irregular-shaped region of high thermal maturity centered in Taylor County whereas in southern West Virginia it defines a northwestward-protruding salient of higher thermal maturity that crosses southern Raleigh County and northern Summers County (Figs. 8 and 9). CAI 2.5 to 3.5 isograds closely conform with the CAI 4 isograd to produce two large, westward-protruding salients of higher thermal maturity (Figs. 8 and 9). The northern salient coincides with the Rome trough and the adjoining central West Virginia arch (Fig. 9). Farther eastward, a narrow reentrant of northeast-trending lower maturity rocks (CAI 2.5 to 3.5) separates the northern high maturity salient from the Valley and Ridge province (Fig. 8). Between the Allegheny structural front and the North Mountain fault, isograds in the Valley and Ridge province increase gradually eastward from CAI 3.5 to 4, with a small isolated region of CAI 3 in Grant and Hardy

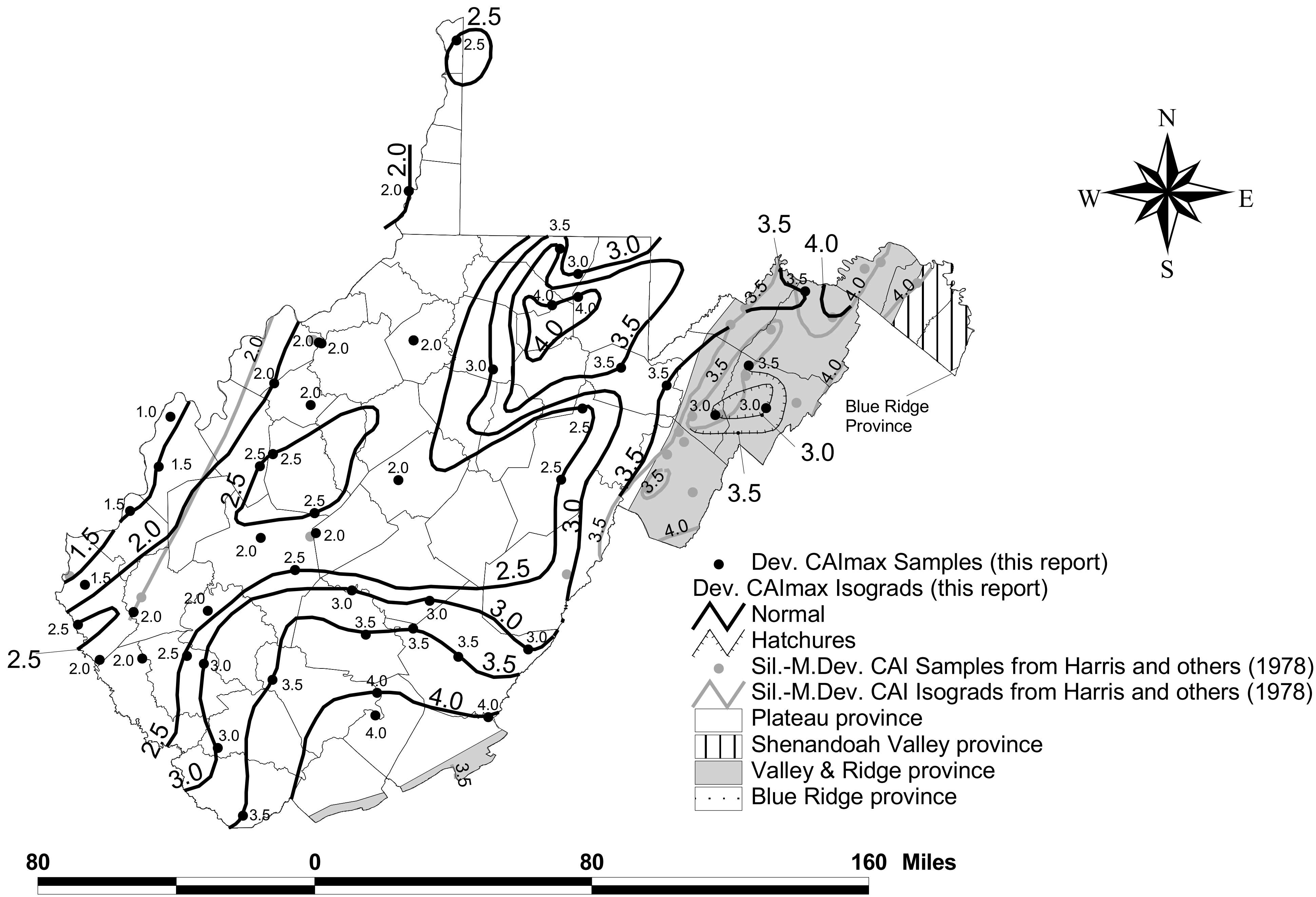

Figure 8. Devonian conodont alteration index (CAImax) isograds for West Virginia based largely on data collected in this study. Also shown are the structural provinces of West Virginia (Cardwell and others, 1968; Milici, 1980)

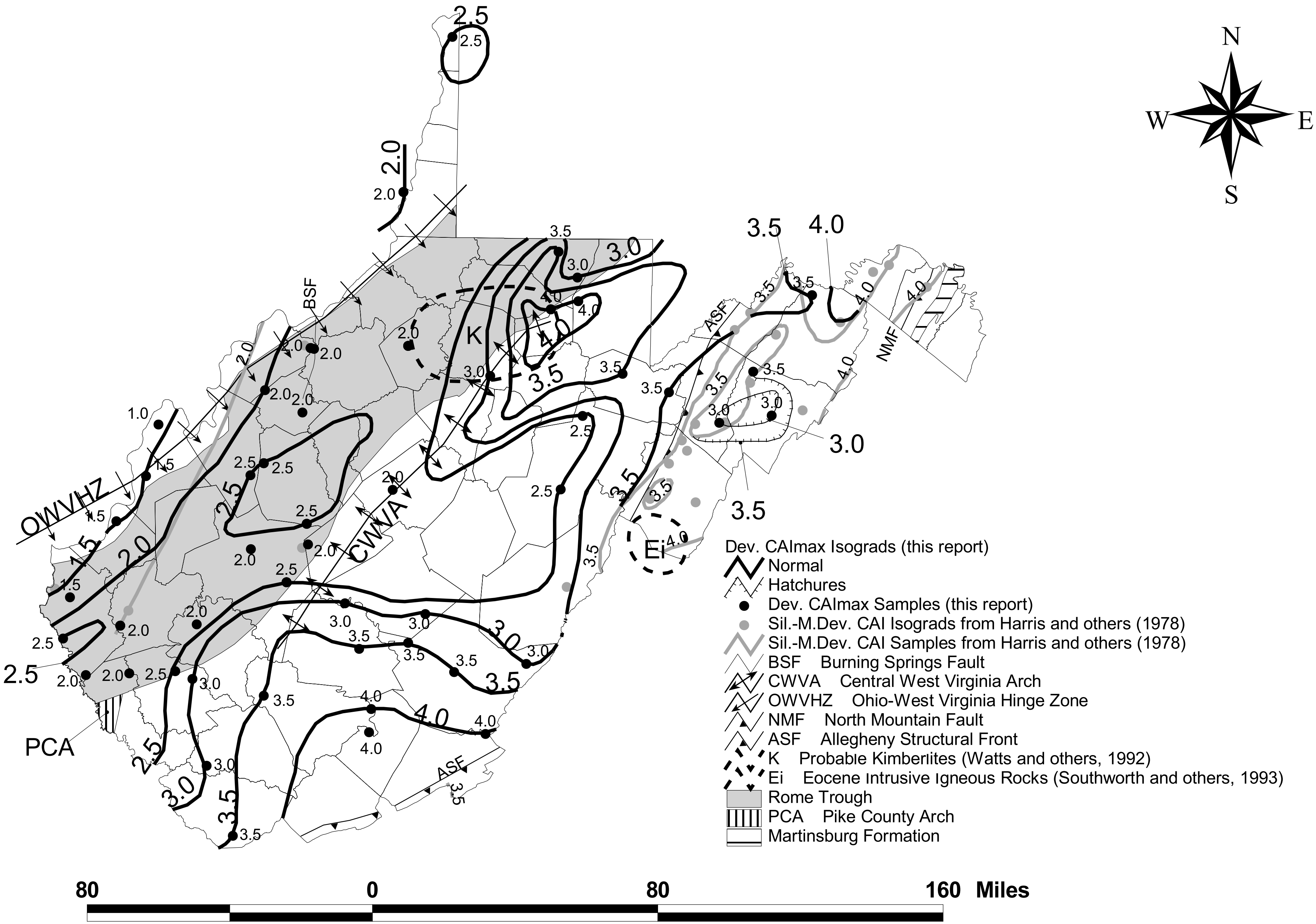

Figure 9. Devonian conodont alteration index (CAImax) isograds for West Virginia superimposed on selected structural features in West Virginia.

Counties (Figs. 8, 9). These CAI 3.5 to 4 values recorded in the Valley and Ridge province of West Virginia are comparable to values in other Lower and Middle Devonian rocks in the Valley and Ridge province of south-central and central Pennsylvania (Harris and others, 1978; Repetski and others, 2002). The Devonian CAI isograds appear to continue across the Allegheny structural front without apparent offset due to Alleghanian deformation (Fig. 9).

CAI 2.5 isograds reappear west of the high thermal maturity salients where they define a 50-mi-long, northeast-trending oval-shaped area of closure centered on Roane County and a smaller unclosed area located in Wayne County (Figs. 8, 9). Both of these areas coincide with the center of the Rome trough (Fig. 9). CAI 1.5 to 2 isograds in western West Virginia show the same dominant northeast trend as the CAI 2.5 isograds (Figs. 8, 9) and they generally coincide with the northwest flank of the Rome trough and the adjoining Ohio-West Virginia hinge zone (Ryder and others, 1996).

Our Devonian CAI isograd trends were compared with the Silurian through Middle Devonian CAI isograd trends from Harris and others (1978) on Figures 8 and 9. The Silurian through Middle Devonian isograd map of Harris and others (1978) was used for a comparison, rather than their Upper Devonian through Mississippian map, because it most closely represents the Devonian intervals that we sampled. Harris and others (1978) based their Silurian through Middle Devonian isograd map on 5 subsurface and 13 outcrop collections from West Virginia (Fig. 8) and on numerous outcrop collections from the adjoining states of Maryland, Pennsylvania, and Virginia; however, they were unable to interpret CAI isograds for the majority of the state because of the absence of subsurface data points. Along the western and eastern margins of West Virginia, where

Devonian conodont assemblages were reported both in this study and in Harris and others (1978), the isograds are compatible.

Although isograd trends shown in Figures 8 and 9 broadly match the isopach trends in the Devonian through Permian overburden (Harris and others, 1978) they correlate best with system-specific isopach maps (Heck, 1943; de Witt, 1975; de Witt and others, 1975). For example, the isotherms that define the southern thermal maturity salient coincide with the 3,000-5,000 ft Mississippian isopachs (de Witt, 1975) and the 2,200 ft Pennsylvanian Pottsville Group isopach (Heck, 1943). A stratigraphic section through the New River Gorge area (Fayette, Raleigh, and Summers Counties, West Virginia)(Englund and others, 1977) further documents thick Mississippian and Pennsylvanian (inferred) strata associated with the southern thermal maturity salient. Moreover, the isograds that define the westward-protruding shape of the northern high thermal maturity salient closely resemble the shape of the Devonian isopachs (de Witt and others, 1975) except that the CAI 4 isograd in the salient is located 50 mi or more west of the maximum (10,000 ft) isopachs. The distribution of Devonian isograd patterns in the Valley and Ridge province (Harris and others, 1978) are generally consistent with eastward thickening Devonian overburden (de Witt and others, 1975).

<u>Distribution of Isoreflectance Lines:</u> Mean vitrinite reflectance values of Devonian black shale samples are listed in Table 3 and plotted in Figure 10. The black shale samples are about evenly divided between the Marcellus Shale and the Rhinestreet and Huron Shales. All 40 Devonian shale samples contained sufficient dispersed organic matter for analysis and 39 of them were suitable for identifying regionally consistent isoreflectance lines

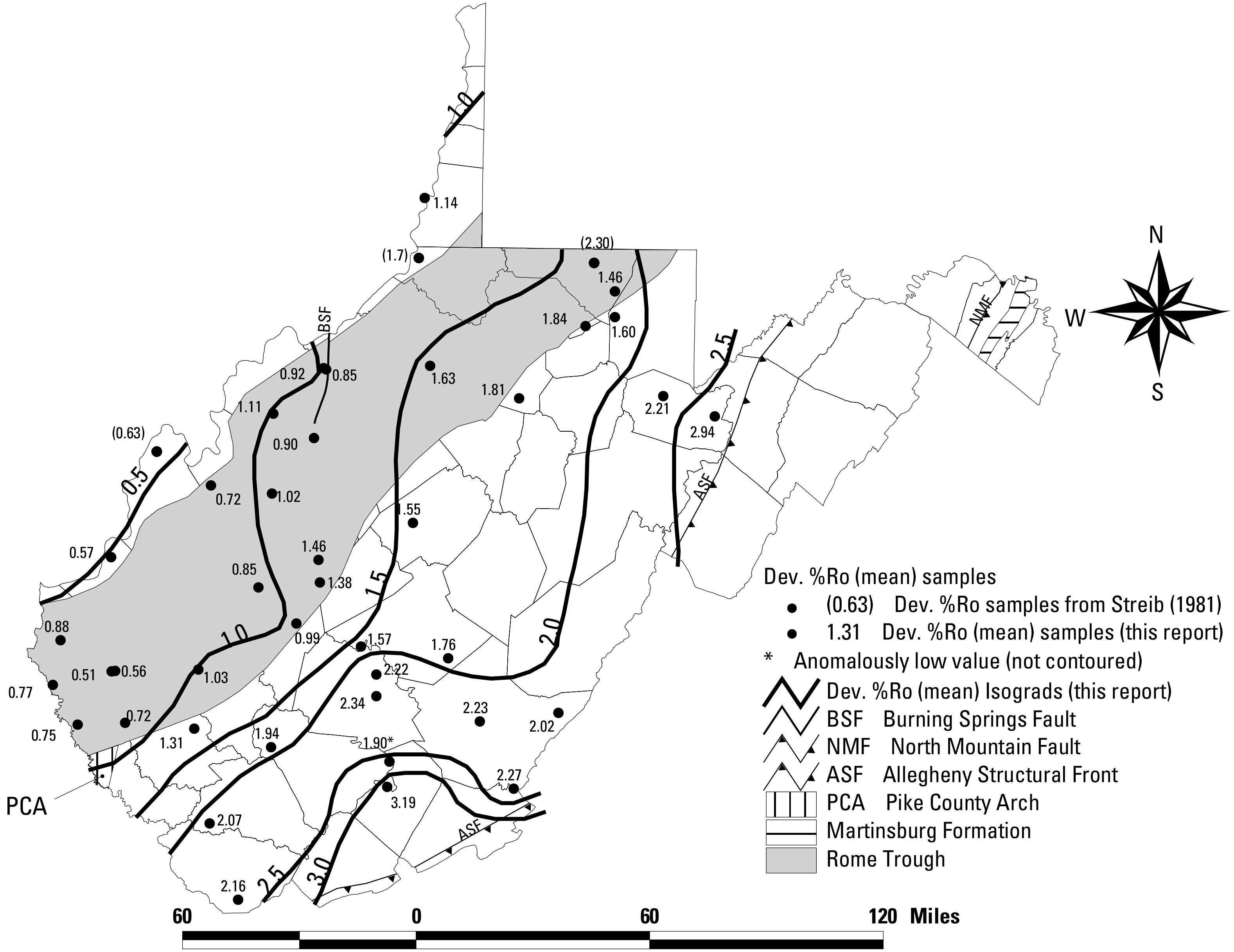

Figure 10. Devonian vitrinite reflectance values (%Ro mean) based on data collected in this study.

