BENZ, George Albert, 1926-
THE 'SINGLE TAX' AS A MEANS OF SUPPORT FOR A LOCAL GOVERNMENT, EDMOND, OKLAHOMA.

The University of Oklahoma, Ph.D., 1969
Economics, finance

University Microfilms, Inc., Ann Arbor, Michigan

BENZ, George Albert, 1926-
THE 'SINGLE TAX' AS A MEANS OF
SUPPORT FOR A LOCAL GOVERNMENT,
EDMOND, OKLAHOMA.

The University of Oklahoma, Ph.D., 1969
Economics, finance

University Microfilms, Inc., Ann Arbor, Michigan

THE UNIVERSITY OF OKLAHOMA

GRADUATE COLLEGE

THE 'SINGLE TAX' AS A MEANS OF SUPPORT FOR A LOCAL GOVERNMENT, EDMOND, OKLAHOMA

A DISSERTATION

SUBMITTED TO THE GRADUATE FACULTY

in partial fulfillment of the requirements for the

degree of

DOCTOR OF PHILOSOPHY

BY

GEORGE ALBERT BENZ

Norman, Oklahoma

1969

THE 'SINGLE TAX' AS A MEANS OF SUPPORT FOR A LOCAL

GOVERNMENT, EDMOND, OKLAHOMA

APPROVED BY

Jim E. Reese

Robert A. Ford

Paul A. Brinker

DISSERTATION COMMITTEE

ACKNOWLEDGMENTS

The author is deeply indebted to the supervisor of the research, Dr. Jim Reese, Professor of Economics, for showing both the patience and support which enabled the author to carry on this research, and to the members of the Committee for their time and guidance.

Thanks goes to Dr. R. B. Melton who was instrumental in the early direction of the author toward an academic career and to the many teachers, both faculty and students, who have helped in various and sundry ways. The author is indebted to his associates on the faculty of St. Mary's University, especially to Dr. Charles N. Weaver and Dr. Samir B. Fahmy for their advice and criticism.

To the Administration of Central State College, Edmond, Oklahoma, the author will be eternally grateful for the several paid summer sabbaticals and for their successful attempt at convincing the author that any college in the country would offer better opportunities than Central State.

Much is owed by the author to many of the townspeople of Edmond; however, the assistance given by the former mayor, Charles Johnson, and Alice and J. Sam Johnson is deeply appreciated.

Special thanks goes to my wife, Jean, who has done all of my typing, and to my Father, Mother, and Daughter who suffered in near silence while attempting in every way possible to help with the project.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF TABLES (continued)

LIST OF TABLES (continued)

THE 'SINGLE TAX' AS A MEANS OF SUPPORT FOR A LOCAL GOVERNMENT, EDMOND, OKLAHOMA

CHAPTER I

INTRODUCTION

Since the publication of Henry George's Progress and Poverty in 1879, much has been written about his views on land value, unearned increment, and the single tax. Although he had developed an elaborate and intricate economic theory based upon an extension of the classical economic theories of Adam Smith and others, as well as on the refutation of Malthusian population doctrines and the Wages-Fund, George's fame rested primarily upon his exposition of a rent theory different enough from that of Ricardo's to support a claim of originality. However, as a result of his theories, it was the establishment of social movements throughout the world to abolish poverty through a land value taxation program or the single tax that made his name a household word.

While much has been written about the single tax, few researchers, if any, have attempted to measure the extent to which unearned increment can accrue to land. For some researchers, the measurement of unearned increment of land with any degree of accuracy was considered to be virtually impossible because of the inadequacy of available information on sales and value.[1] Some maintained that, even if the value could be measured accurately, the amount of tax yield from a single tax on land value would be inadequate to support the level of government expenditures of the more industrialized nations of the world with their expanded military and welfare programs.[2] Still others declared that George's proposal to tax only the unearned increment of land failed to recognize the fact that unearned increment exists in producer and consumer surplus, or in any factor that experiences an inelastic supply function in either the short or long run.[3] However, any investigation of Henry George's single tax thesis and its feasibility should not extend the concept of the single tax and unearned increment beyond the limits placed upon them by their original promulgator.

The objective of this investigation is to measure the amount of unearned increment created through increasing land values in Edmond, Oklahoma, and the amount of local school and governmental expenditures from 1941 through 1965. This data will be used to determine the level of the local school and governmental expenditure needs that could have been met by a single tax upon the unearned increment. The question is: Would a single tax on the unearned increment from land be sufficient to meet

---

[1] L. L. Price, "Some Aspects of The Theory of Rent," Economic Journal, Vol. 1, (March 1891), pp. 122-44.

[2] H. Whitmore, "Real Estate Value in Boston," American Statistical Association Journal, Vol. 5, (March 1896), pp. 1-17. and

John F. Due, Government Finance: Economics of the Public Sector (Homewood, Illinois: Richard D. Irwin, Inc., 1968), p. 432.

[3] Herbert H. Liebhafsky, The Nature of Price Theory (Homewood, Illinois: The Dorsey Press, Inc., 1963), pp. 353-364.

the expenditure needed for both the school system and the city government of Edmond, Oklahoma?

The problem and the methodology employed in the research will be presented in Chapter I in order to delineate the scope of the investigation of the single tax impact upon the local community of Edmond, Oklahoma, from 1941 through 1965. Chapter II will present not only a biographical sketch of Henry George but also an overview of his classical economic background coupled with a discussion of his views concerning economic theory and the single tax. In Chapter III, some selected historical, demographic, social, and economic data about the city of Edmond will be presented for background material. The data for the 1965 property sales will be used in Chapter IV to establish a ratio between the tax assessment value and the actual value of property in Edmond. This ratio will then be used in Chapter V to estimate the amount of single tax revenue available on land-value to meet the expenditure needs for the local government and the local school district from 1941 through 1965. Finally, Chapter VI will present the summary and conclusion of the investigation.

The Problem

The problem of examining George's single tax thesis is twofold: to estimate the amount of unearned increment generated and to determine the amount of expenditure necessary for both the local school district and the city government of Edmond, Oklahoma, for each year from 1941 through 1965. If a single tax upon the unearned increment from land is equal to, or greater than, the expenditure needed for the school district and the city, then George's single tax thesis could be used as a basis for taxation to meet current operational needs. If the unearned increment is significantly larger than school and local needs, there is the possibility that George's thesis may have greater applicability for the nation than has been assumed by many economists. Conversely, if the local expenditure needs are greater than the unearned increment on land, apparently there would be no validity to a single tax thesis even on a local level.

An answer to these questions is somewhat complicated by the lack of data available in a form that would be most useful to the investigation. Much of the data on land value needed to estimate the unearned increment with any degree of exactness must be reconstructed from information that indicates only a general value within a range of several hundred dollars. In many cases an appropriate statistical technique must be used to process the raw data in order to gather information that will reflect more nearly the actual value.

The use of statistical techniques in several areas is complicated by the fact that the value of platted land within a city is not only bimodel, but is distributed in a reverse J curve with the skewness toward the higher values. The extremely skewed nature of the universe requires that a rather large sample be taken in order for the data for the sample to approximate a normal curve distribution.

Further, the investigation was hampered somewhat by the fact that some of the data on educational expenditures that should have been available in the state library was unavailable -- due to material being moved from one building to another, overall inadequate storage facilities, and insufficient library personnel -- all of which contributed to a chaotic filing system. However, most of the missing data could be reconstructed with little loss in the degree of accuracy. In areas where data had to be reconstructed from the only available data, those estimates which would be most disadvantageous to the conclusion of the investigation were used.

Methodology

In an attempt to prove Henry George's thesis that a single tax on the unearned increment of land would be sufficient to meet the expenditure needs of a local government, several approaches and techniques were utilized. To place the study in its proper perspective, an analysis of George's theoretical position was undertaken. An historical approach was used to establish a background for the study, while a statistical investigation was utilized to estimate the amount and degree of value available of taxable land.

The critical portion of this investigation was the determination of land value from 1941 through 1965. To estimate this value, the actual sale value[4] of land in 1965 and its tax assessment value was used to

---

[4]Sale or actual value determined by the market-comparison method is not necessarily the same as capital value. Sale or actual value is the amount that the individual is willing to pay for the land, or has received for any given parcel of land in any given year, and may be more than, less than, or equal to, the income-capitalized value of the property. Capital value or capitalized value is that value which is determined by economic rent or the rental-income, minus all other ownership opportunity costs. Economic rent figured as a percentage of total value is related to prevailing interest rates; e.g., an economic rent of $100 with an interest rate of five per cent will yield a $2,000 capitalized value. However, with the use of the market-comparison method of valuation, any rental income over expenses and/or increase in the sale value that accrues to a nonreproducible factor, land, may be reviewed as an unearned income.

establish a ratio between tax assessment value and actual value after removing the improvement value from all 1965 sales. The ratio of land value to tax assessment value was applied to the statistical characteristics gained from a random sample of all the residential lots in Edmond, Oklahoma.

From the sample data and the estimates on the rural land value of Oklahoma County made by the United States Bureau of Agriculture in 1964, the total value of all land within the city limits was estimated. Once the value of the land for 1965 was established, it was then compared to the original land value in 1890. Next, through the use of the geometric mean technique, a value for land was established for each year from 1890 to 1965.

With the establishment of total yearly land value, it was possible to determine the year by year increase in sale or actual value and the rental income.[5] This data was compared to the actual cost of maintaining the city government and the local school district and then used to either prove or disprove Henry George's single tax thesis for a local community.

Edmond, Oklahoma, was chosen as the site for the investigation for several reasons: The growth pattern over the years, the availability of the data, the size of the city, and the potential unearned increment that would arise from a growing state college -- these were all factors which were taken into careful consideration in the selection.

---

[5]Rental income is a given percentage of the sale value that is received as income by the owner of land.

Several selected social and economic indicators that would reflect the varied growth pattern of Edmond were studied in their historical perspective. However, emphasis was placed upon that data which would reflect the impact of growth in land values resulting from the changes in population, in college enrollment, and in the assessed valuation of Edmond and Oklahoma County.

Single Tax or Site Value Taxation in The United States and The Rest of The World

While there are no major cities in the United States whose revenue rests entirely upon the taxation of land value, there are several enclaves that assess the value of land each year to meet local governmental expenditures.[6] The largest single tax colony with a population of approximately 5,000 and a land area of 4,000 acres is Fairhope, Alabama. There are several smaller enclaves of Arden, Ardentown, and Ardencraft in northern Delaware which are still in operation.[7]

There are also several major cities in Pennsylvania that tax the value of land at a higher rate than the tax on improvements. In Pittsburgh and Scranton a "graded tax" has been applied since 1914 in which the land was taxed at twice the rate on improvements after 1925. Further legislation in 1951 and 1959 has made it possible for 48 additional

---

[6] Harry Gunnison Brown and Others, Land Value Taxation Around the World (New York: Robert Schalkenbach Foundation, 1955), pp. 106-132.

Paul E. and Blanche R. Alyea, Fairhope, 1894-1954 (Birmingham, Alabama: University of Alabama Press, 1956).

[7] Ibid.

cities in Pennsylvania to increase the tax ratio between land and improvement at a higher level than found in Pittsburgh.[8]

The newest success story for site value taxation in America is found in Southfield, Michigan, a city which is located on the outskirts of Detroit. "Land is assessed on a basis of its full market value -- whether it is being used, used poorly or not used at all, zoned or not zoned property."[9] The tax upon the value of buildings is based upon an adjusted net income capitalization method. The net result is that taxes have been shifted from the homeowner to the land speculator and have made land available at reasonable prices for development:

> Since 1960 over three million square feet of office space have been built in Southfield. This is ten per cent. greater than the amount of office space built in Detroit, which ranks as the fifth largest city in the nation.[10]

Also, during the same period of time, the value of the city's land has increased from $30 million in 1961 to about $250 million in 1968.[11]

This latest development gladdens the heart of the most ardent land tax devotee who feels that Southfield is the example needed to prove the tax concepts advocated long ago by Henry George.

Throughout the rest of the world, site value taxation seems to have had a greater impact than in the United States. Australia, New Zealand,

---

[8] Dick Netzer, Economics of The Property Tax (Washington, D.C.: The Brookings Institution, 1966), p. 203.

[9] Ted Gwartney, The Southfield Story: A Lesson in Creative Taxation (Great Britain, Wrexham, Denbighshire: Cambrian Press (Wrexham) Ltd., 1968), p. 2.

[10] Ibid.

[11] Ibid.

