American Metallurgical Coal Quality - A General Overview

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Massey Coal Export

Environments For Coal Formation - A General Consensus

Coal is a heterogeneous mixture of organically derived plant remains which have undergone chemical and physical changes in response to biologic and geologic processes. Nearly all coal scientists agree that coal formed in depressed areas in the earth in or near shallow water. To form coal, plant accumulation must exceed removal. The principal mechanism for removal is decay. Thus, the conditions for profuse plant growth and accumulation does not result in coal formation unless the biochemical environment into which the dead vegetable matter accumulates restricts removal or decay. As the plant material is buried and compacted, the rising water level restricts the activity of aerobic organisms. With the absence of atmospheric oxygen, anaerobic bacteria extract oxygen from the organic matter and the process of peat formation and subsequent coal formation begins. The difference in the original vegetation combined with the relative extent of aerobic (oxidizing) and anaerobic (reducing) decay may be largely responsible for differences in coal type or lithotypes.

Most coal deposits were formed in Parolic environments that were connected with the sea and transitional between marine and freshwater. Parolic coal deposits usually contain a large number of seams terminated by splitting and separated by occurrences of marine sediments which reflect their common association with coastal formations, marshes, coastal plains, deltas, lagoons and estuaries. Parolic coal deposits have great lateral extent, are relatively uniform in thickness, and often display petrographic variations in the seam profile. The two common sites for major parolic coalfield formation are in the foredeeps and on the shelf marginal to cratons. Limnic environments are also sites of coal formation where plant remains were deposited around the margins of lakes. Limnic environments are not directly connected to the sea and when hydrologically closed can develop at any altitude.

Extensive coal deposition did not begin before the Silurian since the abundant plant population required for coal formation was not established earlier. The amount and kinds of plants available for accumulation was partially determined by evolutionary changes and climatic conditions existing at the time but also by the development and distribution of soils and plant nutrients. For instance, low moors which have basic soils that commonly contain a greater variety of plant nutrients than high moors can support a more diverse and abundant vegetation. High moor peats are often associated with low PH environments and form coals that contain lower ash, sulfur, hydrogen, and nitrogen levels and low alkali and calcium contents in the ash forming minerals. Changes in groundwater conditions and humidity can cause low moors to change into high moors. The groundwater level affects both the biological environment in which plants grow and the biochemical environment in which the dead vegetation accumulates. Variations in the centimeter range of water level in a swamp can also cause lithotype changes. Variations in the decimeter range cause lateral migration of moor forces and inorganic detritus may cover the peat in some areas and not in others, while seam splitting may begin with a small cycle of transgression - immersion - regression that halts laterally at the axis of splitting. Variations in the meter range influence formation of or lack of deposition of a whole coal seam. Uneven subsidence alone can influence the water table level and consequently the peat accumulation in localized areas of a depositional basin.

Coal Formation in Appalachia

Tectonic Activity

Coals from the Appalachian region of the Eastern United States account for the majority of metallurgical production originating from America's vast coal reserve base. They were formed in moist tropical coal swamps which were located south of the paleoequator during the Pennsylvanian Period of Geologic time. These swamps formed an elongate slightly depressed wetland area trending NE - SW from New York state to Alabama and bordered on the west by coastal plains containing brackish waters, and on the east by lowlands which gradually graded into highlands further east. According to the "Collision model" proposed by Ziegler, et al (1979) the parent continent of the southern hemisphere referred to as Gondwana rotated clockwise and collided with this slowly emerging northern hemisphere continent of Laurasia causing the formation of highlands, such as the Appalachians east of the major coal forming regions.

Climate Conditions

Due to a combination of emergence (retreat of the seas) and barrier formation events (mountain building) climatic conditions were modified. Climatic changes in terms of relative wetness controlled the amount, kinds, and distribution of coal-swamp vegetation, peat accumulation and ultimately the amount of coal formed.

According to Phillips and Peppers (1984), the Pennsylvanian Period is divisible into five intervals based on relative wetness. Two dry periods, one in Lower Middle Pennsylvanian (Morrowan-Desmoinesian) and the other in Middle Upper Pennsylvanian (Desmoinesian-Missourian) separate the three wetter intervals into an Upper, Middle and Lower Series of coals. These periods of wetness and dryness for coal formation offer a means of grouping coal resources with similar origins. Each wet period was of a different magnitude but in general, each successive interval of coal formation was drier than the preceding period, but some individual seams in the succession were formed in wetter swamps such as the Pittsburgh coal.

Vegetation

The vegetation of the Pennsylvanian coal swamps consisted of a relatively small number of genera and species with long stratigraphic ranges. One or sometimes two communities dominated a peat swamp from which coal was formed. Frequently, these communities were repetitive and following an accumulation of clastic sediments the communities were reestablished to initiate the formation of the next coal seam.

Lycopods, tree ferns and calamites all of which are at least semi-aquatic/semi-woody lower vascular plants without seasonal dormancy dominated wetland swamps while pteridosperms, cordaites and conifers (gymnosperms) formed the principal forest vegetation of the lowlands and uplands. The former contributed proportionally very large amounts of root material to the peat, while the latter contributed more shoot and less roots, resulting in significant fusain accumulations. Lycopods completely dominated the Lower Pennsylvanian coal swamps in Appalachia and root material was more abundant. In the Lower-Middle Pennsylvanian transition, there was a fluctuation in the abundance of tree ferns, seed plants and small herbaceous plants. In the Middle-Upper Pennsylvanian transition, lycopods characteristic of the earlier Appalachian coal swamps became extinct and tree ferns were dominant in most of the last Pennsylvanian coal swamps. Coal resources diminished with loss of lycopod dominance at the Lower-middle Pennsylvanian boundary and with lycopod extinction during the Middle-Upper Pennsylvanian transition.

General Geology - Its Relation to Coal Quality[1]

In general, the Appalachian coals increase in rank from north to south and west to east. Generally, the coals increase in age from north to south. The inference is that older coals were buried deeper and were subjected to greater temperatures for longer times. The sulphur generally increases opposite to rank. The sulphur increases from south to north and from east to west. The sulphur is generally higher north of the Charleston sandstone which is frequently considered the dividing line between the northern high sulphur and southern low sulphur coals basins.

Grady (1979) divided coal seams of West Virginia into; lower, middle, and upper groups based on environmental interpretations. The lower extends from the Pocahontas No. 3 to the Sewell seam while the middle is from the Gilbert to the Cedar Grove seam and the upper is from both Upper and Middle Coalburg to the Upper Waynesburg, Figures 1 - 3. Coals of the upper half of the Pennsylvanian Period exhibit greater variation in maceral composition than those in the lower half. In general, mineral matter is more abundant in the upper half of the Pennsylvanian while inertinite and exinite are higher in the lower half.

High Vol Coal Quality (Tables 1 - 4, Figures 4 - 21)

The Pittsburgh seam is the most prolific, metallurgical producing horizon in the minable stratigraphic sequence of southwest Pennsylvania. Most Pittsburgh seam production originates from large steel company owned or operated underground mines situated in Allegheny, Greene, Washington, and Westmoreland counties of southwest Pennsylvania. Pittsburgh seam coals are generally moderate in ash (6.5%) and high in sulphur (1.45%). Their accessibility to water transportation and proximity to the Pittsburgh Steel producing region have made them a major high volatile blending component in many U.S. coking coal blends. Their exceptional fluid (27000+ ddpms), dilating (185%) and contracting (-24%) properties for their rank (0.87% mean max Ro) have also enhanced their use. Their low alkali (1.6% K2O) and inert content (20%) are also worthy of mention. Pittsburgh seam coals have also been known to produce moderately high coking pressures 1.4 - 1.5 PSI at 50 lbs/ft3 oven bulk density when carbonized in blends with 25% low volatile coal. Their high by-product yield also made Pittsburgh seam coal more attractive for use in coke production during the 1960's and 70's when hydrocarbon supplies were limited.

The only other major high volatile metallurgical producing seam in southwest Pennsylvania is the Freeport. The Freeport seam which is stratigraphically located below the Pittsburgh is understandably higher in rank (0.95% Ro). Like the Pittsburgh, the Freeport exhibits strong fluid (27000+ ddpms) and dilating (179%) characteristics and contains low inert content (18%). However, its higher float ash (7.5%) lower sulfur (0.90%) and relatively high alkali content (2.5% K2O) set it apart from the Pittsburgh. Sizable Freeport coal resèrves located in Southwest Pennsylvania will be the next generation of coal to be mined in the area for metallurgical use.

The Freeport seam possesses metallurgical characteristics over a wide geographic area in Northern Appalachia, extending from Southwest Pennsylvania, east into Central Pennsylvania and Western Maryland where it gradually increases to the rank of low vol and south into Northern West Virginia where it increases to the rank of borderline medium vol in Preston County and decreases back to high vol in Barbour and Upshur counties. The Kittanning seams just below the Freeport are often mined and prepared together with the Freeport in Central Pennsylvania and Northern West Virginia. These Freeport/Kittanning high volatile products originating in Barbour and Upshur counties West Virginia are comparable in rank (0.93% Ro) and contain similar ash (7.8%) and sulfur (0.90%) content to the Freeport produced in Southwest Pennsylvania. Their fluid (25000 ddpms) and dilating (176%) characteristics are also similar. Low alkali and (1.6% K2O) and moderately high inert content (28%) are also distinguishing features of the Freeport/Kittanning high vol production of northern West Virginia.

Moving further south into West Virginia, two distinct borderline high to medium volatile coal groups (1.09 - 1.11% Ro) exist in

Randolph, Webster, Fayette, Raleigh, and Wyoming counties of West Virginia. One consists of Upper and Lower Sewell production only and is concentrated in Nicholas, Randolph and Webster counties, while the other is comprised of #2 Gas (Campbell Creek), Powellton and Eagle seam production from Fayette, Raleigh, and Wyoming counties, West Virginia. Both product groups are relatively high in inert content 25 - 29% but the #2 Gas/Powellton/Eagle production group exhibits exceptionally good fluid (26000 ddpms) and dilating (270%) characteristics for its rank (1.09%), while the Sewell production group exhibits only moderate fluidity (12000 ddpms) and dilation (160%) for its rank (1.11% Ro). Most of the inerts present in the coals represented by both these groups consist of fine granular micrinite that is of less consequence when assessing the detrimental effects that high inert content has on coking properties. In addition, fine granular inerts are commonly associated with exinite or liptinite which can enhance fluid properties.

The product group comprised strictly of Upper and Lower Sewell requires further comment because the quality of the Upper and Lower Sewell seams are distinctly different. The Sewell B or Upper Sewell is generally higher in ash, lower in sulphur, higher in inert content and considerably more fluid, dilating and contracting than the Sewell A or Lower Sewell. However, since the two seams are often mined or blended together as a single product,the Sewell quality is fairly represented herein. The relatively low K2O and Fe2O3 contents of the Sewell seam products are also worth noting.

High volatile production from the Eagle and Peerless seams is concentrated in Nicholas and Kanawha counties West Virginia. Both product groups typically contain moderately low ash (5.4 - 6.0%) and sulfur (0.85 - 0.90%) contents and low P2O5 content (0.1 - 0.2%) for Appalachian coals. The fluidity (25000 - 27000 ddpms) and dilation (165 - 172%) of these product groups are similar to the typical values reported for Northern West Virginia Freeport/Kittanning products. The most notable difference in quality between the Eagle/Peerless seam production originating in Nicholas versus Kanawha counties is in petrographics with the rank of Nicholas coals (0.99 % Ro) being slightly higher than those produced in Kanawha (0.95% Ro) and the inert content of Nicholas coals (19%) being lower than those produced in Kanawha (25%).

In general, there is a gradual trend towards lower dilation, fluidity and contraction for high vol coals when moving south and west, from south central West Virginia to the western-most-metallurgical-producing counties of the eastern Kentucky coalfields. This trend is most evident when comparing high volatile coal quality of the Fayette/Raleigh/Wyoming and Nicholas/Kanawha groups to high volatile production, originating from the heart of southern West Virginia in Boone, Logan, and Mingo counties. Products originating from these areas exhibit only fair rheological properties by American standards with typical fluidities ranging from 17 - 20000 ddpms and dilation from 110 - 114%. Moving South from Boone through Logan and into Mingo County the rank of product gradually increases from 0.92% to 0.98% Ro while the typical inert content decreases from 29 to 23%. Although sulphur content is typically lower for coals produced in Logan County (0.74% average), there is substantial production in Mingo County from the Pond Creek and Alma seams which has sulfur contents below 0.70%. Also worth noting is the typically low Fe2O3 (6%) content of Logan County production and low P2O5 content (0.15%) of production from Logan and Mingo counties, West Virginia.

Moving further southwest into Pike County, Kentucky coking properties deteriorate further with one exception; the coking properties of the Alma, Pond Creek, Elkhorn, and Williamson seam production originating in the Southeast corner of Pike County is comparable to those products mined in Boone, Logan and Mingo counties. In fact, the typical quality is nearly identical to that produced in Mingo County, West Virginia that no further comment is necessary.

In the north central and northeast portions of Pike County, Kentucky there is substantial production of marginal coking high volatile coal which during periods of peak demand have even found a home with domestic steel producers. These products are very high in volatility (38%), low in rank (0.86% Ro), and typically exhibit poor fluidity (1700 ddpm) and dilation (20%). Their poor sole heated oven contraction (-10%) limit their use in conventionally charged coking coal blends to 15 - 20%. However, these coals have been used in much larger amounts in preheated blends. A very similar quality of poor or marginal coking high volatile coal is also produced in the adjacent counties bordering on all sides of Pike County. However, the sulphur content of these products is typically higher (1.02% versus 0.77%) than the marginal coking products originating from Pike. Harlan County, which is located in the extreme Southeast part of Kentucky and is adjacent to Lee and Wise counties, Virginia, supports production of fair coking high volatile coal. Like the other marginal coking high vol production in Kentucky, the typical Harlan production is also low in rank (0.87% Ro) and moderately high in ash content (6.8%). However, the fluidity (7000 ddpms), dilation (70%), and contraction (-14%) of the typical products produced in Harlan County is significantly better and as such can be used in greater amounts in coking coal blends. With the current excess of coking coal supply in the World today most of the Harlan County production has moved away from the metallurgical market into the Utility sector. This trend is likely to continue in the foreseeable future because of the increasing emphasis being placed on acid rain legislation and the efficient operation of existing Utility generating capacity.

In Virginia there are three primary high volatile qualities produced from Buchanan, Dickenson and Russell and Wise counties, Virginia. The typical rank (1.07% Ro) of the Buchanan and Dickenson county products is close to borderline high/medium while that of the typical Wise product is good coking high vol (0.97% Ro). All three qualities exhibit good typical fluidity (20000+ ddpms) and dilation (200%+) for their rank. The most noticeable difference in the Buchanan and Dickenson qualities is in their ash chemistry. Buchanan County coals, which are comprised primarily of Splashdam, Blair, Eagle, and Hagy seam production, are high in alkalis (2.5% K2O, 0.9% Na2O) while Dickenson/Russell county coals, which originate from the Tiller/Jawbone series of seams, are high in calcium oxide (9%) and moderately low in alkali especially K2O content (1.51%). The high calcium oxide in combination with a moderately high iron oxide content (11%) makes Dickenson/Russell county coals relatively low fusion by metallurgical standards. The low sulphur (0.67%) and high inert content (29%) of typical Dickenson/Russell county quality is also a distinguishing feature as is the relatively low inert content (22%) and good contraction properties (-25%) for Wise County production.

Although there is some high and borderline high/medium volatile production from the Sewanee seam in Tennessee the extent of production and recent redirection of same into the Utility market makes a discussion of this quality unnecessary.

Alabama is still a substantial producer of high volatile coking coal in southern Appalachia. The lower typical fluidity (13000 ddpms) dilation (145%) and contraction (-17%) for the typical rank (0.97% Ro) of high vol coal produced in Alabama is attributed to the abundance of surface mining activity or the shallow cover over deep mine production. The high iron (15%) and low inert content (19%) of Alabama coals make their resultant coke carbons or chars more reactive than normal for their rank.

