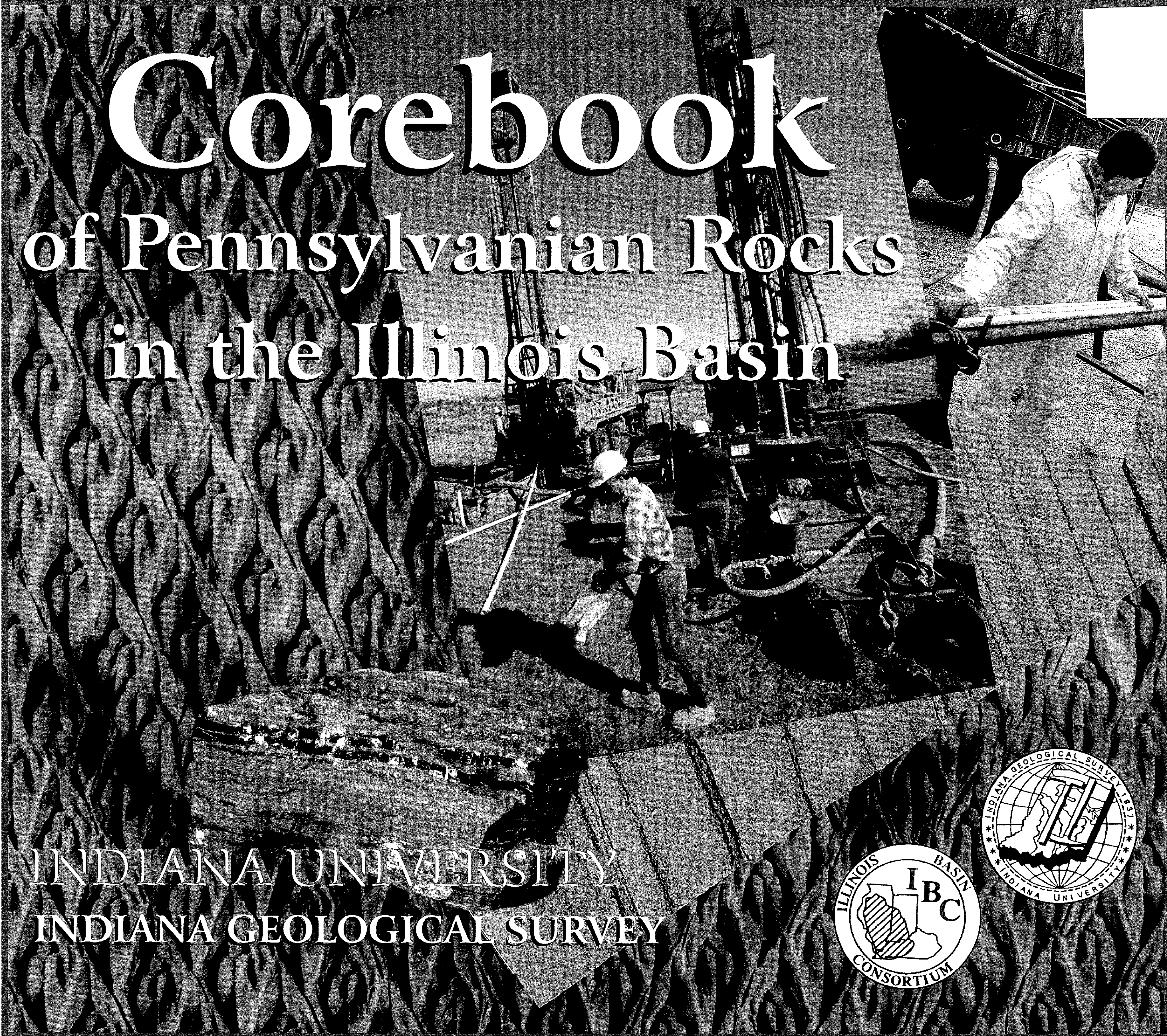
Corebook
of Pennsylvanian Rocks in the Illinois Basin



INDIANA UNIVERSITY

INDIANA GEOLOGICAL SURVEY

COREBOOK OF PENNSYLVANIAN ROCKS IN THE ILLINOIS BASIN

by

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A Note to the Users of This Corebook

from Norman C. Hester
Director and State Geologist, Indiana Geological Survey

The description of rocks is a mix of art and science that commonly produces subjective results. Such subjectivity often leads to oral and written communication problems when attempting to describe or to interpret descriptions of the coal-bearing sequences within the Illinois Basin. Too often the collection, transfer, and storage of descriptive reliable rock core data suffers as a result.

To help overcome this problem, the Indiana Geological Survey has developed a standardized method of Pennsylvanian rock core description for the Illinois Basin which is designed for multiple users—geologists, engineers, drillers, miners, teachers, archivists, and regulators. Although discussions about the benefits of this work have gone on for a number of years, this product did not take form until Mark Barnhill and Huitang Zhou assumed the challenge of developing a rock corebook that would have applicability throughout the Illinois Basin. One hundred and thirty-eight rock cores were examined in Indiana, Kentucky, and Illinois. Of the hundreds of rock core samples collected, 66 different lithologies were selected, an assemblage that represents most rock types. Samples typical of seven different coal types are presented in addition to the 66 rock samples.

The authors completed a first draft of the core workbook, but were unable to complete the effort due to a job change for Barnhill and academic commitments for doctoral student Zhou. Without their commitment to and enthusiasm for the work, this book would have remained only a concept. However, had not Brian Keith and Todd Thompson assumed responsibility for revising and editing the corebook, this project may never have reached fruition.

Originally, I thought that inclusion of discussions of sedimentary environments of the various facies would provide an added benefit to instructional and applied geology; however, the sedimentologic component remains too controversial to treat with brevity and is the subject of ongoing research within the Illinois Basin Consortium. I also considered the idea of including rock-mechanics data and chemical analyses but, again, the present inaccessibility to and the variability in physical and chemical properties of particular facies preclude the addition of these data for this edition. We agreed that a standardized description of the various facies in the Pennsylvanian rocks should be produced and, in a format that was easy to use, durable, and adaptable to revisions and reformatting: thus, the loose-leaf synthetic paper presentation. It is our plan to add future modules to the corebook on sedimentary environments, engineering properties, and chemistry of coals and associated rocks. In addition, we are developing computer software to print out stratigraphic columns using the codes in the corebook.

We would not consider our job complete if we did not offer training on how best to receive the maximum benefit from the corebook. The Indiana Geological Survey offers, as part of our program in Educational Outreach, workshops on applications of this corebook to rock core description, interpretation, computer data management, and data processing that will also include a workbook on applying the corebook.

I believe you will find the corebook interesting and unique, but, more importantly, we hope that you will find it useful. In return we would appreciate any comments from you, the user, about the corebook, especially ideas for what to add, either as individual plates or as modules to make it more useful.

About the cover

The background pattern on the cover is a bark impression of the plant fossil *Lepidodendron* that has been preserved in a mudstone. These plants were a major constituent of the flora and, thus, the coals of the Pennsylvanian. The rotary drilling rig operations shown in the inset photographs are typical of those used for shallow coring in the Illinois Basin and other areas. The rock core photograph is of a cross-bedded sandstone (plate Ssxz2). The coal photograph is of a durain sample (plate Odzz1).

Design by W.E. Stalions; production and imaging by B.T. Hill.

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Contributors to the cost of publication of this corebook include: AMAX Coal Company, Black Beauty Coal Company, Indiana Geological Survey, Indiana University Research and Graduate School, Illinois State Geological Survey, Kentucky Geological Survey, Little Sandy Coal Company, Phoenix Natural Resources, Solar Sources Inc., and the United States Geological Survey. Their contributions are gratefully acknowledged.

Care of the Corebook

This book is printed on a synthetic paper that is resistant to tearing, cracking, staining, ultraviolet damage, and is waterproof. However, the color inks used in the core photographs will fade or change upon continued exposure to sunlight, and mineral oil (and similar petroleum products) will damage the synthetic paper. The pages can be cleaned by wiping with warm soapy water—harsh cleaning agents should not be used.

Acknowledgments

Personnel of the Illinois State Geological Survey and Kentucky Geological Survey were helpful in locating cores (as well as logs and core descriptions) in their respective states for possible inclusion and for supplying core samples for photography. The efforts of outside reviewers John Ferm (University of Kentucky), Robert Milici (United States Geological Survey), Paul Potter (University of Cincinnati, retired), and Lee Suttner (Indiana University) are appreciated. Their comments improved the corebook as did those of Illinois Basin Consortium reviewers Lloyd Furer, Nancy Hasenmueller, and Walter Hasenmueller (Indiana Geological Survey), Heinz Damberger and David Morse (Illinois State Geological Survey), and David Williams and Jerry Weisenfluh (Kentucky Geological Survey). In particular, the assistance of Jerry Weisenfluh in classifying the rocks in the corebook according to the Ferm code and in providing feedback on the design of Figure 4 is most gratefully acknowledged. Responsibility, however, for any errors on Figure 4 and in assigning the Ferm codes lies with the senior editor (BDK). The authors also wish to acknowledge Richard Hill as production manager, and Licia Weber for assistance with layout and design at the beginning of this project. Finally, appreciation is expressed to the financial contributors without whom publication would not be possible.