South Africa, Western Canada, Jamaica, British West Indies -- all have some form of site value taxation or a tax rate which falls more heavily upon the value of land than upon improvements to the land.

According to Under Secretary S. Haviland, in an article written in 1955, "it appears that in the near future local government rates in New South Wales will be levied wholly upon the unimproved capital value of Land."[12] In 1957, Roy Hendy, the Town Clerk of Sydney, Australia, indicated that "There has never been any serious proposal to revert to the rating [taxation] of improvements."[13] And, in 1953, "Mr. H. S. Mabin, M.A., stated: 'The Johannesburg Chamber of Commerce strongly favors the rating of land values only. We are of the opinion that this system had had a good deal to do with the development of Johannesburg....'"[14] Similar comments can be made for Wellington, New Zealand,[15] New Westminster, British Columbia,[16] and several other towns and provinces in Australia, New Zealand, and Western Canada.[17] Since the first of April, 1959, Jamaica, British West Indies, has had "a system of tax based on real land

---

[12] H. Bronson Cowan, Municipal Improvement and Finance: As Affected by the Untaxing of Improvements and the Taxation of Land Values (New York: Harper & Brothers, 1958), p. 3.

[13] Ibid., p. 4.

[14] Ibid., p. 5.

[15] Ibid., p. 6.

[16] Ibid., p. 7.

[17] Ibid., pp. 8-49.

values..."[18] which has reduced the taxes for about 90 per cent of the tax payers while placing an increased tax burden upon those who own vast estates on the island.

One of the few areas to have both a tax levied on land-value and a land tax on increments in land values is Denmark. There is still, however, a tax upon improvements, but there has been an attempt to shift the tax from improvements to land:

> The result seems to be that, in Denmark, through land-value taxation, the increment duty and public ownership of land, nearly half of the total economic rent is being collected by State and local authorities for the benefit of the whole nation.[19]

From the range of successful experiments throughout the world, it would appear that site value taxation has much merit. However, there are critics of the system who claim that many of the virtues cited for site value taxation are not as apparent as those who advocate it would believe. However, Dick Netzer, in his exhaustive study of the property tax, states that "the site value tax should <u>tend</u> to produce positive effects on urban redevelopment."[20] And, in reference to land value increment taxation he states that:

> As a supplement to other local taxes, it would tend to encourage more intensive uses of land by reducing the net after-tax return available from withholding land from use for speculative resale.[21]

---

[18] Noah P. Alper, <u>The Way Ahead in Jamaica</u> (Pamphlet), (Circa, 1960), based upon the May 1956 issue of <u>Land and Liberty</u> published in London, England.

[19] Harry Gunnison Brown and Others, <u>Land-Value Taxation Around The World</u> (New York: Robert Schalkenbach Foundation, 1955), p. 57.

[20] Dick Netzer, <u>Economics of the Property Tax</u> (Washington, D.C., The Brookings Institution, 1966), p. 208.

[21] <u>Ibid</u>., p. 213.

Nevertheless, the ability to remove the gains that can be made from speculation upon land may be rather difficult to achieve. As Philip Stern has noted in The Great Treasury Raid, "the deck is heavily stacked against tax reform."[22]

Some Recent Investigations of Rent Property Tax

Among the significant contributions which have been made to the theory of rent and property taxation in recent years have been the works of Joseph S. Keiper and others, Theory and Measurement of Rent in 1961, and Dick Netzer, Economics of the Property Tax, in 1966. Keiper, who is Director of the Lincoln Foundation Research Projects, indicates in the preface of his book that, "This study was undertaken to trace the origin and development of the theory of land-rent, to reappraise the conclusions and analysis with an up-to-date measure of land-rent."[23] From the studies of Doane,[24] Goldsmith,[25] Keller,[26] Kuznets,[27] and the 1957

---

[22] Philip M. Stern, The Great Treasury Raid (New York: The New American Library, 1965), p. 251.

[23] Joseph S. Keiper and Others, Theory and Measurement of Rent (New York: Chilton Company, 1961), p. ix.

[24] Robert R. Doane, The Anatomy of American Wealth (New York: Harper & Brothers, 1940).

[25] Raymond W. Goldsmith, A Study of Savings in the United States (Princeton, N.J.: Princeton University Press, 1955).

[26] Edward A. Keller, A Study of Physical Assets, Sometimes Called Wealth of the United States, 1922-1933 (Notre Dame, Indiana: University of Notre Dame, 1938).

[27] Simon Kuznets, National Product Since 1869 (New York: National Bureau of Economic Research, 1946).

____________, National Income and Its Composition, 1919-1938 (New York: National Bureau of Economic Research, 1941).

Census of Government,[28] information was gained which indicates that land-rent, if taxed, would be insufficient to meet the governmental need in the United States.[29] This leads to the conclusion that "modern theories of economic rent and surpluses give no support to those who would find the solution to the problem of governmental finance in a tax based on a single form of income."[30]

Additional support is given to this thesis by Dick Netzer in his Economics of the Property Tax. Netzer has doubts about the merits of the property tax in its present form, and he emphatically states his objections in the final sentence in the book: "The essential message of this study is that the decision to continue with the property tax we do have is just such a choice and that it is not at all obvious that it is the best -- or worst -- of all possible choices."[31] However, Netzer feels that alternative forms for the property tax, such as taxation of site value and taxation of land value, as well as some other taxation types, "appear to rank a good deal higher on efficiency and equality grounds than the existing American property tax system."[32]

While one may accept Keiper's statement of the inadequacy of a single tax on land-value to meet governmental need, Netzer does indicate

---

[28] U. S., Bureau of the Census, Census of Governments: 1957, Vol. V.

[29] Keiper, Theory and Measurement of Rent, pp. 101-104.

[30] Ibid., p. 125.

[31] Netzer, Economics of the Property Tax, p. 220.

[32] Ibid., p. 217.

that a site-value taxation and a taxation of incremental land value may hold some promise over the current property tax system. It will be one of the objectives of this study to determine on a local level the accuracy of both of these statements.

CHAPTER II

HENRY GEORGE AND THE SINGLE TAX

Biography of Henry George

Henry George[1] was born in Philadelphia on September 2, 1839, the son of a publisher of the "General Episcopal Sunday School Union" and various other religious tracts, and the grandson of a man who was one of the leading shipmasters in America shortly after the American Revolution. The family hoped that Henry would become a clergyman, and they consequently provided him with the best educational opportunity that their meager income would allow. Through his father's connections the son was allowed to enroll at a reduced tuition in a school which was a training ground for future Episcopalian bishops. This special consideration apparently rankled George, however, for he left school at the age of fourteen to take up the printer's trade. At sixteen, George had a chance to follow his grandfather's profession by shipping out to sea. But the life of a seaman made him restless and, after returning home for a short period, he was given the chance to go to the West Coast by George Curry, acting governor of the Oregon Territory. In order to work his passage to the new territory, George shipped out on a government lighthouse steamer.

---

[1]Cf. Charles Albro Barker, Henry George (New York: Oxford University Press, 1955); Anna George DeMille, Henry George, World Citizen (New York: Robert Schalkenbach Foundation, 1944); and Henry George, Jr., The Life of Henry George (New York: Robert Schalkenbach Foundation, 1960).

It was in California where the culmination of George's background was to reach fruition. As a sailor, he had witnessed both the immense poverty and the baronial splendor of the orient, as well as the injustice of a seaman's life aboard ship. In California he had felt the power of big business when his Western Union independent wire service was discontinued under pressure from the Associated Press because he had scooped it several times. To George, the railroads in their march across the lands cared little about the progress they might bring. Their interest appeared to center in the accumulation of largess from the federal, state, and local governments, much of it in land. He witnessed the expanding economy, the inflationary rise in rents and land values, and the subsequent increase in the misery of the poor and dispossessed who appeared to get poorer as the wealth of California became greater.

It was while riding in the hills of California above San Francisco, an area of intense land speculation, that George conceived the idea that with an increase in the population there is more than a corresponding increase in land values. If, through speculation, made profitable by a combination of increasing land values and low taxes, land is removed from the market, then George reasoned that the man who works the soil must pay more and more for the privilege of being productive.

In July of 1871, as a result of his observations, he wrote Our Land and Land Policy, National and State, in which he recognized, as Smith and Mill before his, the nature of an "unearned increment" upon land. In his book, George proposed the idea that this increase in land value which accrues to the land owner might well be the source of society's economic ills. Society, with its increasing population, brings about an increase in the demand for the fixed factor of production, land, and the result is an income allocation based upon ownership rather than upon production. If land in the original state of nature has no value except through application of labor, then society, in its demand for the products of land, creates the value of land, George reasoned, and society should receive the benefits that result from any natural increase of this value. However, because of the laws of ownership and speculation, the value of land is held artificially high by those with vast land holdings in order to "reap where they have not sown." To cure the world of the evil of poverty, George argued, the state has merely to tax away the "unearned increment" and apply it toward socially desirable ends, thus eliminating once and for all poverty and all of its attendant evils.

George worked and reworked this idea until it appeared in published form in his book Progress and Poverty. From its date of publication in 1879, the sales of the book moved gradually upward and then quickened in pace to make it the second most widely-read book of its time. It has been estimated that from two to seven million books were sold by the turn of the century. Progress and Poverty also received wide attention in foreign countries, and George became the toast of the speaking halls of Europe. As a result of the ideas expressed in his book, George has been given much credit for the stimulation of the already smouldering anti-landlord sentiment in England and for the impetus that his work had upon the Fabian socialists.[2]

---

[2]Cf. Elwood P. Lawrence, Henry George in the British Isles (East Lansing: The Michigan State University Press, 1957).

Also, George's views upon land and land rent naturally led him to the Irish movement, in which he was to take an active part as a speaker and propagandist for the cause. In fact, his success was so great that he at one time felt he should run for Parliament, although he returned home to New York instead to engage in political activity. He ran twice for mayor of New York and once for Secretary of State. Although defeated in all elections, he gave the Tammany Hall interests the scare of their political lives when he was beaten by a narrow margin in what many believed to be a rigged election.[3] During his final campaign in 1897, running as a third party candidate, with the support of labor, and against his doctor's orders, Henry George, after delivering four speeches in one day, died just five days before the election.

But, with his widely read book translated into about fifteen languages, George's influence was to continue in many ways after his death. The men who were influenced by him constitutes both a long and impressive list, one which would include Tolstoi, Dr. Sun Yat Sen, Hamlin Garlin, Lincoln Steffens, Clarence Darrow, Newton Baker, Louis Post, John Bates Clark, John R. Commons, Thorstein B. Veblen, and many others.[4] Since Louis Post and Newton Baker were in the cabinet of Woodrow Wilson and exerted considerable influence upon him, some have even speculated that, if World War I had not broken out when it did, much of the economic philosophy of Henry George would have found its way into the laws of our land.

---

[3]George, Jr., The Life of Henry George, p. 481.

[4]George R. Geiger, The Philosophy of Henry George (New York: The Macmillan Company, 1933), Chapter VII. and

David Reisman, Thorstein Veblen (New York: Charles Scribner's & Sons, 1953), p. 175.

There is little of the Georgeian influence in effect today in the United States, although there have been some changes in various city and state tax laws which indicate an attempt to separate the value of land from the value of buildings in order to tax each at a different rate. There has been, however, some agitation in the various states experiencing rapid growth and development for some type of tax which will impede land speculation and stop the spiraling land values. Furthermore, no one except some rather conservative Australians, who desire a reduction in government activity, feels that a single tax upon land could secure enough revenue to finance a level of government that is necessary in most industrial countries of today.[5] Even so, there appears to be ample revenue to finance local governments on a much larger and more effective scale than they are currently being financed. However, to evaluate George's contribution to economic thought and the place of the Single Tax within his system, we must first investigate the economic system that he inherited, developed, and used.

The Economics of Henry George

Economics to Henry George is an exact science built upon a logical system that is both simple and easily comprehended. To him, the Laws of Production and Distribution followed the Natural Laws of the universe and fit into the scheme of the universe as any other set of social or physical phenomena. Once the fundamental Laws of Production and Distribution are discovered, George felt, then all that is needed to ensure

---

[5]Keiper, Theory and Measurement of Rent, p. 125.

progress is to allow the Natural Laws to operate in an unimpeded manner. Since the violation of these laws leads to retrogression, George believed that it was the duty of the economist to discover these laws and make them known to society. However, it is at this point that a major problem arises.