Finally the high volatile coal produced in other locations in North America range from marginal coking in Illinois, Oklahoma, Utah and Colorado to fair coking in New Mexico. These coals have been used effectively in cokemaking in the U.S. for many years due to their proximity to the consuming locations. Western coals in Utah, Colorado and New Mexico have also been exported to Pacific rim countries for their consumption in briquette blending or other advanced cokemaking techniques where poor or non-coking coals are being used in the production of metallurgical coke.

Medium Vol Quality (Table 5, Figures 22 - 27)

Central Pennsylvania and Northern West Virginia medium volatile coals are produced from the Freeport and Kittanning seams which typically contain inherently high ash (8.5%) and sulphur (0.94%) contents. The low inert content (20%) of these coals contribute to their relatively high pressure (3.6 PSI) for their rank (1.22% Ro).

Typical Sewell and Fire Creek medium vol quality from Fayette and Greenbrier counties, West Virginia is low in ash (4.8%) and sulfur (0.80%) and moderate in fluidity (4000 ddpm) and dilation (153%) for its rank (1.29% Ro). The P2O5 content of these coals like those produced for the Gilbert and Red Ash seams in McDowell and Wyoming counties is relatively high at 0.7%. The Red Ash seam which is low ash (4%) and sulfur (0.7%) is blended with the Gilbert which is high ash (9%) and sulfur (1.00%) to produce a typically moderate ash (6.80%) and sulfur (0.90%) medium volatile product in McDowell and Wyoming counties, West Virginia. The high fluidity (10000 ddpm), dilation (200%) and good contraction (-5%) for this rank of medium volatile coal (1.22% Ro) make it an all purpose product for cokemaking. This product's low K2O content (1.5%) is also noteworthy.

The Bradshaw, Horsepen and Poca 4 - 12 seam production in McDowell County, West Virginia typically is low sulfur (0.70%), high in Fe2O3 (12%) and CaO (4.0%) and low in P2O5 (0.2%) content. It also exhibits moderately low fluidity (2500 ddpm) but is exceptionally contracting (-6%) for its rank (1.32% Ro). The high inert content (32%) helps moderate its pressure producing characteristics (2.4 PSI). This typical quality of medium vol spills over into Buchanan, Virginia where the Jewell, Jawbone, Kennedy Raven and Tiller seams combine for a high Fe2O3 (13%) and CaO (3.5%) in the ash. Inert content is once again moderately high 28% and pressure is relatively low (2.5 PSI) for the rank (1.28% Ro).

The Blue Creek medium vol of Alabama is unique for its relatively low Fe2O3 (8%) high CaO (4.8%) combination but more so for its low expanding (-8%) and pressure (2.0 PSI) producing characteristics for its rank (1.30% Ro). This products high moisture (9%), ash (8%), and relatively low total alkali content in the ash is also noteworthy.

The small amount of medium vol production outside of Appalachia originates from the Stigler seam in Oklahoma and the Placita V, B and A seams in Colorado. The high Fe2O3 (25%), CaO (21%), fluidity (11000 ddpms), dilation (212%) and low inert content (14%) of the Oklahoma Stigler product is noteworthy.

<u>Low Vol Quality</u> (Table 6, Figures 28 - 35)

The Freeport and Kittanning seams are the major low volatile metallurgical producing horizons in Central Pennsylvania and Western Maryland. The major difference between the typical product qualities from these two regions is as follows. Typical Western Maryland production is lower in ash (7.0% vs 8.2%) and higher in sulfur (1.1% vs 1.0%) than that originating from Central Pennsylvania. The fluidity (245 ddpms) dilation (80%) and sole heated oven expansion (+13%) for Western Maryland production is considerably higher than that found for central Pennsylvania products and high for the rank of coal (1.60% Ro) produced. The exceptionally low inert content (10%) of Maryland low vols account for its strong rheological characteristics. In contrast, high pressure generating capacity (14 PSI) is characteristic of Central Pennsylvania low vols. Maryland low vols are believed to be less pressure prone than Central Pennsylvania low vols because of their high fluid and dilating characteristics for their rank. Finally the high P2O5 content (0.7 - 0.9%) of both Central Pennsylvania and Western Maryland low vols is worthy of mention.

In West Virginia low vol can be categorized into four main categories as follows: Low Rank Beckley/Sewell, High Rank Beckley, High Rank Sewell, and High Rank Pocahontas. The lower rank variety (1.53% Ro) of Beckley and Sewell products are favored by furnace coke makers and particularly foundry coke makers in Western Europe because of their superior rheological properties which typically include high fluidity (600 ddpm) dilation (95%) and low expansion (+6%) and pressure (5 PSI) tendencies. Their low P2O5 content (0.2%) is also worthy of mention.

Of the three higher rank varieties the Sewell is typically lowest in ash (4%) followed by Beckley (5%) and Pocahontas (6%). Although most of the Sewell currently in production is typically lower in sulfur (0.70%) than most Pocahontas (0.77%) reserves there is considerable quantities of low sulfur Pocahontas for which sulfur levels of 0.58 - 0.65% are more characteristic. Beckley seam production on the other hand rarely falls below (0.70%).

Sewell production is typically highest in alkali and Pocahontas lowest. Sewell is highest in fluidity (131 ddpm) dilation (75%) and sole heated oven expansion (+12%) and Pocahontas lowest with 75 ddpms, 25% dilation and 6% expansion. Beckley seam is typically more pressure prone than Sewell or Pocahontas (13 vs 11 and 10 PSI, respectively). Finally, Sewell is lowest in rank (1.60% Ro) and inert content (22%) Beckley intermediate (1.63% Ro and 24% inerts) and Pocahontas highest in rank (1.64% Ro) and inert content (29%).

The typical Pocahontas 3 and 4 quality produced in Buchanan and Tazwell counties, Virginia is considerably lower in ash (4.5%) and inert content (22%) and higher in rank (1.68%) than its West Virginia counterpart. The high rank and low inert content contributes to their high expansion (+16%) and pressure generating (14 PSI) propensity. Perhaps more unique is the combination of high Fe2O3 (15%) and CaO (7.3%) content in the ash of these products. The exceptionally low P2O5 content (0.1%) for these coals is also noteworthy. Because of its comparable and unique ash chemistry one product produced in McDowell, West Virginia, was also grouped with Virginia Pocahontas production for establishing typical quality characteristics.

The Blue Creek low vol produced in the Warrior Basin of Alabama is typically high ash (8.2%) low sulfur (0.6%), low rank (1.52% Ro) and moderate in inert content (25%). Its typical high fluidity (500 ddpms) and dilation (73%) non expanding tendency (-1%) and low pressure (4 PSI) producing capacity make the Blue Creek a good base blend low volatile coal. The low iron (6%) moderately high CaO (3.4%) combination and moderately low alkali (1.8%) K2O, 0.5% Na2O) for the low vol production corresponds to the Blue Creek medium vol quality which is also produced in the Warrior Basin of Alabama. The combined attributes of the Blue Creek seam account for its ability to produce the lowest reactivity coke of any coal in North America.

Production of low volatile coal in Arkansas and Oklahoma has been limited by both geographic and quality constraints. The high Fe_2O_3 (15%), CaO (7.2%), P_2O_5 (1.0%) and pressure (17 PSI) typical of production from this area has limited its use in cokemaking.

Conclusions

From the foregoing discussions, it is clear that the variety of U.S. coal qualities found in Appalachia clearly emulate different combinations of depositional environments, plant development, and climate conditions existing at the time of their formation. A similar comparison of coal qualities can be made for the coal fields of the world and their similarities and differences explained in the context of the geologic and biologic processes prevalent at the time of their formation. For instance, there is considerable biological and paleontological evidence to suggest that during carboniferous time North America was joined to the Eurasian continent (Europe & Asia) while South America was joined to the bottom of the Southern Hemisphere with the Indian peninsula sandwiched between Africa and Australia (Gondwana). Furthermore, a cold, nearly glacial, climate condition apparently existed at this time in the Southern Hemisphere with a moist tropical one dominating in the Northern Hemisphere. The petrographic, chemical, and rheological similarities of coals being produced today from the continents that comprised these hemispheres support these positions. Perhaps some day the geologist and the coal technologist will devote the time necessary to piece the entire puzzle together that has been locked away in geologic time for over 300 million years.

References

1. Typical quality and ranges presented in this paper represent a consolidation of data by geographic region for U.S. metallurgical products that have been in production over the past 30 years.

West Virginia Description of Seams

Geologic Units	Seam Names	Production Area & Quality
Dunkard Group	Washington	
Mongahela Group	Waynesburg Uniontown Sewickley Redstone Pittsburgh	
Conemaush Group	Little Pittsburgh Little Clarksburgh Elk Lick Harlem Upper Bakerstown Bakerstown Brush Creek Mahoning	PA and MD High Med and Low Northern WV High (Barbour, Upshur) and Med (Preston)
Allegheny Formation	Upper Freeport Lower Freeport Upper Kittanning Lower Kittanning Clarion, No. 5 Block	

FIGURE 1

West Virginia Description of Seams

Geologic Units	Seam Names	Production Area & Quality
Kanawha Formation	Upper Mercer	
	Stockton - Lewiston	
	Coalburg	
	Buffalo Creek	
	Winifrede	
	Chilton "A"	West Central &
	Chilton	Southern WV, High
	Hernshaw	(Nicholas, Kanawha,
	Dingess	Boone, Logan, Mingo)
	Williamson	
	Cedar Grove	
	Lower Cedar Grove	
	Alma	
	Peerless	
	Campbell Creek	
	Campbell Ck (#2 Gas)	
	Powellton	
	Matewan	
	Eagle	
	Bens Creek	Central WV
	Little Eagle	High & Med
	Cedar	(Nicholas, Randolph,
	Lower War Eagle	Webster, Fayette,
	Glenalum Tunnel	Raleigh, Greenbrier)
	Gilbert	& Southern WV Med and
	Douglas	Low (Raleigh, Wyoming,
	Lower Douglas	McDowell)
New River Formation	Iaeger	
	Castle	
	Sewell "B"	
	Sewell	
	Welch	
	Little Raleigh	
	Beckley	
	No. 9 Pocahontas	
	No. 8 Pocahontas	
Pocahontas	No. 7 Pocahontas	
	No. 6 Pocahontas	
	No. 5 Pocahontas	
	No. 4 Pocahontas	
	No. 3 Pocahontas	
	No. 2 Pocahontas	

FIGURE 2

Virginia Description of Seams

Geologic Units	Seam Names	Production Area & Quality
Wise Formation	High Splint	
	Morris	
	Pardee	
	Wax	
	Phillips	
	Low splint	
	Taggart	
	Kirk	
	Harlan/Up.Standiford	VA High (Wise)
	Cedar Grove	
	Lower St. Charles	
	Pinhook	
	Kelly	
	Imboden/Campbell Creek	
	Clintwood	
	Eagle	
	Blair	
	Lyons	
	Dorchester	
Norton Formation	Norton	
	Hagy	
	Splashdam	
	Upper Banner	VA High and Med
	Lower Banner	(Buchanan, Dickenson,
	Big Fork	Russell, Tazwell)
	Kennedy	
	Aily	
	Raven	
	Jawbone	
	Tiller	
Lee Formation	Upper Seaboard	
	Greasy Creek	
	Middle Seaboard	
	Lower Seaboard	
	Upper Horsepen	
	Middle Horsepen	
	"C"	
	War Creek	
	Lower Horsepen	
	Pocahontas #9	
	Pocahontas #8	
Pocahontas Formation	Pocahontas #7	
	Pocahontas #6	
	Pocahontas #5	
	Pocahontas #4	VA Low (Buchanan)
	Pocahontas #3	
	Pocahontas #2	
	Pocahontas #1	

FIGURE 3

County(s)/ State(s) Seams(s)	Allegheny, PA Greene, PA Washington, PA Westmoreland, PA Pittsburgh	
Volatile	37	36 - 38
Ash	6.5	5.5 - 7.0
Sulfur	1.45	1.3 - 1.6
Fe2O3	14	11 - 17
CaO	2.4	1.7 - 3.4
K2O	1.6	1.0 - 1.8
Na2O	0.6	0.3 - 0.8
P2O5	0.5	0.3 - 0.7
DDPM's	27000	17 - 28+(000)
% Dilation	185	164 - 200
Con/Exp	-24	-13 - (-30)
Pressure	NA	
Ro	0.87	0.83 - 0.91
Inerts	20	18 - 23

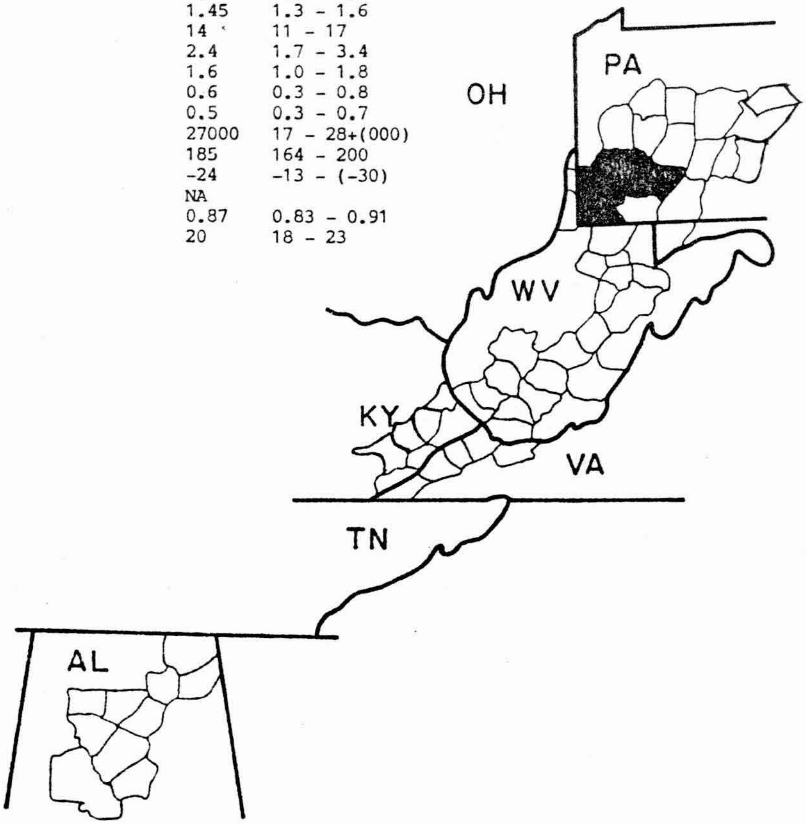

FIGURE 4

County(s)/ State(s) Seams(s)	Allegheny, PA Armstrong, PA Greene, PA Washington, PA Freeport	
Volatile	35	34 - 37
Ash	7.5	7 - 8
Sulfur	0.90	0.7 - 1.0
Fe2O3	8	4 - 12
CaO	2.1	1.2 - 3.0
K2O	2.5	2.0- 3.2
Na2O	0.7	0.5 - 1.1
P2O5	0.7	0.5 - 1.0
DDPM's	27000	25 - 28+(000)
% Dilation	179	150 - 196
Con/Exp	-19	-16 - (-21)
Pressure	NA	
Ro	0.95	0.93 - 0.98
Inerts	18	15 - 20