(Fig. 10). One vitrinite reflectance value (1.90) from the Rhinestreet Shale in Raleigh County was not contoured because it was considered anomalously low when compared to the regional pattern. The effects of vitrinite suppression in rocks with abnormally high total organic carbon (TOC>5) were not evaluated.

The trends of the isoreflectance lines are compatible with the eastward increasing Devonian CAI isograds including the westward-bulging salient of higher thermal maturity in southern West Virginia (Figs. 9 and 10). Also, for a given area, the $\%R_o$ values indicate approximately the same level of thermal maturity as the CAI values. An obvious discrepancy between the Devonian CAI and $\%R_o$ maps is the absence of the northern high thermal maturity salient on the $\%R_o$ map (Fig. 10). For reasons unknown, mean vitrinite values in 4 localities in northern West Virginia ($\%R_o$ = 1.60 to 1.84) are much lower than the expected ($\%R_o$ 2.5 to 3.5) based on the accompanying CAI 3 to 4 isograds that define the northern salient (Fig. 9). The $\%R_o$ = 2.30 value reported by Streib (1981) for Marcellus Shale samples in northern Monongalia County, however, does corroborate the high CAI isograds shown in northern West Virginia (Fig. 10). Also, two additional $\%R_o$ values reported by Streib (1981) in West Virginia, the $\%R_o$ =1.7 in western Wetzel County and the $\%R_o$ = 0.63 in northern Mason County are consistent with their respective adjoining CAI isograds (Figs. 9 and 10). These consistently higher %Ro values reported by Streib (1981) have resulted in isoreflectance lines on his vitrinite map that are higher for a given area than lines on our map (Fig. 10). At this time, our only explanation for these differences in $\%R_o$ values is variability in laboratory and (or) operator procedures. Our map is broadly similar to the vitrinite reflectance maps by Hamilton-Smith (1996) and Curtis and Faure (1997), when comparing the 0.5 to 1 reflectance lines, but the maps differ markedly when comparing the 1.5 to 2 isoreflectance lines.

Location of Devonian Oil and Gas Fields with respect to Isograds: Natural gas fields in the Lower Devonian Oriskany Sandstone of West Virginia occupy two regions: 1) a large region in northeastern West Virginia that coincides with the northern part of the Plateau province and the adjoining Valley and Ridge province (Flaherty, 1996; Harper and Patchen, 1996) and 2) a smaller region in north-central West Virginia that coincides with the west-central part of the Plateau province (Patchen and Harper, 1996) (Fig. 11). CAI values in the northeastern region range from 2.5 to 4 (%R_o 1.5 to 3.5) (Fig. 11) and are compatible with the high methane content of the Oriskany gas produced here (Claypool and others, 1978; Moore, 1982). In contrast, CAI values in the smaller north-central region range from 2 to 2.5 (%R_o 1 to 1.5) (Fig. 11) and are compatible with the wet gas, condensate, and local oil produced from the Oriskany Sandstone in this region (Patchen and others, 1992; Patchen and Harper, 1996). Probably minimal migration was required for the Oriskany gas before entrapment because of its close proximity to overlying Middle Devonian Marcellus Shale and Rhinestreet and lower Huron Shale source rocks (Patchen and others, 1992; Harper and Patchen, 1996).

Oil and gas fields in Upper Devonian sandstones and associated CAI isograds in northern West Virginia are plotted in Figure 12. The oil fields are largely confined to a region marked by CAI 2 to 2.5 isograds whereas the gas fields, generally located farther eastward, are largely confined to a region marked by CAI 2.5 to 4 isograds. A 30- to 40-mi-wide zone of overlap occurs between the dominant regions of oil and gas (Fig. 12).

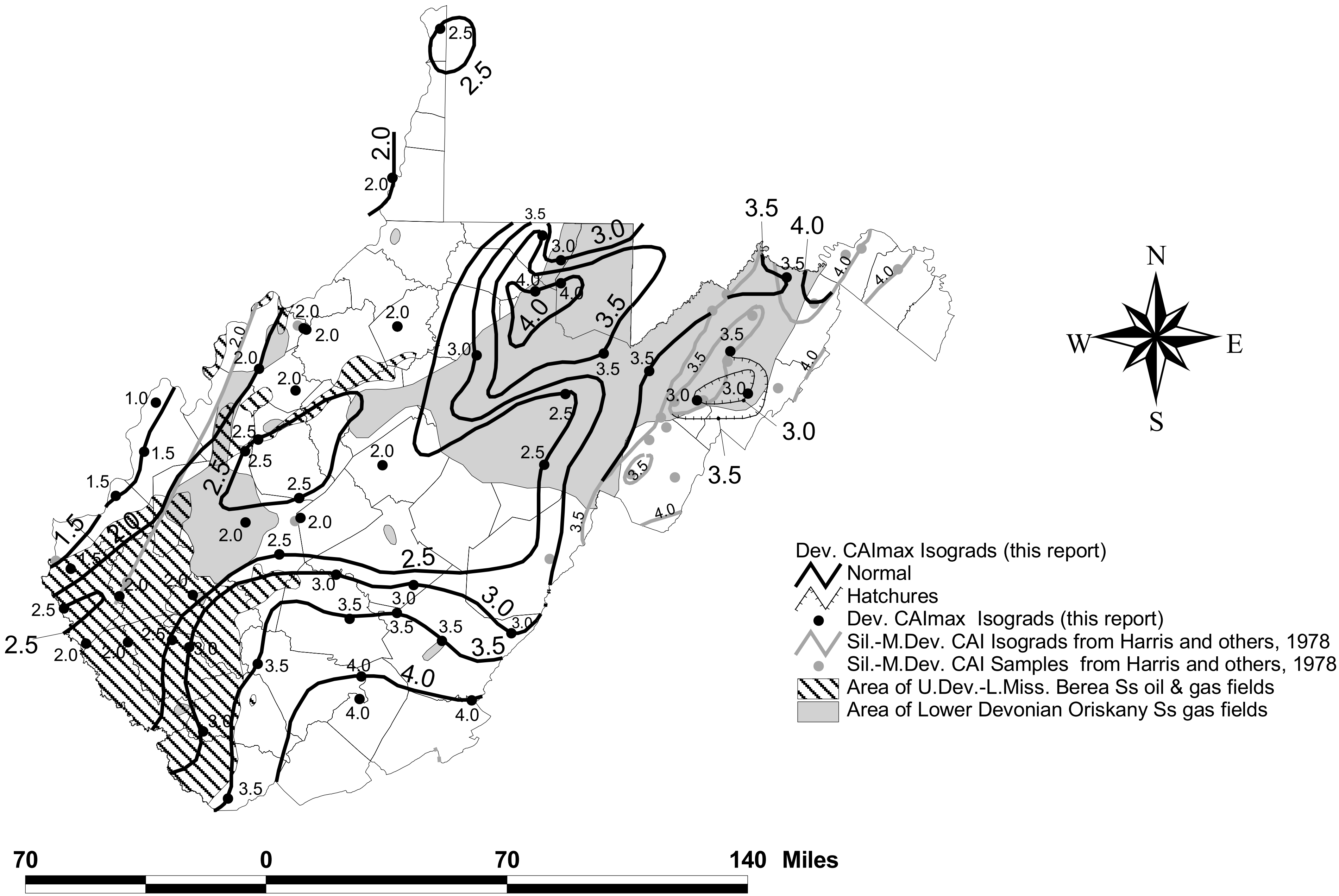

Figure 11. Devonian conodont alteration index (CAImax) isograds for West Virginia superimposed on Lower Devonian gas fields and Upper Devonian-Lower Mississippian oil and gas fields (fields from Cardwell, 1982; Cardwell and Avary, 1982; Roen and Walker, 1996)

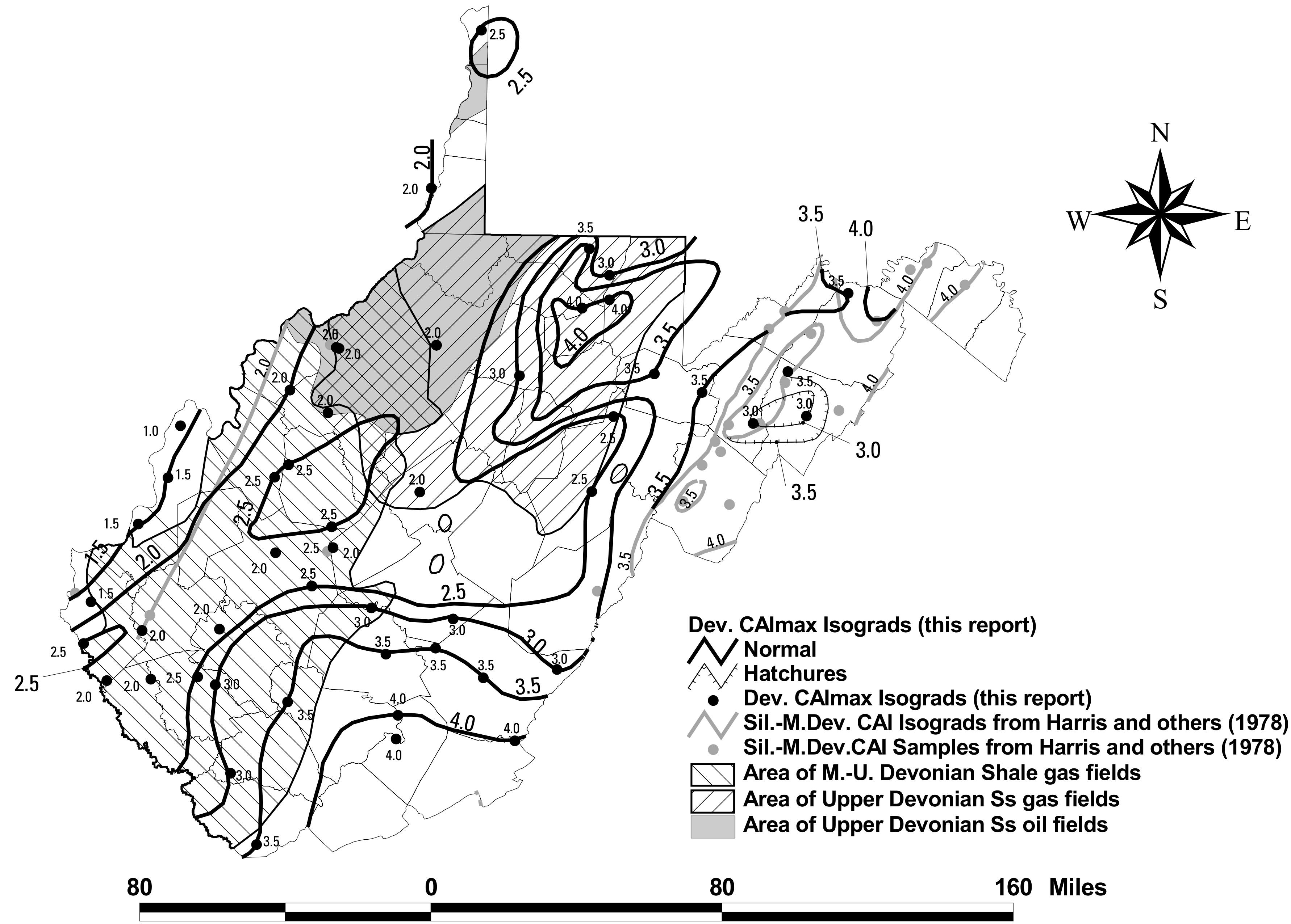

Figure 12. Devonian conodont alteration index (CAImax) isograds for West Virginia superimposed on Upper Devonian oil and gas fields and Upper/Middle Devonian gas fields (fields from Cardwell, 1982; Cardwell and Avary, 1982; Roen and Walker, 1996)

The CAI 2 to 2.5 values and their respective $\%R_o$ 1 to 1.5 values (Fig. 7) for the oil fields represent thermal maturity indices that are indicative of the "window" of oil and wet gas preservation (Dow, 1977; Harris and others, 1978; Tissot and Welte, 1984; Hunt, 1996). In comparison, the CAI 2.5 to 4 values and their equivalent $\%R_o$1.5 to 3.5 for gas fields represent thermal maturity values in the "window" of wet and dry gas generation and preservation. Middle and Upper Devonian black shales are the source rocks for the oil and gas described in these fields (Boswell, 1996; Donaldson and others, 1996; Milici, 1996) and their level of thermal maturity is characterized by the CAI and $\%R_o$ values measured in Devonian limestone and shale for this study. The compatibility between the CAI isograds shown on Figure 12 and the produced petroleum phases in the Upper Devonian sandstone reservoirs imply that the oil and gas was generated near their respective regions of entrapment.

Natural gas accumulation in self-sourced Middle and Upper Devonian black shale in western West Virginia is associated with CAI 1.5 to 3.5 isograds (Fig. 12). These CAI values are equivalent to $\%R_o$ <1 to 3 values (Fig. 7) which, in turn, indicate the "window" of oil/wet gas through dry gas generation and preservation. The presence of oil in the shale gas in Pleasants and Ritchie Counties (Patchen and Hohn, 1993) and the general southward increase in the methane composition (dryness) of the shale gas (Claypool and others, 1978; Moore, 1982) are consistent with the isograd patterns shown on Figure 12. The stable isotope compositions of Devonian/Mississippian (?) shale gas in Lincoln, Mason and Upshur Counties (Claypool and others, 1978) support a thermogenic origin of the shale gas.

Oil and gas fields of the Upper Devonian-Lower Mississippian Berea Sandstone are distributed across western and northwestern West Virginia (Pepper and others, 1954; Tomastik, 1996) where Lower and Middle Devonian CAI values range from 1.5 to 3.5 (%R_o <1 to 3) (Fig. 11). These thermal maturity values are generally consistent with the range of petroleum phases that are produced from the Berea Sandstone, however, the widespread occurrence of oil in the Berea is inconsistent with the CAI 2.5 to 3.5 values (%R_o 1.7 to 3) (Fig. 11). This minor discrepancy suggests that the thermal maturity of the source rocks for the Berea petroleum is overestimated by Lower and Middle Devonian CAI isograds on Figure 11. That is, had the CAI values been measured from beds that were stratigraphically closer to the Upper Devonian (Ohio Shale on Fig. 3) and Lower Mississippian (Sunbury Shale not shown on Fig. 3) black shale source rocks (Tomastik, 1996) — which are located 1,000 to 1,500 ft above the Lower and Middle Devonian carbonates used in this study — they should be more compatible with the common occurrence of oil in the Berea Sandstone.

Discussion

Harris and others (1978) concluded that the CAI isograd patterns in the Appalachians reflect regional structural trends and accompanying overburden thicknesses. Moreover, they recognized that many of the isograds, particularly near the outcrop edges of the basin, suggest that paleotemperatures are too high to have been produced by the present-day thickness of overburden. Harris and others (1978) further suggested that by assuming a representative geothermal gradient, the overburden thicknesses of the basin can be restored from the isograd values.

Likewise, Ordovician CAI isograds and Devonian CAI isograds/%R_o isoreflectance lines identified in this investigation indicate much greater paleotemperatures than can be explained by the existing overburden. Other thermal maturity investigations in West Virginia have led to similar conclusions, such as those based on burial history curves (Evans, 1995; Nuccio and others, 1997), fluid inclusions (Evans, 1995), %R_o/coal rank (Trinkle and others, 1978; Evans, 1995; Curtis and Faure, 1997; Hulver, 1997), and apatite fission tracks (Roden, 1991; Hulver, 1997).

