OKLAHOMA GEOLOGICAL SURVEY
Chas. N. Gould, Director

Bulletin No. 40-B

OIL AND GAS IN OKLAHOMA

SUBSURFACE DISTRIBUTION AND CORRELATION OF THE PRE-CHATTANOOGA ("WILCOX" SAND) SERIES OF NORTHEASTERN OKLAHOMA

By
Luther H. White
J. A. Hull Company

NORMAN
JUNE, 1926

WHAT THE MAP SHOWS

The oil producing horizons below the Mississippi lime have been sought by hundreds of test wells in Oklahoma during the past few years and the search for the elusive so-called "Wilcox" sand series is constantly increasing. In some parts of the State many tests which were supposed to go to the "Wilcox" have been plugged and abandoned because they found water in what the driller thought to be the "Wilcox" sand but which later scientific investigation has shown to be a formation above the objective horizon. These tests, therefore, were not conclusive and the economic losses which have resulted from ignorance of the stratigraphy, or succession of formations, below the Chattanooga black shale, have amounted to hundreds of thousands, probably millions of dollars.

The map (Plate II) which accompanies this report shows in detail the areas where the various formations below the Chattanooga black shale are found in contact with that reliable marker. In other words, a well drilled in the vicinity of Sapulpa would pass from the Chattanooga into the "Wilcox" sand, while in the vicinity of Okmulgee the drill finds the Sylvan shale directly beneath the Chattanooga shale and must pass through the Sylvan, and the Viola limestone ("White Lime" or "buttermilk" lime) before reaching the "Wilcox" sand. Farther south, near Okemah, the map shows that the Hunton limestone lies directly beneath the Chattanooga and the Hunton is separated from the "Wilcox" by the Sylvan shale and Viola limestone.

This map may be considered as an areal geologic map with all the upper formations, including the Mississippi limestone and the Chattanooga shale, scraped off, leaving the base of the Chattanooga exposed as a surface. The various formations outcrop in the areas shaded by different symbols.

The map is of special value to the operator since it is sectionized. It enables one to tell at a glance just what formation to expect after drilling through the Chattanooga shale. Having identified that formation, the accompanying cross-section (Plate I) shows the other strata to expect in order.

CONTENTS

ILLUSTRATIONS

FOREWORD

In 1917 the Oklahoma Geological Survey issued Bulletin 19, Part II, entitled "Petroleum and Natural Gas in Oklahoma." This volume was so popular that the supply was soon exhausted, and for several years copies have not been obtainable.

The present Director has seen the need of a revision of this bulletin. On account of the lack of appropriations he has not been able to employ sufficient help to compile the data, and has called on some twenty representative geologists throughout the State to aid in the preparation of reports on separate counties. These gentlemen, all busy men, have contributed freely of their time and information in the preparation of these reports.

It will be understood that the facts as set forth in the various reports represent the observation and opinion of the different men. The Oklahoma Geological Survey has every confidence in the judgment of the various authors, but at the same time the Survey does not stand sponsor for all statements made or for all conclusions drawn. Reports of this kind, are at best, progress reports, representing the best information obtainable as of the date issued, and doubtless new data will cause many changes in our present ideas.

Mr. Luther H. White, the author of the present paper, has spent a number of years in studying the subsurface geology of northeastern Oklahoma, and is recognized by geologists as being our best authority on the subject as of the year 1926. Mr. White read a paper on this subject at the Dallas meeting of the American Association of Petroleum Geologists in March 1926. The article in a modified form also appeared in the Oil and Gas Journal of the date of April 1st, 1926.

It is the present policy of the Oklahoma Geological Survey to give as wide publicity as possible to all pertinent data that will in any way aid in developing the mineral resources of Oklahoma, therefore, Mr. White's article is republished herewith.

CHAS. N. GOULD,
Director

June 15, 1926.

OIL AND GAS IN OKLAHOMA

SUBSURFACE DISTRIBUTION AND CORRELATION OF THE PRE-CHATTANOOGA ("WILCOX" SAND) SERIES OF NORTHEASTERN OKLAHOMA

By

Luther H. White

INTRODUCTION

The subsurface phase of petroleum geology has been rapidly increasing in importance during the past decade. It was only about five years ago that the value of subsurface studies was recognized generally to be of sufficient importance to cause work of this nature to be undertaken by nearly all of the progressive oil companies maintaining geologic departments. The results of this work have been so gratifying from both the practical and scientific standpoints that unparalleled development of this branch of practical geology has been witnessed within the last two years. The extent to which more scientific work has come to be appreciated by both the layman and geologist is indicated by the fact that the number of oil companies which have added technical men and women to their geologic departments, employed for the express purpose of studying the mineralogy and micropaleontology of drill cuttings, has been larger during the past year than during any two previous years. In the past, petroleum geologists have been criticised by the more academic students, for their apparent mercenary and unscientific attitude toward the great science of geology. The developments of the last few years have operated to undermine any possible foundation for their unfair criticism. The work that is being done at this time by petroleum geologists is of a truly research nature. In every way the science is being applied in a more scientific manner.

Acquisition of the data upon which this paper is based is due to the large number of men in the Mid-Continent region who are doing scientific subsurface work. The first paper on this subject was written by Aurin, Clark and Trager in 1921.[1] Since this beginning many geologists in Oklahoma with the above work as a guide have been studying the lower oil producing horizons in great detail by means of microscopic and mineral analysis of drill cuttings from the deeper wells throughout the state. This intensive study has led to a more exact determination and correlation of the so-called "Wilcox" sand

1. Aurin, F. L., Clark, G. C., and Trager, Earl A. Notes on the subsurface pre-Pennsylvanian stratigraphy of the northern Mid-Continent oil fields, Am. Assoc. Pet. Geol., Bull. vol. 5, No. 2, 1921.

series than has been possible before. This paper is a summing up of these later conclusions, and, of course, is based only upon the data available at this date, March, 1926.

Should an attempt be made to offer acknowledgment to all those who have been of assistance in the preparation of this paper it would be necessary to practically read the roster of the Tulsa Geological Society as well as the names of many men in Ponca City, Okmulgee, Bartlesville, and many other cities. So many friends have contributed materials, information, and a free exchange of ideas that to enumerate them would appear boastful. The author has called freely upon his best friends for their most secret bits of information and the results are published in this paper. Dr. E. O. Ulrich's "Revision of the Paleozoic System"[2] has proved itself indispensable in checking the soundness of conclusions reached in this paper.