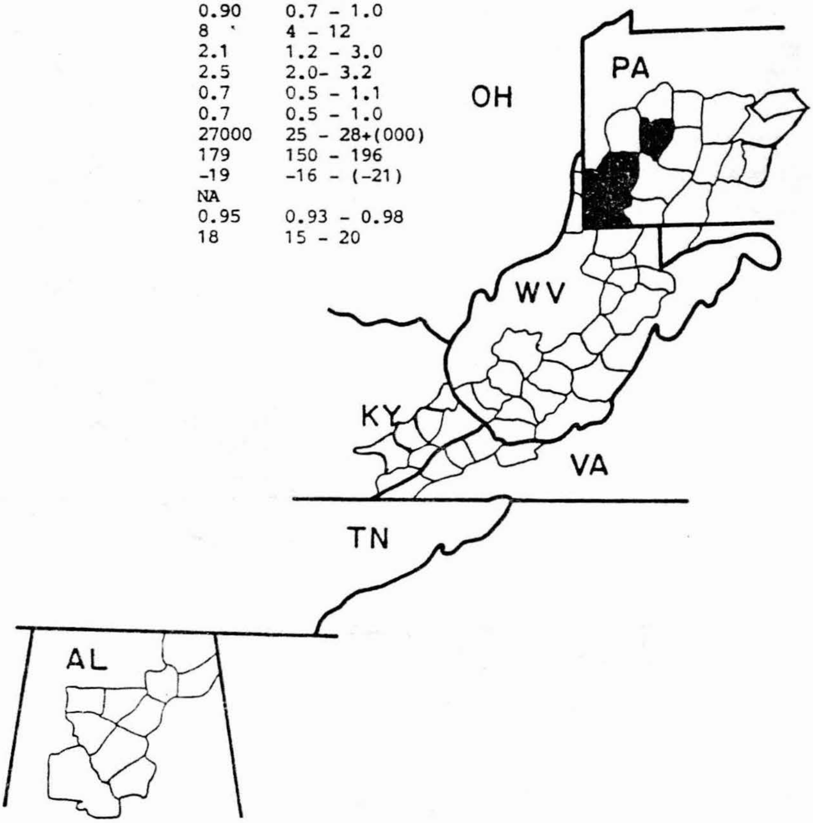

FIGURE 5

County(s)/ State(s) Seams(s)	Barbour, WV Upshur, WV Freeport Kittanning	
Volatile	35	33 - 37
Ash	7.8	6 - 9
Sulfur	1.0	0.8 - 1.3
Fe2O3	10	6 - 13
CaO	3	1.9 - 4.9
K2O	1.6	1.1- 2.3
Na2O	0.4	0.3 - 0.6
P2O5	0.5	0.15 - 0.8
DDPM's	25000	20 - 28+(000)
% Dilation	176	80 - 300
Con/Exp	-25	-16 - (-35)
Pressure	NA	
Ro	0.93	0.85 - 1.02
Inerts	28	18 - 37

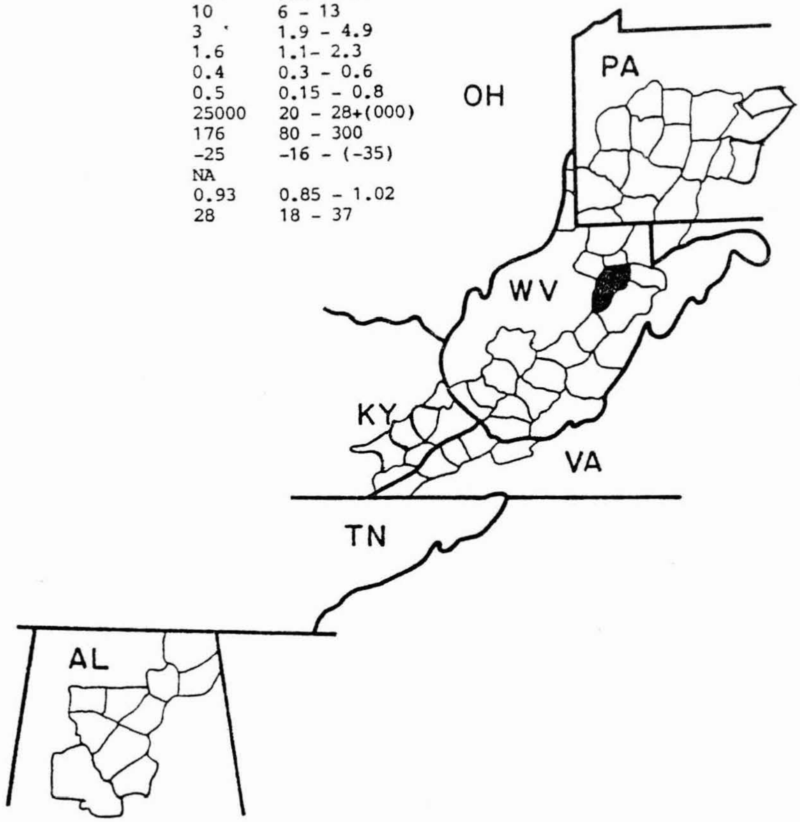

FIGURE 6

County(s)/ State(s) Seams(s)	Nicholas, WV Randolph, WV Webster, WV Upper Sewell Lower Sewell	
Volatile	30	29 - 31
Ash	6.8	5.0 - 9.5
Sulfur	0.76	0.5 - 1.1
Fe2O3	6	5 - 10
CaO	2.3	1.6 - 3.0
K2O	1.8	1.1 - 2.7
Na2O	0.7	0.3 - 1.4
P2O5	0.5	0.25 - 1.5
DDPM's	12000	6 - 25(000)
% Dilation	160	125 - 220
Con/Exp	-16	-10 - (-23)
Pressure	NA	
Ro	1.11	1.04 - 1.15
Inerts	29	20 - 40

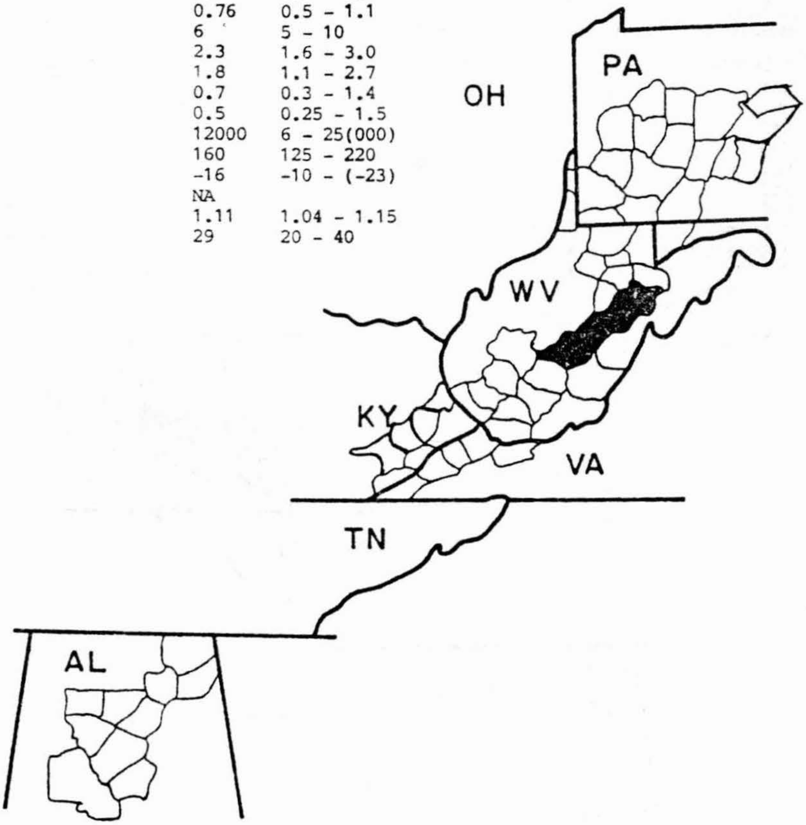

FIGURE 7

County(s)/ State(s) Seams(s)	Fayette, WV Raleigh, WV Wyoming, WV #2 Gas Campbells Creek Eagle Lower War Eagle Peerless Powellton	
Volatile	31	28.5 - 33.5
Ash	5.9	4.5 - 7.0
Sulfur	0.88	0.7 - 1.2
Fe2O3	9	5 - 20
CaO	1.4	0.7 - 3.0
K2O	2.3	1.3 - 2.9
Na2O	0.6	0.3 - 1.1
P2O	0.3	0.1 - 0.7
DDPM's	26000	20 - 28+(000)
% Dilation	270	175 - 300+
Con/Exp	-16	-4 - (-30)
Pressure	NA	
Ro	1.09	1.01 - 1.19
Inerts	25	19 - 34

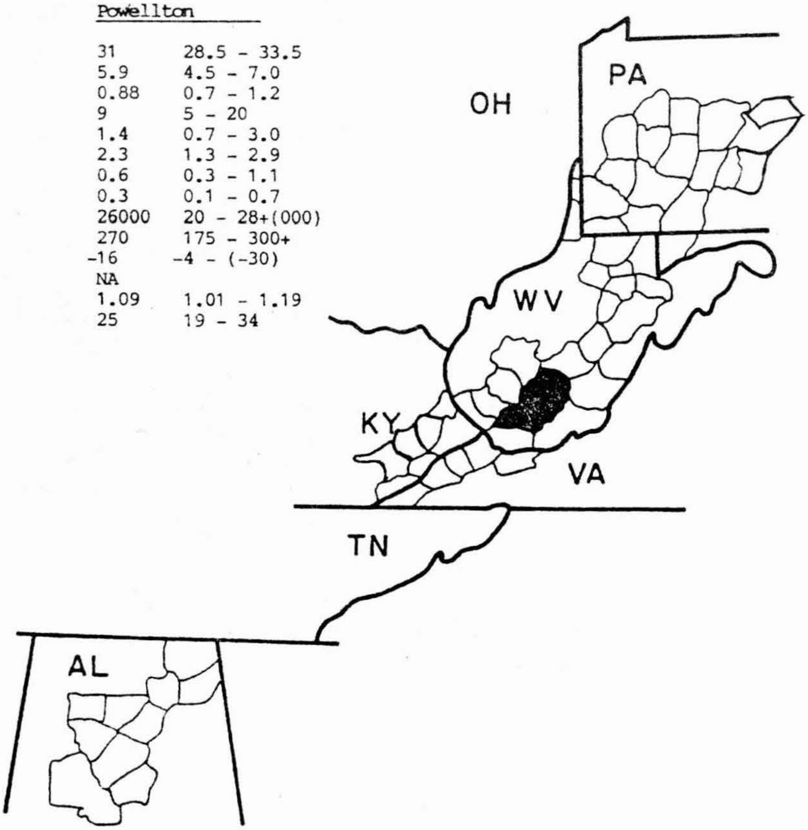

FIGURE 8

County(s)/ State(s) Seams(s)	Nicholas, WV Eagle Peerless	
Volatile	35	34 - 35.5
Ash	5.4	5.3 - 5.5
Sulfur	0.85	0.8 - 0.9
Fe2O3	7	6 - 8
CaO	1.7	1.4 - 1.9
K2O	2.3	2.1 - 2.5
Na2O	0.7	0.6 - 0.9
P2O5	0.2	0.1 - 0.3
DDPM's	27000	25 - 28+(000)
% Dilation	172	153 - 190
Con/Exp	-17	-14 - (-20)
Pressure	NA	
Ro	0.99	0.97 - 1.00
Inerts	19	17 - 22

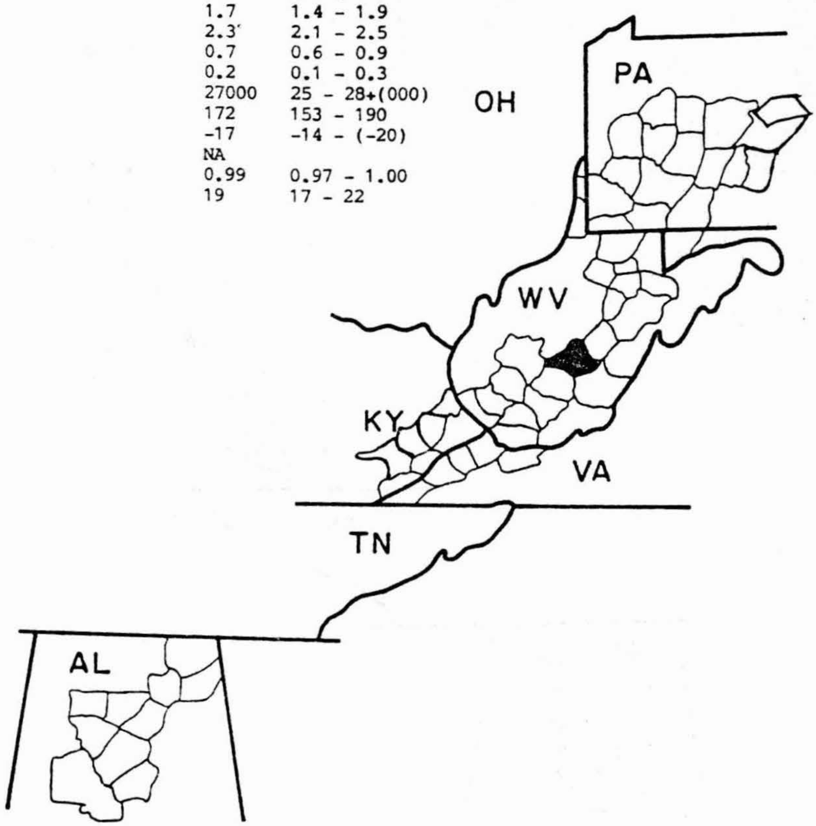

FIGURE 9

County(s)/ State(s) Seams(s)	Kanawha, WV #2 Gas, Eagle, Peerless	
Volatile	36	34 - 39
Ash	6.0	5 - 7
Sulfur	0.90	0.75 - 1.15
Fe2O3	9	6 - 12
CaO	1.5	0.9 - 2.3
K2O	2.2	1.8 - 2.5
Na2O	0.7	0.5 - 1.2
P2O5	0.1	0.07 - 0.13
DDPM's	25000	5 - 28+(000)
% Dilation	165	50 - 250
Con/Exp	-20	-15 - (-27)
Pressure	NA	
Ro	0.95	0.87 - 1.02
Inerts	25	21 - 27

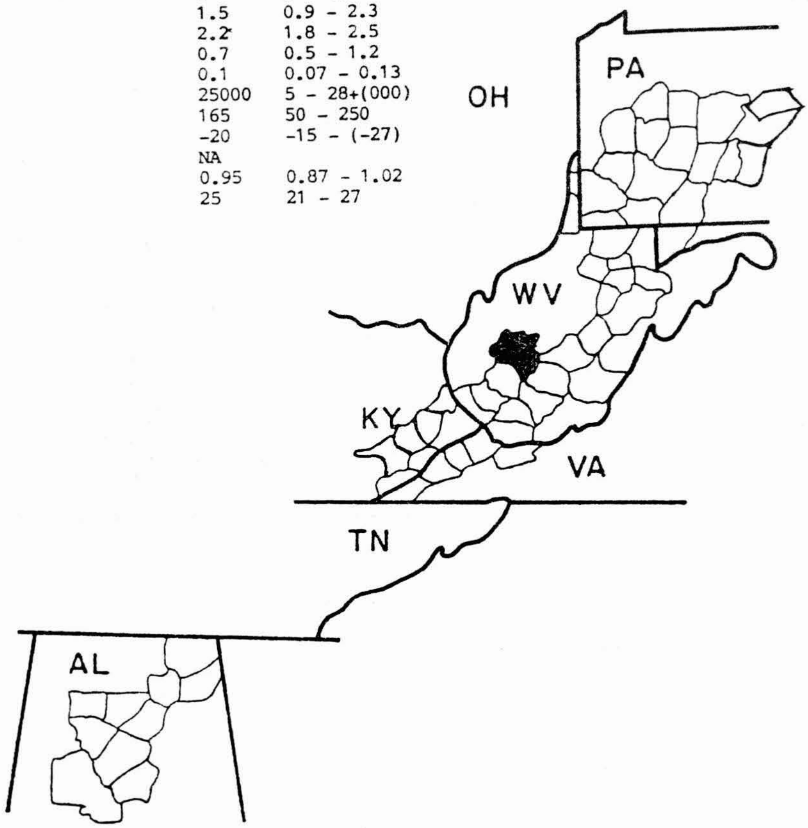

FIGURE 10

County(s)/ State(s) Seams(s)	Boone, WV Cedar Grove, Dorothy Hernshaw, Winifrede	
Volatile	36	34 - 39
Ash	5.8	5 - 7
Sulfur	0.82	0.7 - 1.0
Fe2O3	6.5	4 - 10
CaO	1.5	0.8 - 2.1
K2O	1.9	1.1 - 2.1
Na2O	0.6	0.3 - 1.3
P2O5	0.3	0.1 - 1.0
DDPM's	17000	1 - 28+(000)
% Dilation	112	10 - 205
Con/Exp	-18	-11 - (-30)
Pressure	NA	
Ro	0.92	0.84 - 1.02
Inerts	29	19 - 39

