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CIRCULAR NO. 135

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REPRINTED FROM THE TRANSACTIONS OF THE ILLINOIS STATE ACADEMY OF SCIENCE
VOL. 39, PP. 86-95, 1946

PRINTED BY AUTHORITY OF THE STATE OF ILLINOIS

URBANA, ILLINOIS

1947

REFLECTIONS ON RECENT DIAMOND-DRILL EXPLORATION IN THE ILLINIOS COAL FIELD

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Diamond-drilling to obtain cores of the rock penetrated has long been the most approved method for coal bed exploration. It is obvious why this is so.

Coal mining and exploration companies drilled many hundreds of diamond-drill holes in the Illinois coal fields before 1915. When these holes were being drilled, either the present State Geological Survey was not yet in existence, or it was a new organization and the exploration agencies were reticent in allowing representatives of the Survey access to the cores and to the highly confidential information that these contained. In these early years the Survey occasionally added cores to its collections, particularly from one exploration company that drilled many holes in southern Illinois between 1912 and 1915, and was able to examine others in the field. However, most of the information about this early drilling came to the Survey files some time after the holes were drilled, usually in the form of generalized and commonly unsatisfactory driller's logs. One of these early cores provided the basis for the type succession of the McLeansboro formation[1]. Another was the core of the deep hole at New Haven, White County, which extended through the Pennsylvanian beds from about the position of the New Haven ("Shoal Creek") limestone.[2]

The number of cores actually logged by the Survey was only a small percentage of those drilled. Even as late as 1920 the Survey had not had access to cores of any holes drilled in Franklin County.

Between 1915 and 1940, deep core-drilling in the State was infrequent, except for a considerable number of holes drilled by the Madison Coal Corporation in Sangamon, Madison, and Williamson counties between 1920 and about 1925. The records of this drilling, such as it was, have largely come to the Survey files, and the cores of most of the holes drilled by the Madison Coal Corporation were examined by members of the Survey staff some time after the holes were drilled. Some of the cores representing the deeper holes were obtained for the Survey collection.

Mining operations in Illinois by 1940 had gone far toward exhausting the supply of coal explored in previous years. The increased productivity of the war years forced the exploration of new areas in the anticipation of the approaching need for new supplies of coal upon which to maintain the industry. Furthermore, although certain areas not yet exploited had been drilled, the records of such drilling were seen to be unsatisfactory for evaluating the coal resources and the quality of the coal and for planning mining opera-

[1] Udden, J. A., Delafield drill core: Illinois Geol. Survey Bull. 4, p. 203, 1907.
[2] Cady, G. H., Coal resources of District V: Illinois Geol. Survey Coop. Mining Ser. Bull. 19, p. 18, 1919.

tions. Accordingly redrilling of such areas was often regarded as necessary. As a result, the last three years have seen a noteworthy revival of exploratory diamond-drilling in the southern half of the State, an activity which is probably not at an end.

The recent drilling has been in Bond, Madison, Randolph, Christian, Fayette, Franklin, Jefferson, Saline and Williamson counties. In the central-eastern part of the State there has been considerable exploration in Douglas County. With most of this drilling the Survey through the Coal Division has been in close touch, actually being on the ground when hundreds of feet of the cores were pulled. In addition we have had opportunity to log numerous cores of holes located adjacent to the east boundary of Illinois in Vigo and Sullivan counties in western Indiana. Altogether, some 45 to 50 thousand feet of cores have been logged by members of the Coal Division in the last three years.

This increase in detailed information concerning the Pennsylvanian succession has been mainly with respect to the McLeansboro and the upper part of the Carbondale groups down to and including Harrisburg (No. 5) coal bed. However, additional information has been obtained from several drill-holes in Franklin County, from one in Madison County, from two in Lawrence County, and from several in Vigo County, Indiana, regarding strata lying near or below the base of the Carbondale group.