The Indiana Geological Survey gratefully acknowledges the services of Rheitone, Inc. of Indianapolis; Metropolitan Printing Service, Inc. of Bloomington, Ind., and Indiana University Printing Services of Bloomington, Ind. for their help and cooperation in the production and printing of this book.

COREBOOK OF PENNSYLVANIAN ROCKS IN THE ILLINOIS BASIN

Introduction

Rock cores provide some of the most valuable and detailed information on subsurface rock sequences and are an essential component of stratigraphic investigations. Rock coring is an expensive technique for acquiring data, not only because of the actual cost of drilling, but also because of the ongoing cost of storing cores after they are collected. This tremendous wealth of data is lost if cores are discarded after cursory examination and description. One way to better obtain and preserve these valuable data is to use a standardized method of rapid and meaningful description. Such a system maximizes the information derived from coring operations and facilitates the transfer of that information from those describing the cores, such as drilling personnel, to those needing the information, such as geologists, engineers, and regulators.

Corebooks provide a fast and accurate method of standardized core description that can be used easily by persons with diverse technical backgrounds, but which still preserves essential geologic information. Matching the core to color photographs of actual core segments allows for a more objective description that does not rely on individual interpretations.

Application to Pennsylvanian Rocks

Pennsylvanian rocks cover a large area of the Illinois Basin (fig. 1) and are economically important because they contain abundant coal resources. Consequently, the Pennsylvanian section is the most commonly cored interval in the Illinois Basin and is the focus of this corebook. John Ferm and colleagues (first at the University of South Carolina and then at the University of Kentucky) made a major contribution to the description of Pennsylvanian cores by publishing several corebooks of Pennsylvanian rocks in the Appalachian Basin (Ferm and Melton, 1977; Ferm and Smith, 1981; and Ferm and Weisenfluh, 1981) and one corebook for the Rocky Mountain area (Ferm and others, 1985). These, however, do not show the full range of lithotypes observed in Pennsylvanian rocks of the Illinois Basin. In addition, the format of this corebook is markedly different from those of the Ferm books in that each core sample is placed in a vertical sequence in the corehole showing the gamma-ray well-log signature (if available) for that sequence and in its emphasis on primary structures and secondary features in the cores. These features are unique to this corebook.

This corebook was prepared with six major applications in mind: 1) to standardize Pennsylvanian rock core descriptions for the coal industry; 2) to help mining engineers identify lithologies that have potential for problems with roof control, slope stability, or acid mine drainage; 3) to help correlate gamma-ray well-log responses to specific rock types and successions; 4) to assist construction engineering companies in identifying rock types that present potential stability problems for roads and other man-made structures; 5) to be used as a teaching tool to aid in the identification of primary and penecontemporaneous sedimentary structures, which can be used in some cases as indicators of coal proximity, quality, and correlation; 6) to expedite the mine permitting process; and 7) to provide a uniform key for rock types for computer database construction. Not all these applications are addressed directly in this corebook (for example, mining and construction applications are not considered), however, the format of the corebook is designed for the addition of sections that deal with topics not presently included. Other issues may be addressed by adding separate modules according to user need and interest.

Sample Data Base

All the photographs presented with the exception of the coals (and one other sample, which is from a mine wall) are of rock core.

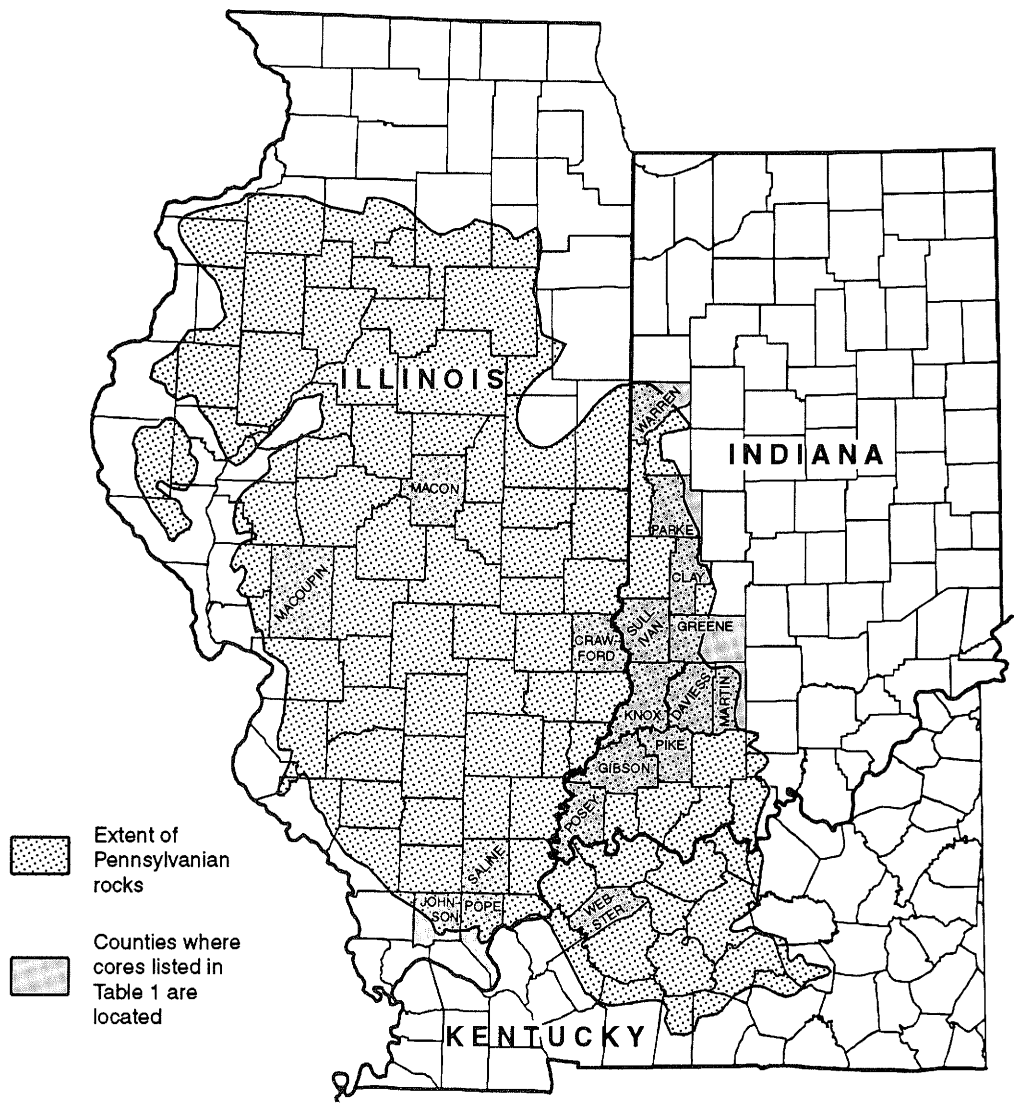


Figure 1. Map showing extent of Pennsylvanian rocks in the Illinois Basin and location of counties from which core was collected for sampling (see Table 1).

Half of each core was cut and polished to reveal a maximum of detail; the other half was simply cleaned prior to photographing. The rock core and coal samples are from a variety of repositories and sources, including the Indiana Geological Survey, the Illinois State Geological Survey, coal companies, oil companies, and the U.S. Army Corps of Engineers' project for the Department of the Navy. Assistance in collecting the cores was provided by both the Illinois State and Kentucky Geological Surveys. A total of 23,459 feet of core from 138 different core holes that span the entire Pennsylvanian section in the Illinois Basin was initially examined. This sample set provided 412 hand specimens from which 66 of the most common Pennsylvanian sedimentary rocks were selected for inclusion. (See Table 1 for a complete list of the core samples and locations. The seven coal samples are representative of Illinois Basin coal types; their precise locations are unknown, but they are included in Table 1.)

Color Plate Format

Figure 2 illustrates the format of the 66 colored plates and explains the various elements on each plate. Because the coal examples are hand specimens, their format is different. On the reverse side of each plate is descriptive information. By including the written information appropriate to each sample on the back of the plate, the modular format of the book is preserved. In this way, each plate stands alone, and the book can easily be organized as required by the user. Thus, if a user wants a more simplified version of the corebook that shows only one or two examples of each facies, the extra plates can simply be removed. The book is also designed to be reduced to a more convenient field-book size by cutting each page in half (note the vertical dashed line on Figure 2) and clipping the plates together with the rings that are provided with the book.