This paper will discuss primarily the pre-Chattanooga sections in two provinces of Oklahoma as outlined in Oklahoma Geological Survey Bulletin No. 35, entitled "Index to the Stratigraphy of Oklahoma," by Chas. N. Gould. This bulletin is, indeed, a much needed and creditable piece of work. In this small volume Dr. Gould has digested the more important publications dealing with the various formations in Oklahoma. He reports the consensus of opinion of all authors in a brief outline for each formation giving its nomenclator, type locality, character, thickness, occurrence, age, correlation, characteristic fossils and citations of the principal authors dealing with the formations. The bulletin was published to accompany the new colored geologic map of Oklahoma compiled by H. D. Miser, of the U. S. Geological Survey. Therefore, if the work contains errors, corrections should be made as early as possible and it is with that idea in mind that certain changes of correlation are suggested in this paper.

In the northeastern Oklahoma province the formations discussed include "Ordovician dolomite," "Burgen" sandstone, Tyner formation, St. Clair marble, Sylamore sandstone, and Chattanooga shale. Sylamore sandstone is not shown in the Index, by oversight. In the Arbuckle mountain province the formations discussed include Arbuckle limestone, Simpson formation, Viola limestone, Sylvan shale, and Hunton formation. Some reference will be made to the Woodford formation which overlies the Hunton. The various producing horizons of the so-called "Wilcox" sand series of northeastern Oklahoma oil fields are carefully correlated with the formations of these two provinces. This has been accomplished by comparing drill cuttings with outcrop specimens. Samples from the many deep wells in this area furnish a connecting link between the northeastern and south central provinces. This has made possible a more accurate correlation of the formations of these two areas than that shown in the Index mentioned above. In addition to this, the map accompanying this report records the subsurface relations and extent of these formations over the northeastern quarter of the State. Control of formation boundaries has been established, in the main, by an examination of well cuttings at many points. Between these points the boundaries have been projected on a basis of well records and structural conditions. In some areas positive data are so meager that accurate mapping is not possible at this time. For this reason the detail of the map is much more accurate in its central portion than in the eastern and western extremities. In some places errors several miles in extent will doubtless be found in the location of a boundary. Great hesitancy is sometimes felt in the publication of such a piece of work for which more accurate data continues to be obtained.[3] However, if this rough draft may be used as a guide for the future preparation of a more accurate map, for which data will be collected for many years to come, it will be a great step forward toward a better understanding of Oklahoma geology.

2. Ulrich, E. O., Geol. Soc. America Bull. vol. 22, No. 3, 1911.

THE PROBLEM

PRE-CHATTANOOGA ("WILCOX" SAND) SERIES.

For a description of the confusion which arose in connection with the earliest production from pre-Mississippian formations the reader is referred to the opening statements of Aurin, Clark, and Trager.[4] In that paper the "Burgen" sandstone was not differentiated from the Tyner formation and the "Wilcox" sand was correlated with the Tyner. Consequently they referred all pre-Mississippian production to the Tyner or to the underlying Ordovician "Siliceous Limestone." Since that time it has been possible to differentiate the "Burgen" and Tyner over broad areas. It has also become apparent that the "Wilcox" sand rests upon the Tyner and should not be correlated with it. The "Burgen," Tyner, and "Wilcox" are the northern equivalents of members of the Simpson formation. There are also members of the Simpson younger than the "Wilcox" which have recently yielded limited production. For lack of a more definite term these beds are referred to as the post-"Wilcox" Simpson. The latter group of rocks, "Burgen" to post-"Wilcox" inclusive, may be referred to indiscriminately, therefore, as Simpson rocks but not as Tyner rocks.

The Hunton formation was first pointed out as a producing horizon by George D. Morgan.[5] Since that time it has yielded greater production in other areas. The youngest member of the "Wilcox"

3. Note: Since the subsurface, areal, geologic map accompanying this report was prepared for publication the following changes should be made. In the vicinity of Collinsville the northern boundary of "Burgen" sandstone has been shown to be about four miles too far north. This correction should apply doubtless for some distance to the northwest. In sec. 23, T. 20 N., R. 24 E., at the little town of Flint, the Chattanooga shale has been observed resting upon an unmapped exposure of "Burgen" sandstone. The new geologic map of Oklahoma shows Chattanooga shale resting upon Ordovician dolomite (Arbuckle limestone) in sec. 12, T. 19 N. R. 20 E. However, a field examination by the author at the latter locality has shown that the Chattanooga at that place is resting upon a thin wedge of lower Tyner green shales probably about 10 feet thick. The Tyner rests upon an exposed thickness of about 25 feet of "Burgen" sandstone. The Ordovician dolomite is probably not exposed.
4. Loc. op. Cit.
5. Morgan, George D., A Siluro-Devonian oil horizon in southern Oklahoma. Oklahoma Geol. Survey circ. 10, 1922.

group is the Sylamore sandstone known as the "Misener" sand. All of the formations mentioned above have been confused with the "Wilcox" sand. Geologists and operators have endeavored to untangle this complex situation and in doing so they have given the different producing horizons oil-field names which together with their formation equivalents and age may be outlined as follows:

Oil Field Name	Formation Equivalents		Age
"Misener" sand	Sylamore sandstone		Early Mississippian
"Hunton Lime"	Hunton formation		Siluro-Devonian
Post-"Wilcox"		UPPER and MIDDLE SIMPSON FORMATION	Ordovician
"Wilcox" sand			
Green Series or "Irish" sand	Tyner formation		
"Hominy" sand	"Burgen" sandstone		
"Siliceous Lime" or "Turkey Mountain" sand.	Eroded surface of Arbuckle limestone		Cambo-Ordovician

These producing horizons range in age from Cambro-Ordovician to early Mississippian. Several of them are in no way related to the "Wilcox" sand. Others are limestones and not sands at all. They vary greatly among themselves in their value as a source of oil production. The average production per acre from the "Wilcox" sand, for example, is several times greater than that of the others. For these reasons the term "Wilcox sand series" appears misleading. Some such group name is desirable, however, for the sake of convenience and therefore the name pre-Chattanooga series is suggested. This term appears fitting since each member of the series is at some place, in northeastern Oklahoma, overlain by the Chattanooga under normal conditions.