Most Appalachian investigators have accounted for the mismatch between thermal maturity indices values and accompanying present-day overburden by post-orogenic uplift and erosion of Late Carboniferous, Permian, and early Mesozoic overburden. For example, based on CAI and coal rank data and a typical foreland basin geothermal gradient of 25˚C/km, Hulver (1995; 1997) estimated that post-Alleghanian denudation of the Appalachian area, including the West Virginia part, ranged from 2 to 6 km with increasing amounts of erosion from west to east. In comparison, Beaumont and others (1987), using coal moisture data, predicted that 2.5 to 4.5 km of post-Alleghanian erosion occurred in West Virginia. Moreover, burial history curves generated by Evans (1995) for several wells in northern West Virginia, constrained by fluid inclusion data and a geothermal gradient of 28˚C/km, predict the removal of 2 to 3 km of Late Pennsylvanian to Permian overburden. Based on a 2-D burial/thermal history model, Rowan and others (2004) concluded that Ordovician and Devonian CAI isograds in this report and Pennsylvanian vitrinite reflection values (L.F. Ruppert, USGS, unpubl data) are best explained by an eastward-thickening wedge of Pennsylvanian/Permian/Triassic overburden rocks up to 7,200 ft (2.2 km) thick. These estimates of post-Alleghanian erosion by Evans (1995), Hulver (1995, 1997), Beaumont and others (1987), and Rowan and others (2004) are consistent with an overburden of at least 3.4 km calculated by Roden (1991) from an apatite closing temperature of 100˚C ± 20˚C and a geothermal gradient of 25˚C/km.

Apatite fission-track ages of Middle Devonian to Carboniferous rocks in West Virginia are younger than the depositional age of the rocks and vary between ~240 Ma and ~33 Ma (Roden, 1991; Hulver, 1997). The older of these dates are concentrated in northern West Virginia suggesting that erosion was initiated there in Triassic to Early Jurassic time and corresponds broadly with the age of rifting along the Atlantic continental margin. The younger fission-track ages that are reported in south-central West Virginia by Hulver (1997) (~90-100 Ma) and Roden (1991) (~33-48 Ma) suggest that this area cooled more recently than north-central and eastern West Virginia.

Although overburden thickness is a very important control on the distribution of thermal maturity values identified in this study there are several parts of West Virginia where the CAI isograds appear to be too high to be explained by overburden thickness alone. For example, the Ordovician CAI 4.5 to 5 isograds (Fig. 5) and the Devonian CAI 3.5 to 4 isograds in northern West Virginia (Fig. 9) may in part have resulted from an elevated geothermal flux caused by crustal thinning and the emplacement of mantle-derived rocks in the Rome trough and adjoining central West Virginia arch. Heat flow probably was greatest during the initial phases of rifting in the Middle Cambrian and tapered off gradually into the Late Ordovician. Early Mesozoic reactivation of the Rome trough and central West Virginia arch may have introduced a second phase of high heat flow caused by the intrusion of Mesozoic kimberlite igneous bodies whose presence is suggested in Harrison, Doddridge, and Taylor Counties by stream sediment samples (Watts and others, 1992) and by high-intensity aeromagnetic anomalies (Zeitz and others, 1980). These probable kimberlite bodies are on trend with known Mesozoic kimberlite intrusions exposed above the Rome trough in southwestern Pennsylvania (Parrish and Lavin, 1982; Phipps, 1988; Shultz, 1999). In outcrop, the kimberlites are small and have a minor alteration halo but at depth they may merge with larger igneous bodies that had greater thermal influence on the overlying sedimentary rocks of the basin. The impact of Eocene magmatic intrusions in Pendleton County, West Virginia and adjoining Virginia (Southworth and others, 1993)(Figs. 5, 9) on the thermal maturity of Ordovician and Devonian strata cannot be evaluated with the available data.

Westward-bulging salients in the Devonian CAI 2.5 to 4 isograds (Fig. 9) may represent migration routes of hot, basin-derived fluids. The northern salient is particularly convincing because it is not associated with an obvious overlying depocenter. Moreover, had burial been the chief cause of the salient, it should have left a similar imprint on Ordovician isograds (Fig. 5). Dorobek (1989) suggested that hot, basin-derived fluids left a fluid-inclusion imprint on Devonian rocks in the Valley and Ridge province of northern West Virginia, about 120 km (75 mi.) east of the northern salient. However, he considered the flow rate of the migrating fluids to be too high to leave an anomalously high CAI imprint. The northwest-trending Parsons lineament of Wheeler (1980), between Pendleton and Taylor counties, may have partly influenced the westward flow of hot fluids through Devonian strata in northern West Virginia.

The southern salient was primarily caused by burial beneath a thick overburden of Mississippian and Pennsylvanian rocks, as shown by isopach maps (Heck, 1943; de Witt, 1975). Isoreflectance lines (%R_o = 1.4 to 1.8) derived from Pennsylvanian coal beds show a similar northwestward-bulging salient in southern West Virginia that coincides with a region of thick Pottsville Group rocks (Cole and others, 1979). Heck (1943) proposed that the high thermal maturity of the coal beds was caused by deeper burial, whereas Cole and others (1979) proposed that the high maturity was caused by igneous activity along the 38th parallel lineament of Heyl (1972). We favor the explanation by Heck (1943).

Cercone and others (1996) suggested that low conductivity coal- and carbonaceous shale-bearing Carboniferous strata had an important effect on the temperature history of the Appalachian basin by acting as an insulator. Consequently, strata that contain large quantities of organic matter may increase the temperature of underlying rocks to such a degree that it may account for anomalous thermal maturity values in the basin. Also, Devonian black shale beds may contribute significantly as an insulator. Although plausible, the validity of this mechanism must be tested with burial history models.

In several Valley and Ridge province localities, the Ordovician isograds of Harris and others (1978) show that rocks of higher thermal maturity have been thrust over rocks of lower thermal maturity. This structural dislocation of isograds implies that isograd values in the allochtonous rocks do not necessarily charactize those values in underlying autochthonous rocks. In this study, for example, thrust-faulted Ordovician rocks in the No. 1 Sponaugle well contain rocks with CAI 3.5-4 values resting in thrust contact on rocks with CAI 5 values (Figs. 5, 6; Table 3). A similar pattern of lower maturity hanging wall rocks in contact with higher maturity footwall rocks was defined by vitrinite reflectance data in Pennsylvanian rocks of the Pine Mountain thrust fault system of southeastern Kentucky (O'Hara and others, 1990). Both types of the above-described thermal maturity reversals have been measured across repeated sections in the subsurface of the disturbed belt of the southeastern Canadian Cordillera (England and Bustin, 1986). They interpret higher maturity in successively deeper thrust sheets to be the result of postorogenic maturation whereby the temperature of the footwall rocks is increased by heat transfer from "hot" hanging wall rocks (also see Furlong and Edman, 1984). In contrast, a decrease in thermal maturity beneath a thrust sheet led England and Bustin (1986) to suggest that the hanging wall was too thin and (or) cool to overprint the pre-orogenic level of thermal maturity. The same range of conditions described by England and Bustin (1986) probably are applicable to the Appalachian Valley and Ridge thrust faults.

The Valley and Ridge province seemed to be thermally isolated from the adjoining provinces based on its slightly lower CAI values in comparison to CAI values in the adjoining Plateau and Shenandoah Valley provinces (Figs. 4, 8). For example, the Valley and Ridge province is characterized by Devonian CAI 3 – 3.5 values, whereas the adjoining Plateau and Shenandoah Valley provinces are characterized by Devonian CAI 3.5 – 4 values (Fig. 8). In comparison, Ordovician CAI 4 values in the Valley and Ridge province are flanked by Ordovician 4.5 to 5 values in the Plateau and Shenandoah Valley provinces (Fig. 4). Perhaps the central Valley and Ridge province was a more stable tectonic block that escaped crustal extension or magmatic intrusion, or, possibly, the overburden was thinner in this region because it was located east of the basin depocenter.

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TABLE 1. Conodont data from Ordovician samples from the subsurface of West Virginia.

COUNTY API number[1] USGS Collection Number	WELL NAME; FOOTAGE (Latitude North/ Longitude West)	STRATIGRAPHIC UNIT (Based on picks provided by the West Virginia Geological Survey)	CORE? OR CUTTINGS	CONODONT FAUNA	AGE RANGE OF CONODONTS	CAI	REMARKS
Cabell 011-00537 USGS 11938-CO	No. 1 E. Kingrey; 5720-5770 ft 38.523887/ -82.263055	Trenton	Cuttings	*Phragmodus undatus* Branson & Mehl; *Plectodina* cf. *Pl. tenuis* (Branson & Mehl); *Yiaoxianognathus abruptus* (Branson & Mehl)	late Middle or Late Ordovician; *Ph. undatus* to *O. velicuspus* Zone (latest Blackriveran to Maysvillian)	1.5	123.0 g sample processed (71.0 g +20-mesh, and 23.6 g of 20- to 200-mesh insoluble residue remained)
Grant 023-00002 USGS 11939-CO	Greenland Lodge (10768); 5100-5110 ft 39.194721/ -79.14167	Trenton	Cuttings	*Drepanoistodus suberectus* (Branson & Mehl); *Phragmodus inflexus* Stauffer	Middle Ordovician; *C. sweeti* to *Ph. undatus* Zone (mid-Chazyan to Rocklandian)	4	100-200 g sample processed (18.1 g of 20- to 200-mesh insoluble residue remained)
Hancock 029-00080 USGS 11940-CO	S. Minesinger No. 1; 8965-9140 ft 40.539722 -80.556114	Trenton	Cuttings	*Belodina compressa* (Branson & Mehl); *Panderodus gracilis* (Branson & Mehl); *Phragmodus undatus* Branson & Mehl; *Plectodina* sp. or *Aphelognathus* sp.; *Polyplacognathus ramosus* Stauffer	late, but not latest, Middle Ordovician; *Ph. undatus* Zone to lowest *B. confluens* Zone (=latest Blackriveran to middle Shermanian)	3	262.0 g sample processed (131.4 g +20-mesh, and 25.1 g of 20- to 200-mesh insoluble residue remained)
Jackson 035-01366 USGS 11941-CO	L. Stalnaker # 1; 8730-8830 ft 38.729718/ -81.572503	Trenton	Cuttings	*Drepanoistodus suberectus* (Branson & Mehl); *Phragmodus undatus* Branson & Mehl	late Middle or Late Ordovician; *Ph. undatus* Zone to end of Ordovician (latest Blackriveran to latest Gamachian)	2.5 to 3	172.7 g sample processed (19.2 g +20-mesh, and 75.2 g of 20- to 200-mesh insoluble residue remained)
Kanawha 039-03462 USGS 11942-CO	Sally D. Todd (20659-T); 8780-8890 ft 38.296669/ -81.370835	Trenton	Cuttings	*Drepanoistodus suberectus* (Branson & Mehl); *Phragmodus undatus* Branson & Mehl; *Plectodina* sp. or *Aphelognathus* sp.; ?*Rhodesognathus elegans* (Rhodes); 1 P element fragment; *Scyphiodus* cf. *S. primus* Stauffer	late Middle Ordovician; *Ph. undatus* Zone to *Pl tenuis* Zone (Rocklandian to Shermanian)	3.5	208.1 g sample processed (64.3 g +20-mesh, and 35.2 g of 20- to 200-mesh insoluble residue remained)
Marion 049-00244 USGS 11943-CO	No. A-1 Finch; 13110-13270 ft 39.431946/ -80.012223	Trenton	Cuttings	*Phragmodus undatus* Branson & Mehl	late Middle or Late Ordovician; *Ph. undatus* Zone to end of Ordovician (latest Blackriveran to latest Gamachian)	4 to 4.5	121.9 g sample processed (17.0 g of 20- to 200-mesh insoluble residue remained)
Mingo 059-00805 USGS 11937-CO	Columbia Gas (well 9674-T); 5385-7800 ft 37.904452/ -82.169442	Middle to Upper Ordovician	Cuttings	1 *Curtognathus* sp., cardiodelliform element; *Phragmodus*? sp., 1 P element fragment; *Plectodina* sp., 1 P element, 5 S elements, 2 M elements; 4 – indeterminate multidenticulate fragments	Middle or Late Ordovician	2	Sample processed and originally analyzed by A.G. Harris; unpublished collection WVA-O-3.

[1]Because all samples are from West Virginia, the state API prefix, 047-, was omitted for brevity.

COUNTY API number[1] USGS Collection Number	WELL NAME; FOOTAGE (Latitude North/ Longitude West)	STRATIGRAPHIC UNIT (Based on picks provided by the West Virginia Geological Survey)	CORE? OR CUTTINGS	CONODONT FAUNA	AGE RANGE OF CONODONTS	CAI	REMARKS
Mingo 059-00879 USGS 11936-CO	Columbia Gas (well 20500-T); 7000-7200 ft 37.88306/ -82.26250	Black River	Cuttings	1 unassigned, most likely dichognathiform, element fragment	Middle or Late Ordovician	1.5 to 2	Sample processed and originally analyzed by A.G. Harris: USGS internal fossil examination and report O-78-106.
Monroe USGS 11041-CO	Joy Mfg. Co. No WVAC-1; 2998-2999 ft 37.607778/ -80.266667	Black River	core	2 *Panderodus*? sp; 2 robust multidenticulate element fragments; 2 indet. coniform elements with circular cross-section; 1 unassigned drepanodontiform element 1 indeterminate coniform element	Middle Ordovician or Late Ordovician	3.5 to 4	Approx. 500 g sample processed. Sample published in USGS Map I-2495 (1996)
Pendleton 071-00001 no USGS colln #	Neil Harper 1; 20-165 ft 38.81111/ -79.3625	Trenton	Cuttings	BARREN	Not determined	N/A	100-200 g sample processed (12.2 g +20-mesh, and 28.2 g of 20- to 200-mesh insoluble residue remained)
Pendleton 071-00006 USGS 11944-CO	Ray Sponaugle 1 (8800-T); 10040-10250 ft 38.54805/ -79.51278	Trenton	Cuttings	*Erismodus* sp. 2 elements; Indeterminate element fragments - 10	Middle Ordovician; upper *Histiodella holodentata* Zone to *Pl. tenuis* Zone (mid-Whiterockian to Shermanian)	4.5	100-200 g sample processed (4.0 g +20-mesh, and 17.7 g of 20- to 200-mesh insoluble residue remained)
Preston 077-00086 USGS 11945-CO	No. A-1 H.G. Walls; 14010-14195 ft 39.466669/ -79.870278	Trenton	Cuttings	?*Drepanoistodus suberectus* (Branson & Mehl); 1 drepanodontiform element fragment; *Phragmodus undatus* Branson & Mehl; 1-unassigned oistodontiform element	late Middle or Late Ordovician; *Ph. undatus* Zone to end of Ordovician (latest Blackriveran to latest Gamachian)	4.5-5	159.8 g sample processed (23.4 g +20-mesh, and 23.2 g of 20- to 200-mesh insoluble residue remained)
Randolph 083-00103 USGS 11946-CO	WV Board of Control (10228); 12695.3 ft 38.707218/ -79.96917	Chazy	Core	2 indeterminate euconodont element fragments	Paleozoic; Ordovician or younger	2.5-3	120.0 g sample processed (10.4 g +20-mesh, and 23.8 g of 20- to 200-mesh insoluble residue remained)
Randolph 083-00103 no USGS colln #	WV Board of Control (10228); 12721.5 ft 38.707218/ -79.96917	Chazy	Core	Barren	Not determined	n/a	100-200 g sample processed (8.3 g of 20- to 200-mesh insoluble residue remained)
Roane 087-00019 USGS 11947-CO	J.W. Heinzman (4053); 8875-9055 ft	Trenton	Cuttings	*Panderodus gracilis* (Branson & Mehl); *Phragmodus undatus* Branson & Mehl	late Middle or Late Ordovician; *Ph. undatus* Zone to end of Ordovician (latest Blackriveran to latest Gamachian)	3	140.5 g sample processed (29.3 g +20-mesh, and 24.2 g of 20- to 200-mesh insoluble residue remained)