The examination of these cores has provided a detailed picture of the stratigraphic succession for several areas, from a position that appears to represent the Curlew limestone of the upper Tradewater group to a position somewhat above that of the Millersville limestone of the upper part of the McLeansboro group. In Fayette County, a core has been logged from a short distance above the Millersville limestone (which is exposed in outcrop in the immediate region) to the No. 6 coal bed. In Jefferson County the cores logged extended from about 300 feet above what is called the "Shoal Creek" limestone in that county to below the position of the Harrisburg (No. 5) coal bed. In Franklin County the drilled section extends from above the "Shoal Creek" limestone to the upper part of the Tradewater group down to a short distance below what is believed to be the Curlew limestone. In Madison County the explored section extends from a short distance above the Carlinville (possibly the same as the Shoal Creek) limestone to the La Salle (No. 2) coal bed. In Vigo County, Indiana, the strata explored extend from what is thought to represent the Shoal Creek limestone to Indiana No. III coal bed. In Lawrence County drilling started in the Pennsylvanian beds some 200 to 250 feet above the "Shoal Creek" limestone and continued to the coal bed that probably represents the No. III coal bed of Indiana.

The study of these diamond-drill cores and the information provided by the field and laboratory work in connection with the logging of rotary drill-holes suggest a few more or less significant generalizations and raises certain problems in regard to Pennsylvanian sedimentation and succession in the Illinois coal field.

1) The "Shoal Creek" limestone seems to be one of the most widespread limestone members of the Pennsylvanian strata within the area bounded by its outcrop. Its similarity from hole to hole in Franklin and Jefferson counties is remarkable, as is likewise the simi-

larity of the limestone in the cores with the limestone outcropping in the northern part of Washington County, northwest of Nashville. However, there are places in the central part of the Illinois Basin where, if present, it is not readily recognized.

2) The Herrin limestone or caprock of No. 6 coal bed is probably the most widespread Pennsylvanian limestone in Illinois. It is also notably uniform in character, but in southwestern Illinois it takes on nodular structure not generally found elsewhere. But this limestone is not absolutely continuous, as witness its common absence above the Grape Creek coal bed in Vermilion County, above the "Second Vein" in La Salle County, and in places in the thick coal area in Franklin County.

3) All other limestones appear to have a fringe-like distribution with respect to the border of the depositional area. The Cutler and Bankston limestones fringe the southwestern edge of the coal basin; the Lonsdale limestone fringes the western and northern and possibly also the eastern margins as the West Franklin limestone.

4) Recent drilling has not yet produced final answers to the problems of the relation of the Carlinville and Shoal Creek limestones, of the Millersville, the La Salle, and one or more limestones designated as Livingston and Shaw Point, of the Greenup and Omega limestones. Although the position of the Scottville limestone is definitely established as being between the Piasa and Carlinville in Macoupin county, none of the drilling in Madison, Bond, and Christian counties has penetrated a limestone at the position appropriate for the Scottville. It also appears to be one of the "fringe" limestones mentioned above.

It is probable that certain of the higher limestones of the McLeansboro also have restricted "fringe" distribution. This appears to be the case for the La Salle, Shaw Point, Millersville, Omega, and Greenup, and possibly the limestone or limestones designated as the Livingston. In general, core drilling has not been so distributed as to penetrate the horizon of those higher limestones, and much uncertainty continues to exist about their relationships.

5) Marine limestones are by no means always underlain by coal beds. Limestones with which coal beds are commonly associated are the St. David (No. 5 coal bed), Herrin (No. 6 coal bed), Cutler (Cutler coal bed), and there are a number of others that are less well known. On the other hand, marine limestones with coal beds but a short distance above them are the Stonefort, Herrin, Bankston Fork, and West Franklin; and others less well known.

6) Special attention has been paid to the character of the strata intervening between fairly widely spaced coal beds. This is the position in which erosion disconformities are most commonly found. However, it seems to the writer that the arrangement and relationship of beds just as often and, indeed more commonly except at certain positions, are indicative of complete transition in deposition from one coal bed to the next. The transitional succession most commonly and characteristically proceeds downward from the nodular-bearing greenish-gray massive clay-shale beneath the underclay of the coal bed to a greenish-gray clay shale also usually massive, containing frequent sideritic or calcareous veinlets, granules, or spongy masses of siderite or calcite or both. This in turn grades down into a greenish-gray shale at first faintly