ARBUCKLE LIMESTONE

The Arbuckle limestone or its equivalent probably underlies most of Oklahoma as well as adjoining states. As revealed in well cuttings it consists of medium or fine crystalline dolomitic siliceous limestone. After boiling in acid the residue will consist largely of quartz fragments with an occasional quartz crystal. This suggests vein quartz or drusy cavities, such as may be observed at the Spavinaw outcrop. True sand

grains are seldom found in average well samples although the formation is known to contain some thin beds of sand. Samples of Arbuckle limestone from widely separated wells resemble each other so much that it is difficult to distinguish between them.

Thickness: In northeastern Oklahoma test wells have shown the absence of the Arbuckle in the case of a few very steep domes where granite is encountered below a very thin mantle of Tyner or "Burgen" beds and it is expected that even Mississippian or Pennsylvanian beds may be found resting on these old granite cores.[6] The local absence of the Arbuckle limestone is due to erosion. On other domes 400 or 500 feet of Arbuckle may be encountered before reaching granite. Wells drilled off structure may encounter 1,000 to 1,500 feet of Arbuckle limestone before reaching granite.

Depositional Overlaps: The Arbuckle limestone develops a thickness in excess of 5,000 feet in the Arbuckle Mountains where it is underlain by the Reagan sandstone of Cambrian age. The Reagan has a thickness of 300 feet or more and rests on the granite floor.

In south-central and southeastern Missouri there are deposits of sandy dolomitic limestones having a combined thickness of 2,000 feet or more. These beds range in age from Cambrian to Canadian. They are underlain by the Lamotte sandstone of Cambrian age. The Lamotte has an average thickness of 200 feet and rests upon the granite floor.

In northwestern Arkansas there is in excess of 2,000 feet of sandy, dolomitic limestone which is divided into several formations of Ordovician age. The base of this series is not exposed in Arkansas so that neither the total thickness or the nature of the formation which preceeds the limestone series are known. Should a test well be drilled to

6. The logs and samples of Tidal Oil Company Wildhorse wells No. 18, No. 19, and No. 20 in sec. 32, T. 22 N., R. 10 E. show the following:

Formation	No. 18	No. 19	No 20
Elevation	809	822	763
Chattanooga	Absent	2200-2220	2130-2160
Tyner and "Burgen"	2138-2217	2200-2300	2160-2267
"Siliceous Lime"	Absent	2300-2387	Absent
Granite (samples)	2217-2222	2387-2434	2267-2290

Samples of Minnehoma Oil Company, Richards No. 1 in NE. cor. NW. 1-4, NW. 1-4, sec. 9, T. 20 N., R. 8 E., show the following:

Chattanooga	2850-2886
Tyner	2886-2930
"Burgen"	2930-2982
"Siliceous Lime"	2982-3058
Granite	3058-3072

Samples from a well drilled in SW. cor. SE. 1-4 of NW. 1-4 of sec. 35, T. 20 N. R 17 E. show the following:

Boone limestone (Cherty)	412-438
Chattanooga	Absent
Tyner and "Burgen"	Absent
Granite Wash	438-482
Fresh Granite	482-520

The first sample from this well was obtained at a depth of 412 feet. The identification of the cherty limestone as Boone instead of "Siliceous Limestone" may be questioned.

sufficient depth, however, it seems reasonable to expect that it would encounter a sandstone similar in age and character to the Reagan of Oklahoma and the Lamotte of Missouri. In southeastern Kansas test wells have encountered the northward equivalent of the Arbuckle limestone. Little is known of its average thickness. The deep well at Iola, however, encountered over 2,200 feet of sandy dolomitic limestone and sandstone of Cambro-Ordovician age.[7] From the early reports of this well it seems possible that there may be considerable sandstone at the base of the limestone series. The sandstone, if present, is probably closely related to the Reagan and Lamotte.

Drill cuttings from deep wells in northeastern Oklahoma show that on structural highs, at least, no sandstone is encountered at the base of the Arbuckle before granite is found. The author knows of no case where sand is known to occur at this horizon either on or off structure. It is reported in some wells but in the absence of samples this is considered very unreliable data.

From this data the author draws the conclusion that the southwestern Ozark region which included northeastern Oklahoma was a land area during the time of the deposition of the Cambrian sands represented by the Reagan and Lamotte in southern Oklahoma and eastern Missouri and possibly similar sands in Kansas and Arkansas. This old Ozark Island in the Cambrian sea was the first uplift which has affected the later deposits over this region. After the deposition of the basal sandstones, together with a few limestone beds of Cambrian age, the deposition of the Arbuckle limestone began in a sea which was advancing over the old granite land area to the northeast. In all probability the granite cores of many of the domes and anticlinal folds of northeastern Oklahoma were small islands in the early Arbuckle Sea and their later submergence resulted in considerable overlapping of the Arbuckle beds. The extent of this overlap is uncertain and awaits more careful paleontologic work.

Regarding the possibility of these granite islands representing the cores of the present folds, the following outline of events suggests itself after a study of the folds of this area. It seems to be the most plausible interpretation of the stratigraphic relations found on the structures which are being mapped at present. This statement may seem out of place at this point but it has a bearing on all of the formations to be discussed in this paper and the author has never found it possible to gain a clear conception of the history of any area without first outlining the mechanics of the problem.

Some of the granite islands mentioned above were due to structural uplift. They were, therefore, local positive areas. This meant that during the geologic history of the overlying sedimentaries these areas were the first to be subjected to erosion and the last to be sub-

7. Moore, R. C., and Haynes, Winthrop P., State Geol. Survey of Kansas, Bull. No. 3, pp. 82 and 218, 1917.

merged. Moreover, even after submergence many of them were topographic highs on the sea floor with the result that deposition was less over their crests than on their flanks. This cycle of uplift, erosion, submergence, decreased deposition, uplift, etc., has been repeated several times in the history of most of the anticlines and domes of northeastern Oklahoma. In some cases very little erosion may have occurred but there is always the evidence of a decreased amount of deposition indicating the contemporaneity of deposition and uplift. Much space might be devoted to an enumeration of the variations of these events. Suffice it to say that it is everywhere evident that the uplifts of northeastern Oklahoma began in pre-Cambrian time and have continued with various fluctuations down to very recent time. This same outline of geologic history probably applies to broad areas throughout the Mississippi Valley and the Appalachian region. Regarding this point Ulrich[8] says "Appalachian folding certainly was not all accomplished at one time or during a single period. It began in a pre-Cambrian era and probably is going on at prsent."

