XXXVI. SUBSURFACE STUDIES

R. D. Reed

From the Department of Geology of the University of Oklahoma.

The practice of using well records to supplement the information that may be gained from surface studies is probably as old as the science of geology. In a good many instances unfortunately the work has been rather carelessly and uncritically done. In the last few years, however, the phenomenal rise of subsurface work in the oil fields of the Mid-Continent has directed attention as never before to this source of information. "Subsurface geologists" now have a place on the ordinary oil company geological staffs. Courses in "subsurface geology" are given more or less adequately in the colleges. So much attention to the subject has naturally developed the technique of extracting information from well records. At the same time, the average standard of well records is probably higher than ever before.

These facts, combined with the ever-increasing number of well records available, make it probable that there is now on hand more definite information in regard to the actual stratigraphic relations of the formations encountered in drilling in Kansas and Oklahoma than about any area of similar size and structure in the world. Whether or not this information will ever be made available to the general geologist is doubtful. Some general studies of note, and a few detailed studies of small area have already been published. The vast majority of the data is still gathering dust in the archives of the oil companies and of the Geological Surveys.

In the belief that these data have much value to the stratigrapher and to the general geologist, this paper is submitted as a study of well records and their possibilities.

The deficiencies of well records, as compared with well-made columnar sections, are innumerable. Some of the records are hopelessly bad,—made, in some cases, for the purpose of misleading the curious. Others fail to discriminate between such tolerably dissimilar rocks as sandstone and limestone. In some of them, measurements of depths and thicknesses, particularly of the non-petroliferous beds, are very inaccurately given. In the best of them there is a lack of fine discrimination that is very annoying. The most dissimilar types of sandstone are all lumped together as "sand." The more than two and seventy types of limestone are all "lime." Shales, which as a matter of fact are commonly not examined at all by the driller, are subdivided more commonly, but not much more usefully.

In spite of these and other deficiencies, the most far-reaching decisions as to drilling, care of wells, and so forth, are habitually

made by the large oil companies on the advice of geologists and engineers who study well records. If the records are good enough to decide such expensive matters, they ought also to be worth considering for the stratigraphic data they may furnish. As a matter of fact, even in comparison with well made columnar sections, well records have some advantages. The depths and thicknesses are often more accurately given than is possible from surface studies. There are no gaps due to lack of exposures. And the records are in many districts numerous and easily obtained.

The value of a well record depends, of course, upon the interpretative ability of the man who is to use it. The record, if honestly made, gives the driller's impression of the character of the rock with which he was dealing. This fact ought to give the geologist a valuable hint, at least, as to the character of the rock. It is important for the geologist to take as sympathetic an attitude as possible toward the driller and his work. If he does so, he will consider the driller, not as an ignoramus, but as a skilled workman whose whole life is spent in a struggle with various kinds of rocks. The driller knows no petrography, but he knows a great deal about how different rocks affect his drill, and that depends on their properties. He considers rocks merely as obstacles to be overcome, but in overcoming them he must learn many things about them very well. On the basis of these facts of his experience he makes his classification of rocks.

If a rock drills slowly and abrades the bit, no examination of it is necessary to tell the driller that it is a "sand." It may in some cases actually be a chert, of course, or some other hard rock, but it is usually a sandstone. If it drills slowly but does not "cut the bit," it is a "lime," which examination usually shows to be a limestone. Rocks that drill easily are the "shales" and "slates." Contrary to established petrographic usage, however, the driller's "slate" is commonly the softer of the two varieties. If the rock breaks up into chips which are recognizable as such in the cuttings, it is a "shale;" otherwise it is a "slate."

Some other terms used as rock names in the logs from Kansas and Oklahoma are "cave," "shell," "break," "chat," "granite," and "soapstone." Most of these names are of rather obvious meaning. One or two are less obvious. "Shell," for example, is a thin hard stratum that temporarily holds up drilling operations, and then allows the bit to break through; thin sandstones or limestones, or bands of ironstone, serve equally well. "Break," on the other hand, is a thin shale stratum separating two harder layers.

With all that can be done to get at the real meaning of the dril-

ler's words, however, it still remains advisable to supplement the data from the ordinary logs with facts secured in other ways. In actual practice, three distinct methods may often be used for this purpose. These are, first, measurements across the outcrops; second, study of sample taken from the bailer during the drilling operation; third, search for the exceptional driller who makes accurate discriminations of the kinds of rocks in which he is drilling.

In spite of the fact that in eastern Kansas a stratum one thousand feet deep outcrops twenty or thirty miles away, experience demonstrates that studies of the outcrops are worth making. Study of cuttings, when they can be secured, is of such obvious importance that it need not be insisted upon here. The admirable investigations by Dr. Udden and others have made this sort of work well known. Careful study even of an occasional well record from the cuttings gives to subsurface work a degree of certainty and accuracy that is possible in no other way. The recent success of diamond drilling for oil in Mexico gives ground to hope that in the future even better samples may occasionally be available for study.

The last method mentioned above, that of hunting for the exceptional driller, is in some cases much the easiest to apply, and often not inferior to the other methods in the value of its results. In most of the districts in which drilling has been carried on for a few years there can be found at least one man who is an artist in the making of logs. He is commonly a geologist who was denied the privilege of a geological education in his youth. With an interest in rocks, and an interest in setting down the facts as he finds them, he will furnish records that are sometimes not much worse than would be kept by a professional geologist. Such a man is likely to keep records of all the wells upon which he works, and to take an interest in showing them to anybody who appreciates them. He may be so extremely valuable to the geologist who wishes to become familiar with the underground conditions in an oil field that it seems surprising that he is so seldom searched for and so seldom recognized.