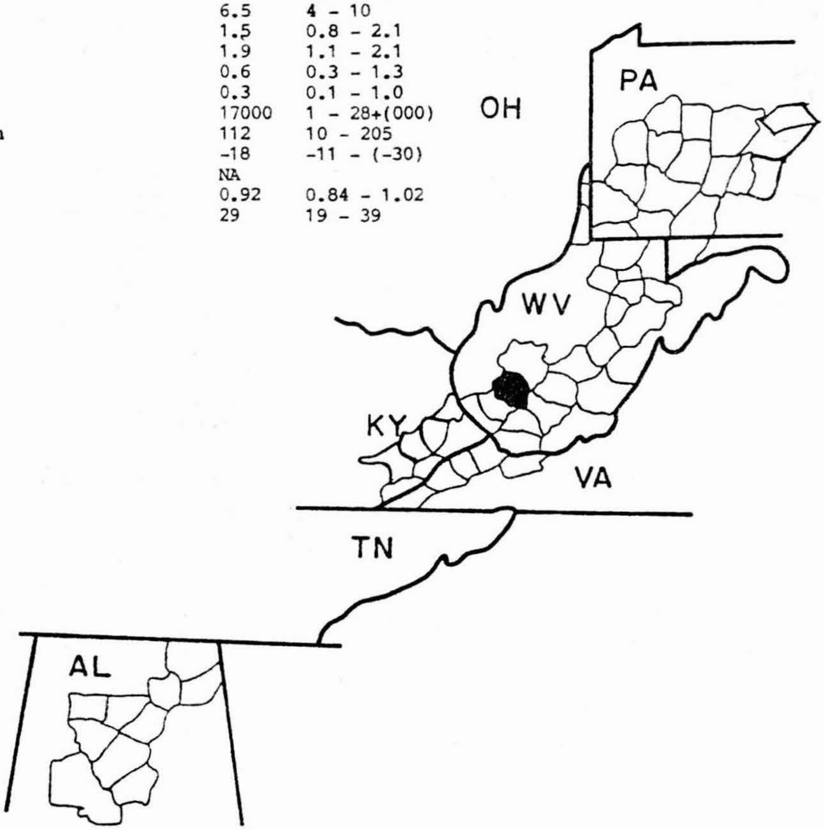

FIGURE 11

County(s)/ State(s) Seams(s)	Logan, WV #2 Gas, Alma, Cedar Grove, Chilton, Pond Ck.	
Volatile	35.5	34 - 37.5
Ash	6.0	5 - 9
Sulfur	0.74	0.6 - 0.9
Fe2O3	6	3 - 8
CaO	2.0	0.7 - 2.9
K2O	2.1	1.3 - 3.6
Na2O	0.7	0.4 - 1.0
P2O5	0.14	0.03 - 0.3
DDPM's	20000	9 - 28+(000)
% Dilation	114	73 - 204
Con/Exp	-19	-13 - (-27)
Pressure	NA	
Ro	0.95	0.91 - 1.00
Inerts	28	20 - 35

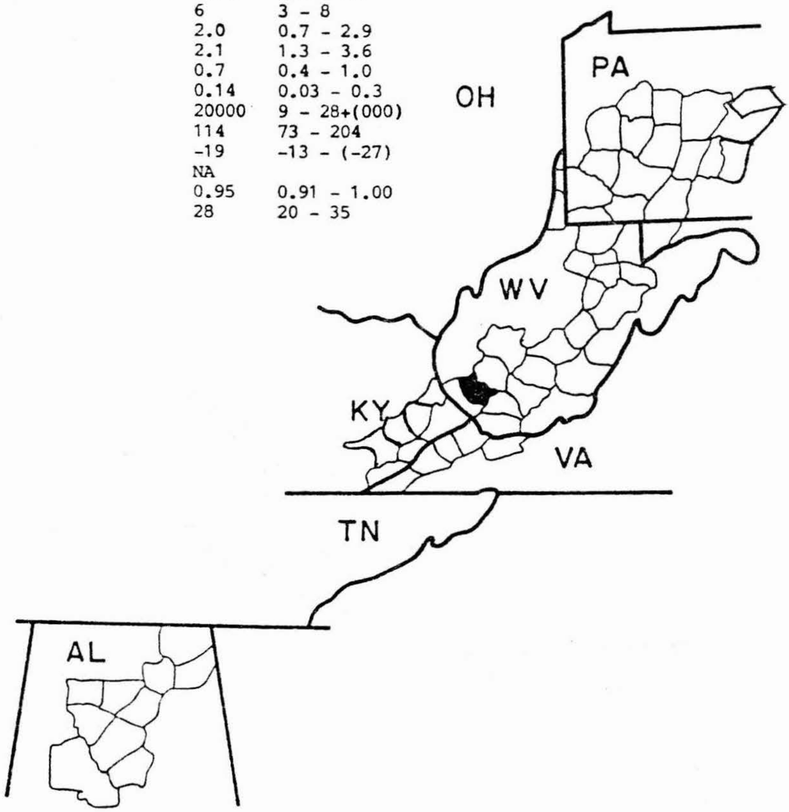

FIGURE 12

County(s)/ State(s)	Mingo, WV	
Seams(s)	Alma, Pond Ck.	
Volatile	35.5	35 - 36
Ash	6.1	5 - 8
Sulfur	0.84	0.6 - 1.2
Fe2O3	8	6 - 10
CaO	1.4	1.3 - 1.5
K2O	2.4	2.2 - 2.6
Na2O	0.7	0.5 - 0.9
P2O5	0.16	0.1 - 0.2
DDPM's	18000	15 - 23(000)
% Dilation	110	103 - 170
Con/Exp	-18	-17 - (-18)
Pressure	NA	
Ro	0.98	0.96 - 0.99
Inerts	23	19 - 25

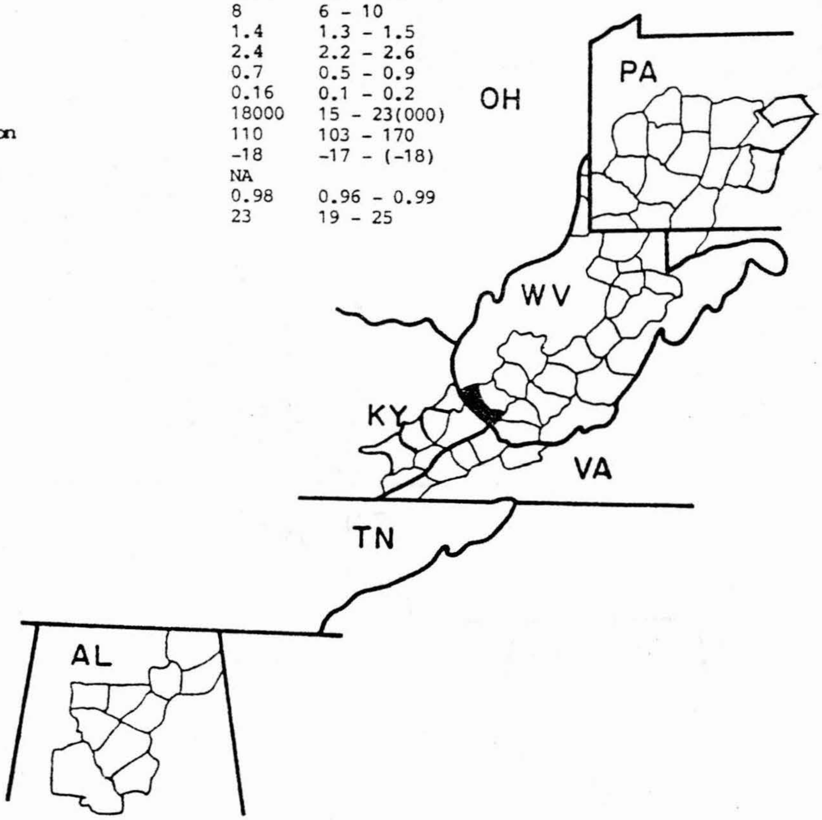

FIGURE 13

County(s)/ State(s) Seams(s)	Pike, KY Alma, Elkhorn, Pond Ck., Williamson	
Volatile	34.5	33 - 37
Ash	6.1	5.0 - 7.5
Sulfur	0.74	0.55 - 1.25
Fe2O3	7	5 - 12
CaO	1.3	1.1 - 1.6
K2O	2.2	2.1 - 2.6
Na2O	0.8	0.5 - 1.1
P2O5	0.2	0.05 - 0.5
DDPM's	20000	7 - 28(000)
% Dilation	120	95 - 165
Con/Exp	-21	-13 - (-35)
Pressure	NA	
Ro	0.98	0.88 - 1.04
Inerts	27	20 - 35

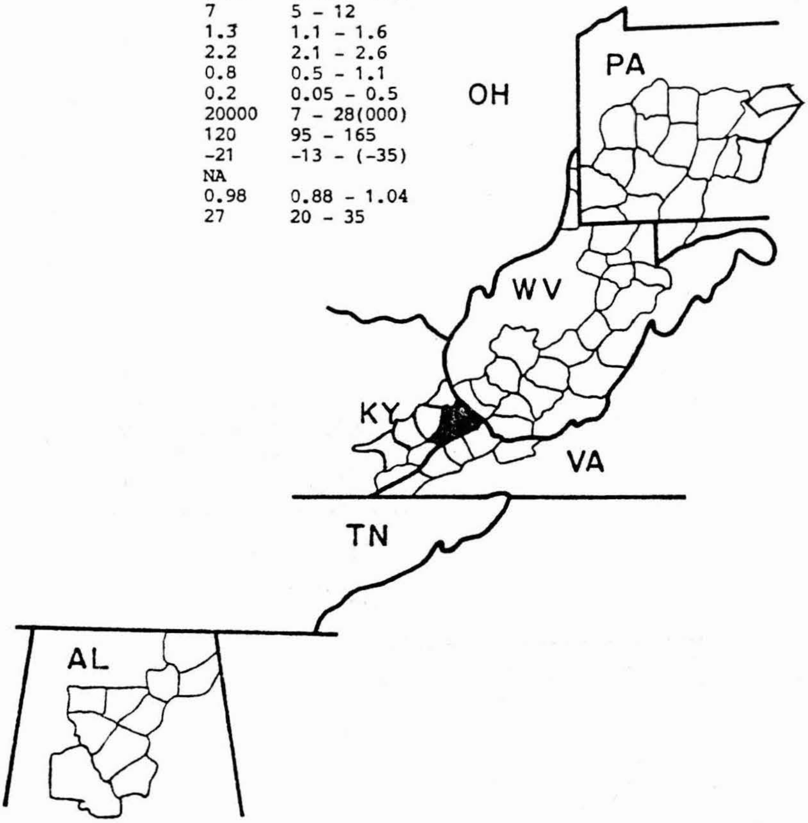

FIGURE 14

County(s)/ State(s) Seams(s)	Pike, KY Elkhorn Pond Creek	
Volatile	38	36 - 40
Ash	6.7	6.0 - 8.5
Sulfur	0.77	0.6 - 1.15
Fe2O3	6	4 - 8
CaO	2.1	1.3 - 3.0
K2O	2.3	1.8 - 3.0
Na2O	0.7	0.6 - 1.0
P2O5	0.15	0.08 - 0.20
DDPM's	1700	600 - 4000
% Dilation	20	-10 - 55
Con/Exp	-10	-7 - (-12)
Pressure	NA	
Ro	0.86	0.77 - 0.93
Inerts	24	19 - 36

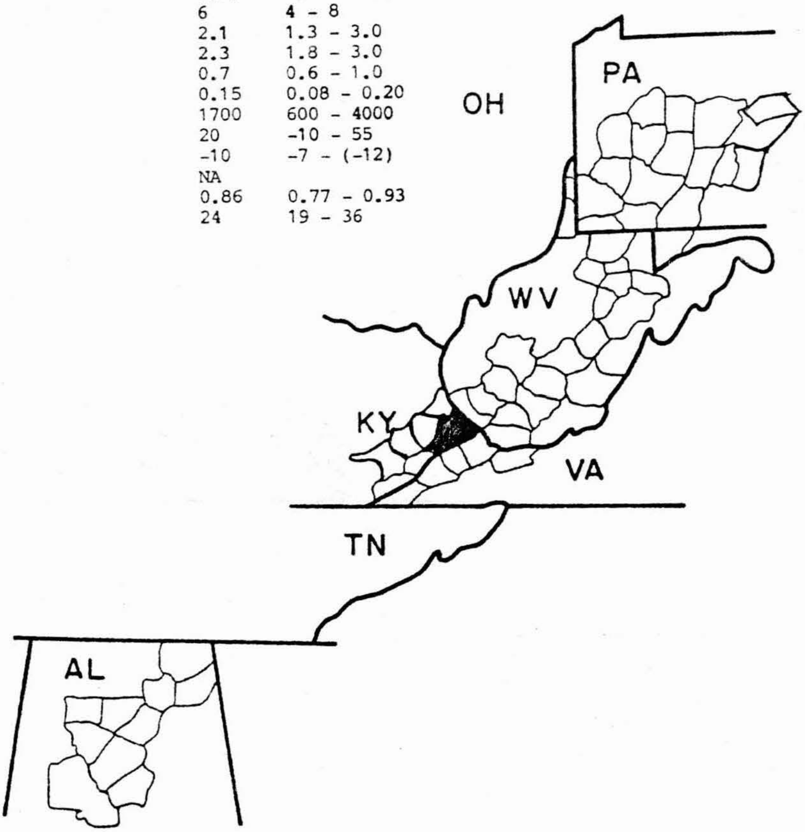

FIGURE 15

County(s)/ State(s) Seams(s)	Floyd, Knott Letcher, Martin Perry, KY Elkhorn, Hazard Pond Creek	
Volatile	38	36 - 40
Ash	6.6	4 - 10
Sulfur	1.02	0.7 - 1.7
Fe2O3	10	5 - 17
CaO	2.5	1 - 4.7
K2O	1.9	1.1 - 3.0
Na2O	0.7	0.4 - 1.0
P2O5	0.4	0.1 - 1.4
DDPM's	1500	100 - 3500
% Dilation	28	-18 - +67
Con/Exp	-10	-5 - (-14)
Pressure	NA	
Ro	0.84	0.74 - 0.93
Inerts	26	19 - 35

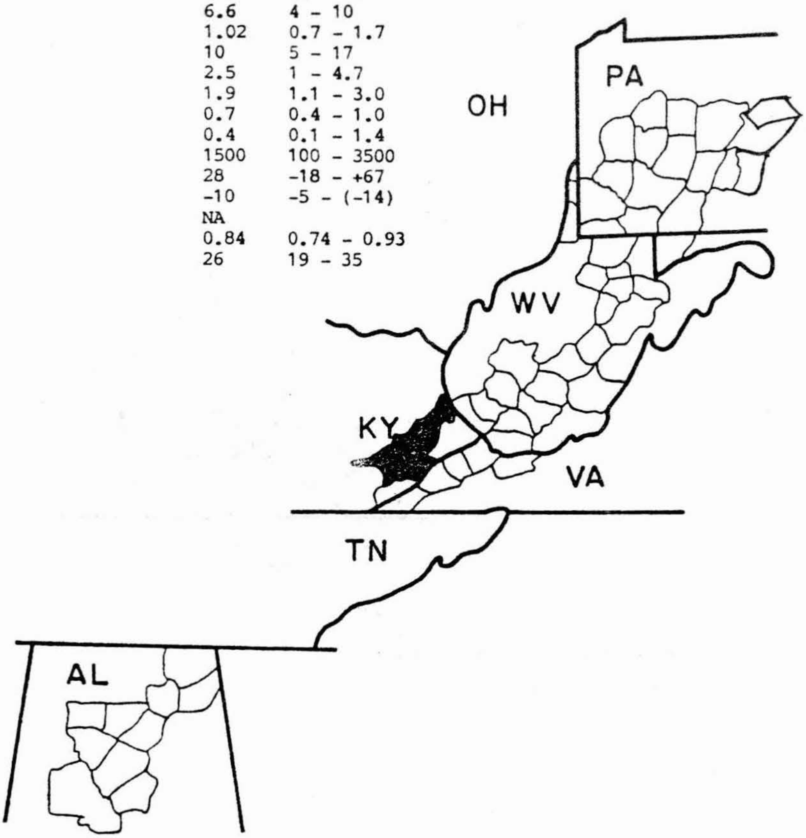

FIGURE 16

County(s)/ State(s) Seams(s)	Harlan, KY E, D, A, Darby, Harlan, High Splint	
Volatile	37.5	35 - 39
Ash	6.8	4 - 8
Sulfur	0.9	0.65 - 1.50
Fe2O3	10	4 - 17
CaO	1.5	1 - 3
K2O	2.1	1.3 - 3.9
Na2O	0.5	0.3 - 0.7
P2O5	0.4	0.1 - 0.7
DDPM's	7000	150 - 21000
% Dilation	70	30 - 125
Con/Exp	-14	-11 - (-29)
Pressure	NA	
Ro	0.87	0.80 - 0.91
Inerts	23	16 - 32