Located at the lower left of each plate is a rock type (name) and a classification code unique to each plate. The rock type consists of a lithologic name, such as shale or sandstone, that is preceded by modifiers indicating primary structures and secondary features, where identified. This classification code consists of four boxes that (from left to right) indicate rock type, primary structure (if identified), secondary feature (if identified), and a number indicating which example of that particular rock type the sample represents (for example, there are two examples of massive conglomerate, Grmz1 and Grmz2). The terms that make up the classification code and their abbreviations are listed in Figure 3. Where a primary structure or secondary feature is not present (or not identified), a "z" is used. The classification code is, therefore, unique to the sample and allows for additional samples to be added to the book (for example, if another massive conglomerate were added later, its code would be Grmz3). Obviously, users need not include the numbers in the code when identifying core sections unless it is necessary to make reference to specific plates.

Also at the lower left of each plate is the Carolina Coal Group Classification code developed by Ferm and colleagues (fig. 4), and informally referred to as the "Ferm code." Since Ferm's classification system commonly is used in segments of the coal industry, we have included it on the plates for the benefit of those users familiar with that system. It is based on some of the same properties as the system in this book, but it is significantly different in that it is strictly numeric and emphasizes a combination of color and composition as a single property. Figure 4 summarizes how the three-digit Ferm code is derived although some of the terminology has been modified to be consistent with usage in this corebook. (For more information on the Ferm system, refer to Ferm and others [1983] and Smith [1982].)

Listed at the top of each plate is the location of the well. Wells in Indiana and Illinois are located using the Congressional section, township, and range system. Wells in Kentucky are located using the Carter Coordinate system in which letters and numbers are used to designate five-minute divisions of latitude and longitude. Below the location information are four figures. A one-to-one scale color photograph of the whole core is on

Table 1. List of rock core and coal samples with the classification code developed for this Illinois Basin Consortium (IBC) corebook; the Carolina Coal Group codes (Ferm) are included for comparison. [*Note*: The samples listed in this table are presented in the order in which the plates appear.]

IBC Code	Ferm Code	State	County	Location	Well Designation	Depth (feet)	Rock Type
Grmz1	754	IN	Warren	29-23N-8W	SDH 331	137	Massive conglomerate
Grmz2	754	IN	Parke	25-17N-7W	SDH 354	307	Massive conglomerate
Brmz1	751	IL	Johnson	25-11S-4E	COGEO S-4	243	Massive breccia
Brmz2	751	IN	Gibson	34-3S-9W	SDH 294	165	Massive breccia
Ssmz1	564	IN	Greene	33-7N-6W	SDH 212	294	Massive sandstone
Ssmz2	564	IN	Sullivan	28-7N-9W	SDH 300	733	Massive sandstone
Ssmz3	753	IL	Saline	29-10S-5E	COGEO S-2	261	Massive sandstone
Ssmb1	548	IN	Clay	36-9N-7W	SDH 217	214	Bioturbated massive sandstone
Ssmr1	547	IN	Martin	20-5N-3W	NSWC (D)5	23	Rooted massive sandstone
Ssmr2	547	IN	Posey	15-5S-13W	SPS IN-4	607	Rooted massive sandstone
Ssmd1	019	KY	Webster	19-M-21	B #594	726	Disturbed-bedded massive sandstone
Sshz1	563.6	KY	Webster	16-M-21	B #545	466	Horizontal-bedded sandstone
Sshz2	563.6	IN	Gibson	34-3S-9W	SDH 293	139	Horizontal-bedded sandstone
Ssxz1	561	KY	Webster	16-M-21	B #545	378	Cross-bedded sandstone
Ssxz2	551	IL	Saline	29-10S-5E	COGEO S-2	212	Cross-bedded sandstone
Ssxz3	561	IN	Martin	17-5N-3W	NSWC (G)2	25	Cross-bedded sandstone
Ssxz4	561	IN	Gibson	18-1S-9W	SDH 327	280	Inclined-bedded sandstone
Ssrz1	553.5	IN	Martin	5-5N-3W	WES-10C-35	70	Ripple-bedded sandstone
Ssrz2	553.5	IL	Pope	8-11S-6E	COGEO E-2	132	Ripple-bedded sandstone
Ssrz3	553.5	IN	Pike	3-1S-9W	EIBIND-9	79	Ripple-bedded sandstone
Ssrb1	553.8	IN	Martin	8-5N-3W	NSWC (F)7	80	Bioturbated ripple-bedded sandstone
Ssfz1	563.5	IN	Posey	15-5S-13W	EXXON IN-4	521	Flaser-bedded sandstone
Ssfz2	553.5	IN	Martin	5-5N-3W	WES 10-C-24	26	Flaser-bedded sandstone
Sswz1	553.5	IN	Martin	17-5N-3W	NSWC (G)2	152	Wavy-bedded sandstone
Sswz2	553.5	KY	Webster	19-M-21	B #594	947	Wavy-bedded sandstone
Sswz3	533.5	KY	Webster	19-M-21	B #594	746	Wavy-bedded sandstone

Table 1. (cont.) List of rock core and coal samples with the classification code developed for this Illinois Basin Consortium (IBC) corebook; the Carolina Coal Group codes (Ferm) are included for comparison. [*Note*: The samples listed in this table are presented in the order in which the plates appear.]

IBC Code	Ferm Code	State	County	Location	Well Designation	Depth (feet)	Rock Type
Ssiz1	332.6	KY	Webster	19-M-21	B #593	935	Interlaminated sandstone and shale
Ssiz2	332.5	IL	Saline	29-10S-5E	COGEO S-2	203	Thinly interbedded sandstone and shale
Ssiz3	322.5	IL	Johnson	36-11S-3E	COGEO C-5	254	Thinly interbedded sandstone and shale
Ssib1	548	IN	Knox	9-5N-6W	EIBIND-18CH1	184	Bioturbated interlaminated sandstone
Ssib2	548	IL	Johnson	25-11S-4E	COGEO S-4	278	Bioturbated interlaminated sandstone
Ssid1	010 faulted	IL	Johnson	36-11S-3E	COGEO C-5	234	Disturbed-bedded interlaminated sandstone
Ssid2	018	IN	Martin	20-5N-3W	NSWC (D)5	169.5	Disturbed-bedded interlaminated sandstone and shale
Ssid3	322.8 rip	IN	Martin	20-5N-3W	NSWC (D)5	148	Disturbed-bedded interlaminated sandstone and shale
Ftmr1	327	KY	Webster	14-M-21	B #571	868	Rooted massive siltstone
Ftmr2	337	IN	Posey	35-5S-9W	SDH-285	824	Rooted massive siltstone
Ftmr3	377	KY	Webster	25-M-21	B #613	727	Rooted massive siltstone
Fthz1	363	IN	Gibson	29-2S-9W	SDH-322	472	Horizontal-bedded siltstone
Fthz2	323.6	KY	Webster	19-M-21	B #593	788	Horizontal-bedded siltstone
Fthb1	328	KY	Webster	16-M-21	B #545	383	Bioturbated horizontal-bedded siltstone
Ftlz1	322.5	IN	Martin	24-5N-4W	NSWC (A)4	35	Lenticular-bedded siltstone
Fttz1	322.6	IN	Martin	20-5N-3W	NSWC (D)5	160	Rhythmic-bedded siltstone
Fttz2	322.6	IN	Pike	3-1S-9W	EIBIND-9	127	Rhythmic-bedded siltstone
Fmzd1	010	IL	Macon	2-14N-1E	Nicor M-7	523	Disturbed-bedded mudstone
Fmmz1	257	IL	Crawford	2-6N-14W	Test Hole #1	386	Structureless mudstone
Fmmz2	247	KY	Webster	14-M-21	B #571	332	Structureless mudstone
Fmmz3	457	KY	Webster	25-M-21	B #613	724	Structureless mudstone
Fmmr1	327	KY	Webster	19-M-21	B #593	445	Rooted massive mudstone
Fmhz1	123	KY	Webster	16-M-21	B #545	654	Horizontal-bedded mudstone
Fmhb1	158	KY	Webster	16-M-21	B #545	436	Bioturbated horizontal-laminated mudstone
Fmhr1	137	KY	Webster	19-M-21	B #594	356	Rooted horizontal-laminated mudstone
Fszz1	119	IL	Saline	29-10S-5E	COGEO S-2	96	Shale

Table 1. (cont.) List of rock core and coal samples with the classification code developed for this Illinois Basin Consortium (IBC) corebook; the Carolina Coal Group codes (Ferm) are included for comparison. [*Note*: The samples listed in this table are presented in the order in which the plates appear.]