PERIOD OF EROSION AT CLOSE OF ARBUCKLE TIME

Following the deposition of the Arbuckle limestone and previous to or during early Simpson time the Ozark area was uplifted and subjected to erosion. The beds were truncated to much lower levels to the north than to the south. Dr. Sidney Pewers[9] collected some fossils from the unnamed Ordovician dolomite at Spavinaw, Oklahoma, which were identified by Mr. R. D. Mesler, of the U. S. Geological Survey, as *Turritoma milaniformis and Orospira bigranosa, Liospira.* According to Mr. Mesler these belong to Ulrich's "Swan Creek zone" of the Cotter formation in Missouri of Canadian age. According to Ulrich this is older than the bulk of the Arbuckle limestone which is Ordovician. This would indicate considerable truncation of the Arbuckle in northern Oklahoma. Morgan[10] discovered evidence of this period of erosion in his study of the Simpson in the Stonewall quadrangle. Referring to the thickness and character of the Simpson he states: "The absence of the lower portion of the Simpson formation to the north and the more clastic nature of subsequent portions of the formation in that direction, suggest an Ordovician land mass to the north of the Arbuckle area over which the Simpson sea gradually encroached."

It is uncertain whether the entire Ozark area was submerged beneath the sea represented in Missouri by deposits referred to by Dake (School of Mines and Metallurgy, Univ. of Missouri, Bulletin vol. 6, 1921), as the "St. Peter Group," and in Oklahoma by deposits of the Simpson "Burgen" or Tyner formation. The fact that the present northern extremities of the "Burgen," Tyner and higher members of Simpson in Oklahoma show no evidence of shoreward deposition, leads one to

8. Ulrich, E. O., Geol. soc. America, vol. 22, No. 3, p. 410, 1911.
9. Communication by letter to the author by Dr. Powers, 1925.
10. Morgan, George D., Bureau of Geol. Bulletin No. 2, p. 26, 1924.

suspect that these formations originally extended much farther north than at present. Also the entire mass of the Sylamore sandstone represents only that small portion of the erosion product, derived from these formations, which was preserved at the beginning of Mississippian time by the deposition of the Chattanooga shale. This indicates a tremendous amount of erosion quite sufficient to have removed any probable deposits of Simpson age that may have extended over this area.

In case the Simpson Sea did not submerge this area it is probable that the Arbuckle in this area suffered erosion from the close of its period of deposition until the beginning of Mississippian time. At any rate it is certain that the Arbuckle limestone suffered further truncation over northeastern Oklahoma during that period of time represented by the hiatus between the Hunton formation and the Chattanooga shale. Faunally this hiatus may not appear great but stratigraphically it does because it was during this period of time that all of the pre-Mississippian formations in Oklahoma, or as a matter of fact over practically the entire Mississippi Valley, were truncated and baseleveled.

In the light of these facts therefore it may be seen that much older beds of Arbuckle will be found in contact with the overlying formations to the north than to the south. The Ordovician dolomite at Spavinaw therefore would appear to be the equivalent of neither the upper or the lower Arbuckle of the type locality to the south but more comparable to some middle portion.

"TURKEY MOUNTAIN" SAND.

The truncated upper surface of the Arbuckle limestone is what has generally been referred to as the "Turkey Mountain" sand, or the "Siliceous Lime." The "Turkey Mountain" sand occurs immediately below the "Burgen" sandstone which is equivalent to the St. Peter sandstone. The "Turkey Mountain" is a highly crystalline dolomite. The crystals are usually sub-megascopic in size but sometimes appear quite large. This dolomite is sometimes so porous that it has a spongy appearance. In drilling, it is generally very soft, while true Arbuckle limestone below is much harder.

The "Turkey Mountain" beds may be lower Simpson in age and therefore comparable to the Everton dolomite in Arkansas. The latter occurs immediately below the St. Peter with conformable contact, and rests upon the older beds unconformably.[11] Because of an apparent lithologic difference between definite "Turkey Mountain" limestone and definite Arbuckle limestone below and for other reasons the classification of "Turkey Mountain" as lower Simpson is considered correct by some. This classification would make it easier to explain why the "Siliceous Lime" is practically non-productive over that part of northeastern Oklahoma where it is in contact with the overlying Chattanooga shale because there the lower Simpson (or "Turkey Mountain" limestone) would normally be absent.

11. Purdue, A. H., and Miser, H. D. U. S. Geol. Survey Geol. Atlas, Eureka Springs-Harrison folio, (No. 202), p. 5, 1917.

The question as to whether the "Turkey Mountain" horizon is Simpson or Arbuckle in age may be answered in eastern Oklahoma if some new exposure of "Burgen" sandstone may be found which would disclose the nature of its contact with the underlying beds. If it should be found to rest conformably upon a dolomite which in turn should rest unconformably upon the Arbuckle limestone, it would indicate the Simpson age of the "Turkey Mountain" sand.

The term "Ordovician Siliceous Limestone" was first employed by Aurin, Clark and Trager in 1921.[12] It was applied to that thick deposit of limestone encountered in wells below the "Wilcox" sand series in northern Oklahoma and to the limestone resting upon the granite at Spavinaw. Since that time the term has been abbreviated to the "Siliceous Lime." These authors also suggested that this limestone was the equivalent of a part of the Arbuckle limestone of southern Oklahoma and a part of the Yellville of Arkansas. This correlation does not appear questionable any longer. For obvious reasons, therefore, this limestone when encountered in wells should be called Arbuckle limestone instead of "Siliceous Limestone." In case the "Turkey Mountain" horizon should be proved to be of Simpson age then "Turkey Mountain" and "Siliceous Lime" would not be equivalent terms.