Although it was the duty of the "Great Minds" of Political Economy to discover and translate these natural laws in such a manner that the ordinary man can understand them, their need to interject a personal or cultural value system or to present a system of thought which will not upset the vested interests can easily obscure the laws. Thus, the academic presentation of economics in our universities, according to George, was taught in a manner calculated to serve the powerful interests which dominate our educational institutions. The subject matter was made difficult and obscure in order to confuse both the student and the public. And, among some of the "Great Thinkers," there are those who may have seen the truth but were afraid to follow their conclusions to their logical ends. Under such conditions the differentiation of the true from the false is almost impossible. The "Great Minds," once they have contributed to the confusion make it impossible for most to differentiate between the alternatives. Once a theory, true or false, has been accepted by the majority, it was unpopular as well as unwise for the individual to question that theory -- no matter how much he as an individual might wish to do so.[6]

---

[6]This is still true today. See the discussion of conventional wisdom in John Kenneth Galbraith, The Affluent Society (Boston: Houghton-Mifflin Company, 1958), Chapter II.

Nevertheless, according to George's reasoning, false theories must be eliminated before the truth can flourish -- and the truth can flourish only upon new intellectual foundations.

George indicated his philosophical indebtedness to the Classical Economists by using their own methodology to refute some of their "false" theories. He presented the "truth" in Progress and Poverty[7] while pointing out the errors of the orthodox economists who were in pursuit of "conventional wisdom." Following the classical pattern of economic writing, George indicated the problem, defined his set of terms, and rejected two major tenets of the classical economic system, the Wages Fund and the Malthusian Population Doctrines, before he began establishing the cause and the cure for the paradox of progress and poverty.

The Problem

There are two problems that confront anyone who wishes to investigate the paradox of progress and poverty: One is poverty and the other is the cause of poverty. For George, it was inconceivable that God would allow anyone to be born into a world that could not provide enough of the essentials of life for the individual to be free from want and starvation. The Creator had provided for all; therefore, poverty must be caused by man. George felt that, if one could find and establish the cause of man-made poverty, then it would be possible to alter the prevailing economic system to make it conform to the Natural Laws and consequently provide a plentiful bounty for all.

---

[7]Henry George, Progress and Poverty (New York: Robert Schalkenbach Foundation, 1960), p. xvi.

It was obvious to George that one cause of poverty on a more general level was the fact that man in his methods of production and distribution of goods had established a set of institutions which were out of phase with the Natural Laws. Bring production and distribution into harmony with the Natural Laws, George felt, and abundance will flourish around the world. Progress was economic achievement measured by an increasing wealth which depends upon production, and it could be viewed as an economic function governed by economic laws which explain production and distribution. Poverty which was neither the opposite of progress nor the lack of economic achievement, but rather the misery and injustice that arises in a society with an imbalance in its system of production and distribution, can be explained and altered only by knowing these fundamental economic laws and applying them properly. Therefore, it was essential that these laws be understood and made to operate for the benefit of all before the forces of progress outside of, and in opposition to, the Natural Laws can create a condition under which no nation can survive:

> This association of poverty with progress is the great enigma of our times. It is the central fact from which spring industrial, social, and political difficulties that perplex the world, and with which statesmanship and philanthropy and education grapple in vain. From it come the clouds that overhang the future of the most progressive and self-reliant nations. It is the riddle which the Sphinx of Fate puts to our civilization and which not to answer is to be destroyed.[8]

[8] _Ibid._, p. 10.

George is saying that the ability to solve this great enigma is readily available and within easy grasp of the political economist who can brush aside dogma and search for "a certain set of facts," the "sequence of certain phenomena," "mutual relations," and then "identify cause and effect, just as the physical sciences seek to do in other sets of phenomena."[9] The basis for such a scientific investigation can be found in the self-evident truth "that men seek to gratify their desires with the least exertion."[10] The proof of this axiom can be demonstrated through a cross cultural comparison of this basic hedonistic concept. However, before George could proceed further in his investigation into the laws that govern political economy, he had to dispell two of the anachronistic theories held by economists of his time. Before the truth could be presented for acceptance, the false theories of the Wages-Fund and the Malthusian Population Doctrines must be relegated to the limbo which already held the theories of the medieval alchemists.

The Criticism of the Wages-Fund and the Malthusian Population Doctrines

The doctrine of the Wages-Fund first formulated by Nassau Senior, but found in the earlier works of Ricardo, was based upon an institutional concept arising from an agricultural-oriented economy in which the next year's investment in agricultural production would be available from the supply put aside from this year's harvest.[11] George viewed this doctrine,

---

[9] Ibid., p. 11.

[10] Ibid., p. 12.

[11] Eric Roll, A History of Economic Thought (3d ed.; Englewood Cliffs, N.J.: Prentice-Hall, Inc., 1957), p. 136. "In a discussion ... [Turgot] showed that the surplus created by the cultivator of the soil was the only fund from which the other members of society could draw their subsistence."

as Francis A. Walker had at an earlier date, as an inadequate explanation of the productive nature of a machine society. There is a flow of goods rather than a once yearly or static production effort from which the wages can be paid. The source of wage income would be derived from the value added by the additional work put forth daily.

Georges' reasoning on the wages-fund doctrine was thus:

> Wages are fixed by the ratio between the number of laborers and the amount of capital devoted to the employment of labor, and constantly tend to the lowest amount on which laborers will consent to live and reproduce, because the increase in the number of laborers tends naturally to follow and overtake any increase in capital. The increase of the divisor being thus held in check only by the possibilities of the quotient, the dividend may increase to infinity without greater result.[12]

Thus, an interaction between the amount of capital set aside for wages and the number of workers drawing upon the fund determined the wages paid. George thought the concept of wages-fund to be false for several reasons: there is no fund of capital set aside for the payment of wages and, as population increases, the increase in production that will result from the division of labor and specialization will grow faster than population. In order to prove his contentions, George began by defining the basic concepts of labor, land, capital, value, and wealth.

To George, "Labor includes all human exertion in the production of wealth, and wages, being that part of the produce which goes to labor, includes all reward for such exertion."[13] "Land embrases ... all natural

---

[12] George, Progress and Poverty, p. 17.

[13] Ibid., p. 32.

materials, forces, and opportunities...."[14] Capital is "neither land nor labor, but [that] which has resulted from the union of these two original forces of production."[15] "Nothing is capital that is not wealth."[16] And "the word 'wealth' is applied to anything having exchange value."[17] However, all items that have exchange value are not wealth, inasmuch as their increase or decrease does not affect the sum of wealth:

> Such are bonds, mortgages, promissory notes, bank bills, or other stipulations for the transfer of wealth. Such are slaves, whose value represents merely the power of one class to appropriate the earnings of another class.[18]

George accepts the distinction between value in use and value in exchange held by Adam Smith, but he felt that value in exchange was the only one used by economists. It had two parts: value from production and value from obligation. Production results in the creation of value while obligation, the right to command exertion of others, adds nothing to the total wealth. According to George, the acceptance of this distinction, pointed out previously by Smith, would have eliminated an error by the Austrian school when it made value the ability of one good to command other goods in exchange. Therefore, absolute value measured by the demand rate and determined by the operation of marginal utility would be completely relative. However, George, who could not accept the relative nature of value felt that:

---

[14] Ibid., p. 38.

[15] Ibid., p. 39.

[16] Ibid., p. 39.

[17] Ibid., p. 39.

[18] Ibid., p. 40.

> What the idea of value really springs from, is not the relation of each thing having value to all things having value, but the relation of each thing having value to something which is the source and natural measure of all value -- namely, human exertion, with its attendants irksomeness or weariness.[19]

This idea of George's is just another variation of the labor theory of value, for it had been expressed by the classical economists in much the same manner. Moreover, it is essentially the same argument that Smith used:

> The value of any commodity, therefore, to the person who possesses, it, and who means not to use or consume it himself, but to exchange it for other commodities, is equal to the quantity of labour which it enables him to purchase or command. Labour, therefore, is the real measure of the exchangeable value of all commodities.
>
> The real price of everything, what every thing really costs to the man who wants to acquire it, is the toil and trouble of acquiring it.... Labour was the first price, the original purchase-money that was paid for all things. It was not by gold or by silver, but by labour, that all the wealth of the world was originally purchased; and is value, to those who possess it, and who want to exchange it for some new production, is precisely equal to the quantity of labour which it can enable them to purchase or command.
>
> . . . .
>
> Labour, therefore, it appears evidently, is the only universal, as well as the only accurate measure of value, or the only standard by which we can compare the values of different commodities at all times and at all places.[20]

The labor theory of value or the value from production is also the basis for wealth. Value from obligation, individual wealth, is merely the command

---

[19] Henry George, <u>The Science of Political Economy</u> (1962 Reprint; New York: Robert Schalkenbach Foundation, 1897), p. 228.

[20] Adam Smith, <u>The Wealth of Nations</u> (New York: The Modern Library, 1937), pp. 30-36.

over the exertion of others and is not real wealth. The real wealth of a community consists of the goods available to it. Labour embodied in matter to make it into a usable form is wealth. To Smith, wealth depends upon labor expenditure; value upon labor expenditure; value upon labor saving. The confusion that surrounds the concepts of value and wealth, according to George, is the greatest source of the failure of political economy.

A further distinction of wealth is made by George. Wealth used in the production of more wealth is capital. It is not different from wealth except in its use. All capital is wealth, but all wealth is not capital. Both are forms of stored-up labor.

> Wealth, in short, is labor, which is raised to a higher or second power, by being stored in concrete forms which give it a certain measure of permanence, and thus permit of its utilization to satisfy desire in other times or other places. Capital is stored labor raised to a still higher or third power by being used to aid labor in the production of fresh wealth or of larger direct satisfactions of desire.[21]

Land which is not a product of labor must be kept separate from the concept of capital. While wealth is the joint action of land and labor, land is passive and is excluded from wealth in its natural state. If wealth is the result of the joint action of land and labor and land is excluded from wealth because of its passive nature, then capital which is wealth consumed in an indirect manner is labor also. It is apparent that the labor theory of value of the classical school is also the basis for value in the Georgian system.

---

[21] George, The Science of Political Economy, p. 296.

With George's definitional framework established, it is now possible to investigate his refutation of the wages-fund doctrine. In the first place, George thought that the classical economists had made several errors in their observations on money and capital. Because wages are paid in money before the completion of a project, and out of a fund established by the owner from savings or money set aside for the specific project, then a fund for wages must be established before production can begin. However, George recognized that industrial production, unlike agricultural production, is a flow or continuous process, in which there is a constant addition to the value-added as long as labor is exerted towards the project's completion. The wages-fund advocates maintained that wages could not be paid out of unfinished production. George, however, not only indicated the flow nature of production, but pointed out that unfinished goods have a market just like finished goods. The classical economists who accept the wage-fund doctrine are merely indicating the impact of the operational economy upon their theories. In agriculture the producer held his product until completion, and the small manufacturer took the raw material and fashioned it into an end product. George, who lived at a later date than the classical economists, observed a more complicated industrial process. He was aware of this significance when he made it quite clear in his statement that capital increases the power of labor to produce by permitting the division of labor. Thus, the finished product of one man becomes the raw material for another.[22]

---

[22]George, Progress and Poverty, p. 80.

When any producer withholds a finished or saleable product from the market, his function as an employer of labor changes into that of the commercial speculator who, because of his position and knowledge of the market, can make more money through speculation than by selling the finished product. Although this action by the former employer of labor would lead to greater return on investment, it would make any fund of capital (inventory) withheld from the market appear to be static. Actually, the producer and the speculator are one and the same individual and, more than likely, operate out of the same financial stream. This combination of entrepreneurial activity may make it appear that the sum of money set aside for the production of goods will be exhausted when the last wage is paid. However, in changing his function from a producer to a speculator, the entrepreneur has stopped the flow of funds in this particular case but not the flow of value. His employee has advanced a week's or month's wage value to the employer before payment is due. Thus, the worker through his labor produces the fund of wages available for his payment. The greater the effort of the worker, the greater will be the fund available for wages.

Wages, raw materials, or subsistence are not provided by capital. Capital merely assists labor in the production of wealth by permitting increased efficiency through the division of labor and the utilization of resources. Capital sets a maximum to wage level, but it cannot set the minimum. Nevertheless, the greatest impact upon the production of wealth is through what George terms cooperation: "the union of efforts to a common end."[23] Specialization and division of labor made possible through the exchange mechanism can create economies to scale which make possible a return to the worker of an amount greater than the original fund set aside by an employer for the immediate payment of wages. Labor is its own source of funds and, through multiplication, can increase the fund rather than diminish it.

After completing his refutation of the wages-fund theory, George next directed his attention to the second major tenet of the theoretical system of the classical economists: the Malthusian Population Doctrines.