IBC Code	Ferm Code	State	County	Location	Well Designation	Depth (feet)	Rock Type
Fszz2	124	KY	Webster	19-M-21	B #593	995	Shale
Fszd1	010	IL	Macon	2-14N-1E	Nicor M-7	566	Disturbed-bedded shale
Fszf1	119	KY	Webster	19-M-21	B #593	329	Fossiliferous shale
Fslz1	322.8	IL	Saline	29-10S-5E	COGEO S-2	116	Lenticular-bedded shale
Fslz2	322.5 bio	IN	Posey	15-5S-13W	SPS IN-4	1,060	Lenticular-bedded shale
Fstz1	323 rhy	IN	Daviess	24-3N-6W	Little Sandy #1 Pit	34	Rhythmic-bedded shale
Fsiz1	322.5	IN	Daviess	8-5N-6W	SDH-213	184	Interlaminated shale and sandstone
Fsib1	322.8	IL	Johnson	25-11S-4E	COGEO S-4	200	Bioturbated interlaminated shale and sandstone
Cpmb1	998	KY	Webster	16-M-21	B #555	100	Bioturbated massive packstone (Limestone)
Cphf1	992	KY	Webster	19-M-21	B #593	656	Horizontal-bedded packstone (Limestone)
Cwmf1	997	KY	Webster	14-M-21	B #571	832	Massive wackestone (Limestone)
Cwmf2	992	KY	Webster	19-M-21	B #594	311	Massive wackestone (Limestone)
Cmmb1	908	KY	Webster	16-M-21	B #545	444	Bioturbated massive mudstone (Limestone)
Cmmr1	907	IL	Macoupin	15-10N-6W	MOS-77-11	336	Rooted massive dolomitic mudstone (Dolomite)

IBC Code	Ferm Code	Coal Type
Ovzz1	021	Humic coal–Bright coal (Vitrain)
Oczz1	021	Humic coal–Banded coal (Clarain)
Odzz1	024	Humic coal–Dull coal (Durain)
Ofzz1	021 fus	Humic coal–Fusain
Okzz1	024	Sapropelic coal–Cannel coal
Oizz1	034	Mixed organic/siliciclastic rocks–Bone (impure) coal
Oszz1	113	Mixed organic/siliciclastic rocks–Carbonaceous shale

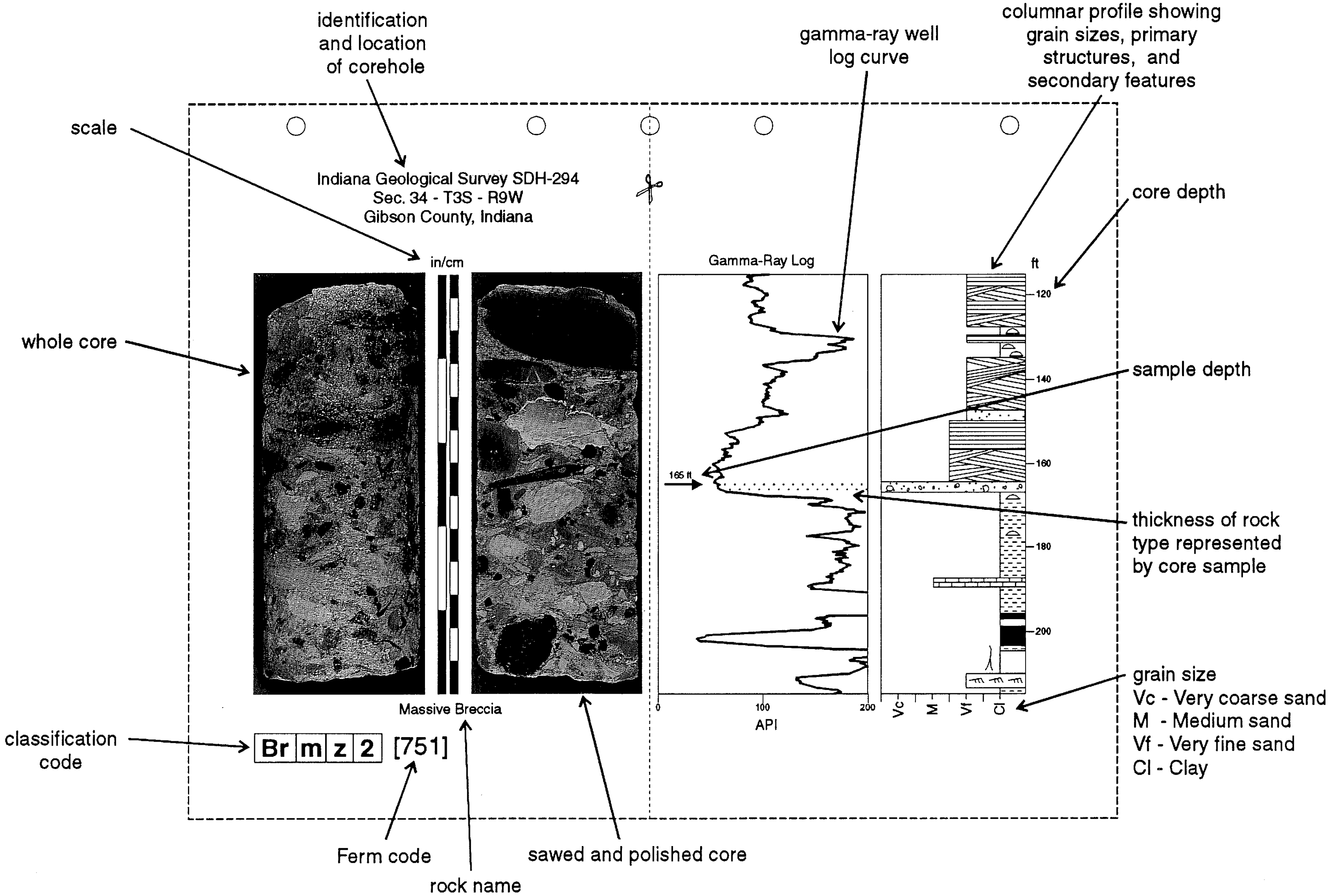


Figure 2. Example plate with explanation of the various components.

Lithology	Primary Structure	Secondary Feature
Gr - conglomerate Br - breccia Ss - sandstone Fm - mudstone (undifferentiated mixture of silt and clay) Ft - siltstone Fc - claystone Fs - shale Or - coal undifferentiated Ov - bright coal (vitrain) Oc - banded coal (clarain) Od - dull coal (durain) Of - fusain Ok - cannel coal Ob - boghead coal Oi - bone coal Os - carbonaceous shale Ca - carbonate undifferentiated Cs - siderite Cg - grainstone Cp - packstone Cw - wackestone Cm - mudstone Cb - boundstone Si - chert (silicified)	m - massive h - horizontal and low-angle bedding or lamination x - cross-bedding and inclined bedding r - ripple bedding f - flaser bedding w - wavy bedding l - lenticular bedding t - rhythmic bedding i - interlaminated/thinly interbedded z - other than above or not described	b - bioturbated r - rooted d - disturbed bedding f - fossiliferous s - slickensides z - other than above or not described

Figure 3. Abbreviations used in classification code.

the far left side of the page; the sawed and polished core is center left. A bar scale (inches and centimeters) is located between the photographs. To optimize the true color, cores were photographed using Fujicolor Reala film and tungsten lights.

On the right side of each plate are two figures representing the vertical stratigraphic sequence. On the center right a gamma-ray well-log (if available) represents 100 feet of section including 50 feet of section above and below the location of the core sample shown in the photographs. Where the gamma-ray curve goes off scale (above 200 API units), it is shown with a diagonal pattern. In a few cases the portion of the curve above 200 API units cannot be shown because it is not present on the original log (see Brmz2 at 190 ft). An arrow points to the exact location and depth where the core sample was taken, and a stippled pattern shows the thickness of the facies represented by the sample. On the far right is a graphic vertical profile showing the grain size and sedimentary structures of the facies represented by the core sample, and the rocks 50 feet above and below the sample. Figure 5 is an explanation of the symbols used in the stratigraphic columns. The depths shown are taken from core. In cases where the log depths are not the same as the core depths, the log curve has been shifted to match the core. The graphic profiles show the width of individual units as a function of the average Wentworth grain size for that unit. The size range used is from Cl (clay) to Vc (very coarse sand). Units plotting