However this may be, the truncated upper surface of the Arbuckle limestone, as stated above, is what has generally been considered the "Turkey Mountain" horizon. It can not consist of the same bed of Arbuckle at any two places except where production occurs along the strike of the Arbuckle beds. Drill cuttings show the Arbuckle to be quite as dolomitic as limestones of Simpson age. This fact together with the long period of weathering to which it was subjected would account for sufficient porosity to permit of the oil accumulation in case the "Turkey Mountain" really belongs to this formation. The fact that this horizon is really a very porous limestone accounts for the high initial production and quick recovery shown by wells producing from this zone. In fact, the performance of wells in this horizon is so pronounced in this respect that production from a new well is often accurately ascertained to be coming from the "Siliceous Lime" before samples can be obtained. Such wells seldom require much "drilling in." This horizon needs only to be punctured to obtain an unusual large production considering the depth at which it is encountered. In this respect it is similar to most other limestone production.

"BURGEN" ("HOMINY") SANDSTONE

Some students of this problem believe it is impractical to attempt the differentiation of "Burgen" sandstone in well cuttings from the overly-

12. Aurin, Clark, and Trager, Am. Assoc. Pet. Geol. Bull. vol. 6, No. 2, 1921.

ing Tyner formation. The writer's observations in this respect are as follows: All complete sets of samples examined from wells drilled to the Arbuckle limestone in that territory south of the northern boundary of "Burgen" sandstone shown on the pre-Chattanooga map (Plate II) and northeast of Okmulgee show various amounts of "Wilcox" sand beneath which occur about 100 to 150 feet of green sandy shales with red streaks. Below this formation a bed of sandstone averaging 50 feet or more in thickness is encountered before penetrating Arbuckle limestone. No "Wilcox" sand will be found north of its northern boundary of course and from this point the thickness of the green sandy shale decreases northward due to erosion. But in every case a bed of sand is found below the green series before Arbuckle is reached. Some of these wells are only a few miles west of the Tahlequah exposures of Tyner and "Burgen" and since a series of green sandy shales overlying a bed of white sandstone is such a remarkably close parallel to the aspect of Tyner overlying "Burgen" as observed at the outcrop, the differentiation and correlation suggested in well cuttings appear unquestionable.

The "Burgen" may be absent locally due to the fact that exceptionally high areas were not submerged below the northward advancing Ordovician Sea until after "Burgen" time.

In character the "Burgen" sand is often so well cemented and glassy that it approaches quartzite. When broken down its grains are found to be a heterogeneous mixture of very large and very small rounded grains with etched surfaces with enough angular grains of various sizes thrown in to make it a good mixture. For a better description and illustration of this feature the reader is referred to the excellent work of Messrs. Trowbridge and Mortimor.[13]

The "Burgen" sandstone was first called "Hominy"[14] sand because it was thought to be the principal source of deep production around the town of Hominy in Osage County. Since that time however, it has developed that most of that production was probably coming from the underlying "Siliceous Limestone." Cementation prevents the "Burgen" from offering a suitable oil reservoir as evidenced in its superposition above the Arbuckle limestone in most of the many pools where the latter has been a prolific producer.

TYNER FORMATION

The Tyner formation, at the outcrop, is composed of green sandy shale interstratified with thin beds of sand and some sandy dolomitic limestone. The formation displays the same character in well cuttings with the addition of some thin beds of red shale near the middle portion

13. Trowbridge, A. C., and Mortimer, M. E., Correlation of oil sands by sedimentary analysis. Econ. Geol. Vol. 20, No. 5, August, 1925.
14. Informal paper by the author before the Tulsa Geological Society in the fall of 1924.

which have not been observed at the outcrop. The basal portion becomes more dolomitic to the northwest of Tulsa and the entire formation appears to carry more sand and less green shale to the south.

The Tyner is the source of production in a number of scattered wells and is the principal source of production in some small pools.

"WILCOX" SAND

For a description of the physical character and microscopic analysis of this sand the reader is again referred to Trowbridge and Mortimer.[15] After making microscopic examination of complete sections of this sand from many wells the writer's observation is that the "Wilcox" sand is a much more uniform fine grained sand than the "Burgen." The characteristic of this sand, in the main, is a high percentage of fine angular grains accompanied by few large rounded, etched grains and more small rounded grains. It is questionable, however, if this difference in character between "Wilcox" and "Burgen" can be emploved as suitable criteria for identification of single samples. Many individual samples of "Burgen" show a predominance of fine angular sand and conversely many individual samples of "Wilcox" show a predominance of large rounded grains. The "Wilcox" and "Burgen" may vary laterally in this respect. In general the author's observation has been that when large rounded grains are found in the "Wilcox" sand, they occur at the top of the sand as encountered in the well rather than farther into the sand body, where the sand is generally fine and angular.

The "Wilcox" sand thickens from a few feet at its northern limit to a maximum of 250 to 300 feet in the vicinity of Stroud and Henryetta. In its thickest portion it remains a remarkably pure sand of uniform character. This is the chief reason for differentiating this sand from the Tyner formation. Taff differentiated Tyner and "Burgen" on a basis of lithology. The author finds more abundant evidence for the differentiation of Tyner and "Wilcox" on a basis of lithology than Taff had for Tyner and "Burgen."

It is the author's hope that these three formations may be eventually identified with definite members of the Simpson formation in the Arbuckle Mountains. Surprisingly few detailed sections of this formation are to be found in the literature. It is to be hoped that more detailed work of this kind will be done at the various outcrops of Simpson. So far the best evidence indicates that the "Wilcox" sand is equivalent to the bed of glass sand in the quarry at Roff, Oklahoma.

The "Wilcox" sand is so well known as an oil producing horizon that it requires no further discussion here. The author's idea of the future production from this entire series of sands may be obtained by referring to a paper entitled "Remarks on the Possibilities of Future

15. Op. cit.

Production from the pre-Chattanooga Series of Northeastern Oklahoma," read before the February, 1926, meeting of A. I. M. E.[16]

POST-"WILCOX" SIMPSON

The group of rocks referred to as the post-"Wilcox" Simpson is a series of brown or gray sandy dolomitic limestones interstratified with some green shale and thin sandstone members. Wells in the vicinity of Holdenville, Okemah, Stroud and Cushing and all intervening territory encounter a series of this character having a maximum thickness near Stroud of 140 feet. At the latter point it is composed almost entirely of light brown dolomite with about 5 feet of sand at its upper contact. This group occurs between the Viola limestone above and the "Wilcox" sand below. It is referred to as the Simpson because the sand grains are rounded and etched, the shales present are green and the dolomite is more characteristic of the Simpson than the Viola limestone. It is desirable to differentiate it from the "Wilcox" sand since it produces oil and gas in small quantities, the oil generally being much lower in gravity than that found in the "Wilcox" sand. It is also possible that water may be encountered in this horizon before reaching the "Wilcox" sand. This would lead to the abandonment of a well before a thorough test had been made. Many wells have been abandoned in this horizon. It is a huge economic waste to spend $50,000.00 to $100,000.00 for the purpose of testing the "Wilcox" sand and fail by so small a margin.