Population Theory

George felt that critical evaluation of the wages-fund doctrine had been hampered by the blind acceptance of Malthus' population theories, merely because they appeared to be a self-evident truth. It is the self-evident nature of this doctrine that George criticizes the most, for it is built upon assumption and data that, under closer scrutiny, may appear to be of a totally insufficient nature.

The Malthusian doctrine is defined by George in its strongest and, to him, its least objectionable form:

> That population, constantly tending to increase, must, when unrestrained, ultimately press against the limits of subsistence, not as against a fixed, but as against an elastic barrier, which makes the procurement of subsistence progressively more and more difficult. And thus, whatever reproduction has had time to assert its power, and is unchecked by prudence, there must exist that degree of want which will keep population within the bounds of subsistence.[24]

---

[23]George, The Science of Political Economy, p. 371.

[24]George, Progress and Poverty, p. 95.

This doctrine, which became a foundation stone for Classical thought, was refuted by George on several different points: mathematical precision, specialization and division of labor, and the imbecile institutions.

Mathematical Precision

George doubted the mathematical precision of Malthus' work for several reasons. In the first place, there was no proof anywhere in the world, except in some small isolated places like Pitcairn's Island, where population had a tendency to outrun food supply. This condition was due primarily to a lack of trade with the outside world, rather than any particular natural law involving food production and population growth. Furthermore, there was no statistical study to support the assertion that food grows by arithmetic progression and population by geometric progression. If these laws were, as it appeared, developed through introspection, then George felt that it was possible to view the past, utilizing the same approach that Malthus used to look into the future.

> The web of generations is like lattice-work on the diagonal threads in cloth. Commencing at any point at the top, the eye follows lines which at the bottom widely diverge; but beginning at any point at the bottom, the lines diverge in the same way to the top. How many children a man may have is problematical. But that he had two parents is certain, and that these again had two parents each is also certain. Follow this geometrical progression through a few generations and see if it does not lead to quite as 'striking consequences' as Mr. Malthus' peopling of the solar systems.[25]

If one were to trace a couple back to the beginning of time, then a man and a woman required four parents; the four parents would have eight parents;

[25] Ibid., pp. 112-13.

the grandparents would have sixteen parents, etc. In order to have two people living presently there would have been, in years gone by, literally millions upon millions of antecedents for just the two. Therefore, the logic of Malthus' theory of the natural progression of population growth could be refuted by the use of a similar logical system for the population growth of the past.

Specialization and Division of Labor

The concept of specialization and division of labor discussed quite extensively by Adam Smith indicated that, when men and capital are applied to a specific function, the rate of production will be greater through specialization than when applied in a more generalized manner. George therefore theorized that production could be condensed into a smaller space and over a shorter period of time -- resulting in startling increases in production per man per year. This idea led to his observation that the growth in population would enable still greater specialization and division of labor -- which would result in an increase in production that would be greater than the growth of population.

Institutional Impediment

China, India, and other areas of the world which have a vast population and massive poverty seem to refute George's observations. They appear to be unable to produce an adequate amount of goods to meet the needs of the people. But, according to George, it was <u>not</u> the lack of adequate resources, capital, or manpower that created poverty, but the inability to properly utilize these factors of production. The institutional structure simply immobilizes their effective use.

According to George, the problem in India was not the inability of the land to support the masses, but the lawless nature of the English rule, the unequal distribution of income, the excessive taxation, and the general repression of the population to a perpetual state of poverty, misery, and famine. The Indian peasant was ground under by oppressive taxation which supported the enormous desire for wealth, capital accumulation, and capital gain of the English. Consequently, the Indian peasant who was taxed more and more each year began to produce less and less until he ultimately began to produce less than he needed to survive. The cause of continual want in India was not the fault of nature but the result of the institutional problems of man.

The vast populations of both India and China do appear at first sight to be proof of the Malthusian law. However, if one looks at the population densities of China and India as compared to Belgium, England, the Netherlands, Italy, and Japan, one finds that the population per square mile is greater in these countries than it is in India or China.[26] Furthermore, George recognized that, as man's income grew, the number of children per family began to diminish. During George's time and even before, there were indications that family size was not associated with the ability to support more children, but with the ability and/or desire to use some type

---

[26] Ibid., pp. 113-26.

of contraceptive device or technique which limited the number of children per family. The ability to limit the number of children per family was quite evident in the homes of the wealthy, but the poor either lacked the knowledge or desire to utilize the necessary measures to restrict their number.

George reasoned that man is different from an animal and is not governed by the same set of laws that control the animal: Man is in control of his destiny and not controlled by his destiny. The laws of population developed by Malthus are based upon the ability of any particular species to outgrow its food supply. While it is evident that some of the species of the world engage in this practice at various and sundry times (for example, the limmering of Norway), much of the world is capable of producing infinitely more than it currently is producing. Man is able to control the productive potentials of nature; the animal is not. Where ten animals grew before in their natural state, hundreds and even thousands can now grow. Man is capable of helping nature to produce more than its current productive capacity allows if nature is left alone to produce. Therefore, man, by an intelligent use of his resources, can produce far more than nature in a natural state can either supply or is willing to supply. Man is the controller of his destiny as a producer of food, whereas the animal is not. Thus, George reasoned, the use of the animal as an example to show that population, may, and does, in certain areas of the animal kingdom, outrun food supply, is a false application of an analogy to prove the Malthusian thesis.[27]

---

[27] Ibid., Book II, Chapter III.

Man is in no danger of outrunning his food supply. He depends, for subsistence, upon vegetables and animals whose rate of reproduction is extremely high. Through his ability to utilize resources, man can make these reproductive potentials available to himself:

> Both the seal and the man eat salmon, but when a seal takes a salmon there is a salmon the less, and were seals to increase past a certain point salmon must diminish; while by placing the spawn of the salmon under favorable conditions man can so increase the number of salmon as more than to make up for all he may take, and thus, no matter how much men may increase, their increase need never outrun the supply of salmon.[28]

Further, the productive power of man appears to be more than equal to his reproductive power. The ability of man to produce more than he can consume is quite evident. George readily admitted that when population increases poor productive soils must be utilized, but the increase in productive power is greater than the resort to the poor soil.

According to George, the problem of poverty is not caused by the growth in population, but is the result of a system of faulty distribution of production. The unequal distribution of income and the ability of a few to command any additional production creates the problem of both progress and poverty. Therefore, the problem is one of distribution rather than one of production or population: "In the unequal distribution of wealth is to be found the explanation of the correlation between minimum wages and maximum production, between progress and poverty!"[29]

---

[28] Ibid., p. 131.

[29] Ernest Teilhac, Pioneers of American Economic Thought in the Nineteenth Century (New York: The Macmillan Company, 1936), p. 131.

Laws of Distribution

In the Georgian system there are only three factors of production: land, labor, and capital. The return to the factors are rent, wages, and interest. Entrepreneurial income, or profit, existed, but George felt that profit was really an income from the combination of land and labor.[30] While other political economists, according to George, had separated these three factors into distinct analytical categories, he felt that if the theories of rent, interest, and wages were to be meaningful, there must be some kind of unity established between them. For George, the unity could be found in his theory of rent, which was similar to the theory develcped by Ricardo.

George accepted the equivalent of Ricardo's definition of rent, but he made a slight change to emphasize the monopolistic element of rent which was not found in Ricardo.[31] Land value was a price monopoly and land rent, therefore, was an unearned increment. George placed the value of land in the same category as value from obligation, with its value dependent upon neither labor nor use, but upon the ability to withhold the land from use. Rent was a passive and not an active element in the distribution process. It does not produce; it merely gives leave to produce; consequently, the return to land must be secured from the

---

[30]George, Progress and Poverty, pp. 156-57.

[31]Mark Blaug, Ricardian Economics: A Historical Study (New Haven: Yale University Press, 1958), p. 55.

product of labor and capital. Because rent must be paid first, wages and interest were dependent upon rent and were residual in nature.[32]

This reasoning led to George's formulation of the laws of distribution:

> Produce = Rent + Wages + Interest,
>
> Therefore, Produce - Rent = Wages + Interest.[33]

The interdependence of these three factors was indicated further by the use of the law of diminishing returns in its application to rent. With wages and interest as residual claimants, any payment made to rent which was affected by the law of diminishing returns also affects both wages and interest. This was made abundantly clear by George in the following statement:

> RENT depends on the margin of cultivation, rising as it falls and falling as it rises.
> WAGES depend on the margin of cultivation, falling as it falls and rising as it rises.
> INTEREST (its ratio with wages being fixed by the net power of increase which attaches to capital) depends on the margin of cultivation, falling as it falls and rising as it rises.[34]

Thus, it can easily be seen that both wages and interest vary inversely with rent and that all three are determined by the margin of cultivation. This, to George, is the unity: the establishment of rent, interest, and wages upon one basic principle. However, it is also the

---

[32] George, Progress and Poverty, pp. 171-72.

[33] Ibid., p. 171.

[34] Ibid., p. 218.

major cause of poverty, for as rent increases, wages and interest must decrease. Looking for an explanation of the causes of rent increase, George found three major reasons. The first is increasing population; the second, the improvement of the arts of production; the third, the phenomena of speculation.

The impact that the increase in population has upon the rent from land is more or less self-evident. The constantly increasing demand for the limited supply of land by a growing population would automatically increase the rent that any owner would receive, while any improvement in the art of production would appear to increase the residual payments to wages and interest. However, George indicates that improvements in the art of production increase the ability of civilization to utilize additional land. In doing so, the margin of cultivation is reduced, thereby increasing rent which signals the slow, gradual decreasing of wage and interest payments. Land of lower capability is brought into production. A widening of the production gap between the rich and poor land increases the rental income and decreases the wage and interest payments. Furthermore, speculation, by withholding a supply of land from use, forces an unnatural decrease in the available supply of land, while the increase in demand brings about a further increase in the rent payments which result eventually in lowering the interest and wage payments. Therefore, the problem behind the paradox of progress and poverty is the payment of rent which is both an unearned increment and a drain upon earned income. The income of rent goes to those who have, and is taken from the effort of those who have not. The have-nots provide the labor and the haves receive the rent. It is the unequal distribution of income, resulting from land ownership, which has created the poverty in the midst of plenty.[35] And, obviously, the solution to the problem is to make land common property. However, to George, common property did not mean common ownership in land. All such concepts are distinctly repudiated by him.[36]

The solution, to the problem of poverty, according to George, is to socialize economic rent: "It is not necessary to confiscate lands; it is only necessary to confiscate rent.... What I therefore propose ... is to appropriate rent by taxation.... To abolish all taxation save that upon land value."[37]

Economic rent, or the rent of land, is a completely social product and the only completely social product. Wealth and capital are not; therefore, taxes should be placed upon the economic rent which leaves wages and interest alone. George's solution is a rather simple one: by making the economic rent which is created by society available to society, the problems of progress and poverty would be overcome. This simple solution, a single tax upon land, would secure, for the good of the community, the economic rent that is available.

---

[35] Ibid., pp. 284-85.

[36] Ibid., pp. 397-98.

[37] Ibid., pp. 405-406.

Henry George's concept of the interaction of economic rent, wages, and interest led to his theory on the causes and cures of business cycles. To him, business cycles become more acute as a particular society grows in complexity. Although the various factors of production were available, people were not producing; men were idle, and families were going without. There had to be an explanation that would fit into observable Natural Laws and yet reveal the interference of man with the Natural Order.

The explanation for the cause of economic disorders, according to George, could be traced to speculation in land. Speculation caused land value to increase by withholding land from cultivation and forcing the use of land of lower fertility or productivity. The use of land of lower marginal productivity lowered wages and interest while increasing rent. Eventually, those portions of capital and labor yielding smaller returns could not be used. Soon the reduction in the use of marginal capital and labor resulted in an inadequate demand which was transmitted to all segments of the economy. Thus, an industrial depression would set in until rent returned to its normal level or until there was an increase in population that would push normal rent up to the speculative rent level. Another alternative would be for labor and capital to accept a lower return as their factor payment. However, if capital and labor were unable to receive their full product, there would be a constant tendency toward unemployment, depressions, and poverty. Until society transfers the rent which has been created by society to society, depressions will be commonplace.

With the transference of economic rent to the government, though, speculation would stop and land would be available to the user. The distribution of income would be more nearly equal, each man would earn only what he could produce through his own efforts, and man's propensity to take advantage of others would be checked. The economy would be free of the disturbing influences of land speculation, unearned income, grossly unequal distribution of income, and depressions and poverty. A "single tax" upon all the unearned increment on land would be the economic panacea.