and then more strongly interlaminated with light gray or nearly white siltstone. The amount of siltstone commonly increases downward and the interbedded or interlaminated shale and siltstone is likely to display ripple-marked, slumping, and marbleoid pattern. The shale also changes color from greenish-gray to gray. These beds may grade on the one hand into gray massive, micaceous coarse siltstone which gradually become finer and finer, more fossiliferous, and more calcareous as the next coal bed is approached, or the transition may be to more sandy beds. Usually the change from these sandy beds to the underlying fine shale above the next coal bed is rather sharp, but evidences of erosion and basal conglomerates are the exception rather than the rule. In the drill-cores that have been examined in the last three years, particularly those in southern Illinois and Lawrence County, the sideritic massive greenish-gray clay shales may be included among the characteristic members of the Pennsylvanian succession along with the marine limestones, black sheety shales, coal beds, underclays, and underclay limestones; indeed they are almost as frequently encountered as the coal beds and underclays. When subjected to weathering these sideritic, massive, greenish-gray clay-shales exhibit little resistance and tend to disintegrate almost completely. Hence their unweathered character is probably not commonly apparent in outcrop or distinguishable from that of the overlying underclays.

7) The conglomerates of the Pennsylvanian system are not widespread. These most commonly occur at or near the base of massive to somewhat crossbedded and more or less local sandstones, suggesting rapid deposition in fluctuating currents. The larger fragments of the conglomerates are of various kinds of materials, but probably ironstones and shale blebs are the most common constituents, although limestone pebbles and coal shreds and fragments are also very common. Some conglomerates consist of a sandstone matrix in which may be embedded one kind of larger fragment of shale, coal, or ironstones, others are mixtures. Not uncommonly the conglomerate is very calcareous, being composed almost entirely of fragments of limestone embedded in a sandy but very calcareous matrix. Furthermore, some conglomerates are not basal in the sandstone section but appear as though floating in the sandstone formation. Usually the base of the conglomeratic bed, if it rests upon shale, appears to be uneven. At any rate, there is a sharp change from conglomerate to shale.

It is usually not possible to identify the source of the pebbles contained in the conglomerates in the rocks penetrated in the cores. However, in a conglomerate penetrated in a drill-hole located in southern Jefferson County the pebbles scattered in the sandstone closely resembled the gray siltstone which was the member immediately underlying the sandstone. In Jefferson County a thickening of what is believed to be the Anvil Rock sandstone (which cuts down across the position of No. 6 coal bed) carries pebbles and shreds of coal in great quantity, forming a coal-sandstone conglomerate at about the position of the coal bed. In southern Sangamon County, a recently drilled hole penetrated a boulder and fragments of coal in a sandstone at about the position of No. 6 bed. Spore analysis yielded spores characteristic of No. 6 bed. At about the appropriate distance below, the drill passed through No. 5 bed in normal position.

Conglomerates of the kind described seem to be most prevalent in a relatively narrow stratigraphic zone extending from a little above the Cutler, Piasa, Lonsdale, and West Franklin limestone zone to the base of the McLeansboro. Where a conglomerate is found in the Anvil Rock sandstone it seems probable that the base of the McLeansboro may protrude into the upper part of the Carbondale formation as a channel deposit.

Conglomerates of much the same kind are found occasionally but not commonly at other positions in the McLeansboro group, and it may be that it is only because so much of the drilling has been in the lower 500 feet of the McLeansboro. Now that more holes penetrate strata 500 to 800 feet above this coal bed, the picture may change somewhat.

The Pennsylvanian conglomerates have more or less unique characteristics in two particulars. They are poorly sorted with respect to hardness: Limestone, ironstone, and shale pebbles or blebs are commonly found in the same conglomerate, unsorted as to size or character. Secondly, the components of the conglomerate are commonly exceedingly irregular in form with a conspicuous angularity or aciculate form. This is particularly true in the case of the softer materials such as shales and coal. It seems strange that such angular soft material could have been transported even a few feet along with the sand with which it is associated without being entirely disintegrated. Shale fragments of this type would even today maintain their sharp edges only the briefest time if simply immersed in water even without agitation. Some conglomerate consists of sandstone in which such fragments of coal or irregular pieces of shale have been suspended.

The fact that the type of conglomerate described is particularly common in the lower part of the McLeansboro gives some plausibility to a belief that special conditions account for its peculiarities. Any postulated conditions that are sufficiently generalized to explain ordinary conglomerates without explaining their special concentration at the stratigraphic position would be unsatisfactory. Furthermore, it seems probable that unusual conditions which would result in the formation of the angular sedimentary conglomerates of soft material would give rise to other phenomena, peculiar to the sedimentary beds of this same general period.