	First Digit	Second Digit (properties)				Third Digit (sedimentary structures)					
	Lithology	Sandstone	Shale or sandy shale	Coal, limestone, or other	Conglom-erate matrix	Sandstone	Shale or sandy shale	Coal or bone	Limestone or shaly limestone	Conglom-erate clasts	Disturbed rocks
0	Coal, bone, flintclay, ironstone, deformed, or no rock recovered			No rock recovered or limestone without fossils				Undifferentiated			Undifferentiated
1	Shale		Black	Deformed	Calcareous sandstone	Cross-bedded		Banded		Shale and/or ironstone	Undifferentiated
2	Shale with limestone nodules	Tan or buff	Dark gray	Coal		Interbedded (layered)	Interbedded (layered)	Layered	Layered	Shale	Undifferentiated slump
3	Siltstone or sandy shale	Light gray	Light gray	Impure or bone		Horizontally laminated (streaked)	Horizontally laminated (streaked)	Streaked		Ironstone	Slumped shale
4	Sandy shale with limestone nodules	Medium gray	Green		Gray sandstone	Massive	Fissile	Cannel or massive dull	Massive	Quartz	Slumped sandy shale
5	Sandstone	Crystallized white or gray	Red and green		Crystalline sandstone	Undifferentiated bioturbated/ rooted	Undifferentiated bioturbated/ rooted		Mosaic	Rock fragments	Slumped sandstone
6	Carbonate cemented sandstone	Hard	Red		Hard sandstone	Mixed bioturbated and rooted	Mixed bioturbated and rooted		Nodular	Fossils	Undifferentiated mudflow
7	Conglomerate, breccia, or pebbly sandstone		Gray/green	Ironstone	Clay or silt	Rooted	Rooted	Shale layers	Rooted	Limestone	Shale mudflow
8	Shaly limestone		Red/ red-green		Mixed clay and lime mud	Bioturbated	Bioturbated	Shale streaks	Bioturbated	Coal bands	Sandy shale mudflow
9	Limestone			Limestone, shaly lime-stone, or flint clay with fossils	Lime mud	Fossils	Fossils	With pyrite		Coal spars	Sandstone mudflow

Figure 4. Carolina Coal Group rock core coding system (Ferm codes).

Note: Ironstone and flintclay can be further classified by structures for third digit by using the same column as shale; for shales and sandy shales that are interbedded or horizontally laminated (xx2, xx3), a decimal is added (rippled - xx2.5, flat - xx2.6, and bioturbated - xx2.8, and sandy shales with streaks - 3x4.3); for rocks with an additonal structure, it is added as a term (xxx.x rippled).

above Vc are conglomerates and breccias. The pattern of the unit represents a lithology for all rock types except sandstones and some of the finer-grained rocks, which are portrayed by the symbol for the dominant primary structure or secondary feature in the case of disturbed bedding (fig. 5). Rocks underlying coal seams are often referred to by a variety of terms—underclay, fire clay, seat-rock, and seat-earth—and can be represented by a variety of lithologies including mudstones, siltstones, sandstones, and even limestones, thus, they do not have a separate coding for lithology. For simplicity, they are referred to as underclay/paleosol in Figure 5 and are plotted with a distinct pattern (blank) because of their significance as the rooted zone (paleosol) below coal beds. In some cores, a distinct paleosol is not recognized below a coal. In other cases, the coals were too thin to be plotted or were absent; however, the underclay/paleosol is present and is shown in the column, and is an important indicator of the position of the coal. As an alternative, users may want to code these rocks according to their actual lithology. Organic-rich shale beds are also significant because they often overlie coals and serve as markers for correlation. They do not have a separate pattern, but can be recognized as a high gamma-ray spike on the gamma-ray log.

On the reverse side of each plate, the following information is provided for each core sample: 1) a descriptive name; 2) the formation from which it was obtained (see fig. 6 for stratigraphic chart); 3) a description of the sample including texture, composition, primary structures and secondary features, and fossils; 4) gamma-ray well-log characteristics (see fig. 7 for examples of gamma-ray curves); and 5) a reduced-scale map of the Illinois Basin showing the distribution of Pennsylvanian rocks and the approximate location of the well from which the sample was taken.

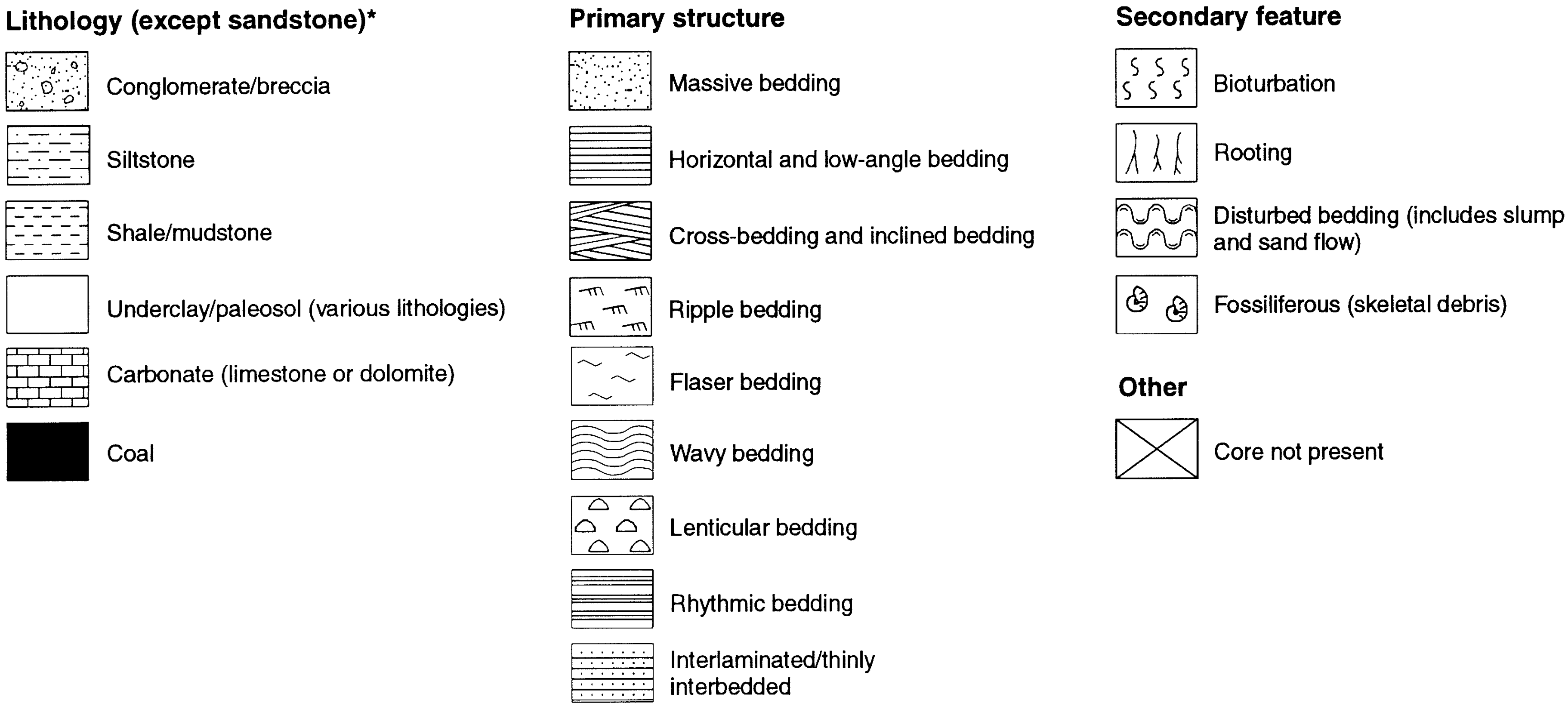
The plates for coals include a color photograph of each hand sample with name and classification code. On the reverse side of each plate the following information is provided for each sample: 1) a descriptive name; 2) a description of the lithotype; 3) a brief interpretation of source material and the interpreted peat-forming environment; and in some cases, 4) remarks emphasizing the practical importance of the lithotype.

Rock Classification In Corebook

Siliciclastic rocks – The siliciclastic rocks are subdivided primarily based on grain size (fig. 8), and secondarily, in the case of conglomerate and breccia, on the shape of the clasts. Further classification based on composition (as shown in fig. 8) or percent matrix was not considered necessary. Fine-grained rocks are subdivided based on their relative proportion of silt versus clay: mudstones are an undifferentiated mixture of silt and clay; siltstones have greater than 67 percent silt; and claystone and shale have greater than 67 percent clay. Shales are differentiated from claystone by the presence of fissility (separation of the rock into thin poker-chip or biscuit-shaped pieces in core). Fine-grained rocks not having fissility are described as structureless, but the term "massive" could be used as well, and they are coded as massive.

Limestone – The limestone subdivision (fig. 9) is primarily textural, reflecting the relative abundance of carbonate grains versus carbonate mud. This distinction is based on the widely used carbonate classification proposed by Dunham (1962). The secondary classification is based on composition (limestone vs. dolomite). The term "lime mudstone" could be used instead of "mudstone" to avoid confusion with siliciclastic rocks.