Single Tax Proposals Prior to Henry George

The payment of taxes to a central administrative body is a comparatively recent development. In primitive societies the needs of the governing body were so insignificant that they were taken care of through a joint effort on the part of each member of the social unit. As these primitive societies grew larger and became more complex, the contribution was viewed not as a gift but as a duty, and eventually the duty became a compulsion.

Somewhere in the development of a system of taxation, however, men began to realize the economic advantage gained from avoidance and evasion of this duty. Both the powerful nobility and the land-rich clergy sought relief from taxation through royal exemption while thrusting the burden of taxation upon the less powerful working and merchant-capitalist classes. However, the merchant-capitalist class pushed as much of the burden upon the working class as it could in the form of higher prices and lower wages. After the Cromwellian Revolution in England which brought the merchant-capitalist class to power, the government directed more of the taxes toward the landed aristocracy.

With the growth of industry and commerce the economic crises associated with the emerging industrial order became more evident and more pronounced. From these crises sprang the reformers: The businessmen with their mercantilist pleas for the theoretical acceptance of their economic concepts; the idealists with their hopes of utopia and the social millenium; and many others of various shapes, sizes, and forms who possessed the political, economic, and social elixers of the moment. Many of these reformers attempted to correct wrongs, real or imaginary, by choosing a solution in light of a current problem.[38]

The increased revenue needs of expanding governments lead to a desire by governmental officials to find indirect taxes that will yield sufficient income to meet these needs. Indirect taxes are sought and levied in order to tax not only the poor but also the privileged classes who are exempt from other forms of taxation. This same motivation was behind some of the various forms of "single taxes" which were promulgated prior to Henry George's publication of _Our Land and Land Policy_ in 1871.

---

[38]Norman J. Ware, "The Physiocrats: A Study in Economic Rationalization," _American Economic Review_, Vol. 21, December 1931, pp. 607-608. /The Single Tax/ "...was a device of the commoner landowner, eager for profit, to escape the multiplicity of taxes which fell on land under the _ancient regime_ and to substitute one tax upon the agricultural surplus, thus insuring to the landowner, not only his cost of production, but a profit before taxation could be applied."

The concept of a single tax had been under consideration for several centuries before the introduction of the "Single Tax" of Henry George. The first single tax concept of record appears to be one upon luxuries proposed by Edward Chamberlayne in 1667. Chamberlayne wanted to place a tax "upon all such Commodities as occasion either Excess or Luxury, Wantonness, Idleness, Pride or corruption of Manners...."[39] There is some doubt, however, as to whether the writer meant a direct or indirect tax. Nevertheless, nineteen years later, as noted by Edwin R. A. Seligman, a Mr. J. M. again proposed a luxury tax in which he proposed that "all Persons Tax themselves according to such Degree as their Extravagancies shall prompt to exceed the Decent and Necessary Uses of them."[40] And, forty-three years later, an anonymous author believed to be Matthew Decker, proposed "One Tax on the Consumers of Luxuries ... [which would] take off all our other Taxes, Excises, and Customs."[41]

These taxes were proposed by these various authors as a method of decreasing wasteful expenditures and consequently placing a heavier tax burden upon the wealthy who were the major consumers of the luxuries.

At a later date, a single tax upon houses was proposed by Decker who, as a mercantilist, felt that the taxes upon imports were thwarting the growth of business and, therefore, the growth of the economy.[42]

---

[39] Edwin R. A. Seligman, The Shifting and Incidence of Taxation (New York: The Macmillan Company, 1902), p. 55.

[40] Ibid., p. 56.

[41] Ibid., p. 57.

[42] Ibid., p. 63.

But Joseph Massie, who opposed this system of taxation, felt that the incidence of such a tax would fall upon the consumer and would be detrimental to the economy by increasing the price and reducing the demand for goods. Massie favored the existing land tax because it fell upon the landowner and could not be shifted. The debate over the single tax upon houses ended, as it had ended in the earlier debate over a single tax on luxuries, when Lord North incorporated a tax upon houses within the prevailing tax structure. John Locke felt that a single tax should be placed upon land, because any tax placed upon the merchant would be shifted to the consumer, resulting in increased prices and reduction in demand. A tax upon the laborers who receive a subsistence wage will automatically force an increase in wages, which also will increase the cost of commodities and reduce their sale. The only tax which would not bring about a price increase and could not be shifted was a tax upon land. Locke proposed that the tax be placed upon the landlord, who eventually would have to pay it.

John Asgill, Cantillon, and others held views similar to those of Locke when they stated that "the weight of every tax upon consumption ultimately falls and set heavy on the proprietors of the soil."[43]

In 1850, Patrick Edward Dove published his book, The Theory of Human Progress, in which he hoped for the reconciliation of science and religion. He recognized the impact that poverty had upon man and refused to accept the age-old explanation that it was God's will. "Dove advanced the identical solution that was later proposed by George,"[44] a solution to

---

[43] Ibid., p. 78.

[44] Geiger, The Philosophy of Henry George, p. 161.

obliterate poverty. However, Dove used a theological approach rather than an economic one. George, when confronted by a charge of plagiarism, recognized the similarity between his work and that of Dove, and he countered the accusation with the statement that the knowledge of truth was not the domain of any one man. It was available to all who possessed clear thought and vision. The recognition by one or many of any truth made it all the more acceptable. However, in his own defense, George maintained that he had not seen the work of Dove until three years after the publication of Progress and Poverty.

The list is long of those early believers who felt that the world's poverty was a cancerous sore upon which misery, greed, and corruption thrived. Many lived and wrote at the time when the philosophy of Descartes and Locke was at its zenith. Therefore, it was only natural that these men, maintaining a Natural Right and Natural Law philosophy, believing in the utopia, the social millinium; and seeking theological, philosophical and/or economic panaceas, would find the alternative solutions to the problem of the era to be few in number. It was eminently possible that men whose economic, political, social, and theological background had greater similarity than dissimilarity would by chance develop similar theoretical systems. The alternative solutions available to these men were too few and the power of the great intellects too great for the average writer and researcher to overcome. The similarity of their views was to be expected, and it merely pointed out the smallness in size of the intellectual community of the Western world. For Henry George to be a member of this august body through the conceptualization and presentation of a body of thought that not only reflected the thoughts of his intellectual peers but his own original ideas as well, indicates the high level of his contribution. However, the strongest advocates of the "single tax" upon land other than George were the physiocrats, who had a tremendous influence upon all the classical economists and their followers.

The Single Tax of the Physiocrats

The development of the Physiocrats, as a school of economic thought,[45] was the result of the efforts of one man, Francis Quesnay. Born the son of a farm owner, Quesnay, through hard study and personal intellect, rose to the position of court physician of Louis XV and Madame de Pompadour. Among his most illustrious followers were the Marquis de Mirabeau, Piere Samuel Du Pont de Nemours, Anne Robert Jacques Turgot, and many others. But, Turgot was "more a fellow-traveller of the Physiocrats than a Physiocrat pur ..."[46]

It was the combination of past environment, education, and philosophy on the part of the Physiocrats which blended into a system of thought and created a desire on their part to alter France's production and distribution system, a system that had been bogged down in the institutional impediments of mercantilism and feudalism for centuries. Quesnay's experience upon the farm led him to make the observation that much of the

---

[45] Ronald L. Meek, The Economics of Physiocracy (Cambridge, Massachusetts: Harvard University Press, 1963).

[46] Ibid., p. 311.

governmental controls over agriculture were restrictive and that industry could be more productive if allowed to produce unfettered by tolls, taxes, and tariffs which impeded the movement of goods. He also commented that the small farmers were burdened by taxes while the "non-productive" landowners were exempt from much of these same taxes.

As a physician, he had observed the human body and its circulatory system, and he drew an analogy from it which he felt was highly applicable to society. Society was a big physical organism whose blood, wealth and goods circulated throughout the whole system. The laws of economic circulation, when impeded, were detrimental to the physical organism, society. Upon this analogy Quesnay developed what is considered to be one of his most important contributions, the Tableau Économique, which describes the circulation of goods and services of the economy and is the basis for the modern concepts of the flow-of-funds and the input-output analysis.

In his philosophy, Quesnay accepted the foundations that had been laid down previously by Descartes, Hobbes, Locke, Hume, and others. He also accepted the mechanistic view of the universe and the concepts of Natural Law and Natural Rights, harmony of interests, laissez faire, and free trade which are based upon it. Descartes and Newton had proven the existence of the Divine Law which controlled all of the universe. All that was needed was for the existing economic and political systems to be brought into conformation with the Divine Law, for, in order for society to function properly, the laws of production and distribution must fit into the overall law of the universe. Laissez Faire and free trade, which allowed unimpeded circulation of goods, were the opposite of those rules and regulations which were in existence in France.

The carry over of the restrictive rules and regulations of feudalism and mercantilism in France were much in evidence during Quesnay's time. The landed aristocracy and the clergy were exempt from taxes, an unhealthy situation which forced the burden of government upon the lower classes. The impoverished Royal Treasury, constantly having to find new taxes to levy, began to destroy the incentive to accumulate wealth and to expand investments. Agricultural production could not move freely from one province to another, and the guilds were engaged in jurisdictional litigation for centuries at a time over what appeared to be the most trivial (to a modern observer) of work rules. It was obvious to those without vested interests that France must undergo a sudden change in its economic system if it were to keep pace with the rapid expansion that was being experienced by England who, at an earlier date, had broken the economic grip of feudalism and mercantilism. Unfortunately, however, the French had to wait about twenty years for the French Revolution before much of the Physiocrat theory of Quesnay and others could be put into practice.

The Physiocrat's major reform efforts were made in an attempt to improve the economy and to increase the rate of growth or progress. They were opposed to all regulations of economic activity, from the consumption of luxuries which thwarted capital accumulation to special tax privileges given to the non-productive and sterile classes. They thought that only agriculture produced a surplus and that it went to the landowner. In their minds, the only solution to the fiscal chaos experienced by the Royal Treasury would be a direct tax, because an indirect tax could be avoided by the privileged classes or easily passed on to others. Therefore, they recommended a single direct tax upon the landowners who were the recipients of the surplus production.

"Their bold policy of an impot unique, or single tax on land rent, was designed not only to solve the state's financial problems, but also, and primarily, to assist in the rehabilitiation of agriculture."[47]

The single tax would reduce the cost of tax collection, would not be shifted to others, would not contribute to the chaos of collection, and would improve capital accumulation and increase the incentive to invest in agriculture production.

The single tax would not fall directly upon the land, but upon the surplus which the land may yield. There would be no attempt to expropriate the surplus value in its entirety, but only that part which was needed to finance the required level of fiscal operation. The Physiocrats felt that the surplus value created in agriculture was far in excess of the needed amount to run the government of France.[48]

The Physiocrats intended to tax one-third of the net product, which would be sufficient revenue for government affairs. They realized that

---

[47] Ibid., p. 25.

[48] Charles Gide and Charles Rist, A History of Economic Doctrines, trans. R. Richards (Boston: D. C. Heath and Company, 1913), p. 39.

a tax upon land would reduce the value of land -- but not the value of its product:

> They argued that none would feel the burden, seeing that no one was really paying it. Land would now be bought at 70 per cent of its former value, so that the 30 per cent nominally paid by the proprietor was in reality not paid by him at all. Land let at £10,000 would be valued at £200,000. But with a tax of £3,000 it is really only yielding £7,000 and its value will be £140,000. The buyer who pays this price, despite the fact that he has paid a tax of £3,000, will enjoy all the revenue to which he has any claim, for he can only lay claim to what he has paid for, and he did not pay for that portion of the revenue which is affected by the tax.[49]

There were many objections to the single tax on net product. To some, it was unjust because it fell on one class and not equally upon all, while others held that the tax would be entirely insufficient to meet all fiscal needs. The Physiocrats countered these two major objections by pointing out that a single tax on net product, while appearing to fall on one class, actually fell upon the only class that created a net product. A tax on "the revenues of the agricultural and industrial classes are not squeezable because they represent the indispensable minimum necessary for the expenses of production."[50]

To the objection that the tax revenue would be insufficient to meet fiscal needs, the Physiocrats held that the removal of taxes from other areas would increase the net product from which additional taxes could be levied. Furthermore, the simplicity of collection would reduce the

---

[49]<u>Ibid.</u>, p. 40.