From a study of the well records in the vicinity of Ada and northward it appears that the rocks referred to here as post-"Wilcox," belong to the upper Simpson and would comprise all the beds from the top of the Simpson formation down to the top of the bed of glass sand at Roff. However it is not certain that a full section of upper Simpson is present at Roff and for this reason some later classification may be necessary. This series of beds should be given a suitable name. The name should not be selected however until the Simpson formation is studied and mapped in more detail. At that time it will be more evident than now, into what units it is desirable to divide the Simpson and such units can then be more appropriately named. The term post-"Wilcox" is not used as a name but merely a descriptive term to indicate a certain portion of the Simpson formation, namely, that part above the "Wilcox" sand.

VIOLA LIMESTONE

The "White Limestone" mentioned by Aurin, Clark, and Trager as occurring above the "Wilcox" sand is now identified with the upper part of the Viola limestone. For a good many years it was known only as the "White Lime" by the geologists of Oklahoma. However,

16. American Institute Mining and Metallurgy. Special volume Petroleum Technology and Development in 1925, pp. 585-593.

since it has been shown to be the equivalent of the upper part of the Viola limestone, the term "White Lime" is rapidly being dropped in every day usage, in favor of the term Viola.

North of Holdenville this phase of the Viola averages 30 to 50 feet in thickness. It is composed of two beds principally. The upper bed is white or grayish-white in color and coarsely crystalline. The drill cuttings are generally coarse. For this reason the drillers in some parts of the country call it the "buttermilk" limestone.

The lower member of the Viola is dense and brownish-gray in color somestimes resembling lithrographic stone. This difference is never reported in well records and is seldom noted by any one except by those making a careful study of the samples.

Taff[17] describes two limestone beds of this character at the top of the Tyner formation northeast of Tahlequah. This exposure was visited by a number of geologists from Tulsa in the summer of 1925 and all agreed that it was exactly the same as what had been known as the "White Limestone" above the "Wilcox" sand. This identification meant that the Simpson formation had been uplifted and eroded to the northeast of the Arbuckle area previous to the deposition of the Viola limestone. This discovery at once made it possible to identify the dolomitic series of sandstones which had been recently discovered to underlie the Viola in the vicinity of Stroud and Okemah. Such occurrences had never before been noted in the "Wilcox" sand and the "Wilcox" was thought to have a conformable contact with the Viola. However, when this contact was shown to be an unconformity and the Viola limestone was seen resting on the Tyner (green series) which was known to occur below the "Wilcox", then the dolomitic sands, encountered at Stroud and elsewhere to the south and west, were at once seen to be members of the Simpson formation higher in the section than "Wilcox," and hence the term post-"Wilcox" Simpson.

It may be seen from the above discussion that the beds of limestone described by Taff as the upper portion of the Tyner formation were erroneously classified with the Tyner and should have received a separate formation name. For the sake of convenince it would be well for these beds to be given a formation name even at this late day. While they are certainly members of the Viola limestone they do not represent its entire thickness but only the upper members. These particular members are so wide-spread and show so little variation from an average thickness of 40 feet, while the full section of Viola limestone in the Arbuckle area exhibits a thickness of 500 to 600 feet, that it is evident they are to be distinguished from the main body of Viola. In this connection it may be pointed out that all authorities agree that the upper Viola is Richmond in age. The position of the Richmond in the time scale, however, has been questioned, some placing it at the top of the

17. Taff, J. A., U. S. Geol. Survey, Geol. Atlas, Tahlequah folio (No. 122.), 1905.

Ordovician while others place it in the lower Silurian. The upper part of the Viola limestone is so much more wide-spread than the lower and thicker portions of the formation and the fact that the Viola-Sylvan contact is conformable, indicates that, from a stratigraphic standpoint, the Ordovician-Silurian boundary should be placed below the Richmond.

A study of drill cuttings from wells in east-central Oklahoma indicates that the upper coarsely crystalline members, observed in the subsurface section over this area, is really the equivalent of the top of the Viola rather than some lower member, since no other member of Viola is ever found above the coarsely crystalline member, even to the south, where the formation as a whole shows a tendency to thicken. This is in agreement with Ulrich's idea, which, according to Morgan[18], is that the Viola varies in thickness due to the absence of the lower beds.

The gray limestone above the Tyner formation northeast of Tahlequah appears to be identical in age, lithologic character, and position with the Ferndale limestone of the Harrison quadrangle in Arkansas.[19] The Sylvan shale which occurs above this limestone in wells drilled southwest of Muskogee and westward, is doubtless represented in the Harrison quadrangle by the Cason shale. The lithologic description of the Cason shows that it is very similar to the Sylvan with the exception that the Cason carries a thin (one foot) bed of conglomerate at the base which rests upon the Ferndale limestone, while no evidence of a depositional break is known at the Viola-Sylvan contact.

After a consideration of the above facts and ideas, therefore, the author suggests that the Richmond phase of upper Viola limestone, which occurs broadly throughout Oklahoma in the subsurface stratigraphy, be differentiated from the main body of the Viola by giving it the name, Ferndale limestone. It may be desirable that this problem receive more study by the paleontologists and stratigraphers before adopting this change. This suggestion was first made by Ulrich[20], however, in 1911, and, in the author's opinion, a study of the subsurface stratigraphy reveals such abundant proof of the early conclusions of this peerless author of Paleozoic history that it is high time some of them be adopted. The surprising thing is that it has taken the geologists of Oklahoma fifteen years to comprehend and verify many of the most remakable deductions contained in Dr. Ulrich's early work, notwithstanding the fact that they were being supplied continually with an abundance of subsurface data in support of these conclusions. However, the author desires to indict none more severely than himself. The only extenuating circumstance that may be offered in this connection is the fact that, unfortunately, Dr. Ulrich's valuable paper entitled "Revision of the Paleozoic System", has long been buried in an out-of-print issue of the Geological Society of America. The author

18. Morgan, George D., Bureau of Geol. Bulletin No. 2, p. 33, 1924.
19. Purdue. A. H., and Miser, H. D., U. S. Geol. Survey Geol. Atlas, Eureka Springs-Harrison folio. (No. 202), 1916.
20. Ulrich, E. O., Geol. Soc. America vol. 22, No. 3, Plate No. 7, 1911.

is informed (verbal communication by George Buchanan) that Dr. Ulrich is now preparing a revised issue of this work in which will be incorporated the results of his studies since 1911.