8) Another of the mysteries of the Pennsylvanian succession in Illinois is the origin of the variegated shales. A useful stratigraphic index of the general position of the No. 6 coal bed in southwestern Illinois is a group of variegated-reddish green, yellow, purple, and gray, clay shales lying 40 to 60 feet above the coal bed. Diamond-drill cores show that there is a good deal of irregularity in the exact position of these clay shales but they generally seem to be present near or at the position of the limestones known as the Piasa, Cutler, Lonsdale, and West Franklin. Whether or not these are the same or different limestones is still a moot question; thus far in the examination of drill-cores none has been seen in which more than one limestone appears to correspond to one or other of these beds, but generally one such limestone is present. It is near such a bed that the red shale is usually found in Madison, Bond, Christian, Fayette, Randolph, and St. Clair counties, Illinois, and in Vigo County, Indiana. Variegated shale is also found in outcrop associated with the Lonsdale limestone in Peoria, Marshall,

and La Salle counties, and with the West Franklin limestone in the Evansville region of southern Indiana. Rarely such variegated shales are seen in cores from southern Illinois.

It may be significant, in connection with consideration of the McLeansboro conglomerates described above, to note that the geographic distribution of the variegated shales corresponds closely with that of the conglomerates. Both of these phenomena may possibly be related to a common cause. At any rate the fact that there seems to be an association of two unusual conditions stimulates the curiosity as to the possibility of there being others. Two others suggest themselves: The first is the fact that coal beds No. 6 and No. 7, in the upper Carbondale and lower McLeansboro groups, respectively, are the only two coal beds of the Illinois Pennsylvanian that are conspicuously and persistently benched, pointing to the existence during their accumulation of several interrupted but individually complete coal formation periods, and several periods, possibly equally long, when peat was not accumulating. The second item of interest is the exceedingly irregular distribution of the No. 7 coal bed. In general it is thickest in the northern part of the coal field but particularly in the northern part of Peoria and in western Marshall County and again in Vermilion County and in certain parts of Indiana mainly north of Terre Haute, but even here it is quite irregular. It is not present in southwestern Illinois in Madison, Bond, and the western part of Christian County, and is irregular in Sangamon County. Whether this No. 7 coal of northern part of the coal basin is the same as the Cutler coal bed is uncertain. The distribution of No. 7 coal bed in Vigo County, Indiana, is very irregular, apparently mainly due to erosive cut-outs.

The present brief paper can do little more than call attention to some of the peculiar aspects of Pennsylvanian sedimentation and stratigraphic succession that have been discovered as a result of the study of diamond-drill cores during the last 30 months. The stratigraphic zone represented by the lower part of the McLeansboro is one of particular interest. By no means all the peculiarities of this zone have been enumerated, and until at least the more obvious ones have been listed and described, their environmental conditions can not be understood. Each unusual feature promotes speculation and suggests one or more hypotheses in explanation. Rarely are conditions more conducive for the operation of the multiple working hypothesis in developing a satisfactory theory of the Pennsylvanian sedimentation. It is an appropriate field of academic research in sedimentation, stratigraphic classification, and paleontologic and paleobotanic stratigraphy.

USE OF INTERNATIONAL BUSINESS MACHINE TECHNIQUE IN TABULATING DRILLING DATA

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The International Business Machines are primarily electrically operated accounting machines, designed to reduce error and time in handling large and complicated financial records.

The system is based on punching the data into cards which form a permanent record and which may be used to compile data in a variety of ways.

There are three principal machines: (1) a punch machine, on which the cards are prepared; (2) a sorter, which mechanically arranges the cards in any desired order; and (3) a tabulating machine, which mechanically prints the data from the punched cards.

The sorter handles 440 cards per minute, and the tabulator prints the data from the cards at the rate of 80 cards a minute.

All cards used in the International Business Machines are of the same size and kind of paper. There are 80 vertical columns across the card, allowing one number or letter to be punched in each. Within a column there is space for twelve accurately located holes to be punched. The position of the hole or holes in any one column determines the number or the letter punched.

When the punched cards are fed into any other machine, these holes permit electric contacts to be made which mechanically sort the cards, list the data, or reproduce the punched holes.

The Coal Division of the Illinois State Geological Survey has adapted the use of these machines to facilitate the handling of tabulated geological data that accompany structural contour maps. Thus it is possible to assemble the necessary data for each datum point for use both in the preparation of the map and for publication.

The information for use with structure contour maps is first written on the lower portion of the "log record" card. Along the upper part of the card are the column headings for the information that is to be punched on the card.