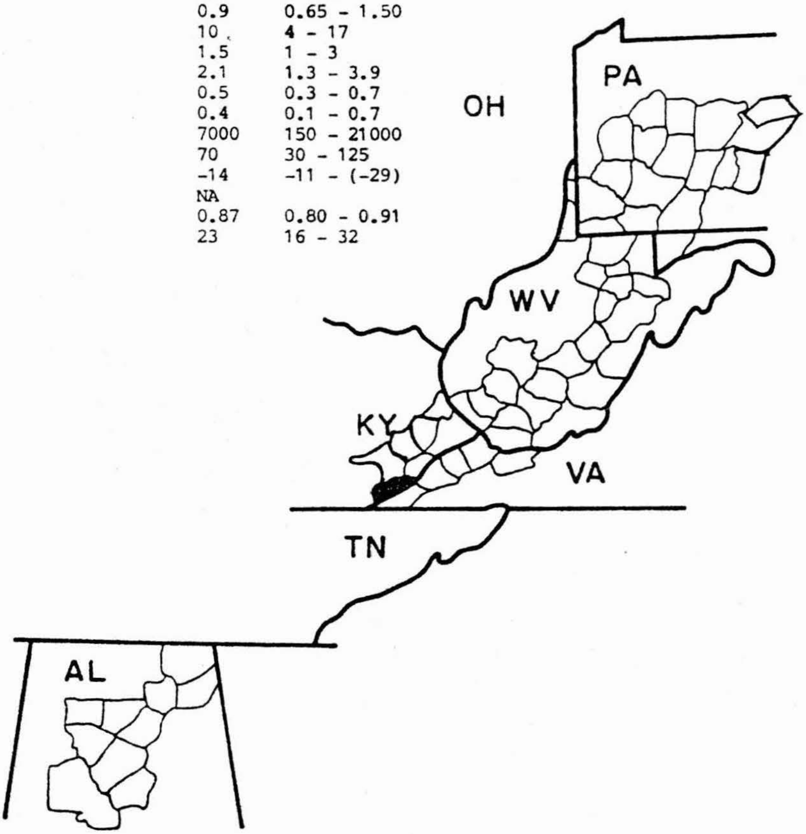

FIGURE 17

County(s)/ State(s) Seams(s)	Buchanan, VA Blair, Clintwood Eagle, Hagy Splashdam	
Volatile	31	29 - 31
Ash	5.7	5.0 - 6.5
Sulfur	0.87	0.80 - 0.95
Fe2O3	10	7 - 16
CaO	2.1	1 - 6
K2O	2.5	1.6 - 3.6
Na2O	0.9	0.3 - 1.1
P2O5	0.3	0.1 - 0.5
DDPM's	21500	11 - 28+(000)
% Dilation	215	185 - 295
Con/Exp	-21	-11 - (-29)
Pressure	NA	
Ro	1.07	1.02 - 1.11
Inerts	24	15 - 32

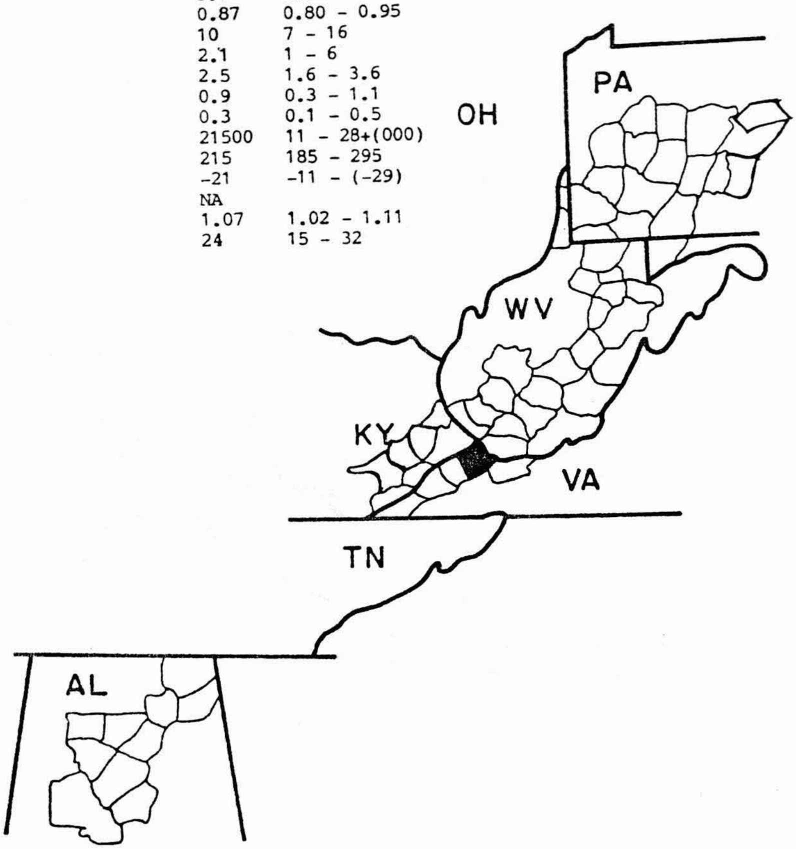

FIGURE 18

County(s)/ State(s) Seams(s)	Dickenson, VA Russell, VA Jawbone, Kennedy, Raven, Tiller	
Volatile	32	31.5 - 32.5
Ash	5.9	5.5 - 6.5
Sulfur	0.67	0.60 - 0.75
Fe2O3	11	10 - 12
CaO	8.6	4 - 13
K2O	1.5	1.1 - 1.8
Na2O	0.8	0.7 - 0.9
P2O5	0.14	0.06 - 0.25
DDPM's	22000	18 - 26
% Dilation	212	171 - 293
Con/Exp	-16	-15 - (-17)
Pressure	NA	
Ro	1.07	1.06 - 1.08
Inerts	29	26 - 31

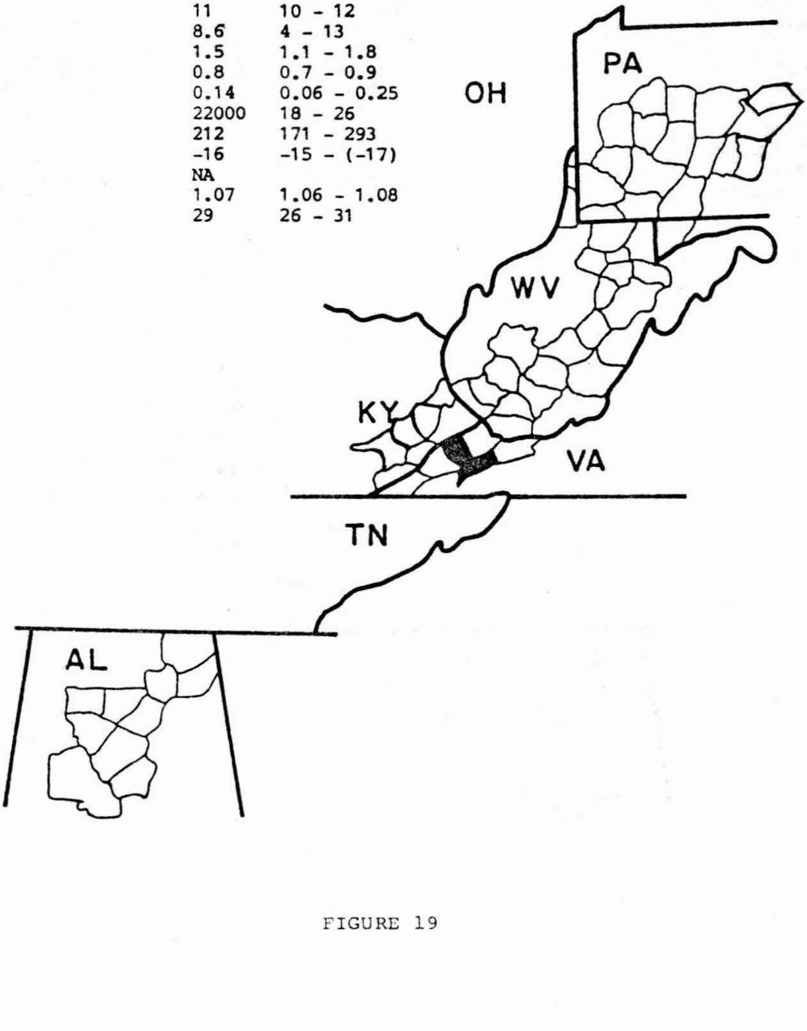

FIGURE 19

County(s)/ State(s) Seams(s)	Wise, VA Banner, Blair Clintwood, Dorchester, Imboden, Lyons, Norton, Taggart	
Volatile	34.5	33 - 36
Ash	5.7	3.0 - 7.5
Sulfur	0.81	0.6 - 1.0
Fe2O3	10	4 - 16
CaO	2.2	1.2 - 5.4
K2O	2.3	1.2 - 3.5
Na2O	0.8	0.2 - 1.5
P2O5	0.4	0.13 - 1.0
DDPM's	23000	17 - 28+(000)
% Dilation	190	150 - 250
Con/Exp	-25	-22 - (-35)
Pressure	NA	
Ro	0.97	0.93 - 1.01
Inerts	22	16 - 27

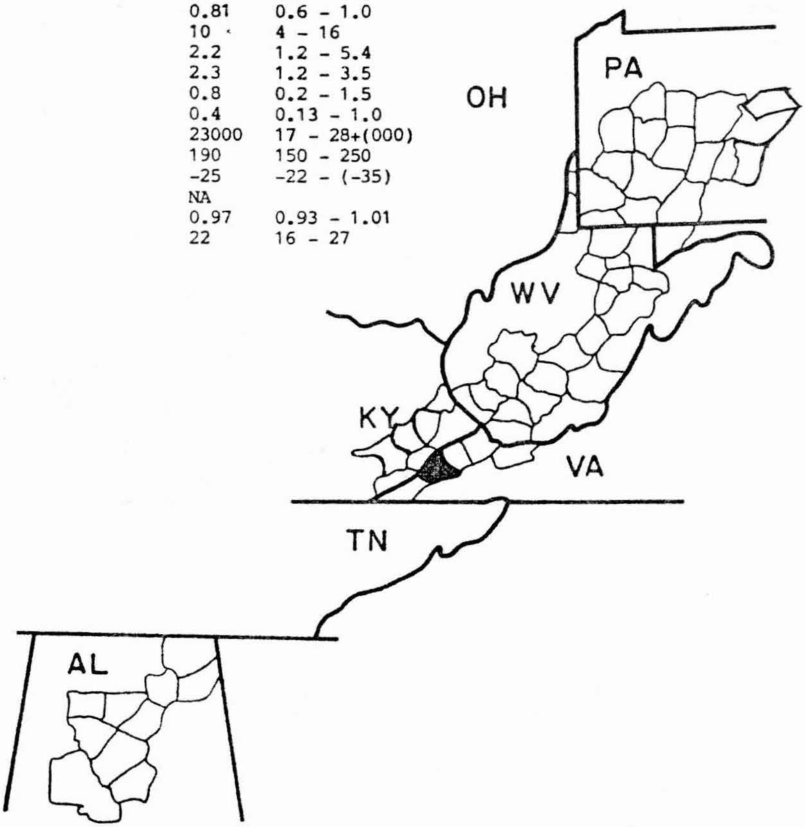

FIGURE 20

County(s)/ State(s) Seams(s)	Bibb, Cullman, Jefferson, Shelby, Tuscaloosa, Walter, AL Atkins, Alice, Black Ck., Carter, Gholsen, Pratt, Nickel Plate	
Volatile	34	29 - 38
Ash	5.2	2.5 - 10.5
Sulfur	0.99	0.6 - 1.8
Fe2O3	15	7 - 25
CaO	3.0	0.9 - 10
K2O	2.2	1.0 - 3.2
Na2O	0.7	0.3 - 1.6
P2O5	0.6	0.2 - 1.4
DDPM's	13000	1500 - 28+(000)
% Dilation	145	40 - 300
Con/Exp	-17	-2 - (-40)
Pressure	NA	
Ro	0.97	0.89 - 1.16
Inerts	19	14 - 23

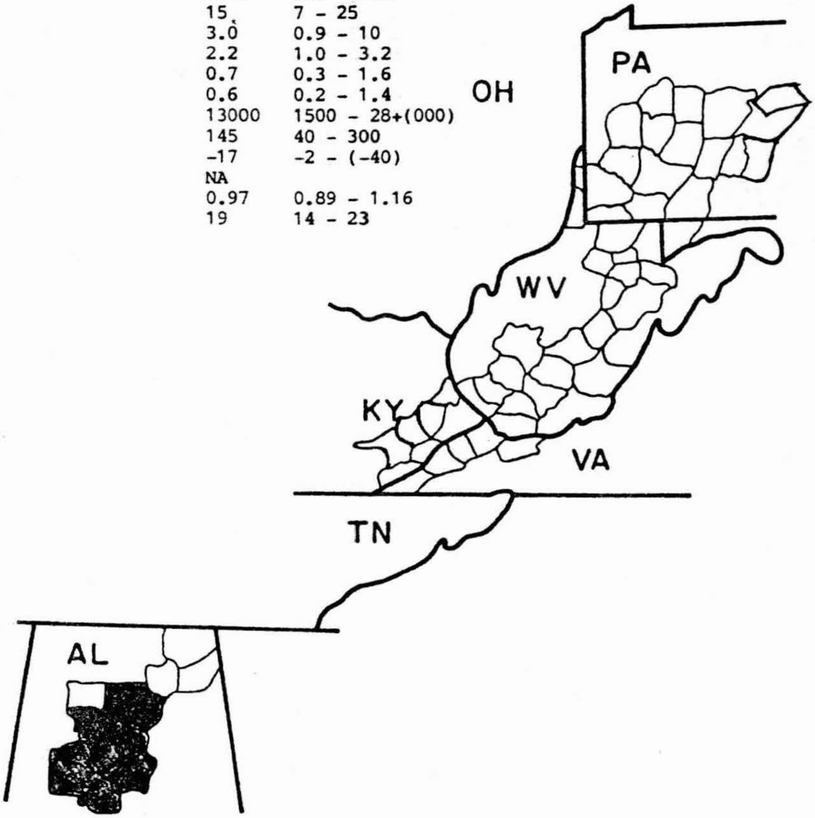

FIGURE 21

County(s)/ State(s) Seams(s)	Cambria, PA Clearfield, PA Indiana, PA Preston, WV Freeport Kittanning	
Volatile	26	24 - 28
Ash	8.5	5 - 12
Sulfur	0.94	0.7 - 1.2
Fe2O3	9	5 - 11
CaO	1.8	1.0 - 3.2
K2O	1.9	1.1 - 2.4
Na2O	0.4	0.2 - 1.0
P2O5	0.6	0.2 - 1.1
DDPM's	6400	200 - 15000
% Dilation	170	54 - 280
Con/Exp	-0.9	-7 - (+5)
Pressure	3.6	1.4 - 5.1
Ro	1.22	1.13 - 1.35
Inerts	20	12 - 30