Coal – The coal classification (fig. 10), compiled by M. Mastalerz for this volume, is based mainly on such physical features as luster, fracture, and color. Megascopic layers of coal are called "lithotypes" and their succession reflects changes in plant communities as well as changes in the chemical and physical conditions that affected the preservation of plant material in the swamp. Four lithotypes of humic coal—bright (vitrain), banded (clarain), dull (durain), and fusain—and two lithotypes of sapropelic coal—cannel coal and boghead coal—are usually distinguished, although the



* Shales and siltstones are represented by patterns for either lithology, primary structure, or secondary feature.

Figure 5. Explanation of symbols used in vertical stratigraphic profiles.

latter two can look identical in hand specimens. Bone coal and carbonaceous shale, which are mixed siliciclastic-organic rocks, are also included in the coal group. There is no precisely defined minimum thickness for lithotypes, and a range of 3 mm to 10 mm commonly is used. In order to avoid confusion, 5 mm is suggested for the Illinois Basin, with the exception of fusain, for which, because of its unique depositional environment, all occurrences above 1 mm should be noted. If a layer of bright, banded, or dull coal is thinner than 5 mm it should be regarded as a part of the encompassing lithotype. For example, if a layer of bright coal 2 mm thick is surrounded by banded coal, it should all be described as banded coal.

Technique For Using Corebook

For those who want to follow the classification scheme used in the corebook, two flow charts are provided. One outlines the procedure for deriving a rock name (fig. 11) and the other for deriving a classification code using the primary structures and secondary features of the rock (fig. 12). The rock types used in the corebook were chosen because they represent, as clearly as possible, primary sedimentary structures. Many structures, however, tend to be transitional between different bed forms. On the back pages of many of the plates additional structures and features that are also present in the sample but which are less prominent are noted.

References

Cant, D.J., 1984, Subsurface facies analysis, *in* Walker, R.G., ed., Facies models, second edition: Geoscience Canada, Reprint Series 1, Geological Association of Canada, p. 297-310.

Dunham, R.J., 1962, Classification of carbonate rocks according to depositional texture, *in* Ham, W.E. ed., Classification of carbonate rocks—a symposium, American Association of Petroleum Geologists, Memoir 1, p. 108-121.

Ferm, J.C., Mathis, S.T., Berger, J.T., and Horger, W., 1983, Computer assisted treatment of borehole data for reserve estimation and mine planning: *in* Proceedings of the First Conference on Use of Computers in the Coal Industry, Society of Mining Engineers of American Institute of Mining, Metallurgical, and Petroleum Engineers, p. 320-324.

Ferm, J.C., and Melton, R.A., 1977, A guide to cored rocks in the Pocahontas Basin: Carolina Coal Group, Department of Geology, University of South Carolina, Columbia, 90 p.

Ferm, J.C., and Smith, G.C., 1981, A guide to cored rocks in the Pittsburgh Basin: Department of Geology, University of South Carolina, Columbia, 109 p.

Ferm, J.C., Smith, G.C., Weisenfluh, G.A., and Dubois, S.B., 1985, Cored rocks in the Rocky Mountain and High Plains coal fields: Department of Geology, University of Kentucky, Lexington, 90 p.

Ferm, J.C., and Weisenfluh, G.A., 1981, Cored rocks of the southern Appalachian coal fields: Department of Geology, University of Kentucky, Lexington, 93 p.

Smith, G.C., 1982, Methods and criteria for producing a photographic core logging manual for the Pittsburgh Basin: unpublished M.S. thesis, University of South Carolina, Columbia, 60 p.

The Tri-state Committee on Correlation of the Pennsylvanian System in the Illinois Basin, in review, Toward a more uniform stratigraphic nomenclature for rock units (Formations and Groups) of the Pennsylvanian System in the Illinois Basin: Illinois Basin Consortium Studies 4.

Suggested Reading

A discussion of the types of depositional environments responsible for each of the 73 samples is beyond the scope of this corebook. The best modern analogies for the Midcontinent Pennsylvanian coal-bearing rocks are now thought to be mud-rich, tropical, tide-dominated settings such as those found in the coastal environments of Indonesia and New Guinea. Unfortunately, these types of peat-producing depositional systems are poorly understood and few detailed depositional models exist for these areas. However, general descriptions of some of these environments can be found in the following publications:

Allen, G.P., Laurier, D., and Thouvenin, J.P., 1979, Etude sedimentologique du delta de la Mahakam: TOTAL, Campagnie Français des Pétroles, Notes et Mémoires, No. 15, 156 p.

Cobb, J.C., and Cecil, C.B., (eds), 1993, Modern and ancient coal-forming environments: Boulder, Colo., Geological Society of America Special Paper 286, 198 p.

(cont. on p. 19)

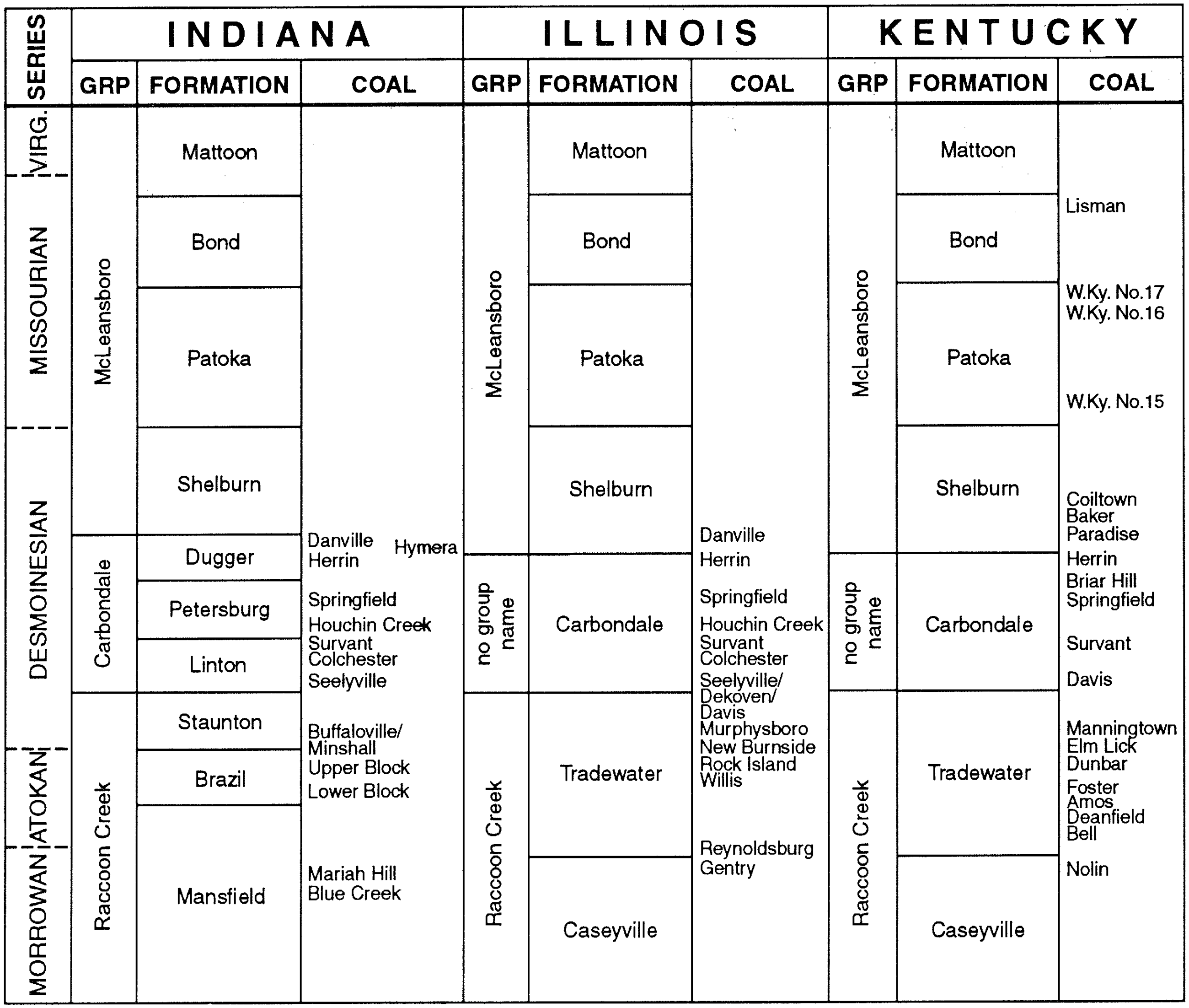


Figure 6. Pennsylvanian stratigraphy of the Illinois Basin. Columns show nomenclature and approximate position of significant coals. (Nomenclature after Tri-state Committee on Correlation of the Pennsylvanian System in the Illinois Basin, in review.)