[50]<u>Ibid.</u>, p. 42.

expense of collection. And, finally, they reasoned that "the State should adapt its needs to meet its revenue, and not *vice versa*."[51]

Their final plea for the single tax on net product was that it fitted into the natural laws and made a fine "barrier against the autocracy of the sovereign -- a barrier that is much more effective than a parliamentary vote."[52]

The Single Tax Thesis of Henry George

The single tax concept can be found in almost all of Henry George's publications. Three excellent sources are available: a book, *Progress and Poverty*[53]; a pamphlet, *The Single Tax: What It Is and Why We Urge It*[54]; and an article, "A Single Tax on Land Values".[55] The Single Tax thesis is important to George because it is the keystone to his system.

His theory is deceptively simple, but when placed within the elaborate framework that he patiently developed in *Progress and Poverty*, it loses its simplicity. "The single tax is not a tax on land. It is a tax on land value -- on that value which attaches to land irrespective of improvements in or on it."[56] All other taxes would be abolished

---

[51] *Ibid.*, p. 43.

[52] *Ibid.*, p. 44.

[53] George, *Progress and Poverty*, pp. 395-431.

[54] Henry George, *The Single Tax: What It Is and Why We Urge It* (New York: Robert Schalkenbach Foundation, No date).

[55] Henry George, "A Single Tax On Land Values," *The Century Magazine*, Vol. XL (July 1890), pp. 394-403.

[56] *Ibid.*, p. 394.

"save that upon land values."[57] The effect of the single tax would permeate the entire economy. It would eliminate land speculation, reduce the cost of product, increase wages and interest, increase employment, and remove, once and for all, the spectre of poverty.

Furthermore, George felt that it was the best possible tax for the following reasons:

> 1. That it bear as lightly as possible upon production--so as least to check the increase of the general fund from which taxes must be paid and the community maintained.
> 2. That it be easily and cheaply collected, and fall as directly as may be upon the ultimate payers--so as to take from the people as little as possible in addition to what it yields the government.
> 3. That it be certain--so as to give the least opportunity for tyranny or corruption on the part of officials, and the least temptation to lawbreaking and evasion on the part of the taxpayers.
> 4. That it bear equally--so as to give no citizen an advantage or put any at a disadvantage, as compared with others.[58]

To George, income from land (land rent) and exchange value of land (sale price) were economic rent or an "unearned increment of land values", and a single tax, "so as to take as nearly as may be the whole of the economic rent"[59] would be "sufficient to bear the entire expense of government."[60]

---

[57] George, Progress and Poverty, p. 400.

[58] Ibid., p. 408.

[59] George, The Single Tax: What It Is and Why We Urge It, p. 3.

[60] George, Progress and Poverty, p. 400.

> I [George] do not propose either to purchase or to confiscate private property in land. The first would be unjust; the second, needless. Let the individuals who now hold it still retain, if they want to, possession of what they are pleased to call _their_ land. Let them buy and sell, and bequeath and devise it. We may safely leave them the shell, if we take the kernel. It is not necessary to confiscate land; it is only necessary to confiscate rent.
>
> Nor to take rent for public uses is it necessary that the State should bother with the letting of lands, and assume the chances of the favoritism, collusion, and corruption this might involve. It is not necessary that any new machinery already exists. Instead of extending it, all we have to do is to simplify and reduce it. By leaving to landowners a percentage of rent which would probably be much less than the cost and less involved in attempting to rent lands through State agency, and by making use of this existing machinery, we may, without jar or shock, assert the common right to land by taking rent for public uses.
>
> We already take some rent in taxation. We have only to make some changes in our modes of taxation to take it all.[61]

This increase in value of land would yield an increase in rent: exchange value (rent), actual rent, and potential rent.[62] The amount of rent will increase with the growth of population,[63] the improvements of technology[64] and with a reduction in the corrupt government.[65] The margin of cultivation influenced by speculation will determine the amount of rent that will be paid.[66]

---

[61] _Ibid._, p. 405.

[62] _Ibid._, p. 166.

[63] _Ibid._, pp. 234-43.

[64] _Ibid._, pp. 245-49.

[65] _Ibid._, p. 254.

[66] _Ibid._, pp. 258-59.

The actual rental amount would be determined by the tax that a user would be willing to pay:

> [The] simple device of placing all taxes on the value of land would be in effect putting up the land at auction to whosoever would pay the highest rent to the state. The demand for land fixes its value, and hence, if taxes were placed so as very nearly to consume that value, the man who wished to hold land without using it would have to pay very nearly what it would be worth to anyone who wanted to use it.
>
> And it must be remembered that this would apply, not merely to agricultural land, but to all land. Mineral land would be thrown open to use, just as agricultural land; and in the heart of a city no one could afford to keep land from its most profitable use, or on the outskirts to demand more for it than the use to which it could at the time be put would warrant. Everywhere that land had attained a value, taxation, instead of operating, as now, as a fine upon improvement, would operate to force improvement. Whoever planted an orchard, or sowed a field, or built a house, or erected a manufactory, no matter how costly, would have no more to pay in taxes than if he kept so much land idle. The monopolist of agricultural land would be taxed as much as though his land were covered with houses and barns, with crops and with stock. The owner of a vacant city lot would have to pay as much for the privilege of keeping other people off of it until he wanted to use it, as his neighbor who has a fine house upon his lot. It would cost as much to keep a row of tumble-down shanties upon valuable land as though it were covered with a grand hotel or a pile of great warehouses filled with costly goods.[67]

Limited vs. Unlimited Single Tax

The interpreters of Henry George's single tax thesis differ as to the extent of the levy on the unearned increment. There are those who choose to support the thesis of a limited single tax which would take

---

[67] Ibid., pp. 437-38.

only that economic rent from land which was necessary to meet the needs of government.[68] Others who advocated the unlimited single tax felt that all unearned increment from land should revert to the people in the form of services provided by the government and paid from the single tax revenue.[69]

The conflict between the advocates of the two forms of single tax arise from the express desire of Henry George to tax all of the unearned increment, even though he realized that it was impossible to determine just how much unearned increment was generated in any given year. This conflict within George reflected in the different stands taken by him on various occasions in the Standard, the official newspaper of the single tax movement.[70] However, when Henry George engaged in a debate with Justice David Dudley Field in 1885, he maintained the following position:

> Field: In whom would you have the title to land vested--in the State, or in the individuals, as now?
>
> George: I would have the land titles as at present.
>
> . . . .
>
> Its effect [Single Tax], however, if carried as far as I would like to carry it, would be to

---

[68]There were many who felt that the single tax would yield more revenue than needed. Steven B. Cord, Henry George: Dreamer or Realist? (Philadelphia: University of Pennsylvania Press, 1965), pp. 38-39, 67-68, 70-71, 85, 121-22, 190-95, 234-35.

[69]Alyea, Fairhope, pp. 108-10.

[70]Ibid.

make the community the real owner of land, and the various nominal owners virtually tenants, paying ground rent in the shape of taxes.

. . . .

Field: If you would have titles as now, then A, who owns a ten thousand dollar house and lot in the city, would still continue to be the owner, as he is at present?

George: He would still continue to be the owner, but as taxes were increased upon land values he would, while still continuing to enjoy the full ownership of the house, derive less and less of the pecuniary benefits of the ownership of the lot, which would go in larger and larger proportions to the State, until, if the taxation of land values were carried to the point of appropriating them entirely the State would derive all those benefits, and, though nominally still the owner, he would become in reality a tenant with assured possession, so long as he continued to pay the tax, which might then become in form, as it would be in essence, a ground rent.

. . . .

Field: ...you would increase that amount indefinitely, if I understand you, up to the annual rental value of the land?

George: I would.

. . . .

Field: ...you propose for the present no change whatever in anything, except that the amount now raised by all methods of taxation should be imposed upon real estate considered as vacant?

George: For a beginning, yes.

Field: Well, what do you contemplate as the ending of such a scheme?

George: The taking of the full annual value of land for the benefit of the whole people. I hold that land belongs equally to all, that land values arise from the presence of all, and should be shared among all.

Field: And this result you propose to bring about by a tax upon land values, leaving the title, the privilege of sale, of rent, of testament, the same as at present?

George: Yes.[71]

The debate indicated that George was a limited single taxer in the short-run, when the unearned increment from land was greater than government need; however, as the need increased, he had no qualms about taking it all. One could argue that George did not advocate the taking of all the rent because it was not politically expedient to exappropriate the value all at once. Nevertheless, he did plan to take it all at some future date if it were ever needed.

---

[71] Henry George, "Land and Taxation: A Conversation Between David Dudley Field and Henry George," The Complete Works of Henry George, Our Land and Land Policy (Garden City, New York: Doubleday, Page and Company, 1911), Vol. VIII, pp. 225-30.

CHAPTER III

THE HISTORICAL, SOCIAL, AND SELECTED ECONOMIC DEVELOPMENT OF EDMOND, OKLAHOMA

Introduction

In looking for an area that would give the best example of Henry George's thesis that land value grows as the population grows, no better place could be found than Edmond, Oklahoma. Its growth, although rapid in the beginning, eventually slowed to a leisurely pace which did not change until after the 1950's. Further reasons for the selection of this city as a research project are the availability of data, the size of the city, and the potential of unearned increment created by a state educational institution.

This chapter will present data on historical, demographic, and selected economic and social characteristics in order to give a clearer picture of the forces that contributed to the growth of land value in Edmond. A discussion of the early history and physical characteristics will be followed by data on population, labor force, employment, retail trade, services, college enrollment, assessed valuation for both Edmond and Oklahoma County, and platted lots and acreage within the city limits from 1941 through 1965.

Early History of Edmond, Oklahoma

The founding of Edmond, Oklahoma, was associated with the land-hungry desires of the white man and the ravished, dwindling number of the resettled, land-rich Indians in Oklahoma. As the Indian population decreased, the land set aside for their use appeared to many whites as excessive and wasted through non use. The pressure placed upon the politician by the "Boomers" to open the land became enormous. Even the Indians felt the pressure; nevertheless, the representatives of the Five Civilized Tribes "agreed in June 1886 to reject all offers from the government for the purpose of land for the use of citizens of the United States."[1]

However, as the pressure to open the land mounted, the Creek Indians decided to negotiate with the federal government before it was too late. In January, 1889, they "released the United States from all restrictions on the use of the entire Creek cession of 1866" and sold over 3,400,000 acres for $2,200,000. The Seminole, following the lead of the Creek, released to the United States over 2 million acres for $1.9 million.

Under the terms of the two agreements, the Creek were to receive $.95 an acre for unassigned land and $.75 an acre for land assigned to other Indians. The Seminole received slightly less per acre (about 15 cents less) because they had been overpaid in the land agreement in the Seminole cession of 1866.

---

[1]Roy Gittinger, The Formation of the State of Oklahoma (Norman, Oklahoma: University of Oklahoma Press, 1939), p. 179.

The formal acceptance of these two proposals, in the form of two bills, was acknowledged when President Cleveland signed them on March 1 and 2, 1889. On March 23, President Harrison issued a proclamation declaring that the Oklahoma District would be open to freeholders at noon April 22, 1889.

However, in the ensuing haste to pass the bills before Congress adjourned, no provisions were made for the county and municipal officials who were needed to help establish town-sites on public land. These deficiencies, and a size limitation of 320 acres placed upon any potential town-site, were to cause problems in the beginning for Oklahoma City, Guthrie, Edmond, and many other towns newly formed in the district.

Edmond, named after Eddy B. Townsend, the successful litigant for the ownership of a part of the original Edmond town-site[2], was to be the county seat of Ventura County. But, with the passage of The Organic Act of May 2, 1890, which gave the territory west of the Five Civilized Tribes a formal government, the number of counties established at the territorial convention at Guthrie in July, 1889, was reduced from ten to six. This provision placed Edmond within the county limits of Oklahoma County. Nevertheless, it was felt in 1890,

---

[2]George H. Shirk, Oklahoma Place Names (Norman, Oklahoma: University of Oklahoma Press, 1965), p. 70.

Other research indicates that "Edmond was named for one of the officials of the Oklahoma Division of the Santa Fe Railroad." Stella Barton Fordice, "History of Edmond, Oklahoma" (unpublished Master's thesis, Department of History, University of Oklahoma, 1927), p. 6.

"that with the settlement of the unoccupied lands county lines will be restored to its former place on the maps of the Territory with Edmond as its capitol."[3] But this was just a dream that would never materialize.