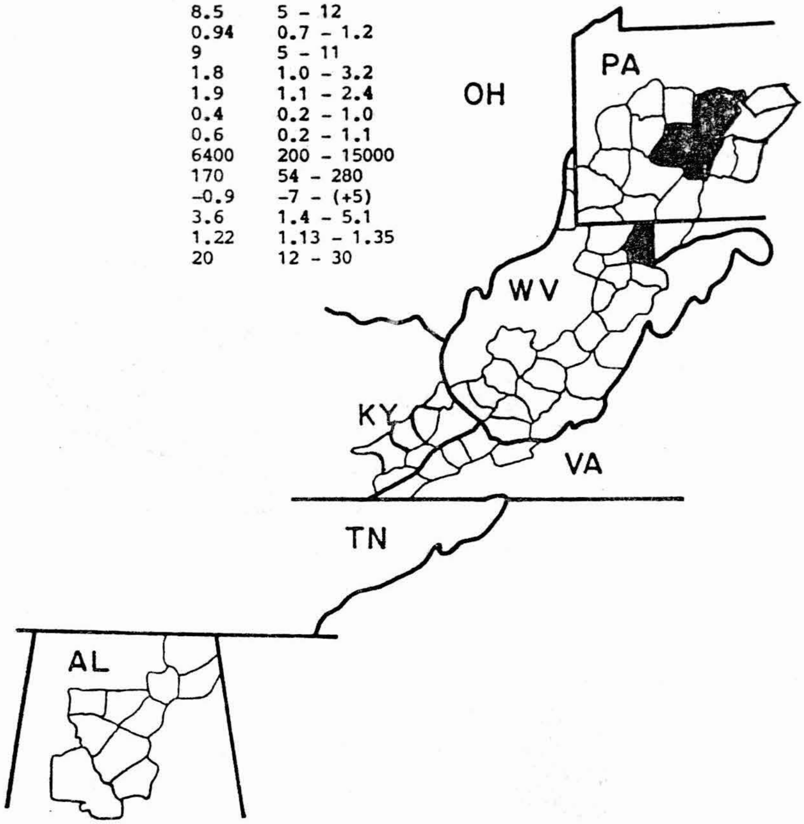

FIGURE 22

County(s)/ State(s) Seams(s)	Fayette, WV Greenbrier, WV Firecreek Sewell	
Volatile	25	21 - 29
Ash	4.8	3.0 - 8.5
Sulfur	0.80	0.6 - 1.3
Fe2O3	10	4 - 26
CaO	2.8	1.1 - 5.7
K2O	2.0	1.1 - 3.2
Na2O	0.8	0.4 - 1.0
P2O5	0.7	0.3 - 1.5
DDPM's	4000	400 - 24000
% Dilation	153	80 - 220
Con/Exp	2.0	-3 - (+5)
Pressure	3.8	2.1 - 5.4
Ro	1.29	1.18 - 1.44
Inerts	22	14 - 30

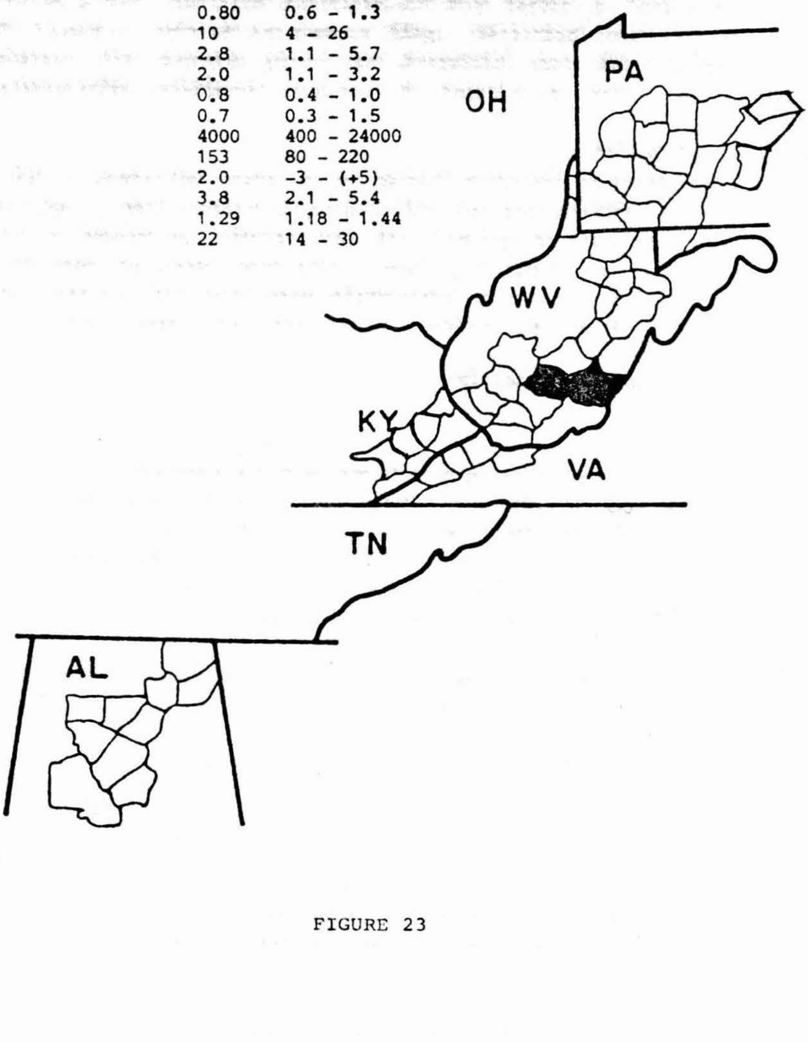

FIGURE 23

County(s)/ State(s) Seams(s)	McDowell, WV Wyoming, WV Gilbert Red Ash	
Volatile	26.5	25 - 30
Ash	6.8	4.0 - 8.5
Sulfur	0.90	0.8 - 1.1
Fe2O3	11	6 - 16
CaO	1.3	1.1 - 1.6
K2O	1.5	1.1 - 2.4
Na2O	0.9	0.6 - 1.1
P2O5	0.7	0.4 - 0.8
DDPM's	10000	5000 - 17000
% Dilation	200	170 - 220
Con/Exp	-5	-2.5 - (-8.5)
Pressure	2.5	2.0 - 3.0
Ro	1.22	1.09 - 1.34
Inerts	27	22 - 28

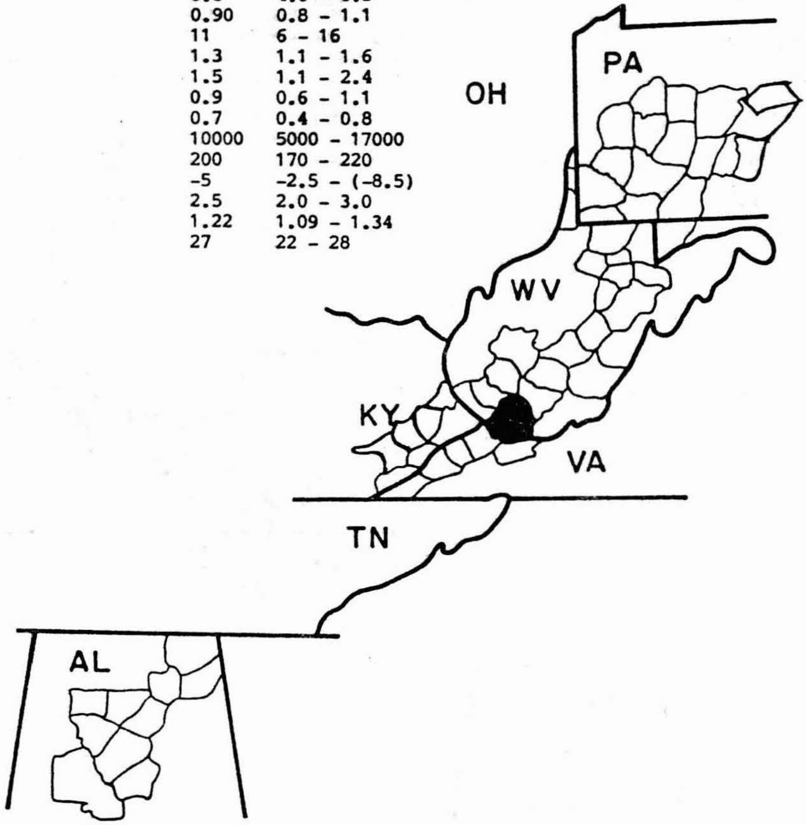

FIGURE 24

County(s)/ State(s) Seams(s)	McDowell, WV Bradshaw, Horsepen Poca 4 - 12	
Volatile	23.7	23 - 24.5
Ash	5.7	4 - 8
Sulfur	0.70	0.55 - 0.80
Fe2O3	12	10 - 17
CaO	4	1.9 - 6.3
K2O	1.8	1.2 - 2.1
Na2O	0.8	0.5 - 1.2
P2O5	0.2	0.14 - 0.34
DDPM's	2500	1000 - 6000
% Dilation	185	120 - 220
Con/Exp	-6	-4 - (-7)
Pressure	2.4	1.6 - 3.1
Ro	1.32	1.24 - 1.41
Inerts	32	30 - 36

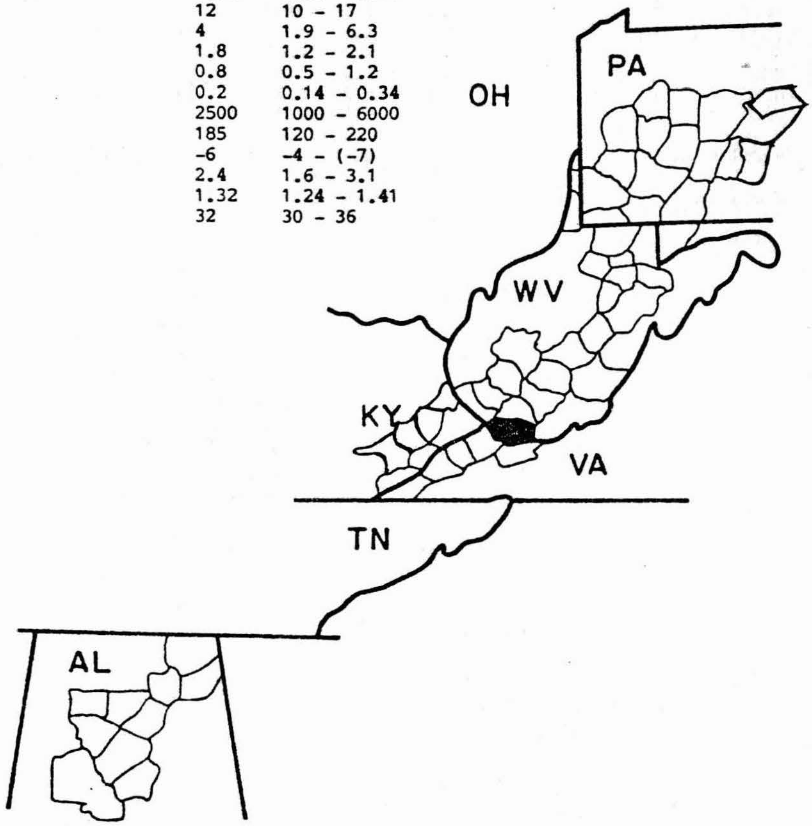

FIGURE 25

County(s)/ State(s) Seams(s)	Buchanan, VA Jewell, Jawbone, Kennedy, Raven Tiller	
Volatile	25	21 - 28
Ash	6	5 - 7
Sulfur	0.80	0.65 - 0.95
Fe2O3	13	10 - 15
CaO	3.5	2.3 - 4.8
K2O	1.7	1.2 - 2.5
Na2O	0.5	0.3 - 0.6
P2O5	0.5	0.3 - 0.9
DDPM's	7500	200 - 18000
% Dilation	180	60 - 235
Con/Exp	1.0	-5 - (+6)
Pressure	2.5	2.2 - 2.8
Ro	1.28	1.11 - 1.44
Inerts	28	19 - 31

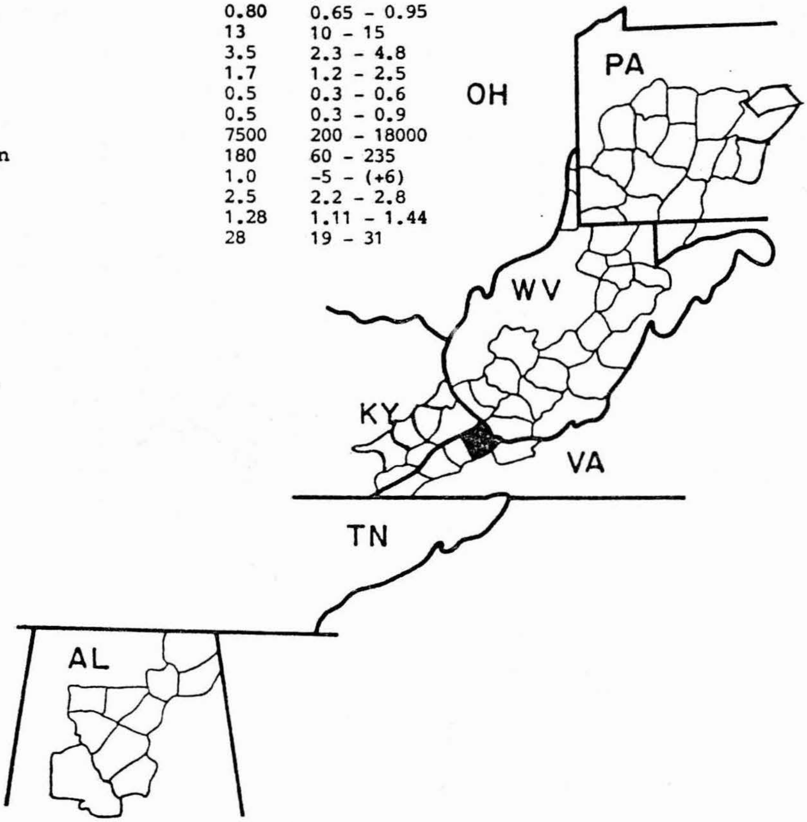

FIGURE 26

County(s)/ State(s) Seams(s)	Tuscaloosa, AL Blue Creek
Volatile	24
Ash	8.7
Sulfur	0.80
Fe2O3	8
CaO	4.8
K2O	1.7
Na2O	0.4
P2O5	0.4
DDPM's	1900
% Dilation	185
Con/Exp	-8
Pressure	2
Ro	1.30
Inerts	24

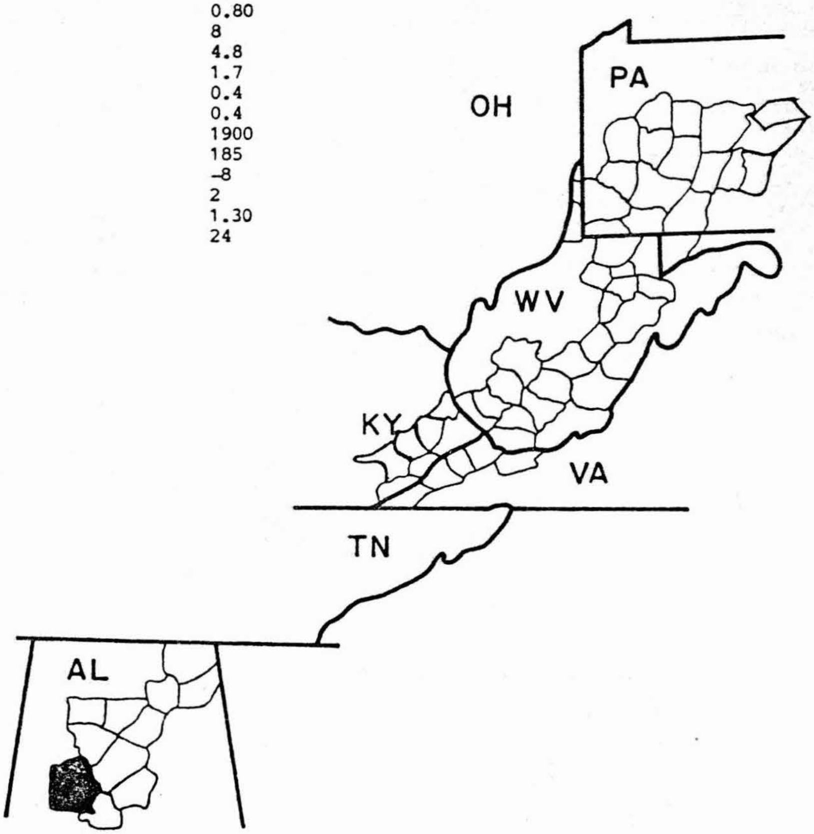

FIGURE 27

County(s)/ State(s) Seams(s)	Cambria, PA Clearfield, PA Huntington, PA Lycoming, PA Somerset, PA Freeport Kittanning	
Volatile	19.5	16 - 24
Ash	8.2	6 - 12
Sulfur	1.01	0.70 - 1.40
Fe2O3	9	8 - 10
CaO	2.0	1.3 - 2.9
K2O	1.8	1.2 - 3.1
Na2O	0.4	0.1 - 0.8
P2O5	0.9	0.4 - 2.0
DDPM's	89	19 - 1690
% Dilation	26	2 - 125
Con/Exp	+9	+4 - (+21)
Pressure	+14	4 - 26
Ro	1.57	1.40 - 1.79
Inerts	20	14 - 29