COUNTY API number[1] USGS Collection Number	WELL NAME; FOOTAGE (Latitude North/ Longitude West)	STRATIGRAPHIC UNIT (Based on picks provided by the West Virginia Geological Survey)	CORE? OR CUTTINGS	CONODONT FAUNA	AGE RANGE OF CONODONTS	CAI	REMARKS
Wayne 099-00465 USGS 11948-CO	Caldwell No. 42 (6181); 5101-5272 ft 37.892224/ -82.39389	Trenton	Cuttings	*Plectodina tenuis* (Branson & Mehl)	late Middle or Late Ordovician; *Pl. tenuis* Zone to end of Ordovician (Kirkfieldian to Gamachian)	1.5 - 2	136.4 g sample processed (23.7 g +20-mesh, and 24.0 g of 20- to 200-mesh insoluble residue remained)
Wood 107-00351 USGS 11949-CO	Hope Nat. Gas Co. 9634; 9532-9543.6 ft 39.256945/ -81.2725	Trenton	core	*Drepanoistodus suberectus* (Branson & Mehl); *"Oistodus"* sp. A of S.A. Leslie (2000); *Panderodus gracilis* (Branson & Mehl); *Periodon grandis* (Ethington); *Phragmodus undatus* Branson & Mehl	late Middle or Late Ordovician; *Ph. undatus* Zone to *O. velicuspus* Zone (latest Blackriveran to Maysvillian)	3 - 3.5	ca. 300 g sample processed (112.7 g +20-mesh, and 64.1 g of 20- to 200-mesh insoluble residue remained)
Wood 107-00351 no USGS colln #	Hope Nat. Gas Co. 9634; 10796.0 ft 39.256945/ -81.2725	Beekmantown	core	BARREN	Not determined	N/A	ca. 300 g sample processed (32.8 g of 20- to 200-mesh insoluble residue remained)
Wood 107-00756 USGS 11950-CO	Exxon No. 1 Deem; 8550-8660 ft 39.080553/ -81.508331	Trenton	Cuttings	*Amorphognathus* sp.; *Drepanoistodus suberectus* (Branson & Mehl); *Phragmodus undatus* Branson & Mehl	late Middle or Late Ordovician; *Ph. undatus* Zone to end of Ordovician (latest Blackriveran to latest Gamachian)	2 - 2.5	195.3 g sample processed (50.7 g +20-mesh, and 24.0 g of 20- to 200-mesh insoluble residue remained)

TABLE 2. Conodont data from Devonian samples from the subsurface of West Virginia.

COUNTY API number[1] USGS Collection Number	WELL NAME; FOOTAGE (Latitude North/ Longitude West)	STRATIGRAPHIC UNIT (Based on picks provided by the West Virginia Geological Survey)	CORE OR CUTTINGS	CONODONT FAUNA	AGE RANGE OF CONODONTS	CAI	REMARKS
Boone 005-00612 no USGS colln #	No. 41 Allen & Pryor (675); 4180-4220 ft 38.11417/ -81.829446	Onondaga	Cuttings	BARREN	Not determined	n/a	154 g sample processed (29 g +20-mesh, and 54 g of 20- to 200-mesh insoluble residue remained)
Boone 005-00612 USGS 13022-SD	No. 41 Allen & Pryor (675); 4354-4417 ft 38.11417/ -81.829446	Helderberg	Cuttings	*Ozarkodina* sp., 2 Pa element fragments; 4 - indeterminate element fragments; 1 - conodont "pearl"	Late Ordovician to Early Devonian	1.5 - 2	159 g sample processed (5 g +20-mesh, and 33 g of 20- to 200-mesh insoluble residue remained)
Braxton 007-00226 USGS 13023-SD	No. 1 E.L. Boggs (8989); 6094-6161 ft 38.684441/ -80.8275	Onondaga	Cuttings	1 - polygnathid Pa element fragment; 1 - ramiform element fragment; 6 - indeterminate conodont fragments	Devonian	2	185 g sample processed (66 g +20-mesh, and 67 g of 20- to 200-mesh insoluble residue remained)
Cabell 011-00537 USGS 13024-SD	No. 1 E. Kingrey; 3330-3402 ft 38.523887/- 82.263055	Helderberg	Cuttings	1 - *Belodella* sp.; 1 - multicostate coniform-ramiform element, e.g., those of *Latericriodus*	Devonian	1 - 1.5	275 g sample processed (78 g +20-mesh, and 21.9 g of 20- to 200-mesh insoluble residue remained)
Clay 015-00513 no USGS colln #	United Fuel Gas (8000-T); 5603-5714 ft 38.453054/ -81.263886	Onondaga	Cuttings	BARREN	Not determined		120.5 g sample processed (35.2 g +20-mesh, and 50. g of 20- to 200-mesh insoluble residue remained)
Clay 015-00513 USGS 13025-SD	United Fuel Gas (8000-T); 5850-6100 ft 38.453054/ -81.263886	Helderberg	Cuttings	7 - conodont fragments; genus & species indeterminate; 1 - conodont "pearl"	Ordovician or younger Paleozoic	2	137.7 g sample processed (22.7 g +20-mesh, and 47.8 g of 20- to 200-mesh insoluble residue remained)

[1]Because all samples are from West Virginia, the state API prefix, 047-, was omitted for brevity.

COUNTY API number[1] USGS Collection Number	WELL NAME; FOOTAGE (Latitude North/ Longitude West)	STRATIGRAPHIC UNIT (Based on picks provided by the West Virginia Geological Survey)	CORE OR CUTTINGS	CONODONT FAUNA	AGE RANGE OF CONODONTS	CAI	REMARKS
Doddridge 017-00071 USGS 13026-SD	No. F-11 Maxwell (GW-43); 6724-6841 ft 39.27445/ -80.760834	Onondaga	Cuttings	icriodid Pa element fragments - 2; Indet. conodont element fragments - 3	Devonian	1.5 - 2	123.1 g sample processed (33.5 g +20-mesh, and 59.9 g of 20- to 200-mesh insoluble residue remained)
Doddridge 017-00071 USGS 13027-SD	No. F-11 Maxwell (GW-43); 7103-7183 ft 39.27445/ -80.760834	Helderberg	cuttings	*Polygnathus* sp., Pa element - 1; icriodid Pa element fragment - 1; coniform element, unassigned - 1; unassigned Pa or Pb element fragment - 1; 10 indet. probable conodont el. frags.	Devonian	2	133.7 g sample processed 35.3 g +20-mesh, and 57.7 g of 20- to 200-mesh insoluble residue remained)
Fayette 019-00042 USGS 13028-SD	Franklin Real (GW-796) 7239-7316 ft 38.031109/ -80.985276	Helderberg	cuttings	*Icriodus* sp. or spp., - 2 Pa elements; Ozarkodinid spp., - 2 Pa element fragments; 8 - indet. conodont element fragments	Devonian	3.5	134.7 g sample processed (22.6 g +20-mesh, and 54.0 g of 20- to 200-mesh insoluble residue remained)
Fayette 019-00241 no USGS colln #	Nuttall Estate (2000-T) 7200-7400 ft 38.113609/ -80.985276	Helderberg	Cuttings	BARREN	Not determined	n/a	125.0 g sample processed (12.0 g +20-mesh, and 68.5 g of 20- to 200-mesh insoluble residue remained)
Greenbrier 025-00002 USGS 13029-SD	No. 1 G.R. Dean 6574-6790 ft 37.944442/ -80.489723	Helderberg	Cuttings	1 - indeterminate conodont element fragment; 2 - probable conodont elements, fragments, indeterminate	post-Cambrian Paleozoic	3 - 3.5	126.5 g sample processed (45.3 g +20-mesh, and 22.0 g of 20- to 200-mesh insoluble residue remained)
Greenbrier 025-00004 USGS 13030-SD	No. 1 J.M. VanBuren Heirs; 1408-1569 ft 37.981385/ /80.119164	Helderberg	Cuttings	*Icriodus* sp., Pa element fragments - 2; ozarkodinid gen. & sp. - Pa(?) el. frag. - 1; indet. multicostate coniform element - 1 indet. conodont element fragments - 7	Devonian	3	143.0 g sample processed (7.7 g +20-mesh, and 33.0 g of 20- to 200-mesh insoluble residue remained)
Greenbrier 025-00013 USGS 13031-SD	No. 1 Damron (8926); 4770-5100 ft 37.69361/ -80.325836	Helderberg	Cuttings	Icriodid P element fragments - 2; Ozarkodinid P(?) element fragment - 1; Indet. ramiform elem. Frags. - 2; Indet. coniform el. frag. - 1; Indet. other conodont el. frags. - 4	Devonian	3.5 - 4	138.1 g sample processed (32.3 g +20-mesh, and 52.8 g of 20- to 200-mesh insoluble residue remained)
Hampshire 027-00012 USGS 13032-SD	O.B. & Ray Duckworth 1; 670-810 ft 39.494444/ -78.63666	Helderberg	Cuttings	Ozarkodinid spp., 2 P elements; Indet. M element - 1; Indet. conodont el. frag. - 1	Devonian	3.5	148.9 g sample processed (39.5 g +20-mesh, and 73.7 g of 20- to 200-mesh insoluble residue remained)

COUNTY API number[1] USGS Collection Number	WELL NAME; FOOTAGE (Latitude North/ Longitude West)	STRATIGRAPHIC UNIT (Based on picks provided by the West Virginia Geological Survey)	CORE OR CUTTINGS	CONODONT FAUNA	AGE RANGE OF CONODONTS	CAI	REMARKS
Hancock 029-00080 USGS 13033-SD	S. Minesinger 1; 4920-5280 ft 40.539722/ -80.556114	Helderberg	Cuttings	*Belodella* sp., 2 elements; Indet. multicostate coniform elements - 2; Indet. P element fragment - 1 Indet. M element - 1; Other indet. conodont element fragments - 16; Conodont "pearls" - 2	Devonian	2.5	313.0 g sample processed (186.2 g +20-mesh, and 23.0 g of 20- to 200-mesh insoluble residue remained)
Hardy 031-00003 USGS 13034-SD	Anna Baughman (9058-T); 7000-7190 ft 39.002774/ -78.849999	Helderberg	Cuttings	Indet. ramiform (S) element fragment - 1	Ordovician or younger Paleozoic	2.5 - 3	155.3 g sample processed (116.5 g +20-mesh, and 24.2 g of 20- to 200-mesh insoluble residue remained)
Harrison 033-00079 USGS 13035-SD	C.S. Gribble (8517); 7400-7505 ft 39.157775/ -80.327225	Helderberg	Cuttings	Indeterminate bicostate coniform element - 1 Indet. P element fragments - 2 Other indet. conodont fragments - 6	Devonian	2.5 - 3	192.9 g sample processed (110.9 g +20-mesh, and 37.7 g of 20- to 200-mesh insoluble residue remained)
Jackson 035-01366 USGS 13036-SD	L. Stalnaker 1; 5440-5580 ft 38.729718/ -81.572503	Helderberg	Cuttings	2 - indeterminate conodont element fragments	Devonian	2 - 2.5	~10 misc. phosphatic fossil fragments 105.9 g sample processed (16.8 g +20-mesh, and 45.4 g of 20- to 200-mesh insoluble residue remained)
Kanawha 039-00205 USGS 13037-SD	No. 1 Robertson (GW-346); 5101-5242 ft 38.427776/ -81.557778	Helderberg	Cuttings	1 - icriodid Pa element fragment; 2 - P element fragments, gen. & sp. indet.; 1 - bicostate coniform element; 10 indet. conodont fragments; 7 - conodont "pearls"	Devonian	1.5 - 2	186.4 g sample processed (31.6 g +20-mesh, and 43.9 g of 20- to 200-mesh insoluble residue remained)
Kanawha 039-03462 USGS 13038-SD	Sally D. Todd (20659-T); 5600-5700 ft 38.296669/ -81.370835	Onondaga	Cuttings	1 - icriodid-type Pa element fragment; 15 - indet. conodont element fragments	Devonian	2 - 2.5	205.1 g sample processed (75.5 g +20-mesh, and 50.0 g of 20- to 200-mesh insoluble residue remained)
Kanawha 039-03462 USGS 13039-SD	Sally D. Todd (20659-T); 5730-5830 ft 38.296669/ -81.370835	Helderberg	Cuttings	3 - *Ozarkodina remscheidensis* (Ziegler)-group Pa elements; 1 - *Pseudooneotodus beckmanni* (Bischoff & Sannemann); 4 - indet. blade element fragments; 29 - indet. conodont fragments	Late Silurian to Early Devonian	2 - 2.5	190.0 g sample processed (56.0 g +20-mesh, and 82.6 g of 20- to 200-mesh insoluble residue remained)
Lincoln 043-01637 USGS 13040-SD	Columbia Gas (well CGSC no. 20403); 4031-4032 ft 38.098889/ -82.224442	Onondaga	core	*Icriodus corniger* group; *Polygnathus costatus costatus* Klapper	Earliest Middle Devonian; early Eifelian	1.5 - 2	Sample processed and analyzed by A.G. Harris (USGS, unpub. Fossil examination & report (E&R) no. DOE-77-1