Edmond, about half-way between the cities of Guthrie and Oklahoma Station (the word City was first used by the Post Office in 1924), was established next to the tracks of the Santa Fe on the first day of the run. Using the Santa Fe tracks as a bench mark, the Seminole Town Company, among several other companies[4], laid out the town-site of Edmond. It was platted incorrectly, as was Guthrie and Oklahoma City, because the railway tracks had been laid in a north-easterly direction and not in a true north and south direction. Other factors complicated the situation as well:

> The original town-site of Edmond included the southeast quarter of section twenty-six, township fourteen, north of range three west, and the northeast quarter of section thirty-five, township fourteen, range three west. Homesteads were filed upon the same lands by E. B. Townsend and A. F. Smith. In the trial of a contest filed by Townsend, the local land office decided in favor of Edmond, and Townsend appealed to the General Land Office. In a compromise with Smith, the town secured free from contest 120 acres.[5]

The settlement of the litigation, although not free from fraud or perjury on both sides, left Townsend in control of forty acres of

---

[3]Marion Tuttle Rock, Illustrated History of Oklahoma (Topeka, Kansas: C. B. Hamilton and Sons, 1890), p. 175.

[4]Luther B. Hill, A History of The State of Oklahoma (Chicago: The Lewis Publishing Company, 1908), pp. 231-33.

[5]Rock, Illustrated History of Oklahoma, pp. 177-78.

Edmond town-site for which he paid $375 or $10 per acre with 2½ acres set aside for "park, school, and other public purposes", and $1.25 per acre for the remaining 120 acres in accordance with the Organic Act of May 2, 1890.[6]

And, in September 1892, the first subdivision, the E. B. Townsend Addition to Edmond, was platted and accepted by the legal authorities of Edmond and Oklahoma County.

The general confusion created at both the federal and local level delayed the official Trustee Deed sales until "The Secretary of the Interior sustained the General Land Office and on February 28, 1891, ordered that Smith's homestead entry be cancelled."[7] In March and April of 1891, the first 90 lots, at an average of $4.15 per lot, were sold and recorded, although Edmond had been officially incorporated on December 31, 1889.

GENERAL CHARACTERISTICS OF EDMOND

Physical Characteristics

The physical characteristics of Edmond were aptly described in 1890 by Marion Rock in his Illustrated History of Oklahoma:

> Surrounding the town in all directions are gently sloping ridges and wooded hills, interspersed with valleys of unsurpassed fertility. Looking from Edmond is seen in the far distance the dim outline of a high

---

[6] Berlin B. Chapman, "The Legal Sooners of 1889 in Oklahoma," The Chronicles of Oklahoma, Vol. XXXV, No. 4, (1957-58), pp. 405-409.

[7] Ibid., p. 406.

> and rolling ridge curving like a horse-shoe, with one heel resting upon the railroad far to the south, and the other an equal distance to the north. That ridge is fifteen miles away, and like a frame to a picture it defines the western limit of Ventura county, and includes about two hundred and twenty-five thousand acres of as rich land as is to be found in any State or Territory, and most of this is tributary to the city of Edmond. In the distance are seen the many bright green ribbons of trees. They mark the tributaries of the three creeks that lend such a charm and beauty to the general landscape. These are from four to five miles apart, and are known as Chisholm, Bluff, and Deer creeks. All have beautiful valleys, and in many places are heavily fringed with excellent oak and walnut timber. They run in a northeasterly direction through the county, and find their way into the Cottonwood, which in turn blends its waters with that of the Cimarron, twenty miles to the northeast.
>
> Between all these creeks the land is just sufficiently undulating to drain well, and nowhere do the valleys and highlands meet so abruptly as to make a striking contrast. They often blend so imperceptibly that it is hard to tell where the one begins and the other ends; and so luxuriant is the growth of bluestem and other grasses that it would be difficult to find a spot that would not yield from one to three tons of hay to the acre.[8]

The ravages of time and civilization have somewhat altered the peaceful valleys and wooded hills found by Mr. Rock. However, the scene so aptly pictured by him, had been highly successful in attracting settlers, many of whom have remained to build the growing town of Edmond.

---

[8] Rock, Illustrated History of Oklahoma, p. 176.

Population

Edmond experienced a rapid growth in the first few years of its existence. After the turn of the century, a more leisurely growth rate of a little over 3 per cent each year was experienced (Table 1), except for the decade of the Great Depression, 1930-40, in which the growth rate trickled off to a mere 1 per cent per year. This trend was to be reversed in the 1940's, with a growth rate of 4.7 per cent achieved from 1940 to 1950. From 1950 to 1960 a rate of 3.5 per cent was sustained, and in the years following 1960 the town experienced a significant increase of 8.6 per cent in population from 1961 through 1964. Beginning in 1964, the population growth estimated by the University of Oklahoma Bureau of Business Research indicates that the growth rates have fallen back to slightly over 4 per cent for the year 1964-65.

Social and Economic Characteristics

In the year of 1960, (Table 2), the total population of Edmond was 8,577, with 1.1 per cent foreign born. The medium educational attainment level was 11.9 per cent with 49.6 per cent completing four years of high school or more. Females represented 38.7 per cent in the labor force, and unemployment was 2.7 per cent, which was below the state average of 4.4 per cent. The medium family income was $5,204, with 20.5 per cent under $3,000 and 11.8 per cent $10,000 or

TABLE 1

POPULATION OF EDMOND, OKLAHOMA, SELECTED YEARS, 1890 - 1965

Date	Population	Date	Population
1890	294[a]	1950	6,086[b]
1900	965[a]	1960	8,577[b]
1910	2,090[b]	1961	9,315[d]
1920	2,452[b]	1962	10,116[d]
1930	3,576[b]	1963	10,986[d]
1940	4,006[b]	1964	11,907[c]
		1965	12,390[c]

Source: [a]*The Oklahoma Red Book*. Compiled by W. B. Richards. (Oklahoma City, Oklahoma, 1912), Vol. II, p. 598.

[b]U.S., Bureau of The Census, *Thirteenth Census of the United States: 1910. Population*, Vol. II,

______. *Fourteenth Census of the United States: 1920. Population*, Vol. II,

______. *Fifteenth Census of the United States: 1930. Population*, Vol. II,

______. *Sixteenth Census of the United States: 1940. Population*, Vol. II,

______. *Seventeenth Census of the United States: 1950. Population*, Vol. II,

______. *Eighteenth Census of the United States: 1960. Characteristics of Population*, Vol. II,

[c]Bureau of Business Research, University of Oklahoma, Norman, Oklahoma. Unpublished Population estimates based upon 2.5 persons per gas meter in use.

[d]Estimates made by use of geometric mean.

$$\text{Log} \frac{\frac{1964\ (11{,}907)}{1960\ (8{,}577)}}{N(4)\ \text{Years}} = \text{Log } 1 + r\ (1.086)$$

TABLE 2

SOCIAL AND ECONOMIC CHARACTERISTICS, EDMOND, OKLAHOMA, 1960

	Number	Per Cent
Total Population	8,577	100.0
Foreign or Mixed Parentage	208	2.4
Foreign Born	98	1.1
Years of School Completed		
Persons 25 Years Old and Over	4,276	100.0
High School, 4 years	861	20.1
College, 1 to 3 years	673	15.7
4 years or more	568	13.3
Median School Years Completed	11.9	....
Employment Status		
Male, 14 Years Old and Over	3,171	100.0
Not in Labor Force	789	24.8
Civilian Labor Force	2,382	100.0
Employed	2,325	97.6
Unemployed	57	2.4
Female, 14 Years Old and Over	3,314	100.0
Not in Labor Force	2,030	61.2
Civilian Labor Force	1,284	100.0
Employed	1,242	96.7
Unemployed	42	3.3
Family Income in 1959		
All Families	2,213	100.0
Families with Income Less than $3,000	454	20.5
Families with Income of $10,000 or Over	261	11.8
Medium Income	$5,204	

Source: U. S. Bureau of The Census, U. S. Census of Population: 1960, Vol. I, Characteristics of Population, Part 38, Social and Economic Characteristics of The Population, For Urban Places of 2,500 to 10,000, Table 81, p. 201.

over, which compares with the state average of $4,620 medium family income with 31.0 per cent under $3,000 and 10.0 per cent $10,000 or over.

Population and Labor Force

In 1960, (Table 3), there were 6,485 persons living in Edmond who were fourteen years old and over, and, of these people, 56.5 per cent were in the labor force and 55.0 per cent were employed. Approximately 1,500 college students living in Edmond during the school year were included as part of the persons fourteen years and over, but not as a part of the labor force unless they were working or looking for work. Unemployed persons were ninety-nine or 1.5 per cent of the fourteen years old and over -- or 2.7 per cent of the total labor force.

Employment by Occupation and Industrial Group

The four largest categories of employment by occupation, (Table 4), are Clerical (665), Professional and Technical (546), Craftsmen and Foremen (535), and Operatives (482). The size and relative importance of the category of Professional and Technical, in comparison to the number employed in other occupations, reflects the economic impact of Edmond's main business, education.

In employment by industrial group, (Table 5), the four largest categories are Professional and Retail Services (22.8 per cent), Wholesale and Retail Trade (22.0 per cent), Construction (8.8 per cent), and Public Administration (8.3 per cent).

TABLE 3

LABOR FORCE TO POPULATION, EDMOND, OKLAHOMA - 1960

	1960 Number	Per Cent
Total Population	8,577	100.0
Persons 14 Years and Over	6,485[a]	75.6
Labor Force		
Employed	3,567	55.0
Unemployed	99	1.5
Total	3,666	56.5
Persons Not in Labor Force	2,819	43.5

Source: Compiled from U.S., Bureau of the Census, U.S. Census of Population: 1960, Vol. I, Characteristics of Population, Part 38, Social and Economic Characteristics of the Population, For Urban Places of 2,500 to 10,000, Table 81, p. 201.

[a]Included approximately 1,580 students.

TABLE 4

EMPLOYMENT BY OCCUPATION, EDMOND, OKLAHOMA - 1960

Occupation	No. of Males	Per Cent	No. of Females	Per Cent	Total Employment
Professional and Technical	303	13.0	243	19.6	546
Farmers and Farm Managers	11	.4	...	....	11
Managers, Officers and Proprietors	283	12.2	26	2.1	309
Clerical	168	7.2	497	40.0	665
Sales Workers	155	6.7	113	9.1	268
Craftsmen and Foremen	527	22.7	8	.6	535
Operatives	407	17.5	75	6.0	482
Private Household	...	....	61	4.9	61
Service Workers	200	8.6	191	15.4	391
Farm Laborers	12	.5	...	....	12
Other Laborers	153	6.6	...	....	153
Not Reported	106	4.6	20	2.3	134
Totals	2,325	100.0	1,242	100.0	3,567
Per Cent	65.2		34.8		

Source: Compiled from U.S., Bureau of the Census, U.S. Census of Population: 1960, Vol. I, Characteristics of Population, Part 38, Social and Economic Characteristics of the Population, For Urban Places of 2,500 to 10,000, Table 81, p. 201.

TABLE 5

EMPLOYMENT BY INDUSTRIAL GROUP, EDMOND, OKLAHOMA - 1960

Industrial Group	Number Employed	Per Cent of Total
Agriculture, Forest and Fish	32	.9
Mining	176	4.9
Construction	315	8.8
Durable Goods Manufacturing	99	2.8
Nondurable Goods Manufacturing	157	4.4
Transport, Communication, and other Public Utility	251	7.0
Wholesale and Retail Trade	785	22.0
Finance, Insurance and Real Estate	167	4.7
Business and Repair Services	65	1.8
Personal Services	217	6.1
Entertainment and Recreation Services	57	1.7
Professional and Related Services	812	22.8
Public Administration	330	8.3
Industry Not Reported	102	2.8
	3,567	100.0

Source: Compiled from U.S., Bureau of the Census, U.S. Census of Population: 1960, Vol. I, Characteristics of Population, Part 38, Social and Economic Characteristics of the Population, For Urban Places of 2,500 to 10,000, Table 81, p. 201.

Enrollment in Central State College

Central State College was established as the Territorial Normal School on December 24, 1890, on land donated by Edmond: "The first school began on November 9, 1891, the twenty-three students meeting in the Epworth League room of the unfurnished building of the First Methodist Church."[9] From its humble beginning, it was to grow in size to a major educational institution in the 1930's with an enrollment of over 4,000 students, (Table 6). However, the Great Depression and its twin catastrophe, the Dust Bowl, created an exodus like the one Steinbeck pictured in The Grapes of Wrath, an exodus which affected not only Oklahoma in general but Central State Normal College in particular. A further decline in enrollment was brought about by World War II. The G. I.'s in uniform bolstered the college enrollment both at Central State College and elsewhere in the nation, but the need for troop replacements to support the Normandy Invasion of June 1944 brought a drop in Central State's enrollment in September, 1944, to a level below that of 1900.