The card is then placed in an Alphabetic Punch machine, which has a keyboard similar to that of a standard typewriter, and the data are punched into the card. Simultaneously with the punching operation, the characters are printed along the upper edge of the card. The card shown in figure 1 has been punched from the information written on it.

As the amount of information which can be punched on any one card is limited (by the number of columns in the card) to 80 characters, it is frequently desirable to use more than one card for any one well record. In such a case, the first card shows the full location of the well by township, range, section, and fraction of section, the ground elevation above sea-level, the year drilled, type of hole, total depth, county map number, company name and number, and the depth, altitude, and thickness of two coal beds. The second card repeats the location and county number but also gives the farm name and number and data regarding two other formations. Additional cards that may be needed repeat only the location and county

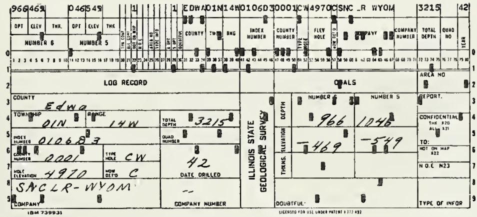

FIG. 1.—Well log record card punched from handwritten data on IBM card.

number (for identification), and give data on any additional two formations. Although the location and county numbers are punched on all the cards for each datum point, these items are printed only once when the data are listed.

The cards are mechanically arranged in the desired order by the sorting machine. This machine will sort according to one column at a time, arranging the cards by the positions of the holes in that column. Thus the cards when removed from the pockets of the machine will be in numerical order 0-9. Each letter is represented by two holes, so that the cards must be sorted twice on a column in order to be arranged alphabetically.

Suppose we wish to tabulate data on 350 wells with two cards for each well, or a total of 700 cards. It takes about 25 minutes to sort all the cards by county number and by location in township, range, section and fraction of section. It takes another 15 minutes to print the list. Each line of printing represents one card.

The printing is done on the Alphabetic Accounting machine or tabulator. The cards are placed in the upper hopper and pass one at a time between two sets of brushes and rollers which make the electric contacts, and then the cards emerge in the lower hopper. The electric contacts send impulses through the machine to a plugboard where they are connected by wires to the type bars.

Figure 2 shows a list of tabulated data arranged by county number. Figure 3 shows a list from the same cards arranged by location.

The data need not be printed in the same order in which it appears on the card or in these lists. This permits considerable flexibility in the use made of the cards.

If the cards have been checked and are known to be correct, there is no further need to proofread these lists.

These lists may be photographed, reduced, and planographed for publication.

In addition to straight listing of data, this machine will add or subtract and print totals. It will omit certain punched data, enabling the same cards to be used for Survey lists and also for publication where confidential information is to be withheld.

By using a reproducing punch machine, it is possible to take the correctly punched cards and mechanically punch all or part of the information into a new set of cards. This is much faster than manual punching.

For instance, we compile mechanically the data for use in preparing maps showing the interval between

LOCATION OF HOLE			COUNTY NUMBER	TYPE OF HOLE	OPERATOR	OPR'S NUMBER	SURFACE ALTITUDE	TOTAL DEPTH	QUAD. NUMBER	YEAR DRILLED	DOUBTFUL INFORMATION	COAL NO 6				COAL NO 5			
TOWNSHIP	RANGE	SECTION										DEPTH (FEET)	ALTITUDE (FEET)	THICKNESS FT	THICKNESS IN	DEPTH (FEET)	ALTITUDE (FEET)	THICKNESS FT	THICKNESS IN
					EDWARDS NOV 15 1945														
1N	14W	6 03	1	CW	SNCLR WYOM BIERHAUS A	1	4970 C	3215		42		966 709	469* 212*			1046 912	549* 415*		
1S	10E	16 E7	2	CW	NELSON DEV REID A	1	4270 0	3388	239	43		940 666	513* 239*			1034 893	607* 466*		
1S	11E	7 G6	3	CW	MAGNOLIA GOULD E	1	5070 C	3350	239	42		926 698	419* 191*			1012 888	505* 381*		
2S	10E	8 E7	4	CW	NELSON DEV BUNTING C	1	4690 C	3447	239	43		975 709	506* 240*			919	450*		
2S	10E	19 A1	5	CW	SUN OC MCKIBBEN R	1	4370 0	3394	239	42		938 646	501* 209*			1015 862	578* 425*		
3S	10E	8 B2	6	CW	SNCLR WYOM PERKINS H	1	4140 C	3410	239	42		878 604	464* 190*			1019 837	605* 423*		
3S	14W	17 H1	7	CW	HALBERT R C PROCTOR	1	4060 0	3100	238	43		844 572	438* 166*			918 792	512* 386*		
2S	14W	20 A6	8	CW	KINGWOOD OC COWLING W	1	4670 0	3247	239	43		928 651	461* 184*			1023 879	556* 412*		
1N	10E	18 02	9	CW	MIDSTATE OC MCKINLEY	1	3940 0	3350		43		946 686	552* 292*			1041 904	647* 510*		
3S	10E	13 H8	10	CW	MIDSTATE OC COAD M		4830 C	3240	239	43		964 711	481* 228*			1055 934	572* 451*		
1N	14W	10 F1	11	CW	MAGNOLIA MATTHES	1	4130 0	2918	234	43		790 548	377* 135*			905 738	492* 325*		
1N	10E	4 C5	12	TO	ILL PROD BARBER H C	1	4420 C	3301		43		955 710	513* 268*			1030 918	588* 476*		
1N	10E	9 A3	13	TO	RYAN FRTNR RALSTON	1	4450 C	3336		43		984 721	539* 276*			1063 943	618* 498*		