COUNTY API number[1] USGS Collection Number	WELL NAME; FOOTAGE (Latitude North/ Longitude West)	STRATIGRAPHIC UNIT (Based on picks provided by the West Virginia Geological Survey)	CORE OR CUTTINGS	CONODONT FAUNA	AGE RANGE OF CONODONTS	CAI	REMARKS
Lincoln 043-01637 USGS 9810-SD	Columbia Gas (well CGSC no. 20403); 4051 ft 38.098889/ -82.224442	Onondaga	core	3 - *Belodella* cf. *B. resima* (Philip); 3 - *Coelocerodontus* sp.; 11 - *Icriodus corniger* group, Pa elements; 12 - *Polygnathus costatus costatus* Klapper, Pa elements; 2 - unassigned Pb elements' 1 - unassigned M element 34 - indet conodont element fragments	Early Middle Devonian; early Eifelian; *costatus* Zone	1.5 - 2	Sample processed and analyzed by A.G. Harris (USGS, unpub. Fossil examination & report (E&R) no. O&G-78-6
Logan 045-00287 USGS 13041-SD	Boone Co. Coal (9677); 5189-5275 ft 37.891391/ -81.841667	Onondaga	Cuttings	1 - *Polygnathus* sp., Pa element fragment' 2 - icriodid Pa element fragments; 1 - ?icriodid Pa element fragment; 1 - unassigned ramiform (S) element frag.; 14 - indeterminate conodont fragments	Devonian	2.5 - 3	136.1 g sample processed (33.2 g +20-mesh, and 40.9 g of 20- to 200-mesh insoluble residue remained)
Logan 045-000864 USGS 13042-SD	C.C. Chambers No. 3; 4670-4780 ft 37.920828/ -81.932221	Helderberg	Cuttings	1 - unassigned ramiform element fragment; 1 - conodont "pearl"	Ordovician to Triassic	2.5	137.0 g sample processed (25.7 g +20-mesh, and 20.4 g of 20- to 200-mesh insoluble residue remained)
McDowell 047-00031 USGS 13043-SD	New River & Poca (6219); 6525-6669 ft 37.255282/ -81.610833	Helderberg	Cuttings	4 - indeterminate conodont P elements; 2 - probable conodont element fragments; 4 - possible conodont el. frags.	Middle Ordovician or later Paleozoic	3 - 3.5	Conodont elements appear to be partially dissolved. 149.2 g sample processed (8.0 g +20-mesh, and 44.1 g of 20- to 200-mesh insoluble residue remained)
Marion 049-00244 USGS 13044-SD	No. A-1 Finch; 6820-6900 ft 39.431946/ -80.012223	Tully	Cuttings	1 - indeterminate conodont element fragment, most likely a Pa element	Post-Ordovician Paleozoic	3.5 - 4	129.8 g sample processed (15.3 g +20-mesh, and 37.8 g of 20- to 200-mesh insoluble residue remained)
Marion 049-00244 USGS 13045-SD	No. A-1 Finch; 7480-7600 ft 39.431946/ -80.012223	Helderberg	Cuttings	4 - icriodid Pa element fragments; 1 - indet. conodont P(?) element fragment	Devonian	4	149.6 g sample processed (58.0 g +20-mesh, and 22.1 g of 20- to 200-mesh insoluble residue remained)
Marshall 051-00221 USGS 13046-SD	No. 1 Ohio Valley S. Sa; 5580-5640 ft 39.903613/ -80.803055	Onondaga	cuttings	2 - icriodid Pa element fragments; 9 - indet. conodont element fragments	Devonian	1.5 - 2	182.2 g sample processed (82.1 g +20-mesh, and 58.6 g of 20- to 200-mesh insoluble residue remained)
Marshall 051-00221 USGS 13047-SD	No. 1 Ohio Valley S. Sa; 5807-5877 ft 39.903613/ -80.803055	Helderberg	cuttings	5 - indeterminate conodont element fragments, consistent with post-Ordovician morphologies; 2 - probable conodont element fragments, indeterminate	Post-Ordovician Paleozoic	2	196.1 g sample processed (102.7 g +20-mesh, and 24.6 g of 20- to 200-mesh insoluble residue remained)

COUNTY API number[1] USGS Collection Number	WELL NAME; FOOTAGE (Latitude North/ Longitude West)	STRATIGRAPHIC UNIT (Based on picks provided by the West Virginia Geological Survey)	CORE OR CUTTINGS	CONODONT FAUNA	AGE RANGE OF CONODONTS	CAI	REMARKS
Mason 053-00069 USGS 13048-SD	Grover Arrington (8803); 3310-3420 ft 38.713895/ -82.117226	Onondaga-Helderberg	Cuttings	1 - *Polygnathus* sp., Pa element; 2 - *Icriodus* sp., Pa element fragments; 3 - unassigned ramiform (S or M) element fragments; 1 - indet. conodont element fragment	Devonian	1.5	185.0 g sample processed (68.0 g +20-mesh, and 41.9 g of 20- to 200-mesh insoluble residue remained)
Mingo 059-00805 USGS 13049-SD	Columbia Gas (9674-T); 3600-3700 ft 37.904452/ -82169442	Onondaga	Cuttings	6 - icriodid Pa element fragments; 2 - indet. conodont element fragments	Devonian	1.5 - 2	100-200 g sample processed (48.5 g +20-mesh, and 56.2g of 20- to 200-mesh insoluble residue remained)
Monongalia 061-20370 no USGS colln #	No. 1 MERC (DOE test well); 7160-7165 ft 36.669167/ -79.974167	Burkett Shale (base of unit)	Cuttings	BARREN	Devonian	N/A	120 g cuttings processed. (2 g +20-mesh; 40 g 20- to 140-mesh insol. residue examined) Sample processed and originally analyzed by A.G. Harris (USGS, unpub. Fossil examination & report (E&R) no. O&G-79-5
Monongalia 061-20370 no USGS colln #	No. 1 MERC (DOE test well); 7165-7170 ft 36.669167/ -79.974167	Tully (top foot)	Cuttings	BARREN	Devonian	N/A	175 g arg. Ls processed (14 g +20-mesh; 15 g 20- to 140-mesh insol. residue examined) Sample processed and originally analyzed by A.G. Harris (USGS, unpub. Fossil examination & report (E&R) no. O&G-79-5
Monongalia 061-20370 USGS 9986-SD	No. 1 MERC (DOE test well); 7179 ft 36.669167/ -79.974167	Tully (10 ft below top)	Core	2 - *Polygnathus linguiformis linguiformis* Hinde, gamma morphotype, Pa elements; 1 - ozarkodinid Pa element, incomplete; 1 - unassigned Pb element; 4 - unassigned ramiform (S) elements 6 - indet. conodont element fragments	earliest Middle to earliest Late Devonian	3 - 3.5	Sample processed and originally analyzed by A.G. Harris (USGS, unpub. Fossil examination & report (E&R) no. O&G-79-5
Monongalia 061-00307 USGS 13050-SD	No. A-1 Clifford J. May; 8020-8280 ft 39.56417/ -79.873055	Helderberg	Cuttings	1 - possible euconodont fragment	Not determined	2 - 3*	*CAI value valid only if fragment indeed is of a conodont element 100-200 g sample processed (58.4 g +20-mesh, and 46.6 g of 20- to 200-mesh insoluble residue remained)
Nicholas 067-00052 USGS 13051-SD	No. 1 Flynn Coal & Lumber; 6397-6500 ft 38.216669/ -81.063332	Helderberg	Cuttings	2 - *Ozarkodina remscheidensis* (Ziegler)-group Pa elements, broken; 1 - *Pseudooneotodus beckmanni* (Bischoff & Sannemann); 12 - icriodid Pa element fragments; 3 - unassigned ozarkodinid Pa elements, broken; 7 - bicostate coniform elements; 10 indet. conodont element fragments; 1 - conodont "pearl"	Late Silurian to Early Devonian	2.5 - 3	100-200 g sample processed (40.6 g +20-mesh, and 58.9 g of 20- to 200-mesh insoluble residue remained)

COUNTY API number[1] USGS Collection Number	WELL NAME; FOOTAGE (Latitude North/ Longitude West)	STRATIGRAPHIC UNIT (Based on picks provided by the West Virginia Geological Survey)	CORE OR CUTTINGS	CONODONT FAUNA	AGE RANGE OF CONODONTS	CAI	REMARKS
Nicholas 067-00194 USGS 13052-SD	No. 1-A New Gauley Coal; 7595-7700 ft 38.178892/ -80.647225	Helderberg	Cuttings	1 - icriodid S element; 2 - indeterminate Pa element fragments; 6 - indet. conodont element fragments	Late Silurian or Early Devonian	3 - 3+	100-200 g sample processed (85.0 g +20-mesh, and 34.8 g of 20- to 200-mesh insoluble residue remained)
Preston 077-00086 USGS 13053-SD	No. A-1 H.G. Walls; 7115-7185 ft 39.466669/ -79.870278	Tully	Cuttings	5 - indeterminate conodont element fragments	Middle Ordovician or later Paleozoic	4	111 g sample processed (11.5 g +20-mesh, and 38.9 g of 20- to 200-mesh insoluble residue remained)
Raleigh 081-00017 USGS 13054-SD	No. 1 Rowland (GW-663); 6042-6141 ft 37.830989/ -81.473244	Helderberg	Cuttings	2 - bicostate coniform element fragments; 2 - indet. bar element fragments	Middle Ordovician or later Paleozoic	3.5	210 g sample processed (8.1 g +20-mesh, and 64.0 g of 20- to 200-mesh insoluble residue remained)
Raleigh 081-00036 USGS 13055-SD	No. 1 C.E. Gwinn (1115); 6198-6395 ft 37.786666/ -80.916664	Onondaga-Helderberg	Cuttings	3 - icriodid Pa element fragments; 1 - indet. conodont element fragment	Silurian or Devonian	4	100-200 g sample processed (19.4 g +20-mesh, and 70.0 g of 20- to 200-mesh insoluble residue remained)
Randolph 083-00102 USGS 13056-SD	WV Board of Control (10182); 2950-3240 ft 38.696387/ -79.9525	Helderberg	Cuttings	4 - icriodid Pa element fragments; 1 - icriodid S element 1 - asymmetrical tricostate coniform element; 5 - bicostate coniform elements; 19 - indet. conodont element fragments	Late Silurian or Early Devonian	2 - 2.5	162.0 g sample processed (55.0 g +20-mesh, and 99.2 g of 20- to 200-mesh insoluble residue remained)
Ritchie 085-01894 USGS 13057-SD	Leora A. Elliott (10160); 5290-5420 ft 39.252778/ -81.2575	Onondaga	Cuttings	9 - icriodid Pa element fragments; 1 - *Polygnathus* sp. indet., Pa element frag.; 2 - indet. Pa element fragments; 1 - unassigned S or M element fragment; 1 - bicostate coniform element; 3 - indet conodont fragments; 1 - ichthyolith	Early or Middle Devonian	2	160.4 g sample processed (55.1 g +20-mesh, and 22.7 g of 20- to 200-mesh insoluble residue remained)
Ritchie 085-01894 no USGS colln #	Leora A. Elliott (10160); 5520-5700 ft 39.252778/ -81.2575	Helderberg	Cuttings	BARREN	Not determined from this sample	N/A	127.5 g sample processed (42.2 g +20-mesh, and 24.2 g of 20- to 200-mesh insoluble residue remained)
Roane 087-00019 USGS 13058-SD	J.W. Heinzman (4053); 5210-5380 ft 38.781388/ -81.503891	Onondaga	Cuttings	1 - *Icriodus* sp. indet., Pa element; 4 - icriodid Pa element fragments; 1 - *Belodella* sp. 1 - indet. conodont element fragment	Late Silurian to Devonian	2	110.4 g sample processed (12.0 g +20-mesh, and 49.0 g of 20- to 200-mesh insoluble residue remained)

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Roane 087-00019 USGS 13059-SD	J.W. Heinzman (4053); 5450-5600 ft 38.781388/ -81.503891	Helderberg	Cuttings	12 - indet. conodont element fragments	Post-Cambrian Paleozoic	2 - 2.5	111.1 g sample processed (2.7 g +20-mesh, and 7.8 g of 20- to 200-mesh insoluble residue remained)
Roane 087-00714 USGS 13060-SD	No. 2 Osborne ((8100-T); 5180-5320 ft 38.537562/ -81.272982	Onondaga	Cuttings	1 - icriodid Pa element fragment; 2 - indet. conodont element fragments	Late Silurian to Devonian	2 - 2.5	143.6 g sample processed 99.2 g +20-mesh, and 26.4 g of 20- to 200-mesh insoluble residue remained)
Roane 087-00714 USGS 13061-SD	No. 2 Osborne ((8100-T); 5420-5530 ft 38.537562/ -81.272982	Helderberg	Cuttings	1 - unassigned acostate coniform element; incomplete	Latest Cambrian to Carboniferous	2.5	144.5 g sample processed (108.6 g +20-mesh, and 12.2 g of 20- to 200-mesh insoluble residue remained)
Summers 089-00005 USGS 13062-SD	Anchor Gas No. 1 Ball; 7040-7150 ft 37.692503/ -80.925004	Helderberg	Cuttings	1 - icriodid Pa element fragment; 4 - unassigned bicostate (S?) coniform elements; 1 - unassigned Pb element; 1 - indet. bar (S or M) element fragment; 3 - indet. conodont fragments; 2 - ichthyoliths	Late Silurian to Devonian	4	184.9 g sample processed (128.5 g +20-mesh, and 19.7 g of 20- to 200-mesh insoluble residue remained)
Tucker 093-00003 USGS 13063-SD	No. 1 (A-418) WVP&T Co.; 7900-8004 ft 39.097781/ -79.387497	Onondaga-Helderberg	Cuttings	1 - indet. probable conodont element fragment	post-Cambrian Paleozoic	3 - 3.5	211.6 g sample processed (99.6 g +20-mesh, and 93.0 g of 20- to 200-mesh insoluble residue remained)
Tucker 093-00013 USGS 13064-SD	USA No. C-1 (GW-1215); 3652-3774 ft 39.171666/ -79.634446	Helderberg	Cuttings	6 - icriodid Pa element fragments; 3 - unassigned multicostate coniform elements; 6 - indet. conodont element fragments	late Silurian to Devonian	3 - 3.5	139.5 g sample processed (6.0 g +20-mesh, and 52.0 g of 20- to 200-mesh insoluble residue remained)
Wayne 099-00138 USGS 13065-SD	No. 2 Saunders; 3301-3141 ft 38.206113/ -82.489167	Onondaga-Helderberg	Cuttings	*Icriodus* sp., 1 Pa, 1 coniform (M) element; 1 - *Polygnathus*? sp., Pa element fragment; 3 - *Ozarkodina*? sp., S element frags.; 8 - indet. conodont element fragments	late Silurian to Devonian	1.5	140.6 g sample processed (41.0 g +20-mesh, and 29.7 g of 20- to 200-mesh insoluble residue remained)
Wayne 099-00162 USGS 13066-SD	No. 3 Glenhayes Co. (559); 2899-2999 ft 38.037224/ -82.517777	Onondaga-Helderberg	cuttings	1 - icriodid Pa element fragment; 1 - *Polygnathus* sp., Pa element fragment 1 - indet. conodont element fragment; 1 - conodont "pearl"	late Silurian to Devonian	2 - 2.5	135.3 g sample processed (13.6 g +20-mesh, and 54.0 g of 20- to 200-mesh insoluble residue remained)

COUNTY API number[1] USGS Collection Number	WELL NAME; FOOTAGE (Latitude North/ Longitude West)	STRATIGRAPHIC UNIT (Based on picks provided by the West Virginia Geological Survey)	CORE OR CUTTINGS	CONODONT FAUNA	AGE RANGE OF CONODONTS	CAI	REMARKS
Wayne 099-00465 USGS 13067-SD	Caldwell No. 42 (6181); 3108-3198 ft 37.892224/ -82.39389	Onondaga-Helderberg	cuttings	1 - icriodid Pa element fragment; 1 - indet. Pa element fragment; 1 - ozarkodinid Sc element; 1 - indet. conodont element fragment	late Silurian to Devonian	1.5 - 2	117.1 g sample processed (19.9 g +20-mesh, and 54.1 g of 20- to 200-mesh insoluble residue remained)
Wirt 105-00068 USGS 13068-SD	No. 500 Roberts; 5000-5135 ft 38.993055/ -81.307779	Helderberg	cuttings	5 - indeterminate conodont element fragments	post-Cambrian Paleozoic	2	118.5 g sample processed (17.9 g +20-mesh, and 64.8 g of 20- to 200-mesh insoluble residue remained)
Wood 107-00351 USGS 13069-SD	Hope Natural Gas No. 9634; 4038-4078 ft 39.256945/ -81.2725	Onondaga	cuttings	1 - icriodid(?), Pa element fragment; 1 - indet. M or S element fragment	late Silurian to Devonian	2	225.8 g sample processed (42.8 g +20-mesh, and 44.5 g of 20- to 200-mesh insoluble residue remained)
Wood 107-00351 USGS 13070-SD	Hope Natural Gas No. 9634; 5940-6100 ft 39.256945/ -81.2725	Helderberg	cuttings	1 - icriodid Pa element fragment; 1 - unassigned bar (Sc) element fragment; 4 - indet. conodont element frags.; 2 - conodont "pearls"	late Silurian to Devonian	2	161.8 g sample processed (49.5 g +20-mesh, and 25.3 g of 20- to 200-mesh insoluble residue remained)
Wood 107-00756 USGS 13071-SD	Exxon No. 1 Deem; 5020-5130 ft 39.080553/ -81.508331	Onondaga	cuttings	4 - icriodid Pa element fragments; 1 - unassigned coniform element	late Silurian to Devonian	1.5 - 2	162.9 g sample processed (61.6 g +20-mesh, and 32.6 g of 20- to 200-mesh insoluble residue remained)
Wood 107-00756 no USGS colln #	Exxon No. 1 Deem; 5200-5310 ft 39.080553/ -81.508331	Helderberg	cuttings	BARREN	Not determined	N/A	120.0 g sample processed (29.8 g +20-mesh, and 37.5 g of 20- to 200-mesh insoluble residue remained)
Wyoming 109-00016 USGS 13072-SD	No. 1 Gilbert (0168); 5797-5887 ft 37.538056/ -81.753052	Helderberg	cuttings	2 - indet. Pa element fragments; 5 - indet. conodont element fragments; 5 - probable conodont element frags., indet.; 2 - ichthyoliths	Middle Ordovician or later Paleozoic	3	165.9 g sample processed (42.5 g +20-mesh, and 36.9 g of 20- to 200-mesh insoluble residue remained)