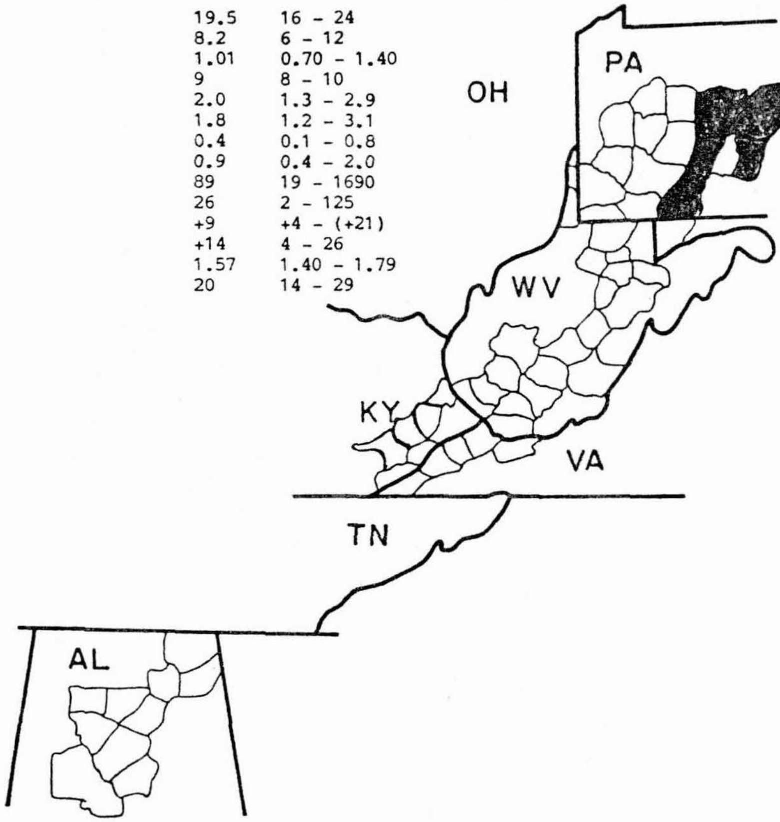

FIGURE 28

County(s)/ State(s) Seams(s)	Garrett, MD Freeport	
Volatile	19.4	17 - 20.5
Ash	7.0	66 - 7.6
Sulfur	1.1	0.9 - 1.2
Fe2O3	10	8 - 11
CaO	2.3	1.7 - 2.8
K2O	1.6	1.0 - 2.0
Na2O	0.4	0.1 - 0.7
P2O5	0.7	0.5 - 0.9
DDPM's	245	100 - 400
% Dilation	80	60 - 100
Con/Exp	+14	+10 - (+20)
Pressure	NA	
Ro	1.60	1.53 - 1.70
Inerts	10	8 - 12

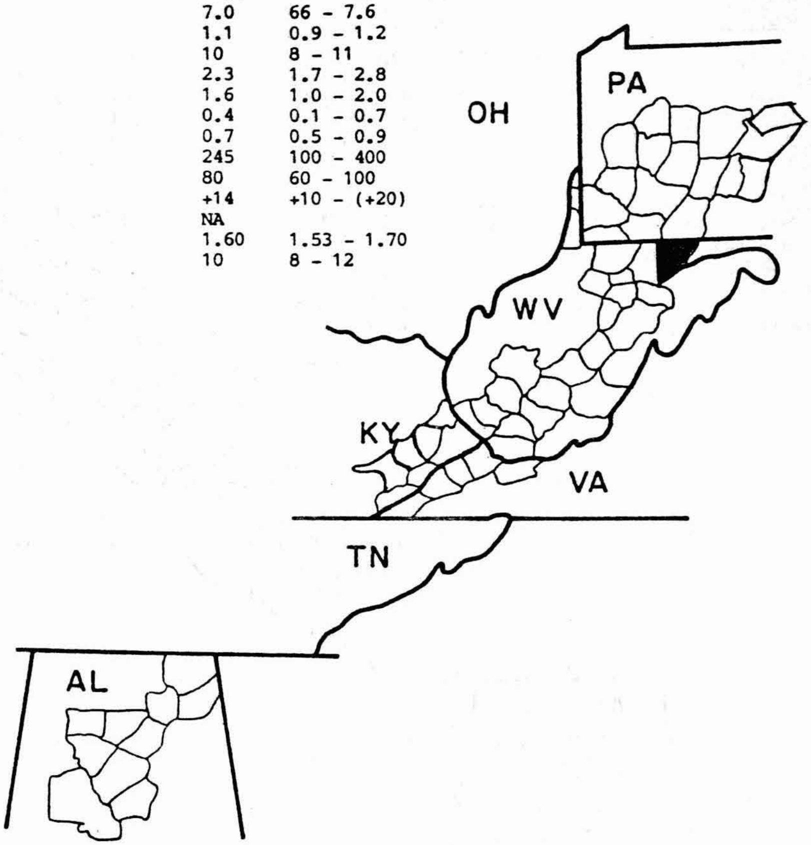

FIGURE 29

County(s)/ State(s) Seams(s)	Fayette, WV McDowell, WV Raleigh, WV Wyoming, WV Beckley Sewell	
Volatile	21.5	20.5 - 22.0
Ash	4.5	3 - 7
Sulfur	0.70	0.55 - 0.80
Fe2O3	12	8 - 15
CaO	1.4	0.9 - 2.2
K2O	2.5	2.0 - 3.4
Na2O	0.9	0.6 - 1.2
P2O5	0.2	0.05 - 0.5
DDPM's	600	200 - 1000
% Dilation	95	70 - 120
Con/Exp	6	-2 - (+12)
Pressure	5	2.5 - 10.5
Ro	1.53	1.48 - 1.56
Inerts	23	19 - 27

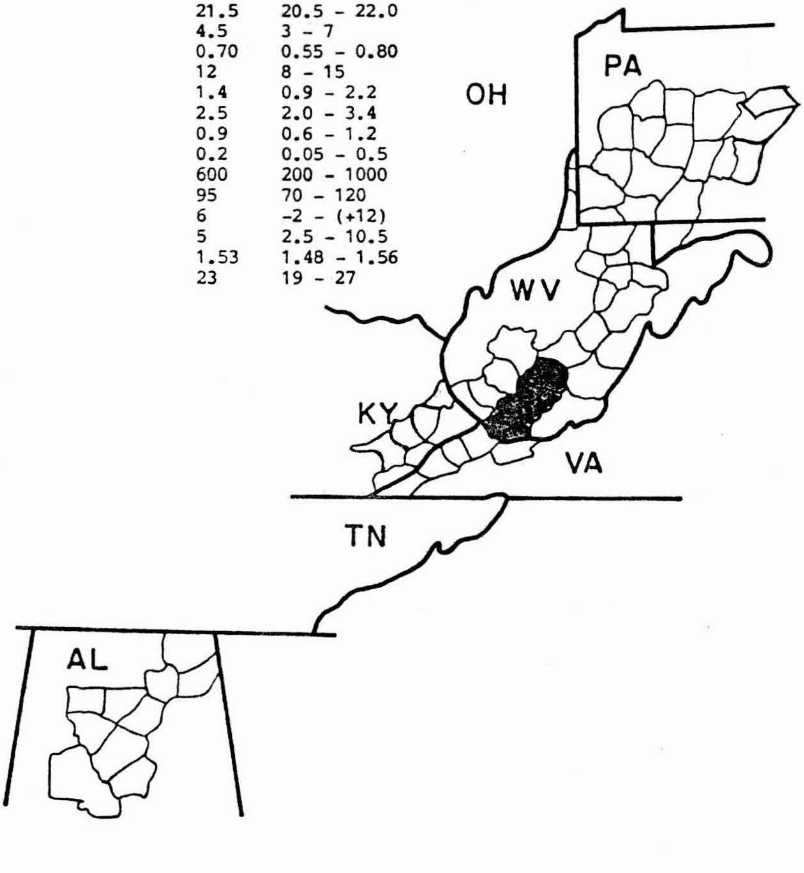

FIGURE 30

County(s)/ State(s) Seams(s)	Raleigh, WV Wyoming, WV Beckley	
Volatile	19	18.5 - 19.5
Ash	5	4.5 - 5.5
Sulfur	0.77	0.75 - 0.85
Fe2O3	7	5 - 8
CaO	1.9	1.9 - 2.3
K2O	2.4	1.9 - 2.8
Na2O	0.9	0.5 - 1.2
P2O5	0.4	0.3 - 0.6
DDPM's	80	35 - 145
% Dilation	32	17 - 65
Con/Exp	11	+9 - (+13)
Pressure	13	12 - 14
Ro	1.63	1.60 - 1.65
Inerts	24	20 - 26

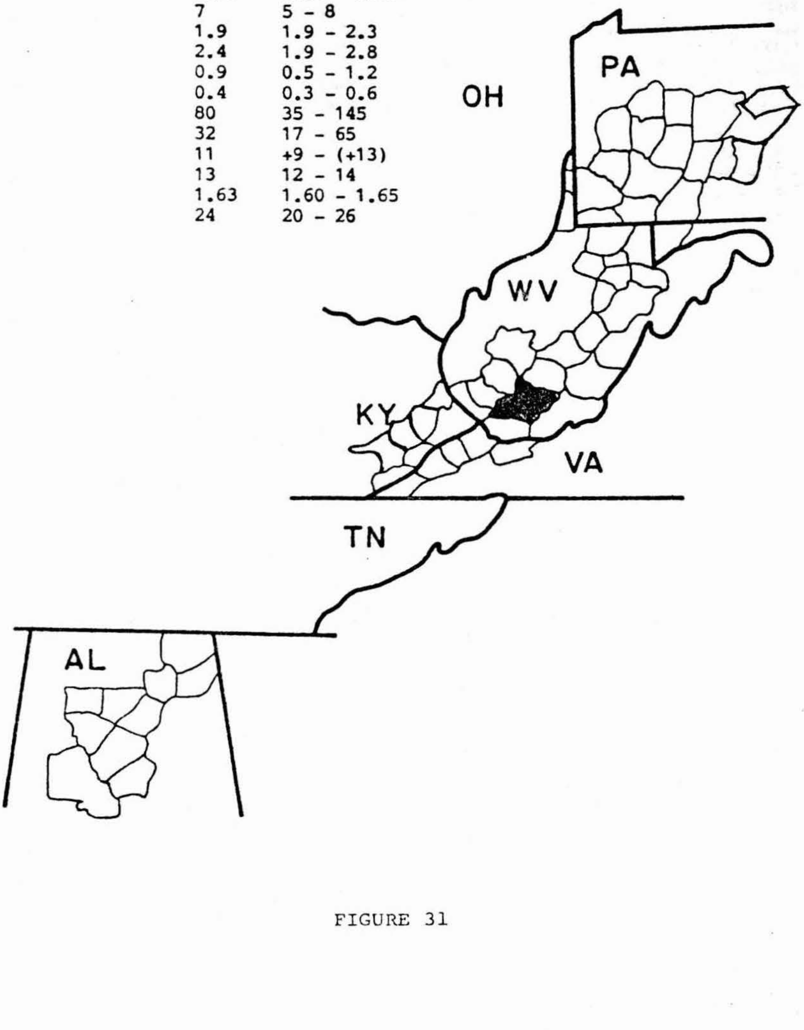

FIGURE 31

County(s)/ State(s) Seams(s)	McDowell, WV Wyoming, WV Sewell	
Volatile	19	18.0 - 20.5
Ash	4	3.5 - 5.0
Sulfur	0.7	0.65 - 0.75
Fe2O3	10	7 - 13
CaO	1.7	1.1 - 2.9
K2O	2.6	2.1 - 3.1
Na2O	0.8	0.5 - 1.1
P2O5	0.3	0.1 - 0.4
DDPM's	131	60 - 400
% Dilation	73	50 - 115
Con/Exp	12	+7 - (+15)
Pressure	11	10 - 12
Ro	1.60	1.57 - 1.64
Inerts	22	18 - 27

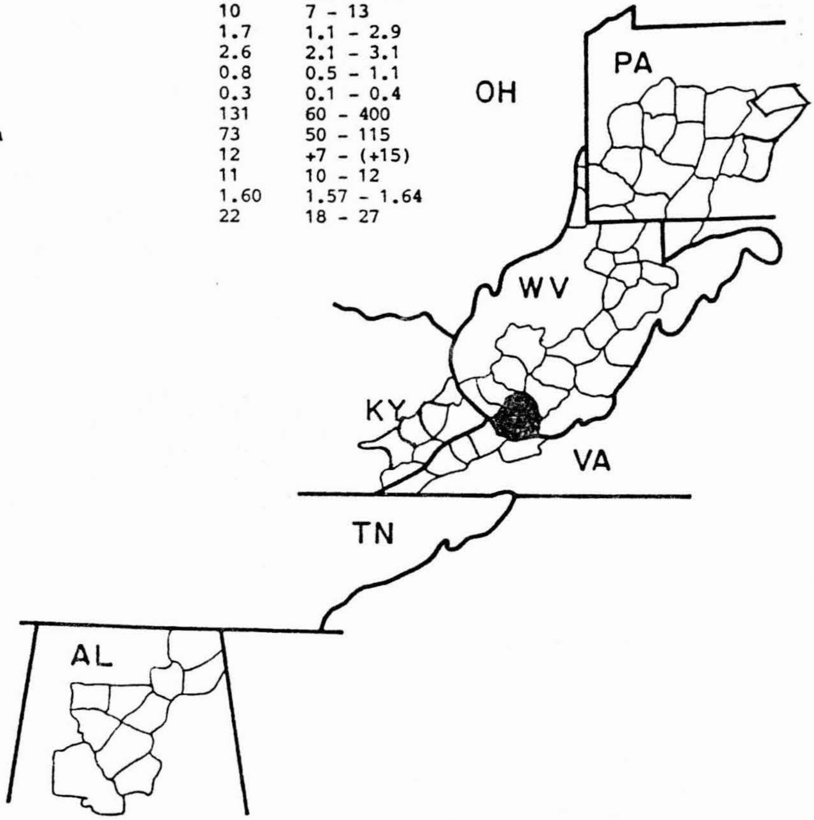

FIGURE 32

County(s)/ State(s) Seams(s)	McDowell, WV Wyoming, WV Poca 3/4/5/6	
Volatile	18.0	16.0 - 20.0
Ash	6.0	4.0 - 8.0
Sulfur	0.77	0.50 - 1.20
Fe2O3	10	8 - 14
CaO	2.1	1.1 - 4.3
K2O	1.6	0.8 - 2.8
Na2O	0.7	0.3 - 1.1
P2O5	0.4	0.12 - 0.7
DDPM's	75	2 - 205
% Dilation	29	15 - 65
Con/Exp	6	+1 - (+13)
Pressure	10	4 - 16
Ro	1.64	1.54 - 1.72
Inerts	29	22 - 38