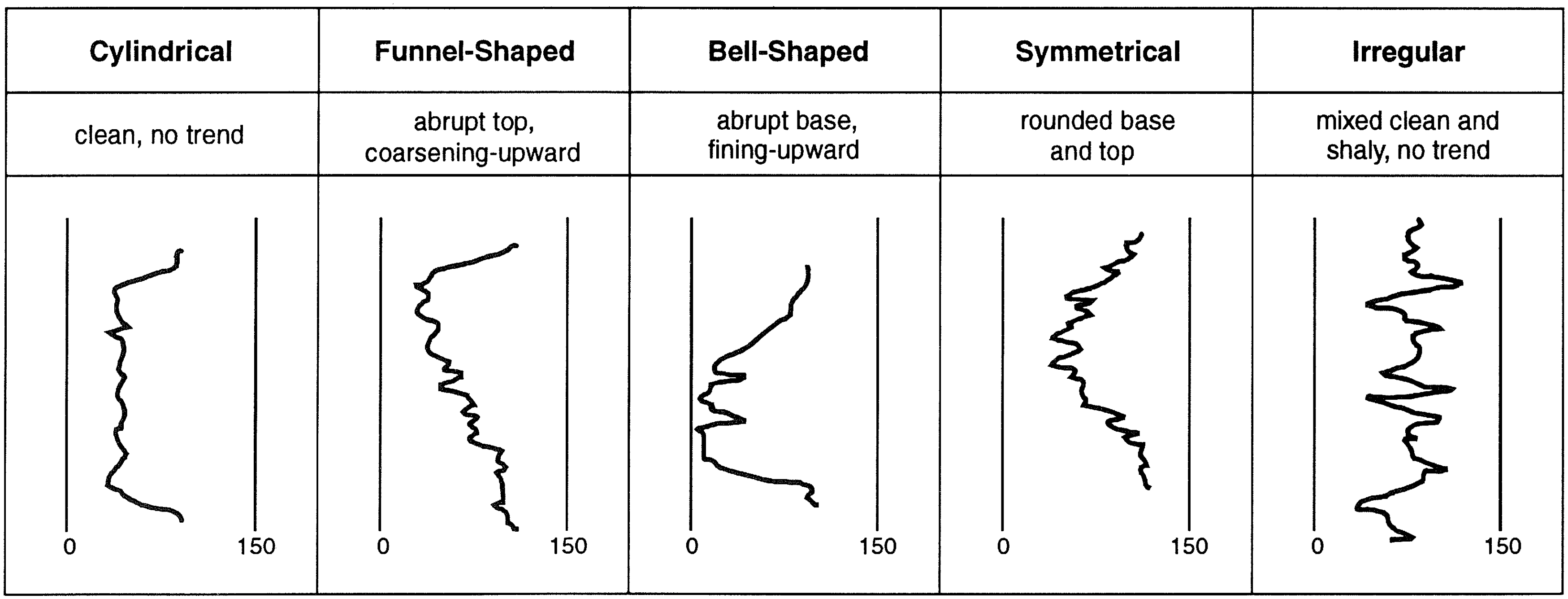


Figure 7. Idealized gamma-ray curve shapes as used in the descriptions on reverse side of plates (modified from Cant, 1984). Standard depositional environment interpretations based on the assumption that gamma-ray intensity is a direct function of clay content have not been included here because of the considerable overlap between different environments and curve shape. Cant (1984) lists some possible interpretations. The most common type of curve shape in the Pennsylvanian in the Illinois Basin is the irregular curve.

Composition

Grain Size		Quartz with <10% accessory mineral	Quartz, feldspar, clay minerals, and at least 10% rock fragments
Gravel-sized (>2 mm in diameter)	Rounded fragments	Quartz conglomerate	Lithic conglomerate
	Angular fragments	Quartz breccia	Lithic breccia
Sand-sized (0.0625 to 2.0 mm in diameter)		Quartz sandstone	Lithic sandstone
Silt- or mud-sized (<0.0625 mm in diameter)		Siltstone (0.0039 to 0.0625 mm) Shale or mudstone (<0.0039 mm) (Composition cannot be accurately determined in hand specimen.)	

Figure 8. Siliciclastic rock classification. Shaded areas included in this book.

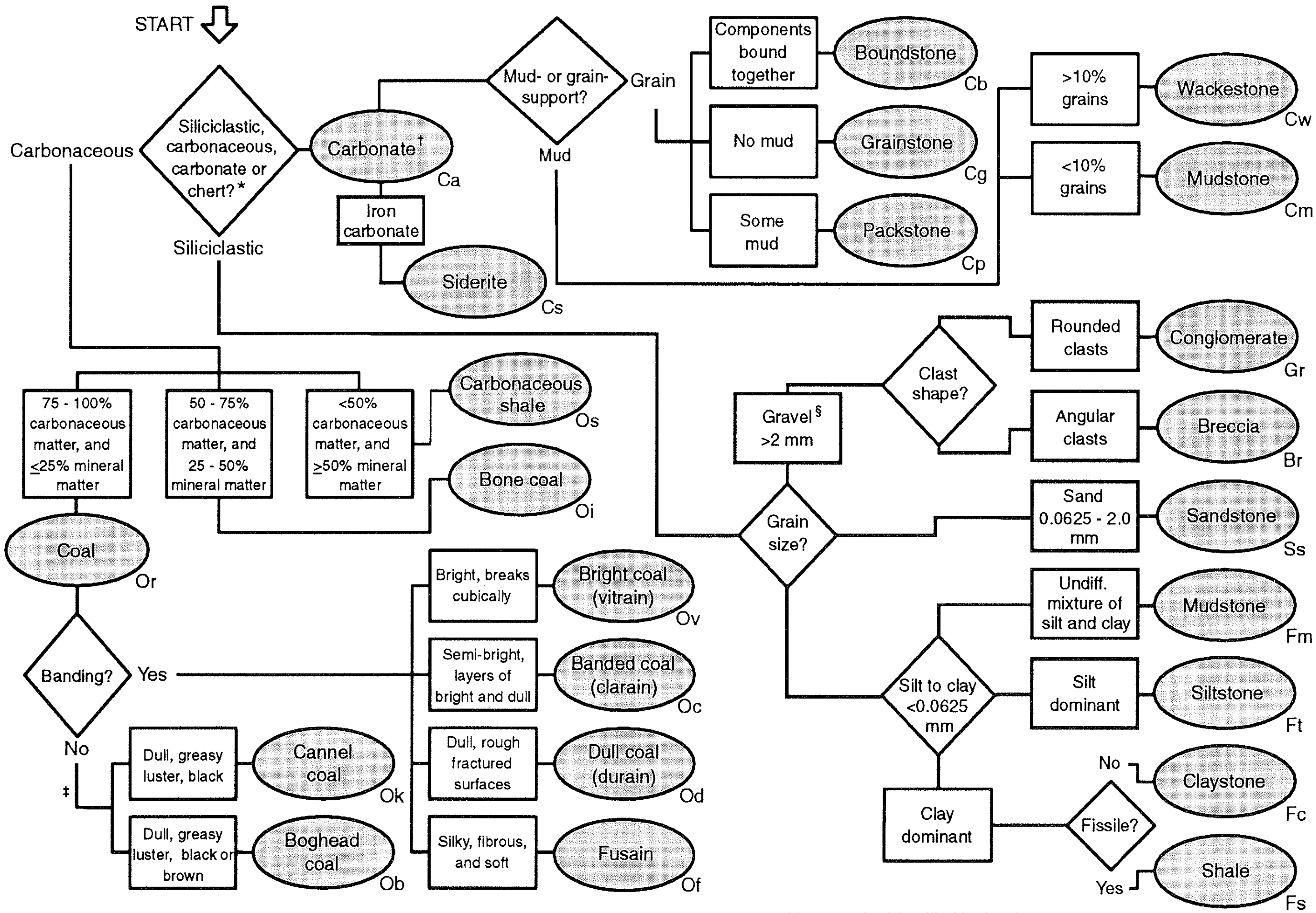
Composition

Texture	Calcite	Dolomite
Original components bound together	Boundstone	Dolomitic boundstone
Grain-supported, no mud	Grainstone	Dolomitic grainstone
Grain-supported, some mud	Packstone	Dolomitic packstone
Mud-supported, >10% grains	Wackestone	Dolomitic wackestone
Mud-supported, <10% grains	Mudstone	Dolomitic mudstone
Crystalline	Limestone	Dolostone (Dolomite)

Figure 9. Carbonate rock classification (after Dunham, 1962). Shaded areas included in this book.

Stratification		Luster and other diagnostic properties	Composition: Coal	Composition: Mixed organic-siliciclastic	
			75 - 100% carbonaceous matter, and <25% mineral matter	50 - 75% carbonaceous matter, and 25 - 50% mineral matter	<50% carbonaceous matter, and >50% mineral matter
Banded (humic coal)		Bright, breaks cubically	Bright coal (vitrain)	Bone coal (impure coal)	Carbonaceous shale
		Semibright, stratified layers of bright and dull coal	Banded coal (clarain)		
		Dull, rough fractured surfaces	Dull coal (durain)		
		Silky, fibrous, soft, dirties hands	Fusain		
Non-banded (sapropelic coal)		Dull, greasy luster, massive, con-choidal fracture, black	Cannel coal		
		Dull, greasy luster, massive, con-choidal fracture, black or brown	Boghead coal		

Figure 10. Coal and related rocks classification. Shaded areas included in this book.