Table 3. Thermal Maturity (CAI, %Ro) and Rock Eval/TOC data from Ordovician and Devonian samples from the subsurface of West Virginia

ID #	API NUMBER	COUNTY	QUADRANGLE	LATITUDE (DEC DEG)	LONGITUDE (DEC DEG)	LEASE NAME	FORMATION	AGE	SAMPLE TYPE	START DEPTH OF INTERVAL SAMPLE	END DEPTH OF INTERVAL SAMPLE
1	47-005-00612	Boone	Madison	38.11417	-81.829446	No.41 Allen & Pryor (675)	Rhinestreet-Marcellus	M.-U.Devonian	cuttings	3927	4105
1	47-005-00612	Boone	Madison	38.11417	-81.829446	No.41 Allen & Pryor (675)	Onondaga	M.Devonian	cuttings	4180	4220
1	47-005-00612	Boone	Madison	38.11417	-81.829446	No.41 Allen & Pryor (675)	Helderberg	L.Devonian	cuttings	4354	4417
2	47-007-00226	Braxton	Gassaway	38.684441	-80.8275	No.1 E.L. Boggs (8989)	Marcellus Sh	M.Devonian	cuttings	5900	6044
2	47-007-00226	Braxton	Gassaway	38.684441	-80.8275	No.1 E.L. Boggs (8989)	Onondaga	M.Devonian	cuttings	6094	6161
3	47-011-00537	Cabell	Athalia	38.523887	-82.263055	No.1 E. Kingery	Rhinestreet	U.Devonian	cuttings	3220	3330
3	47-011-00537	Cabell	Athalia	38.523887	-82.263055	No.1 E. Kingery	Helderberg	L.Devonian	cuttings	n/r	n/r
3	47-011-00537	Cabell	Athalia	38.523887	-82.263055	No.1 E. Kingery	Trenton	Ordovician	cuttings	n/r	n/r
4	47-015-00513	Clay	Clendenin	38.453054	-81.263886	United Fuel Gas (8000-T)	Marcellus Sh	M.Devonian	cuttings	5402	5593
4	47-015-00513	Clay	Clendenin	38.453054	-81.263886	United Fuel Gas (8000-T)	Onondaga	M.Devonian	cuttings	5603	5714
4	47-015-00513	Clay	Clendenin	38.453054	-81.263886	United Fuel Gas (8000-T)	Helderberg	L.Devonian	cuttings	5850	6100
5	47-017-00071	Doddridge	West Union	39.27445	-80.760834	No.F-11 Maxwell(GW-43)	Rhinestreet-Marcellus	M.-U.Devonian	cuttings	6304	6448
5	47-017-00071	Doddridge	West Union	39.27445	-80.760834	No.F-11 Maxwell(GW-43)	Onondaga	M.Devonian	cuttings	6724	6841
5	47-017-00071	Doddridge	West Union	39.27445	-80.760834	No.F-11 Maxwell(GW-43)	Helderberg	L.Devonian	cuttings	7103	7183
6	47-019-00042	Fayette	Winona	38.031109	-80.985276	Franklin Real (GW-796)	Marcellus Sh	M.Devonian	cuttings	6953	7057
6	47-019-00042	Fayette	Winona	38.031109	-80.985276	Franklin Real (GW-796)	Helderberg	L.Devonian	cuttings	7239	7316
7	47-019-00241	Fayette	Winona	38.113609	-80.985276	Nuttall Estate (2000-T)	Marcellus Sh	M.Devonian	cuttings	6630	7030
7	47-019-00241	Fayette	Winona	38.113609	-80.985276	Nuttall Estate (2000-T)	Helderberg	L.Devonian	cuttings	7200	7400
8	47-023-00002	Grant	Greenland Gap	39.194721	-79.14167	Greenland Lodge (10768)	Trenton	Ordovician	cuttings	5100	5110
9	n/a	Grant	Petersburg West	38.973333	-79.125833	n/a	Landes	M.Devonian	outcrop	0	0
10	47-025-00002	Greenbrier	Williamsburg	37.944442	-80.489723	No.1 G.R. Dean	Marcellus Sh	M.Devonian	cuttings	6200	6310
10	47-025-00002	Greenbrier	Williamsburg	37.944442	-80.489723	No.1 G.R. Dean	Helderberg	L.Devonian	cuttings	6574	6790
11	47-025-00004	Greenbrier	Rucker Gap	37.981385	-80.119164	No.1 J.M. VanBuren Heirs	Marcellus Sh	M.Devonian	cuttings	975	1090
11	47-025-00004	Greenbrier	Rucker Gap	37.981385	-80.119164	No.1 J.M. VanBuren Heirs	Helderberg	L.Devonian	cuttings	1408	1569
12	47-025-00013	Greenbrier	Glace	37.69361	-80.325836	No.1 Damron (8926)	Marcellus Sh	M.Devonian	cuttings	4400	4650
12	47-025-00013	Greenbrier	Glace	37.69361	-80.325836	No.1 Damron (8926)	Helderberg	L.Devonian	cuttings	4770	5100
13	47-025-00022	Greenbrier	Quinwood	38.06	-80.733611	Columbia Gas (20059)	Hamilton	M.Devonian	cuttings	7050	8266
14	47-027-00012	Hampshire	Springfield	39.494444	-78.63666	O.B. & Ray Duckworth 1	Helderberg	L.Devonian	cuttings	670	810
15	47-029-00080	Hancock	East Liverpool S	40.539722	-80.556114	S Minesinger 1	Helderberg	L.Devonian	cuttings	n/r	n/r
15	47-029-00080	Hancock	East Liverpool S	40.539722	-80.556114	S Minesinger 1	Trenton	Ordovician	cuttings	n/r	n/r
16	47-031-00003	Hardy	Needmore	39.002774	-78.849999	Anna Baughman (9058-T)	Helderberg	L.Devonian	cuttings	7000	7190
17	47-031-00001	Hardy	Old Fields	39.181667	-78.945	No.1 Williams	Helderberg	L.Devonian	cuttings	785	1370
18	47-033-00079	Harrison	Mount Clare	39.157775	-80.327225	C.S. Gribble (8517)	Marcellus Sh	M.Devonian	cuttings	6805	6885
18	47-033-00079	Harrison	Mount Clare	39.157775	-80.327225	C.S. Gribble (8517)	Helderberg	L.Devonian	cuttings	7400	7505
19	47-035-00615	Jackson	Cottageville	38.805835	-81.79583	No.1 Nellie Sayre King	Rhinestreet	U.Devonian	cuttings	4402	4596

Table 3. Thermal Maturity (CAI, %Ro) and Rock Eval/TOC data from Ordovician and Devonian samples from the subsurface of West Virginia

ID #	API NUMBER	TOC	S1	S2	S3	Tmax	HI	OI	PI	% Ro(mean)	Number of Ro Readings	Min CAI	Max CAI	Comments Regarding CAI Mineralogy & Fossils
1	47-005-00612	1.75	0.8	1.66	0.42	452	95	24	0.33	1.03	48			
1	47-005-00612													
1	47-005-00612											1.5	2	pyrite - fine-grained, minor, euhedral; dolomite - silt-sized
2	47-007-00226	1.69	0.25	0.02	0.09	416	1	5	0.93	1.55	50			
2	47-007-00226											2	2	
3	47-011-00537	2.3	1.59	8.52	0.65	446	370	28	0.16	0.57	51			
3	47-011-00537											1	1.5	pyrite - disseminated, euhedral, spherules/framboids; sphalerite (?) - trace; barite (?) - trace; phosphatic fossil fragments - indeterminate group(s)
3	47-011-00537											1.5	1.5	
4	47-015-00513	1.43	0.54	0.69	0.12	452	48	8	0.44	1.38	50			
4	47-015-00513													
4	47-015-00513											2	2	pyrite - fine-grained, framboids; rare euhedral barite or celestite - common; glauconite - minor; sphalerite - yellow; biotite - uncommon
5	47-017-00071	0.56	0.29	0.17	0.2	421	30	36	0.63	1.63	50			
5	47-017-00071											1.5	2	
5	47-017-00071											2	2	pyrite - fine-grained, framboids, spheres; sphalerite - pale yellow abraded grains; phosphatic shell fragments; zircons (?) - pink, abraded; unknown - clear & light green glassy (rare) grains, abraded
6	47-019-00042	1.68	0.2	0.08	0.36	330	5	21	0.71	2.34	48			
6	47-019-00042											3.5	3.5	pyrite - fine-grained, framboids, replaced fossils (spines, rods); sphalerite - pale yellow; zircons - pink, abraded; fluorite (?) - clear; phosphatic shell fragments - abraded, steinkerns (bryozoan zooecia)
7	47-019-00241	1.61	0.42	0.58	0.33	368	36	20	0.42	2.22	49			N/A
7	47-019-00241													pyrite - fine-grained, euhedral, & replaced fossils (rare); phosphatic irregular blebs, pale-colored abraded hyaline grains, & abraded shell fragments; shiny black metallic spheres (uncommon); sphalerite - yellow & orangish-yellow; zircons - pink (rare)
8	47-023-00002											4	4	pyrite - fine-grained, euhedral, replaced fossils (gastropods, ostracodes, bivalves, indeterminate rods & shell fragments); irregular phosphatic grains; sphalerite - yellowish-orange
9	n/a											3	3	A.G. Harris (unpublished data)
10	47-025-00002	1.48	0.14	0	0.21		0	14	1.00	2.23	50			
10	47-025-00002											3.5	3.5	
11	47-025-00004	1.95	0.35	0.11	0.3	346	6	15	0.76	2.02	50			
11	47-025-00004											3	3	
12	47-025-00013	1.74	0.29	0.11	0.31	396	6	18	0.73	2.27	50			
12	47-025-00013											3.5	4	pyrite - fine-grained, some euhedral, spheres, rare framboids; zircons - pink, rounded; sphalerite - light yellow to yellow-brown, common; phosphatic shell fragments - uncommon
13	47-025-00022											3	3.5	A.G. Harris (unpublished data)
14	47-027-00012											3	3.5	
15	47-029-00080											2.5	2.5	pyrite - fine-grained, 1/4- to 1/2-mm spheres, partially replaced fossils; phosphatic "pellets"; miscellaneous indeterminate fossil fragments; zircons - pink, abraded; glauconite - rare; abraded amber glassy sand-sized grains (conodonts?); barite or fluorite (?) - clear, rare
15	47-029-00080											3	3	
16	47-031-00003											2.5	3	pyrite - fine-grained, euhedral, framboids; blocky phosphate - probably fish bone/teeth fragments; dioptase (?) - rare; unknown bright silvery-black metallic mineral
17	47-031-00001											3.5	3.5	A.G. Harris (unpublished data)
18	47-033-00079	0.47	0.04	0	0.2		0	43	1.00	1.81	48			
18	47-033-00079											2.5	3	pyrite - fine-grained, euhedral, framboids & framboid clusters; 1/4- to 1/2-mm spheres; replaced fossils (ostracodes, spines/rods); sphalerite - yellow; phosphate grains & indeterminate fossil fragments
19	47-035-00615	2.12	0.77	3.21	0.37	440	151	17	0.19	0.72	67			

Table 3. Thermal Maturity (CAI, %Ro) and Rock Eval/TOC data from Ordovician and Devonian samples from the subsurface of West Virginia

ID #	API NUMBER	COUNTY	QUADRANGLE	LATITUDE (DEC DEG)	LONGITUDE (DEC DEG)	LEASE NAME	FORMATION	AGE	SAMPLE TYPE	START DEPTH OF INTERVAL SAMPLE	END DEPTH OF INTERVAL SAMPLE
20	47-035-01366	Jackson	Kentuck	38.729718	-81.572503	L Stalnaker 1	Helderberg	L.Devonian	cuttings	5440	5580
20	47-035-01366	Jackson	Kentuck	38.729718	-81.572503	L Stalnaker 1	Trenton	Ordovician	cuttings	8730	8830
21	47-039-00205	Kanawha	Big Chimney	38.427776	-81.557778	No.1 Robertson (GW-346)	Rhinestreet	U.Devonian	cuttings	4605	4896
21	47-039-00205	Kanawha	Big Chimney	38.427776	-81.557778	No.1 Robertson (GW-346)	Helderberg	L.Devonian	cuttings	5101	5242
22	47-039-03462	Kanawha	Mammoth	38.296669	-81.370835	Sally D. Todd (20659-T)	Rhinestreet	U.Devonian	cuttings	5000	5110
22	47-039-03462	Kanawha	Mammoth	38.296669	-81.370835	Sally D. Todd (20659-T)	Onondaga	M.Devonian	cuttings	5600	5700
22	47-039-03462	Kanawha	Mammoth	38.296669	-81.370835	Sally D. Todd (20659-T)	Helderberg	L..Devonian	cuttings	5730	5830
22	47-039-03462	Kanawha	Mammoth	38.296669	-81.370835	Sally D. Todd (20659-T)	Trenton	Ordovician	cuttings	8780	8890
23	47-043-01637	Lincoln	Ranger	38.098889	-82.224442	Columbia Gas (20403)	Lower Huron	U.Devonian	core	3614	3614
23	47-043-01637	Lincoln	Ranger	38.098889	-82.224442	Columbia Gas (20403)	Onondaga	M.Devonian	core	4031	4032
23	47-043-01637	Lincoln	Ranger	38.098889	-82.224442	Columbia Gas (20403)	Onondaga	M.Devonian	core	4051	4051
24	47-043-01656	Lincoln	Ranger	38.096671	-82.240838	Columbia/McCoy (20402)	Lower Huron	U.Devonian	core	3542	3542
25	47-045-00287	Logan	Clothier	37.891391	-81.841667	Boone Co. Coal (9677)	Rhinestreet	U.Devonian	cuttings	4901	5169
25	47-045-00287	Logan	Clothier	37.891391	-81.841667	Boone Co. Coal (9677)	Onondaga	M.Devonian	cuttings	5189	5275
26	47-045-000864	Logan	Henlawson	37.920828	-81.932221	C C Chambers 3	Helderberg	L.Devonian	cuttings	4670	4780
27	47-047-00031	McDowell	Gary	37.255282	-81.610833	New River & Poca (6219)	Marcellus Sh	M.Devonian	cuttings	6100	6310
27	47-047-00031	McDowell	Gary	37.255282	-81.610833	New River & Poca (6219)	Helderberg	L.Devonian	cuttings	6525	6669
28	47-049-00244	Marion	Fairmont East	39.431946	-80.012223	No.A-1 Finch	Tully	M.Devonian	cuttings	6820	6900
28	47-049-00244	Marion	Fairmont East	39.431946	-80.012223	No.A-1 Finch	Marcellus Sh	M.Devonian	cuttings	6950	7050
28	47-049-00244	Marion	Fairmont East	39.431946	-80.012223	No.A-1 Finch	Helderberg	L.Devonian	cuttings	7480	7600
28	47-049-00244	Marion	Fairmont East	39.431946	-80.012223	No.A-1 Finch	Trenton	Ordovician	cuttings	13110	13270
29	47-051-00221	Marshall	Businessburg	39.903613	-80.803055	No.1 Ohio Valley S. Sa	Marcellus Sh	M.Devonian	cuttings	5306	5443
29	47-051-00221	Marshall	Businessburg	39.903613	-80.803055	No.1 Ohio Valley S. Sa	Onondaga	M.Devonian	cuttings	5580	5640
29	47-051-00221	Marshall	Businessburg	39.903613	-80.803055	No.1 Ohio Valley S. Sa	Helderberg	L.Devonian	cuttings	5807	5877
30	47-053-00069	Mason	Arlee	38.713895	-82.117226	Grover Arrington (8803)	Onondaga-Helderberg	L.-M.Devonian	cuttings	3310	3420
31	47-053-00146	Mason	Cheshire	38.925	-82.0625	No.3 D&K Farms	Rhinestreet	U.Devonian	core	3308	3308
31	47-053-00146	Mason	Cheshire	38.925	-82.0625	No.3 D&K Farms	Rhinestreet	U.Devonian	core	3316	3316
31	47-053-00146	Mason	Cheshire	38.925	-82.0625	No.3 D&K Farms	Rhinestreet	U.Devonian	core	3325	3325
31	47-053-00146	Mason	Cheshire	38.925	-82.0625	No.3 D&K Farms	Rhinestreet	U.Devonian	core	3336	3336
31	47-053-00146	Mason	Cheshire	38.925	-82.0625	No.3 D&K Farms	Rhinestreet	U.Devonian	core	3346	3346
31	47-053-00146	Mason	Cheshire	38.925	-82.0625	No.3 D&K Farms	Rhinestreet	U.Devonian	core	3356	3356
31	47-053-00146	Mason	Cheshire	38.925	-82.0625	No.3 D&K Farms	Rhinestreet	U.Devonian	core	3366	3366
31	47-053-00146	Mason	Cheshire	38.925	-82.0625	No.3 D&K Farms	Rhinestreet	U.Devonian	core	3374	3374
31	47-053-00146	Mason	Cheshire	38.925	-82.0625	No.3 D&K Farms	Rhinestreet	U.Devonian	core	3384	3384
31	47-053-00146	Mason	Cheshire	38.925	-82.0625	No.3 D&K Farms	Onondaga	M.Devonian	core	3422	3422
32	47-059-00805	Mingo	Trace	37.904452	-82.169442	Columbia Gas (9674-T)	Rhinestreet	U.Devonian	cuttings	3720	3840