SYLVAN SHALE

Drill cuttings show the Sylvan shale to be a light blue calcareous shale averaging 75 to 125 feet in thickness. Where it is overlain by the Hunton formation, the upper 5 to 15 feet of the Sylvan is often greenish-blue or light olive green in color. North of the Hunton boundary this green phase seldom appears because of erosion. In some areas a greater thickness of the Sylvan exhibits this greenish tint, particularly in fresh, wet samples. The Sylvan is also composed of a very dark shale in certain other areas toward its base. This dark color appears to be of local extent.

Taken as a whole the Sylvan shale is remarkable in its lithologic uniformity over broad areas. A hand specimen taken as cavings from a well near Cushing can scarcely be distinguished from a hand specimen taken from the outcrop southwest of Ada. It had long been recognized as a distinct formation in well records before it was identified as Sylvan shale. Few, if any, thin beds of true limestone exists within it, notwithstanding the fact that many are reported in well records. Effervescence in dilute acid, however, indicates that the Sylvan is more or less calcareous throughout, some beds presenting highly argillaceous limestone characteristics. It is readily distinguished in drill cuttings due to its light color since it is everywhere overlain by the Chattanooga black shale or Hunton limestone and underlain by Ferndale (Viola) limestone.

Ulrich has given the age of the Sylvan as Richmond. Its correlation with the Cason shale of Arkansas is mentioned above. Ulrich[21] also correlates the Sylvan with the Maquoketa shale of the Iowa section.

The Sylvan shale has not been noted in eastern Oklahoma. This is due to the fact that it has been eroded in the Tahlequah area and the horizon of the Sylvan at the base of the St. Clair marble is not exposed farther south in the vicinity of Marble City. However, a diamond drill hole at the latter locality reports about 15 feet of greenish-blue shale below the St. Clair which is taken to be the Sylvan. The author is inclined to the belief that a more diligent search of this area may yet discover an exposure of the base of the St. Clair in contact with the underlying Sylvan shale.

HUNTON FORMATION

Taff[22] described the Hunton formation originally. Reeds[23] descarded the term, on a basis of paleontologic evidence, in favor of four sep-

21. Op. Cit.
22. Taff, J. A., U. S. Geol. Survey, Geol. Atlas, Atoka folio, (No. 79), 1902.
23. Reeds, Chester A., The Hunton formation of Oklahoma, Am. Jour. Sci., vol. 32, October 1911.

arate formations composed of the same group of rocks, namely Chimneyhill limestone, Henryhouse shale, Haragan shale, and Bois d'Arc limestone. He placed the Siluro-Devonian contact between the Henryhouse and Haragan. Morgan,[24] however, showed a tendency to revert to the former term and stated that the name Hunton should be retained as the name of a terrane which includes the same group of rocks designated by Taff as Hunton formation. The term Hunton formation is employed in this paper because of the fact that subsurface studies have so far failed to establish which of Reeds' units are represented in the Hunton beds of the northern subsurface section. Future studies may permit of the use of Reeds' terms. Moreover field studies by the author and many others indicate that the Haragan shale and Henryhouse shale are in reality so limey or marly that it is doubtful if they should be described as shales. They are in reality just softer members of limestone. They decay and weather when exposed at the surface much more rapidly than the beds of harder limestone above and below Reeds' established faunal breaks above and below the Henryhouse member of the Hunton. If these be unconformities they probably become more pronounced to the north of the Arbuckle area and result in the absence of the Haragan and Henryhouse shaly members. It is also possible that these members become less argillaceous in that direction which would account for failure to identify them readily. In the latter case, if these units should be penetrated by the drill some distance to the north of the outcrop, their cuttings would be limestone only less crystalline than the overlying Bois d'Arc and underlying Chimneyhill. Whether this be true or not it is a fact that no one has ever yet found any appreciable amount of shale in drill cuttings from the Hunton formation north of Ada.

At present the formation is really referred to as the Hunton limestone in well cuttings since it appears as a continuous white or gray dolomitic crystalline limestone with such a slight lithologic variation in its vertical section that a differentiation of separate units has so far been impossible. Such a differentiation may be possible later, on a basis of micropaleontology, or a more definite tie may eventually be made between the subsurface section to the north and the Arbuckle section to the south after more wells are drilled.

Samples of the Hunton formation were obtained recently from a well being drilled east of Ada, in the southeast corner of the northwest quarter of section 14, T. 4 N., R. 7 E., in Pontotoc County. Mr. George Buchanan, of the Carter Oil Company, at Tulsa, identified these samples as follows:

Dense, gray limestone	(Bois d'Arc)	3748-3804
Dark gray argillaceous limestone	(Henryhouse)	3804-3907
Coarse crystalline pinkish limestone		3907-3932
Glauconitic white limestone	(Chimneyhill)	3932-3948
White oolitic limestone	(Chimneyhill)	3948-3975

24. Morgan, George D., Bureau of Geology. Bulletin No. 2, p. 36, 1924.

This is the first case so far as the author is aware, that any student has been able to produce good evidence of an identification of so many members of Reeds' section of the Hunton. Also in this case the rock identified as Haragan shows that it is primarily a limestone somewhat argillaceous in character. The coarser character of drillings exhibited by these samples indicates also that this limestone is softer than those above and below. This is further evidence that the Haragan and Henryhouse members of the Hunton should not be classified as shales.