* Chert can be identified by hardness.
† An acid test is needed to identify a limestone or dolostone.
‡ Differentiation is only possible using microscopic examination.
§ Determine if the clasts are predominantly quartz or lithic fragments.

Figure 11. Flow chart for deriving rock name and code. (See fig. 3 for full listing of terms and codes.)

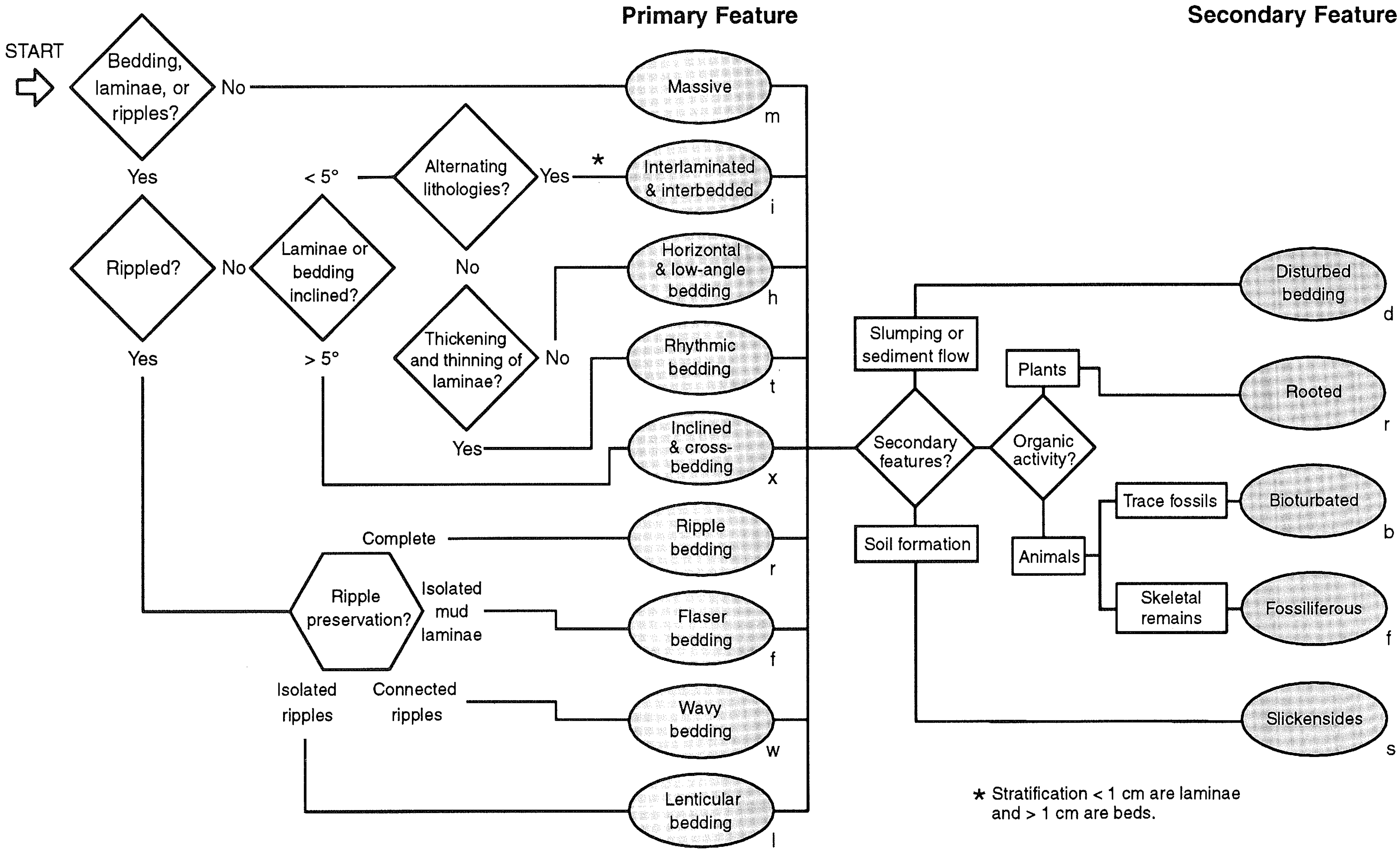


Figure 12. Flow chart for deriving a term and code for rock type incorporating primary structures and secondary features. (See fig. 3 for full listing of terms and codes.)

Staub, J.R., and Esterle, J.S., 1993, Provenance and sediment dispersal in the Rajang River delta/coastal plain system, Sarawak, East Malaysia, *in* Fielding, C.R., ed., Current Research in Fluvial Sedimentology: Sedimentary Geology, v. 85, p. 191-201.
Staub, J.R., and Esterle, J.S., 1994, Peat-accumulating depositional systems of Sarawak, East Malaysia: Sedimentary Geology, v. 89, p. 91-106.

For a discussion of the processes responsible for the generation of the sedimentary structures and carbonate textures illustrated in this corebook, the interested reader is referred to the following:

Allen, J.R.L., 1985, Principles of physical sedimentology: London, George Allen and Unwin, 272 p.
Collinson, J.D., and Thompson, D.B., 1989, Sedimentary structures, second ed.: Boston, Unwin Hyman, 207 p.
Dalrymple, R.W., Boyd, R., and Zaitlin, B.A., 1994, Incised valley systems: origin and sedimentary sequences: SEPM Special Publication 51, 391 p.
Dalrymple, R.W., Makino, Y., and Zaitlin, B.A., 1991, Temporal and spatial patterns of rhythmite deposition on mudflats in the macrotidal, Cobequid Bay–Salmon River estuary, Bay of Fundy, Canada, *in* Smith, D.G., Reinson, G.E., Zaitlin, B.A., and Rahmani, R.A., eds., Clastic tidal sedimentology: Canadian Society of Petroleum Geologists, Memoir 16, p. 137-160.
Devera, J.A., 1989, Ichnofossil assemblages and associated lithofacies of the Lower Pennsylvanian (Caseyville and Tradewater Formations), Southern Illinois, *in* Cobb, J.C., ed., Geology of the Lower Pennsylvanian in Kentucky, Indiana, and Illinois: Illinois Basin Studies 1, p. 57-83.
Harms, J.C., and Fahnestock, R.K., 1965, Stratification, bedforms, and flow phenomena (with an example from the Rio Grande), *in* Middleton, G.V., ed., Primary sedimentary structures and their hydrodynamic interpretation: Society of Economic Paleontologists and Mineralogists Special Publication 12, p. 84-115.
Kvale, E.P., and Archer, A.W., 1990, Tidal deposits associated with low-sulfur coals, Brazil Fm. (Lower Pennsylvanian), Indiana: Journal of Sedimentary Petrology, v. 60, p. 563-574.
Miall, A.D., 1992, Alluvial deposits, *in* Walker, R.G., and James, N.P., eds., Facies models, response to sea-level change: Geological Association of Canada, p. 119-142.
Potter, P.E., and Siever, R., 1956, Cross bedding, sources of basal Pennsylvanian sediments in the Eastern Interior Basin: Journal of Geology, v. 64, p. 225-244.
Reineck, H.E., and Singh, I.B., 1980, Depositional sedimentary environments: Springer-Verlag, New York, 549 p.
Rubin, D.M., 1987, Cross-bedding, bedforms, and paleocurrents, Concepts in Sedimentology and Paleontology, v. 1: Tulsa, Society of Economic Paleontologists and Mineralogists, 187 p.
Scholle, P.A., Bebout, D.G., and Moore, C.H., 1983, Carbonate depositional environments: American Association of Petroleum Geologists Memoir 33, 708 p.
Tucker, M.E., 1982, The field description of sedimentary rocks: Halstead Press (Wiley and Sons), New York, 112 p.
Tucker, M.E., and Wright, V.P., 1990, Carbonate sedimentology: Blackwell Scientific, Boston, 482 p.

For a discussion of coal formation, classification, sampling techniques, and compilation of geological data that will allow coal to be evaluated in terms of mineability and saleability, the reader is referred to the following publications:

Bustin, R.M., Cameron, A.R., Grieve, D.A., and Kalkreuth, W.D., 1983, Coal petrology, its principles, methods, and applications: Geological Association of Canada Short Course Notes 3, second ed., 230 p.
Diessel, C.F.K., 1992, Coal-bearing depositional systems: Springer-Verlag, New York, 721 p.
Thomas, L., 1992, Handbook of practical coal geology: John Wiley and Sons, New York, 338 p.