Table 3. Thermal Maturity (CAI, %Ro) and Rock Eval/TOC data from Ordovician and Devonian samples from the subsurface of West Virginia

ID #	API NUMBER	TOC	S1	S2	S3	Tmax	HI	OI	PI	% Ro(mean)	Number of Ro Readings	Min CAI	Max CAI	Comments Regarding CAI Mineralogy & Fossils
20	47-035-01366											2	2.5	pyrite - mostly fine-grained, fine euhedra (uncommon), framboids, fossil replacement; fossils - rods, sponge spicules, replaced shell fragments, steinkerns (brachiopods, bivalves, ostracodes)
20	47-035-01366											2.5	3	
21	47-039-00205	1.89	1.2	1.4	0.68	448	74	36	0.46	0.85	50			
21	47-039-00205											1.5	2	pyrite - euhedra, framboids (spherical clusters), fine-grained "blebs", fossil replacement (bryozoans, sponge spicules, ostracodes); phosphatic fossil fragments (probably mostly fish fragments); sphalerite (?) - rare; silicified fossils - sponge spicules, bryozoans
22	47-039-03462	0.47	0.01	0.07	0.32	454	15	68	0.22	0.99	16			
22	47-039-03462											2	2.5	pyrite - fine-grained, euhedral, "spheres", replaced fossils (rods & spines; snail); zircons - pink; sphalerite - yellow-brown & pale yellow; glauconite; phosphate grains, steinkerns, & replaced fossils (indeterminate fragments, spines, etc.)
22	47-039-03462											2	2.5	pyrite - fine-grained, euhedral (minor), framboids, spheres; zircons - pink, abraded; phosphate grains & fossil fragments, replaced sponge spicules; sphalerite - pale yellow
22	47-039-03462											3.5	3.5	
23	47-043-01637	5.13	3.52	14.18	0.34	447	276	7	0.20	0.56	50			
23	47-043-01637											1.5	2	A.G. Harris (unpublished data)
23	47-043-01637											1.5	2	A.G. Harris (unpublished data)
24	47-043-01656	6.36	4.2	22.24	0.4	448	350	6	0.16	0.51	51			
25	47-045-00287	1.6	0.56	0.69	0.45	472	43	28	0.45	1.31	50			
25	47-045-00287											2.5	3	pyrite - fine-grained, euhedral, framboids, 1/4- to 1/2-mm spheres; fluorite (?) - clear; phosphate grains & fossils fragments; glauconite - sand-sized, minor; sphalerite - light yellow-brown
26	47-045-000864											2.5	2.5	pyrite - fine-grained, euhedral, framboids, parially replaced fossils (rods/spines); fluorite - root-beer brown; fluorite and/or barite - clear; sphalerite - yellow; miscellaneous fossils - echinoderm fragments
27	47-047-00031	0.99	0.21	0.07	0.39		7	39	0.75	2.16	50			
27	47-047-00031											3	3.5	
28	47-049-00244											3.5	4	pyrite - fine-grained, euhedral, 1/4- to 1/2-mm spheres, replaced fossils (spines, rods, steinkerns - snails, bivalves); fluorite - clear; sphalerite - trace, light yellow to yellow-orange
28	47-049-00244	1.38	0.31	0.05	0.16		4	12	0.86	1.84	18			
28	47-049-00244											4	4	pyrite - fine-grained, euhedral, framboids, replaced fossils (rods); sphalerite - pale yellow to yellow-orange; phosphate fossil fragments & phosphatized steinkerns - echinoderms, bryozoan zooecia, snails, brachiopods, spines), fluorite (?) - clear
28	47-049-00244											4	4.5	
29	47-051-00221	1.98	0.92	1.38	0.2	445	70	10	0.40	1.14	50			
29	47-051-00221											1.5	2	pyrite - framboids, spheroids; sphalerite - pale yellow
29	47-051-00221											2	2	pyrite - fine grained, euhedral (less common), framboid, 1/4- to 1/2-mm spheres; black metallic grains - magnetite?; sphalerite - pale yellow to yellow, common; phosphatic fossil fragments; zircons - pink, abraded
30	47-053-00069											1.5	1.5	pyrite - fine-grained, euhedral, framboids, spheres (1/4- to 1/2-mm), replaced fossils (spicules & rods); sphalerite - light yellow/brown, uncommon; phosphatic shell fragments - uncommon
31	47-053-00146									0.64				Streib (1981)
31	47-053-00146									0.61				Streib (1981)
31	47-053-00146									0.73				Streib (1981)
31	47-053-00146									0.58				Streib (1981)
31	47-053-00146									0.63				Streib (1981)
31	47-053-00146									0.63				Streib (1981)
31	47-053-00146									0.69				Streib (1981)
31	47-053-00146									0.65				Streib (1981)
31	47-053-00146									0.54				Streib (1981)
31	47-053-00146											1	1	A.G. Harris (unpublished data)
32	47-059-00805	3.03	0.26	2.3	0.77	440	76	25	0.10	0.72	48			

Table 3. Thermal Maturity (CAI, %Ro) and Rock Eval/TOC data from Ordovician and Devonian samples from the subsurface of West Virginia

ID #	API NUMBER	COUNTY	QUADRANGLE	LATITUDE (DEC DEG)	LONGITUDE (DEC DEG)	LEASE NAME	FORMATION	AGE	SAMPLE TYPE	START DEPTH OF INTERVAL SAMPLE	END DEPTH OF INTERVAL SAMPLE
32	47-059-00805	Mingo	Trace	37.904452	-82.169442	Columbia Gas (9674-T)	Onondaga	M.Devonian	cuttings	3600	3700
32	47-059-00805	Mingo	Trace	37.904452	-82.169442	Columbia Gas (9674-T)	Reedsville - Trenton - Black River	Ordovician	cuttings	5385	7800
33	47-059-00879	Mingo	Wilsondale	37.88306	-82.2625	Columbia Gas (20500-T)	Black River	Ordovician	cuttings	7000	7200
34	47-061-20370	Monongalia	Morgantown North	39.669167	-79.974167	No.1 MERC	Tully	M.Devonian	core	7179	7179
34	47-061-20370	Monongalia	Morgantown North	39.669167	-79.974167	No.1 MERC	Marcellus Sh	M.Devonian	core	7404	7404
34	47-061-20370	Monongalia	Morgantown North	39.669167	-79.974167	No.1 MERC	Marcellus Sh	M.Devonian	core	7414	7414
34	47-061-20370	Monongalia	Morgantown North	39.669167	-79.974167	No.1 MERC	Marcellus Sh	M.Devonian	core	7423	7423
34	47-061-20370	Monongalia	Morgantown North	39.669167	-79.974167	No.1 MERC	Marcellus Sh	M.Devonian	core	7434	7434
34	47-061-20370	Monongalia	Morgantown North	39.669167	-79.974167	No.1 MERC	Marcellus Sh	M.Devonian	core	7444	7444
34	47-061-20370	Monongalia	Morgantown North	39.669167	-79.974167	No.1 MERC	Marcellus Sh	M.Devonian	core	7452	7452
34	47-061-20370	Monongalia	Morgantown North	39.669167	-79.974167	No.1 MERC	Marcellus Sh	M.Devonian	core	7462	7462
34	47-061-20370	Monongalia	Morgantown North	39.669167	-79.974167	No.1 MERC	Marcellus Sh	M.Devonian	core	7472	7472
34	47-061-20370	Monongalia	Morgantown North	39.669167	-79.974167	No.1 MERC	Marcellus Sh	M.Devonian	core	7481	7481
34	47-061-20370	Monongalia	Morgantown North	39.669167	-79.974167	No.1 MERC	Marcellus Sh	M.Devonian	core	7492	7492
34	47-061-20370	Monongalia	Morgantown North	39.669167	-79.974167	No.1 MERC	Marcellus Sh	M.Devonian	core	7501	7501
35	47-061-00307	Monongalia	Masontown	39.56417	-79.873055	No.A-1 Clifford J. May	Marcellus Sh	M.Devonian	cuttings	7300	7440
35	47-061-00307	Monongalia	Masontown	39.56417	-79.873055	No.A-1 Clifford J. May	Helderberg	L.Devonian	cuttings	8020	8280
36	WVAC-1	Monroe	Paint Bank	37.607778	-80.266667	Joy Mfg. Co. No. WVAC-1	Black River	Ordovician	core	2998	2999
37	47-067-00052	Nicholas	Ansted	38.216669	-81.063332	No.1 Flynn Coal&Lumber	Marcellus Sh	M.Devonian	cuttings	5922	6089
37	47-067-00052	Nicholas	Ansted	38.216669	-81.063332	No.1 Flynn Coal&Lumber	Helderberg	L.Devonian	cuttings	6397	6500
38	47-067-00194	Nicholas	Nettie	38.178892	-80.647225	No.1-A New Gauley Coal	Marcellus Sh	M.Devonian	cuttings	7200	7380
38	47-067-00194	Nicholas	Nettie	38.178892	-80.647225	No.1-A New Gauley Coal	Helderberg	L.Devonian	cuttings	7595	7700
39	47-071-00001	Pendleton	Upper Tract	38.81111	-79.3625	Neil Harper 1	Trenton	Ordovician	cuttings	20	165
40	47-071-00006	Pendleton	Snowy Mountain	38.54805	-79.51278	Ray Sponaugle 1 (8800-T)	Trenton	Ordovician	cuttings	10040	10250
40	47-071-00006	Pendleton	Snowy Mountain	38.54805	-79.51278	Ray Sponaugle 1 (8800-T)	?	M.Ordovician	cuttings	700	1000
40	47-071-00006	Pendleton	Snowy Mountain	38.54805	-79.51278	Ray Sponaugle 1 (8800-T)	?	M.Ordovician	cuttings	10035	10380
40	47-071-00006	Pendleton	Snowy Mountain	38.54805	-79.51278	Ray Sponaugle 1 (8800-T)	?	M.Ordovician	cuttings	11475	11810
41	47-077-00086	Preston	Newburg	39.466669	-79.870278	No.A-1 H.G. Walls	Tully	M.Devonian	cuttings	7115	7185
41	47-077-00086	Preston	Newburg	39.466669	-79.870278	No.A-1 H.G. Walls	Marcellus-Hamilton	M.Devonian	cuttings	7185	7390
41	47-077-00086	Preston	Newburg	39.466669	-79.870278	No.A-1 H.G. Walls	Trenton	Ordovician	cuttings	14010	14195
42	47-081-00017	Raleigh	Arnett	37.830989	-81.473244	No.1 Rowland (GW-663)	Marcellus Sh	M.Devonian	cuttings	5656	5751
42	47-081-00017	Raleigh	Arnett	37.830989	-81.473244	No.1 Rowland (GW-663)	Helderberg	L.Devonian	cuttings	6042	6141
43	47-081-00036	Raleigh	Meadow Creek	37.786666	-80.916664	No.1 C. E. Gwinn (1115)	Rhinestreet	U.Devonian	cuttings	5900	6185
43	47-081-00036	Raleigh	Meadow Creek	37.786666	-80.916664	No.1 C. E. Gwinn (1115)	Onondaga-Helderberg	L.-M.Devonian	cuttings	6198	6395
44	n/a	Randolph	Elkins	38.998333	-79.841667	n/a	Tully	M.Devonian	outcrop	0	0
45	47-083-00102	Randolph	Mill Creek	38.696387	-79.9525	WV Board of Control (10182)	Helderberg	L.Devonian	cuttings	2950	3240
46	47-083-00103	Randolph	Mill Creek	38.707218	-79.96917	WV Board of Control (10228)	Chazy	Ordovician	core	12695.3	12695.3
46	47-083-00103	Randolph	Mill Creek	38.707218	-79.96917	WV Board of Control (10228)	Chazy	Ordovician	core	12721.5	12721.5
47	47-085-01894	Ritchie	Willow Island	39.252778	-81.2575	Leora A. Elliott (10160	Rhinestreet	U.Devonian	cuttings	4690	4800
47	47-085-01894	Ritchie	Willow Island	39.252778	-81.2575	Leora A. Elliott (10160	Onondaga	M.Devonian	cuttings	5290	5420

Table 3. Thermal Maturity (CAI, %Ro) and Rock Eval/TOC data from Ordovician and Devonian samples from the subsurface of West Virginia