Economically, the identification of the Hunton is important because it produces oil in some areas, notably five miles northwest of Stroud and in two areas near the town of Seminole, with numerous scattered showings, but more particularly because of the fact that large volumes of salt water are generally encountered in this formation and since it is encountered at depths ranging from 3,500 feet or more, to over 4,500 feet, it is frequently confused with the "Wilcox" sand, which results in the abandonment of wells before the latter formation has been tested.

More than 150 wells have encountered the Hunton formation in north-central Oklahoma, many of which reported small showings of oil in this formation. The exact import of these widely scattered traces of oil from this formation is not understood at present.

The lithologic similarity of drill cuttings from the Hunton formation and the Ferndale (Viola) limestone is so strong that the two are not easily distinguished on this basis. Frequently such a determination is not possible until the Sylvan shale or the Simpson formation have been identified.

According to Oklahoma Geological Survey Bulletin No. 35, the St. Clair marble is equivalent to the Henryhouse shale. In this paper it is suggested that the St. Clair is equivalent to the lower portion of the Hunton formation. In other words the base of the St. Clair marble is equivalent to the base of the Hunton formation. It is not known how far below the top of the Hunton, the bed occurs, which is equivalent to the top of the St. Clair. The reasons for this are as follows: There is no unconformity at the base of the Hunton. The base of the St. Clair is not exposed. There is an enormous unconformity at the top of the St. Clair-Hunton which cuts more deeply into the beds to the northward.

This sort of correlation between the St. Clair marble and the Hunton formation seems to be in agreement with Ulrich's[25] idea.

SYLAMORE ("MISENER") SANDSTONE AND CHATTANOOGA SHALE

The close of the Devonian time in Oklahoma was followed by a long period of erosion which truncated all of the older formations

25. Ulrich, E. O., Geol. Soc. America, vol. 22, No. 3, p. 559 and Plate 28, 1911.

from the top of the Hunton, to the south, down to horizons well below the top of the Arbuckle, to the north. This period of erosion did not close until the land area over northeastern Oklahoma was practically base-leveled. A surprisingly small amount of erosion debris was left upon this old eroded surface. However, there were a few sand dunes composed of sand derived from the Simpson formation. In addition to a few well developed dunes a thin veil of wind-blown sand was scattered over broad areas. This sand was preserved by the deposition of the Chattanooga shale above it. Where it is exposed in eastern Oklahoma and Arkansas it is known as the Sylamore sandstone. By the drillers in the oil country, it is called the "Misener" sand. Because of its source of origin, therefore, samples of it from wells resemble samples from the "Wilcox" or "Burgen." It is extremely lenticular in extent. Wells drilled to this sand are often dry, even though higher structurally than offset wells producing from it, because of its absence. Where the "Misener" is sufficiently wide-spread for structure to affect the accumulation of oil, it produces on domes or anticlines. In most cases however it produces as a true lense without reference to structure.

The patterns of these sand bodies are generally subcircular in outline. They are never elongated similar to the shoe string sands of Kansas which would suggest shore line or stream valley deposition. For this reason the "Misener" (Sylamore) sand in Oklahoma is considered to be of aeolian origin. While this is the probable manner of deposition over north-central Oklahoma it need not have been true for the south flank of the Ozarks where the old land surface upon which the Sylamore was deposited may have been submerged much earlier than to the west. Dunes may have been forming in the latter area contemporaneously with shallow water and beach deposition elsewhere. Regarding this point Dr. Ulrich[26] writes as follows: "In northern Arkansas the Sylamore sandstone, evidently a beach deposit, presents the prevailing aspect of a sandy basal deposit. The sand stone resembles the much older St. Peter sandstone, and in fact consists chiefly of the more or less cleanly washed soil of areas in which bodies of the St. Peter were then exposed. Though usually less than 2 feet in thickness, the Sylamore expands to much greater thicknesses in places where it fills depressions in the preceding land surface."

The age of the Sylamore sandstone has been considered to be Devonian in most of the publications dealing with it in Oklahoma and Arkansas, this being due to the classification of Chattanooga as Devonian. The early publications of Missouri carried the same age classification for these formations, while the later publications place the Chattanooga in the lower Mississippian.[27] The author considers the Sylamore and Chattanooga in Oklahoma of lower Mississippian age. The latter conclusion is based solely upon the stratigraphic relations shown in the cross-section in Plate I accompanying this paper. The Chattanooga shale follows the Mississippian everywhere in contrast to its relations with the Devonian and older formations. There is no pronounced break between Chattanooga and Mississippian. This is a tremendous break between the Hunton (Devonian) and Chattanooga. Therefore, it seems reasonable that the Devonian-Mississipian time division should be marked by this tremendous stratigraphic hiatus at the base of the Chattanooga rather than by the near conformable contact between the Chattanooga and Mississippian limestone. This latter conclusion is arrived at solely from a study of the stratigraphic relations while the same classification in Missouri was based upon paleontologic evidence.

26. Op. cit. p. 455.
27. Missouri Bureau of Geology and Mines, vol. XVI. 2nd Ser. p. 52, 1922.

The Chattanooga shale has been correlated with the Woodford chert by all previous authors on Oklahoma geology. This correlation appears highly questionable. The Chattanooga shale has an average thickness of less than 50 feet and consists of black bituminous, fissil shale. The same identical character and approximate thickness is displayed throughout the many states in the Mississippi Valley where it generally occurs except where removed by erosion. In this respect it is the most distinctive formation in the post-Devonian geologic column. Subsurface studies in central Oklahoma show that the Chattanooga displays this same character and thickness in well cuttings as far south as the Wewoka area which is about 25 miles north of the northern exposures of the Woodford chert. In section 34, Township 3 North, Range 6 East, the Woodford chert has a thickness in excess of 200 feet and is composed of alternating layers of hard platy black shale and brown to black chert, each layer being more or less than 4 inches thick. Elsewhere in the Arbuckle Mountains the Woodford develops a thickness in excess of 600 feet and exhibits the same regular lithologic character. This is so different in thickness and character from all of the known occurrences of the Chattanooga shale elsewhere and since the Chattanooga is so constant in character over broad areas it seems altogether improbable that it should change so suddenly within such a short distance. It has been suggested that the Woodford is more analagous in character to the southward extension of what has been called the "Mississippi lime." This seems much more reasonable than the correlation between Chattanooga and Woodford. The latter correlation would probably indicate that the Chattanooga had been eroded from the Arbuckle area before the deposition of the Woodford.