In order to show how these principles may be applied, and the sort of results that may be reached, let me give a summary of their application to the district within twenty miles of Independence, Kansas. The conditions in this area are very similar to those in much of Osage, Washington, and Nowata counties, Oklahoma. Like most areas, this one makes it necessary to use all the devices one can muster before it yields its geological secrets. It gave also the opportunity to use all the methods enumerated above and a good many others in supplementing the ordinary logs.

In this area there are two or three drillers who are adepts in the art of making well logs. One man in particular put at my disposal the results of twenty-five years of experience as driller, contractor, and producer in the area. Repeated tests showed that his logs were quite as accurate as the average of the sections measured by a geologist. In the rather large area over which he had drilled, the data which I have are adequate for almost any sort of subsurface study that one could conceivably require.

In spite of the large number of well logs available, some of them of unusually high quality, it was necessary, in order to understand subsurface conditions, to give very close attention to all the available results of former field studies in and near the area. In the Independence district these field studies have been unusually numerous and valuable. Several of the bulletins of the Kansas Geological Survey give much generally accurate information about the distribution and character of the formations which outcrop in and near the district. The Independence Folio, by F. C. Schrader, is likewise very well done. A rather intensive study of it, lasting several months, showed that its main conclusions will probably stand for a long time to come.

In addition to the study of earlier field reports, which in this case were much more abundant than many people think necessary for the purpose of making a subsurface study, we found it advisable to make still further field studies. Some important correlations remained uncertain until we had actually measured and described several formations in the field. The moral is that for adequate interpretation of subsurface conditions, one can hardly know enough about the surface conditions. Conversely, the subsurface studies served to clear up a number of points that the numerous excellent field studies previously made had left uncertain.

In attempting to get such an understanding of the Independence district as would enable us to decide the very practical matter as to the advisability of undertaking further operations there, it was necessary to work out a good many separate problems. Some of these were of a character that at first sight would seem eminently unpractical. We put in much time and effort, for example, in studying the exact thickness and character and variations of all the limestones in different parts of the area. The limestones do not carry much oil, it is true, but they are the markers. By correlating them with the utmost possible accuracy we were able to save ourselves a good many blunders we should otherwise have made in regard to the relations of the various sands.

It happens that the Independence district is located where many

of the prominent limestones of the Kansas Pennsylvanian section give way to the shales and sandstones of northeastern Oklahoma. In regard to the details of this transition, the sections show a good many interesting facts which it would take too long to discuss. They make clear some correlations of Kansas and Oklahoma formations about which even the most recent publications express some doubt.

In studying an oil field, a very important matter is the determination of the character, as well as the correlation, of the sand bodies which contain the oil and gas. To illustrate the results that were obtained, some notes will be given in regard to a few of the more important sands.

The most unusual sand in the Independence district is perhaps the Cherryvale gas sand. This sand body is about ten miles long, from a quarter to a half mile wide, and from nothing to one hundred feet thick. At a depth of about eight hundred feet, it extends from the vicinity of Cherryville to a point northeast of Neodesha. In practically every well which found this sand, commercial quantities of gas were found. The parts which are in synclines seem to have been quite as productive as one part which is on a large anticline.

The origin of a sand body of such character is an interesting problem. The fact that the base of this one appears to be flat, and that the upper surface is convex, appears to indicate that it may have been some sort of barrier beach in the old Pennsylvanian sea, rather than a river deposit. Some very similar deposits farther north, however, have the base convex downward, and are probably channel deposits.

The Independence gas sand, extending about fifteen miles from Independence to Coffeyville, and ranging from a mile up to five or six miles in width, is about at the horizon of the Bartlesville sand, but is apparently a distinct body. Its thickness is commonly from fifty to a hundred feet, and it produced gas in amounts up to thirty-five or forty million feet a day, from nearly every well in which it was found.

The Bartlesville sand of the Independence district is not a continuous sand body, but a series of disconnected lenses in the lower half of the Cherokee shale. It is productive of oil and gas in some small pools, but is not, as it is farther south, the chief reliance of the district as a producing horizon.

In regard to the several shallow sands that produce oil and gas west of Independence, in the old Bolton and Wayside fields and adjacent areas, our subsurface studies cleared up a number of points, but not so many as in the district farther east. The Wayside sand is found to lie immediately under the Coffeyville or Lenapah

limestone, which outcrops from Coffeyville south to Nowata. The Wiser sand, a hundred feet lower than the Wayside, lies under the Altamont limestone, which is the higher of the two limestone scarps near Wimer, Oklahoma. Both the Wayside and Wiser sands are almost unbelievable in their range in thickness, the latter varying from more than sixty feet to nothing within a horizontal distance of eight hundred feet in one instance.

About a thousand feet below the top of the Mississippi lime the wells that have been drilled deep enough have all struck granite without locating any deep oil or gas sands. In contrast to many neighboring areas, the Independence district appears to have in the Mississippi lime a real farewell horizon.

Apart from their bearing on the oil possibilities of the region the studies in this district suggest a good many paleogeographic problems and give some data for their solution. They make it possible to form a fairly definite picture of the locally variable and ever changing conditions in this part of the old Pennsylvanian sea. They indicate, or so it is hoped, that well log studies, if carefully made, may help in solving many problems of general geologic interest.