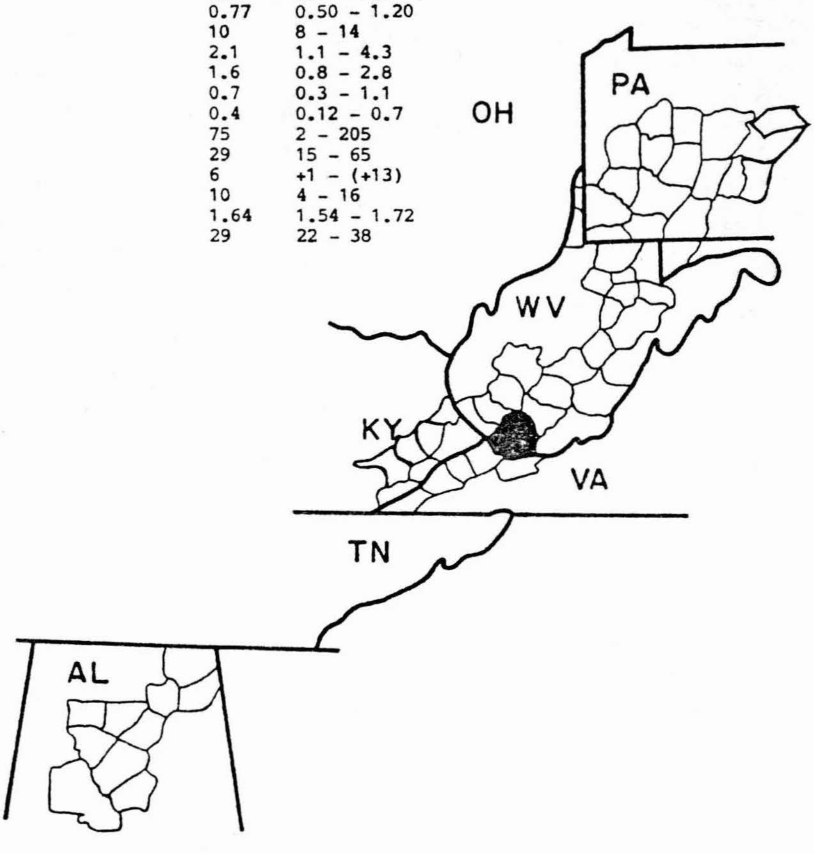

FIGURE 33

County(s)/ State(s) Seams(s)	McDowell, WV Buchanan, VA Tazwell, VA Poca 3/4	
Volatile	18.4	16.0 - 20.0
Ash	4.5	4.0 - 5.0
Sulfur	0.74	0.50 - 1.00
Fe2O3	15	10 - 18
CaO	7.3	5 - 10
K2O	1.4	0.5 - 1.7
Na2O	1.2	0.8 - 1.5
P2O5	0.1	0.02 - 0.17
DDPM's	59	5 - 191
% Dilation	30	9 - 72
Con/Exp	16	+6 - (+21)
Pressure	14	12 - 16
Ro	1.68	1.58 - 1.82
Inerts	22	19 - 34

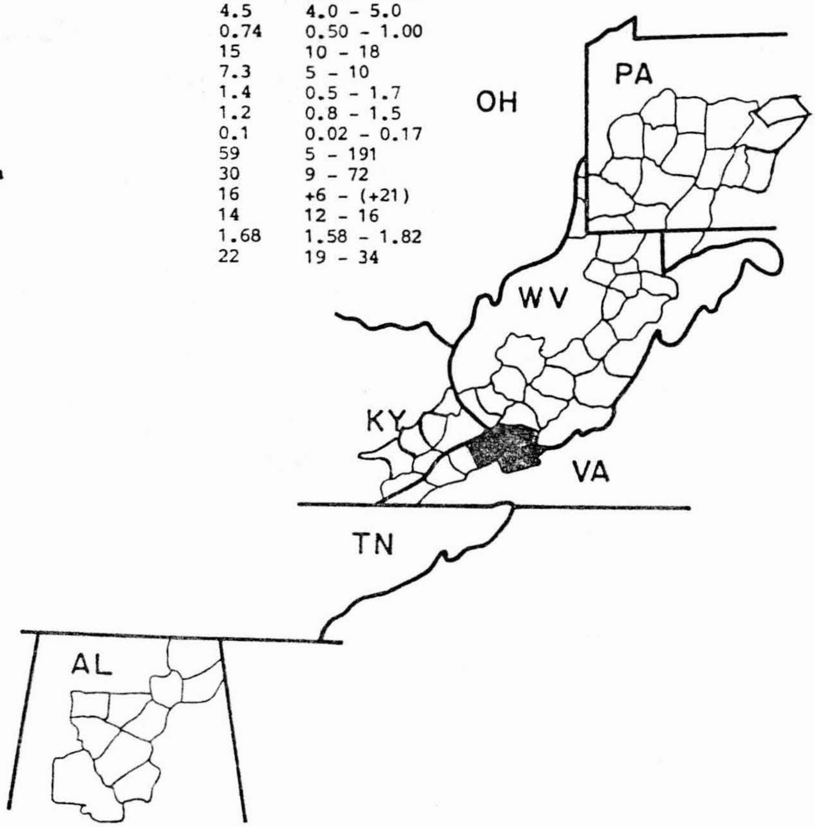

FIGURE 34

County(s)/ State(s) Seams(s)	Tuscaloosa,AL Blue Creek	
Volatile	20	19 - 21
Ash	8.2	7.9 - 8.5
Sulfur	0.6	0.55 - 0.65
Fe2O3	6	5 - 7
CaO	3.9	2.8 - 5.5
K2O	1.8	1.6 - 2.2
Na2O	0.5	0.4 - 0.7
P2O5	0.6	0.4 - 0.8
DDPM's	500	150 - 1900
% Dilation	73	40 - 120
Con/Exp	-1	-0.9 - (-1.0)
Pressure	4	3.0 - 5.0
Ro	1.52	1.47 - 1.57
Inerts	25	22 - 29

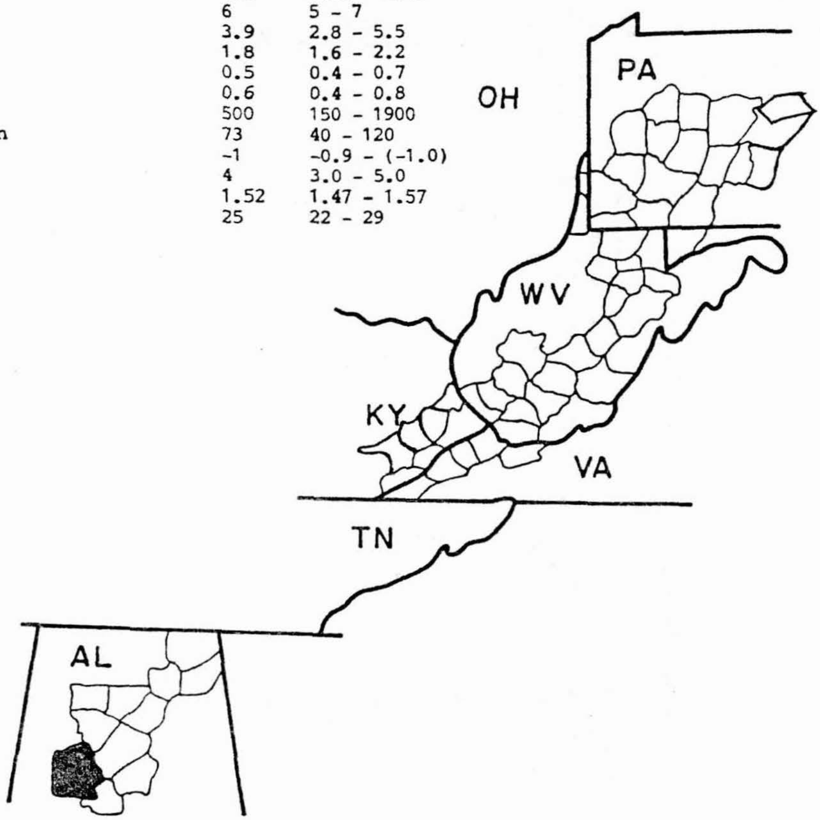

FIGURE 35

American High Vol Coal Quality Characteristics

County(s), State(s) Seams(s)	Allegheny, PA Greene, PA Washington, PA Westmoreland, PA Pittsburgh	Allegheny, PA Armstrong, PA Greene, PA Washington, PA Freeport	Barbour, WV Upshur, WV Freeport Kittanning	Nicholas, WV Randolph, WV Webster, WV Upper & Lower Sewell	Fayette, WV Raleigh, WV Wyoming, WV #2 Gas, Eagle, Powellton	Nicholas, WV Eagle, Peerless	Kanawha, WV #2 Gas, Eagle, Peerless
Volatile Matter, dry	37	35	35	30	31	35	36
Ash, dry	6.5	7.5	7.8	6.8	5.9	5.4	6.0
Sulfur, dry	1.45	0.90	1.00	0.76	0.88	0.85	0.90
Fe_2O_3	14	8	10	6	9	7	9
CaO	2.4	2.1	3.0	2.3	1.4	1.7	1.5
K_2O	1.6	2.5	1.6	1.8	2.3	2.3	2.2
Na_2O	0.6	0.7	0.4	0.7	0.6	0.7	0.7
P_2O_5	0.5	0.7	0.5	0.5	0.3	0.2	0.1
DDPM	27000	27000	25000	12000	26000	27000	25000
% Dilation	185	179	176	160	270	172	165
% Contraction (52:02)	-24	-19	-25	-16	-16	-17	-20
Pressure, PSI (50-51)							
% Mean Max Ro	0.87	0.95	0.93	1.11	1.09	0.99	0.95
Total Inerts	20	18	28	29	25	19	25

TABLE 1

American High Vol Coal Quality Characteristics

County(s), State(s) Seam(s)	Boone, WV Cedar Grove, Dorothy Hernshaw, Winifrede	Logan, WV #2 Gas, Alma, Cedar Grove, Chilton, Pond Ck.	Mingo, WV Alma, Pond Ck.	Pike, KY Alma, Elkhorn Pond Ck., Williamson	Pike, KY Elkhorn, Pond Ck.	Floyd, Knott Letcher, Martin Perry, KY Elkhorn, Hazard Pond Ck.	Harlan, KY E, D, A, Darby, Harlan, High Splint
Volatile Matter, dry	36	35.5	35.5	34.5	38	38	37.5
Ash, dry	5.8	6.0	6.1	6.1	6.7	6.6	6.8
Sulfur, dry	0.82	0.74	0.84	0.74	0.77	1.02	0.90
Fe2O3	7	6	8	7	6	10	10
CaO	1.5	2.0	1.4	1.3	2.1	2.5	1.5
K2O	1.9	2.1	2.4	2.2	2.3	1.9	2.1
Na2O	0.6	0.7	0.7	0.8	0.7	0.7	0.5
P2O5	0.3	0.14	0.16	0.2	0.15	0.4	0.4
DDPM	17000	20000	18000	20000	1700	1500	7000
% Dilation	112	114	110	120	20	2	70
% Contraction (52:02)	-18	-19	-18	-21	-10	-10	-14
Pressure, PSI (50-51)							
% Mean Max Ro	0.92	0.95	0.98	0.98	0.86	0.84	0.87
Total Inerts	29	28	23	27	24	26	23

TABLE 2

American High Vol Coal Quality Characteristics

County(s), State(s) Seam(s)	Buchanan, VA Blair, Clintwood, Eagle, Hagy Splashdam	Dickenson, VA Russell, VA Jawbone, Kennedy, Raven, Tiller	Wise Virginia Banner, Blair, Clintwood, Dorchester, Imboden, Lyons, Norton, Taggart	Bibb, Cullman, Jefferson, Shelby, Tuscaloosa, Walter, AL Atkins, Alice, Black Ck., Carter, Gholsen, Pratt, Nickel Plate
Volatile Matter, dry	31	31.5	34.5	34
Ash, dry	5.7	5.9	5.7	5.2
Sulfur, dry	0.87	0.67	0.81	0.99
Fe2O3	10	11	10	15
CaO	2.1	9.0	2.2	3.0
K2O	2.5	1.5	2.3	2.2
Na2O	0.9	0.8	0.8	0.7
P2O	0.3	0.14	0.4	0.6
DDPM	21500	22000	23000	13000
% Dilation	215	212	190	145
% Contraction	-21	-16	-25	-17
Pressure, PSI (50-51)				
% Mean Max	1.07	1.07	0.97	0.97
Total Inerts	24	29	22	19

TABLE 3

American High Vol Coal Quality Characteristics

County(s), State(s)	Illinois	Oklahoma	Utah High Vol A/B	Utah High Vol B/C	Colorado	New Mexico
Volatile Matter, dry	37	37	40	41	39	37
Ash, dry	6.5	5.5	5.0	8.5	6.8	7.5
Sulfur, dry	1.1	0.6	0.8	0.6	0.6	0.5
DDPM	25	125	40	1	32	15000
% Mean Max Ro	0.68	0.84	0.75	0.53	0.74	0.84
Total Inerts	16	15	17	34	19	23

TABLE 4

American Medium Vol Coal Quality Characteristics

County(s), State(s) Seam(s)	Cambria, PA Clearfield, PA Indiana, PA Preston, WV Freeport Kittanning	Fayette, WV Greenbrier, WV Firecreek Sewell	McDowell, WV Wyoming, WV Gilbert Red Ash	McDowell, WV Bradshaw, Horsepen Poca 4 - 12	Buchanan, VA Jewell, Jawbone, Kennedy, Raven Tiller	Tuscaloosa, AL Blue Creek	Central Oklahoma Stigler	Central Colorado Placita V, B, A
Volatile Matter, dry	26	25	26.5	23.7	25	24	28 (25-31)	28 (23-31)
Ash, dry	8.5	4.8	6.8	5.7	6.0	8.7	5.8	7.6
Sulfur, dry	0.94	0.80	0.90	0.70	0.80	0.80	1.00	0.60
Fe2O3	9	10	11	12	13	8	25	8
CaO	1.8	2.8	1.3	4.0	3.5	4.8	21	5.4
K2O	1.9	2.0	1.5	1.8	1.7	1.7	0.8	0.8
Na2O	0.4	0.8	0.9	0.8	0.5	0.4	1.0	2.8
P2O5	0.6	0.7	0.7	0.2	0.5	0.4	0.7	0.9
DDPM	6400	4000	10000	2500	7500	1900	11000	8000
% Dilation	170	153	200	185	180	185	212	200
% Exp/Cont (52:02)	-1	2	-5	-6	1	-8	NA	-3
Pressure, PSI (50-51)	3.6	3.8	2.5	2.4	2.5	2.0	NA	2.0
% Mean Max Ro	1.22	1.29	1.22	1.32	1.28	1.30	1.19	1.19
Total Inerts	20	22	27	32	28	24	14	18

TABLE 5

American Low Vol Coal Quality Characteristics

County(s), State(s) Seam(s)	Cambria, PA Clearfield, PA Huntington, PA Lycoming, PA Somerset, PA Freeport Kittanning	Garrett, MD Freeport	Fayette, WV McDowell, WV Raleigh, WV Wyoming, WV Beckley Sewell	Raleigh, WV Wyoming, WV Beckley	McDowell, WV Wyoming, WV Sewell	McDowell, WV Wyoming, WV Poca 3/4/5/6	McDowell, WV Buchanan, VA Tazwell, VA Poca 3/4	Tuscaloosa, AL Blue Creek	Arkansas Oklahoma Hartshorne Paris Charleston
Volatile Matter, dry	19.5	19.4	21.5	19	19	18	18.4	20	19
Ash, dry	8.2	7.0	4.5	5.0	4.0	6.0	4.5	8.2	5.6
Sulfur, dry	1.00	1.10	0.70	0.77	0.70	0.77	0.74	0.60	0.86
Fe2O3	9	10	12	7	10	10	15	6	15
CaO	2.0	2.3	1.4	1.9	1.7	2.1	7.3	3.9	7.2
K2O	1.8	1.6	2.5	2.4	2.6	1.6	1.4	1.8	1.6
Na2O	0.4	0.4	0.9	0.9	0.8	0.7	1.2	0.5	1.5
P2O5	0.9	0.7	0.2	0.4	0.3	0.4	0.1	0.6	1.0
DDPM	89	245	600	80	131	75	59	500	65
% Dilation	26	80	95	32	73	29	30	73	15
% Expansion (52:02)	9	13	6	11	12	6	16	-1	6
Pressure, PSI (50-51)	14	NA	5	13	11	10	14	4	17
% Mean Max Ro	1.57	1.60	1.53	1.63	1.60	1.64	1.68	1.52	1.66
Total Inerts	20	10	23	24	22	29	22	25	22

TABLE 6