ID #	API NUMBER	TOC	S1	S2	S3	Tmax	HI	OI	PI	% Ro(mean)	Number of Ro Readings	Min CAI	Max CAI	Comments Regarding CAI Mineralogy & Fossils
32	47-059-00805											1.5	2	pyrite - fine grained, euhedral, framboids & framboid clusters; phosphate grains, fossil fragments, partial steinkerns (bryozoans); sphalerite - yellow; zircons - pink, abraded
32	47-059-00805											2	2	A.G. Harris (unpublished data)
33	47-059-00879											1.5	2	A.G. Harris (unpublished data)
34	47-061-20370											3	3.5	A.G. Harris (unpublished data)
34	47-061-20370									2.47				Streib (1981)
34	47-061-20370									2.03				Streib (1981)
34	47-061-20370									2.39				Streib (1981)
34	47-061-20370									2.28				Streib (1981)
34	47-061-20370									2.29				Streib (1981)
34	47-061-20370									2.24				Streib (1981)
34	47-061-20370									2.29				Streib (1981)
34	47-061-20370									2.23				Streib (1981)
34	47-061-20370									2.36				Streib (1981)
34	47-061-20370									2.22				Streib (1981)
34	47-061-20370									2.43				Streib (1981)
35	47-061-00307	1.09	0.22	0.12	0.27	344	11	25	0.65	1.46	11			
35	47-061-00307											2	3	pyrite - fine-grained, spheres (1/4- to 1/2-mm); sphalerite - yellow-orange
36	WVAC-1											3.5	4	Ryder and others (1996)
37	47-067-00052	0.98	0.14	0.03	0.26		3	27	0.82	1.57	22			
37	47-067-00052											2.5	3	pyrite - fine-grained, framboids, replaced fossils (rods, reticulate meshworks); sphalerite - pale yellow; phosphatic steinkerns (bryozoans, spicules, etc.), fossil fragments, misc.
38	47-067-00194	2.61	0.43	0.28	0.79	347	11	30	0.61	1.76	21			
38	47-067-00194											3	3	pyrite - fine-grained, euhedral, spheres, framboid clusters, fossil replacement (spines/rods); sphalerite - yellow-reddish-orange-brown; phosphate grains, fossil fragments; zircons - pink, abraded
39	47-071-00001													
40	47-071-00006											4.5	4.5	pyrite - fine-grained, euhedral; fluorite - clear
40	47-071-00006											3.5	4	Harris, A.G., unpublished data
40	47-071-00006											4	4.5	Harris, A.G., unpublished data
40	47-071-00006											5	5	Harris, A.G., unpublished data
41	47-077-00086											4	4	pyrite - fine-grained, euhedral, framboids, replaced fossils (rods, spines); fluorite - clear; sphalerite - yellow
41	47-077-00086	1.43	1.59	2.14	0.4	384	150	28	0.43	1.6	50			
41	47-077-00086											4.5	5	
42	47-081-00017	0.72	0.15	0.07	0.22	336	10	31	0.68	1.94	21			N/A
42	47-081-00017											3.5	3.5	pyrite - fine-grained, mostly oxidized; phosphatic blebs, grains, & abraded miscellaneous fossil fragments; sphalerite - yellow-brown (uncommon); mica - rare, oxidized
43	47-081-00036	1.94	0.57	0.75	0.8	372	39	41	0.43	1.9	11			N/A
43	47-081-00036											4	4	pyrite - fine-grained, euhedral; spheres - framboids & framboid clusters, partially replaced fossil fragments; zircons - pink, abraded; spalerite - orange to yellow; phosphate grains - steinkerns (spines, sponge spicules)
44	n/a											2.5	2.5	A.G. Harris (unpublished data)
45	47-083-00102											2	2.5	
46	47-083-00103											2.5	3	pyrite - fine-grained, euhedral (rare), fossil spines/rods (rare); silicified tube (sponge?) weighted with pyrite (rare)
46	47-083-00103													pyrite - small euhedra, fine-grained; fine silt-sized dolomite; zircons - pink, rounded, detrital; unknown grains - clear, rounded
47	47-085-01894	0.87	0.52	0.77	0.24	448	89	28	0.40	0.85	68			
47	47-085-01894											2	2	pyrite - fine-grained, euhedral, framboids; phosphate grains & indeterminate fossil fragments; dolomite silt

Table 3. Thermal Maturity (CAI, %Ro) and Rock Eval/TOC data from Ordovician and Devonian samples from the subsurface of West Virginia

ID #	API NUMBER	COUNTY	QUADRANGLE	LATITUDE (DEC DEG)	LONGITUDE (DEC DEG)	LEASE NAME	FORMATION	AGE	SAMPLE TYPE	START DEPTH OF INTERVAL SAMPLE	END DEPTH OF INTERVAL SAMPLE
47	47-085-01894	Ritchie	Willow Island	39.252778	-81.2575	Leora A. Elliott (10160	Helderberg	L.Devonian	cuttings	5520	5700
48	47-087-00019	Roane	Gay	38.781388	-81.503891	J.W. Heinzman (4053)	Rhinestreet	U.Devonian	cuttings	4840	5200
48	47-087-00019	Roane	Gay	38.781388	-81.503891	J.W. Heinzman (4053)	Onondaga	M.Devonian	cuttings	5210	5380
48	47-087-00019	Roane	Gay	38.781388	-81.503891	J.W. Heinzman (4053)	Helderberg	L.Devonian	cuttings	5450	5600
48	47-087-00019	Roane	Gay	38.781388	-81.503891	J.W. Heinzman (4053)	Trenton	Ordovician	cuttings	8875	9055
49	47-087-00714	Roane	Clio	38.537562	-81.272982	No.2 Osborne (8100-T)	Rhinestreet	U.Devonian	cuttings	4440	4580
49	47-087-00714	Roane	Clio	38.537562	-81.272982	No.2 Osborne (8100-T)	Onondaga	M.Devonian	cuttings	5180	5320
49	47-087-00714	Roane	Clio	38.537562	-81.272982	No.2 Osborne (8100-T)	Helderberg	L.Devonian	cuttings	5420	5530
50	47-089-00005	Summers	Hinton	37.692503	-80.925004	Anchor Gas No.1 Ball	Marcellus Sh	M.Devonian	cuttings	6600	6710
50	47-089-00005	Summers	Hinton	37.692503	-80.925004	Anchor Gas No.1 Ball	Helderberg	L.Devonian	cuttings	7040	7150
51	47-093-00003	Tucker	Blackwater Falls	39.097781	-79.387497	No.1 (A-418) WVP&T Co.	Marcellus Sh	M.Devonian	cuttings	7701	7820
51	47-093-00003	Tucker	Blackwater Falls	39.097781	-79.387497	No.1 (A-418) WVP&T Co.	Helderberg	L.Devonian	cuttings	7900	8004
52	47-093-00013	Tucker	St. George	39.171666	-79.634446	USA No.C-1(GW-1215)	Marcellus Sh	M.Devonian	cuttings	2934	3287
52	47-093-00013	Tucker	St. George	39.171666	-79.634446	USA No.C-1(GW-1215)	Helderberg	L.Devonian	cuttings	3652	3774
53	47-099-00138	Wayne	Wayne	38.206113	-82.489167	No.2 Saunders	Huron-Rhinestreet	U.Devonian	cuttings	2285	3000
53	47-099-00138	Wayne	Wayne	38.206113	-82.489167	No.2 Saunders	Onondaga-Helderberg	L.-M.Devonian	cuttings	3301	3141
54	47-099-00162	Wayne	Louisa	38.037224	-82.517777	No.3 Glenhayes Co.(559)	Huron-Rhinestreet	U.Devonian	cuttings	2205	2897
54	47-099-00162	Wayne	Louisa	38.037224	-82.517777	No.3 Glenhayes Co.(559)	Onondaga-Helderberg	L.-M.Devonian	cuttings	2899	2999
55	47-099-00465	Wayne	Webb	37.892224	-82.39389	Caldwell No.42 (6181)	Rhinestreet	U.Devonian	cuttings	2956	3096.3
55	47-099-00465	Wayne	Webb	37.892224	-82.39389	Caldwell No.42 (6181)	Onondaga-Helderberg	L.-M.Devonian	cuttings	3108	3198
55	47-099-00465	Wayne	Webb	37.892224	-82.39389	Caldwell No.42 (6181)	Trenton	Ordovician	cuttings	5101	5272
56	47-103-20645	Wetzel	New Martinsville	39.67694	-80.82389	Emch and Pyles No.1	Marcellus Sh	M.Devonian	core	6599	6599
56	47-103-20645	Wetzel	New Martinsville	39.67694	-80.82389	Emch and Pyles No.1	Marcellus Sh	M.Devonian	core	6618	6618
57	47-105-00068	Wirt	Burning Springs	38.993055	-81.307779	No.500 Roberts	Rhinestreet	U.Devonian	cuttings	4400	4507
57	47-105-00068	Wirt	Burning Springs	38.993055	-81.307779	No.500 Roberts	Helderberg	L.Devonian	cuttings	5000	5135
58	47-107-00351	Wood	Willow Island	39.256945	-81.2725	Hope Nat Gas No.9634	Rhinestreet	U.Devonian	cuttings	3617	3714
58	47-107-00351	Wood	Willow Island	39.256945	-81.2725	Hope Nat Gas No.9634	Onondaga	M.Devonian	cuttings	4038	4078
58	47-107-00351	Wood	Willow Island	39.256945	-81.2725	Hope Nat Gas No.9634	Helderberg	L.Devonian	cuttings	5940	6100
58	47-107-00351	Wood	Willow Island	39.256945	-81.2725	Hope Nat Gas No.9634	Trenton	Ordovician	core	9532	9543.5
58	47-107-00351	Wood	Willow Island	39.256945	-81.2725	Hope Nat Gas No.9634	Beekmantown	Ordovician	core	10796	10796
59	47-107-00756	Wood	Rockport	39.080553	-81.508331	Exxon No.1 Deem	Rhinestreet	U.Devonian	cuttings	4650	4760

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ID #	API NUMBER	TOC	S1	S2	S3	Tmax	HI	OI	PI	% Ro(mean)	Number of Ro Readings	Min CAI	Max CAI	Comments Regarding CAI Mineralogy & Fossils
47	47-085-01894													pyrite - fine-grained; phosphatic grains & indeterminate fossil fragments; zircons - pink, abraded; indeterminate brownish-amber & clear abraded grains
48	47-087-00019	1.22	1.23	2	0.38	396	164	31	0.38	1.02	43			
48	47-087-00019											2	2	
48	47-087-00019											2	2.5	
48	47-087-00019											3	3	
49	47-087-00714	0.27	0.17	0.26	0.33	443	96	122	0.40	1.46	53			
49	47-087-00714											2	2.5	pyrite - fine-grained, euhedral, spheres, replaced fossils (spines & rods); phosphatic fossil fragments (types indeterminate); fluorite? - clear, uncommon; sphalerite - yellow & reddish-brown, uncommon
49	47-087-00714											2.5	2.5	pyrite - fine-grained, 1/4- to 1/2-mm spheres, framboids (individuals & clusters), replaced fossils (rods/tubes), minor euhedral; sphalerite - pale yellow to pale orange-yellow; unknown clear mineral grains
50	47-089-00005	0.34	0.09	0.12	0.22	354	35	65	0.43	3.19	44			
50	47-089-00005											4	4	pyrite - fine-grained, euhedral; phosphatic grains & fossil fragments & replaced fossils (echinoderm fragments); zircons - pink, abraded, fluorite? - clear
51	47-093-00003	1.85	0.38	0.3	0.35	345	16	19	0.56	2.94	40			
51	47-093-00003											3	3.5	
52	47-093-00013	1.28	0.43	0.38	0.35	403	30	27	0.53	2.21	48			
52	47-093-00013											3	3.5	
53	47-099-00138	2.14	0.95	4.96	0.49	432	232	23	0.16	0.88	48			
53	47-099-00138											1.5	1.5	pyrite - fine-grained, euhedral, framboids, sand-sized spheroids, spherical framboid clusters, replaced fossils (spines, rods); phosphate grains & occasional fossil fragments; sphalerite - yellow to yellow-orange; zircons - pink, abraded, uncommon; unknown clear minerals
54	47-099-00162	2.62	1.66	7.47	0.74	434	285	28	0.18	0.77	58			
54	47-099-00162											2	2.5	pyrite - fine-grained, euhedral, framboids (minor), replaced fossils (rods, spines, partially replaced ostracodes or mollusks), spheres; glauconite - uncommon; sphalerite - yellow; unknown black silvery metallic grains (rare); phosphatic partial steinkerns of bryozoan, etc.; zircons - pink, abraded
55	47-099-00465	1.51	0.59	2.71	0.34	438	179	23	0.18	0.75	58			
55	47-099-00465											1.5	2	
55	47-099-00465											1.5	2	
56	47-103-20645									1.62				Streib (1981)
56	47-103-20645									1.79				Streib (1981)
57	47-105-00068	1.09	0.35	0.96	0.23	446	88	21	0.27	0.9	37			
57	47-105-00068											2	2	
58	47-107-00351	1.85	0.69	2.57	0.48	448	139	26	0.21	0.92	50			
58	47-107-00351											2	2.5	
58	47-107-00351											2	2	pyrite - fine-grained, euhedral, occasional replaced fossils (spines, bryozoan zooecia, ostracode (?)); clear brown mineral - ankerite?, fluorite?; fluorite - clear; phosphatic shell fragments (uncommon); phosphatized echinoderm fragments (rare)
58	47-107-00351											3	3.5	phosphate fossil shell bits, vertebrate scale fragments; pyrite - fossil fragments, fine-grained; phosphate, pyrite & clay matrix bryozoans, brachiopods, sponges, ostracodes, gatropods (?); acicular barite (?) clumps
58	47-107-00351													pyrite - fine-grained, framboids; clear blocky mineral - possibly barite; fine dolomite rhombs, pyrite - framboids, fine-euhedral, fine-grained clumps; unknown clear grains including barite (?)
59	47-107-00756	0.61	0.03	0.29	0.42	443	48	69	0.09	1.11	17			

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ID #	API NUMBER	COUNTY	QUADRANGLE	LATITUDE (DEC DEG)	LONGITUDE (DEC DEG)	LEASE NAME	FORMATION	AGE	SAMPLE TYPE	START DEPTH OF INTERVAL SAMPLE	END DEPTH OF INTERVAL SAMPLE
59	47-107-00756	Wood	Rockport	39.080553	-81.508331	Exxon No.1 Deem	Onondaga	M.Devonian	cuttings	5020	5130
59	47-107-00756	Wood	Rockport	39.080553	-81.508331	Exxon No.1 Deem	Helderberg	L.Devonian	cuttings	5200	5310
59	47-107-00756	Wood	Rockport	39.080553	-81.508331	Exxon No.1 Deem	Trenton	Ordovician	cuttings	8550	8660
60	47-109-00016	Wyoming	Gilbert	37.538056	-81.753052	No.1 Gilbert (0168)	Marcellus Sh	M.Devonian	cuttings	5468	5554
60	47-109-00016	Wyoming	Gilbert	37.538056	-81.753052	No.1 Gilbert (0168)	Helderberg	L.Devonian	cuttings	5797	5887

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ID #	API NUMBER	TOC	S1	S2	S3	Tmax	HI	OI	PI	% Ro(mean)	Number of Ro Readings	Min CAI	Max CAI	Comments Regarding CAI Mineralogy & Fossils
59	47-107-00756											1.5	2	pyrite - fine-grained, euhedral, 1/4- to 1/2-mm spheres, replaced fossils (bivalves, sponge spicules?); sphalerite - yellow to yellow-orange
59	47-107-00756													pyrite - fine-grained, spheres, framboids, rare euhedral dodecahedral; sphalerite - pale yellow to light orange; fossil coral (?), steinkerns (rare); rare phosphatic shell fragments, phosphatic (?) glassy sand-sized beads - brown
59	47-107-00756											2	2.5	
60	47-109-00016	1.8	0.6	0.57	0.45	340	32	25	0.51	2.07	38			
60	47-109-00016											3	3	