FIG. 2.—Wells listed by county number.

two formations, by using our standard "log record" cards. This is done by reproducing the location of the well and the elevations of all formations into a new set of cards containing one card for each well.

The cards are then run through the tabulating machine which me-

Location of Hole: Township	Range	Section	County Number	Type of Hole	Operator	Op'r's Number	Surface Altitude	Total Depth	Quad. Number	Year Drilled	Doubtful Information	Coal No 6: Depth (Feet)	Altitude (Feet)	Thickness Ft	In	Coal No. 5: Depth (Feet)	Altitude (Feet)	Thickness Ft.	In
					EDWARDS NOV 15 1945														
1N	10E	4 C5	12	TD	ILL PROD BARBER H C	1	4420 C	3301		43		955 710	513* 268*			1030 918	588* 476*		
1N	10E	9 A3	13	TD	RYAN FRTNR RALSTON	1	4450 C	3336		43		984 721	539* 276*			1063 943	618* 498*		
1N	10E	9 C5	14	TD	BANDER DLDS IBBOTSON G	1	4550 D	3294		43		1003 737	548* 282*			1082 961	687* 506*		
1N	10E	13 A1	15	TD	WALSH DYE TULL W S	1	4830 C	3302		42		934	451*		0	1013 895	530* 412*		
1N	10E	16 G3	16	TD	ARMOUR ETL RALSTON	2	4710 D	3319		43		1000 737	529* 266*			1076 957	605* 486*		
1N	10E	18 D2	9	CW	MIDSTATE OC MCKINLEY	1	3940 D	3350		43		946 686	552* 292*			1041 904	647* 510*		
1N	14W	6 D3	1	CW	SNCLR WYOM BIERHAUS A	1	4970 C	3215		42		966 709	469* 212*			1046 912	549* 415*		
1N	14W	10 F1	11	CW	MAGNOLIA MATTHES	1	4130 D	2918	234	43		790 548	377* 135*			905 738	492* 325*		
1S	10E	16 E7	2	CW	NELSON DEV REID A	1	4270 D	3388	239	43		940 666	513* 239*			1034 893	607* 466*		
1S	11E	7 G6	3	CW	MAGNOLIA GOULD E	1	5070 C	3350	239	42		926 698	419* 191*			1012 888	505* 381*		
2S	10E	8 E7	4	CW	NELSON DEV BUNTING C	1	4690 C	3447	239	43		975 709	506* 240*			919	450*		
2S	10E	19 A1	5	CW	SUN OC MCKIBBEN R	1	4370 D	3394	239	42		938 646	501* 209*			1015 862	578* 425*		
2S	14W	20 A6	8	CW	KINGWOOD OC COWLING W	1	4670 D	3247	239	43		928 651	461* 184*			1023 879	556* 412*		

Fig. 3.—Wells listed by location.

chanically subtracts one elevation from another and prints a list showing for each well, its location and the interval from the No. 6 coal to each of the other formations.

The machines can also be adapted to handling chemical analyses of coals or other types of data.