The enrollment figures after the war vacilated between one and two thousand until the completion of the Turner Turnpike and the Northwest Express Highway, both of which made access to Edmond easier. Central State College, which is now the third largest college in the state, has experienced an annual growth rate from 1951-52 to 1965-66 slightly over 18 per cent per year, and had an enrollment in 1965 of 8,038.

---

[9] General Catalog (Edmond, Oklahoma: Central State College, 1963-1966), p. 18.

TABLE 6

ENROLLMENT, CENTRAL STATE COLLEGE, EDMOND, OKLAHOMA, SELECTED YEARS, 1900 to 1965[a]

Year	Fall Semester Enrollment	Year	Fall Semester Enrollment
1900	319	1951	779
1910	1,685	1952	939
1920	2,054	1953	1,019
1930	4,075	1954	1,390
1940	1,439	1955	1,885
1941	1,654	1956	2,222
1942	1,903	1957	2,602
1943	1,416	1958	3,112
1944	308	1959	3,028
1945	386	1960	3,375
1946	817	1961	4,490
1947	1,051	1962	5,146
1948	946	1963	5,913
1949	1,090	1964	6,961
1950	1,945	1965	8,038

Source: [a]Data supplied by the Office of Administrations and Records, Central State College, Edmond, Oklahoma.

Income and Expenditures at Central State College

Central State College, the single most important income-generating activity in Edmond, was responsible for much of the local growth. The school's rapid growth in enrollment was matched by an equally rapid growth in the expenditures made by the school to meet yearly current needs and to construct buildings to accommodate the growing student population. The allocation of $4,520,000 in 1965-66 for new construction nearly equals the total construction expenditure of the school for the previous 24 years. The Total Current Expense, much of which was expanded in Edmond, has risen from $220,219 in 1941-42 to $4,916,540 in 1965-66, or slightly more than a twenty-twofold increase in expenditures, while the Instructional Expenditures, which represent the teacher salaries and ancillary costs, have risen from $135,177 in 1941-42 to $2,165,868 in 1965-66, or slightly more than sixteenfold increase in instructional expense, as shown in Table 7.

Retail Trade

The data compiled in the report of the Census of Business, Retail Trade, (Table 8), for Edmond, Oklahoma, shows that while the number of business establishments engaged in retail trade have not grown appreciably since 1948, the receipts have increased at a rate of 7.8 per cent per year from the $5.4 million in 1948 to slightly over $17 million in 1963. Payroll, when figured as a percentage of Receipts, has fallen from a 1948 high of 9.6 per cent to the 1963 level of 8.5 per cent, while in the year of 1954, the Payroll of Receipts fell to

TABLE 7

ANNUAL INCOME AND SELECTED EXPENDITURES FOR
CENTRAL STATE COLLEGE, EDMOND, OKLAHOMA, 1941-1965

Year	Total Current Income	Instructional Expenditures	Total Current Expense	New Construction (Date of Issue)
1965-66	$5,445,596	$ 2,165,868	$4,916,540	$4,520,000
64-65	4,098,512	1,695,833	4,053,136	985,000
63-64	3,819,397	1,637,593	3,706,353	1,925,000
62-63	3,219,822	1,292,431	3,145,640	. . . . .
61-62	3,027,801	1,077,461	2,676,976	1,600,000
1960-61	2,258,887	905,314	2,251,198	280,000
59-60	2,101,847	842,273	1,967,816	. . . . .
58-59	1,709,693	662,044	1,641,237	. . . . .
57-58	1,415,415	547,536	1,395,944	175,000
56-57	1,211,479	458,441	1,128,560	. . . . .
1955-56	1,100,494	404,296	991,872	250,000
54-55	919,815	346,054	829,120	. . . . .
53-54	834,892	337,472	795,931	. . . . .
52-53	716,320	261,408	690,217	. . . . .
51-52	858,443	230,129	724,108	. . . . .
1950-51	696,145	229,628	644,687	275,000
49-50	722,788	233,336	622,765	. . . . .
48-49	633,373	207,359	592,944	. . . . .
47-48	564,924	198,473	545,079	. . . . .
46-47	479,489	157,159	477,280	. . . . .
1945-46	277,423	155,954	286,437	. . . . .
44-45	[a]	[a]	[a]	. . . . .
43-44	374,622	163,873	305,693	. . . . .
42-43	[b]	[b]	[b]	. . . . .
41-42	217,968	135,117	220,219	. . . . .

Source: First through the Thirteenth Biennial Report of the Oklahoma State Regents for Higher Education.

[a]The state appropriations for 1943-44 and 1944-45 are the same, but the data on Total Current Income, Instructional Expenditures, and Total Current Expense were not given in the Second Biennial Report of the Oklahoma State Regents for Higher Education.

[b]The state appropriations for 1941-42 and 1942-43 are the same, but the data on the Total Current Income, Instructional Expenditures, and Total Current Expense were not given in the First Biennial Report of The Oklahoma State Regents for Higher Education.

TABLE 8

RETAIL TRADE - AREA STATISTICS, EDMOND, OKLAHOMA,
YEARS, 1948, 1954, 1958, 1963

Year	No. of Establishments	Receipts ($1,000)	Payroll Year ($1,000)	Paid Employees, Work-week ended nearest November 15. Total (Number)	Full Workweek (Number)	Active Proprietors of Unincorporated Businesses (Number)
1948	83	$ 5,404	$ 517	337	264	89
1954	92	9,498	733	326	283	97
1958	82	10,307	906	380	330	96
1963	86	17,029	1,444	494	...	84

Source: U.S., Bureau of The Census, 1963 Census of Business, Vol. II, Retail Trade-Area Statistics, Part 3. Counties; Cities of 2,500 Inhabitants or More: 1963, Table 3, p. 38-12; data for 1958 from 1958 Ibid., Table 102, p. 36-12; data for 1954 from 1954 Ibid., Table 102, p. 36-10; and, data for 1948 from 1948 Ibid., Table 102, p. 36-10.

the low level of 7.7 per cent. The data for average salary, as determined by the Payroll divided by the Paid Employees, Workweek ended nearest November 15, has risen from $1,534 in 1948 to $2,923 in 1963. While this figure was not indicative of the average salary of full time employees, it does indicate that an appreciable increase in average salary has been achieved. However, in the same time interval, the increase in average sales per employee as determined by the Receipts divided by Paid Employees, Workweek ended nearest November 15, has risen from $16,035 in 1948 to $34,454 in 1963.

The data on sales per employee may reflect several things: the inflation, a change in merchandising technique from one of personal service to self-service, an increase in the number of full time employees in relation to total number of employees hired in the week of November 15, and/or a shift from the smaller store to the larger store -- with some of the businesses being owned and operated by firms whose home offices are not located in Edmond.

<u>Selected Services</u>

In the data gathered by the Census of Business Selected Services, (Table 9), it was shown that the number of business establishments and employees from 1948 to 1963 almost double, while the receipts increased almost fourfold. The growth in Receipts average 9.5 per cent per year for the fifteen year period, while the rate of growth in Payroll for the same period was nearly 9 per cent. Payroll as a per cent of Receipts vacilated widely from 31.3 per cent in 1948 to 22.4 per cent in

TABLE 9

SELECTED SERVICES - AREA STATISTICS, EDMOND, OKLAHOMA, YEARS, 1948, 1954, 1958, 1963

Year	No. of Establishments	Receipts ($1,000)	Payroll Year ($1,000)	Paid Employees, Work-week ended nearest November 15. Total (Number)	Paid Employees, Work-week ended nearest November 15. Full Workweek (Number)	Active Proprietors of Unincorporated Businesses (Number)
1948	39	$ 316[a]	$ 99	75[a]	67[a]	41[a]
1954	43	664	149	82	76	45
1958	70	981	250	144	136	72
1963	67	1,227	360	139	...	70

Source: U.S., Bureau of The Census, 1963 Census of Business, Vol. VII, Selected Service-Area Statistics, Part 3, Counties; Cities of 2,500 Inhabitants or More: 1963, Table 3, p. 38-10; data for 1958 from 1958 Ibid., Vol. VI, Table 102, p. 36-10; data for 1954 from 1954 Ibid., Vol. VI, Table 102, p. 36-9; and, data for 1948 from 1948 Ibid., Vol. VI, Table 102, p. 36-9.

[a]4 Amusement Receipts and Payroll not disclosed.
1 Hotel, motel Receipts and Payroll not disclosed.

1954 to 25.5 per cent in 1958, and then almost back to the original level with 29.3 per cent in 1963. The average salary, as determined by the Payroll divided by the Paid Employees, Workweek ended nearest November 15, has risen from $1,320 in 1948 to $2,590 in 1963. While this figure was not indicative of the average salary of full time employees, it does indicate that an appreciable increase in average salary has been achieved. Meanwhile, the increase in average receipts per employee as determined by the Receipts divided by Paid Employees, Workweek ended nearest November 15, has risen from $4,213 in 1948 to $8,827 in 1963. Much of the increase in receipts per employee must be attributed to the increase in prices of services rather than any real increase in productivity. However, it is possible that some of the increase may have resulted from the increase in efficiency made possible when an increase in demand reduces the idle moments that an employee must spend in waiting for the next customer.

When Retail Sales and Selected Services data were combined, they indicated that the rate of growth per year from 1948 to 1963 for Receipts was 8.4 per cent, Payroll was 7.4 per cent, Employees was 2.9 per cent, and Receipts per establishment was 6.9 per cent. The Receipts per establishment growth rate means an increase in sales from $43,333 in 1948 to $119,320 in 1963.

<u>Assessed Valuation of Edmond and Oklahoma County</u>

The assessed value of personal property, public services, and real estate for Oklahoma County, (Table 10), and Edmond, Oklahoma, (Table 11),

TABLE 10

ASSESSED VALUATION FOR OKLAHOMA COUNTY, ANNUALLY, 1938 - 1965

Year	Personal	Public Services	Real Estate	Total Value	Net[a] Value
1965	$105,127,585	$91,881,112	$480,655,390	$677,664,087	$575,933,402
1964	99,743,660	87,196,316	450,732,055	637,672,031	538,737,996
1963	92,671,315	77,159,721	421,024,435	590,855,471	495,703,451
1962	87,051,735	73,265,028	394,668,140	554,984,903	463,531,888
1961	81,731,470	70,296,576	371,897,800	523,925,846	435,084,821
1960	76,062,195	68,165,362	347,127,685	491,355,242	405,446,962
1959	72,237,920	65,094,517	332,112,790	469,445,227	386,794,282
1958	64,960,420	57,882,636	318,792,565	441,635,621	360,514,996
1957	63,366,500	56,055,945	308,025,320	427,447,765	349,320,675
1956	62,264,655	53,152,344	290,498,475	405,915,474	330,236,464
1955	59,654,960	51,294,794	270,083,835	381,033,589	309,568,014
1954	57,717,310	49,871,821	249,885,675	357,474,806	290,244,046
1953	55,926,630	46,588,480	236,737,320	339,252,430	274,968,620
1952	55,135,230	44,863,177	223,635,005	323,633,406	262,550,826
1951	49,223,515	42,945,587	210,828,270	302,997,372	245,595,507

(Continued)

TABLE 10 -- Continued

Year	Personal	Public Services	Real Estate	Total Value	Net[a] Value
1950	$ 46,115,375	$ 40,183,447	$182,178,530	$268,477,352	$220,029,362
1949	42,819,535	38,746,382	163,790,905	245,356,822	202,704,287
1948	38,836,535	36,393,121	156,463,245	231,692,901	189,170,851
1947	33,771,345	33,719,007	148,877,475	216,367,827	178,538,047
1946	26,965,350	31,787,263	125,889,570	184,642,183	155,283,953
1945	24,769,515	31,064,412	121,974,810	177,808,737	151,379,432
1944	23,009,830	30,253,406	108,821,110	162,066,346	138,229,941
1943	22,054,915	30,123,462	107,365,735	159,544,112	137,492,497
1942	N.A.	N.A.	N.A.	N.A.	N.A.
1941	18,975,490	28,089,542	107,494,630	154,559,662	134,236,552
1940	19,703,004	27,293,079	104,663,410	151,659,493	133,217,738
1939	23,424,500	27,151,263	102,604,975	153,180,738	135,919,638
1938	24,032,185	26,956,721	100,880,377	151,869,283	136,367,019

Source: Oklahoma County Tax Assessor's Office.

N.A.: Not Available

[a]Total value minus tax exempt property.

TABLE 11

ASSESSED VALUATION FOR EDMOND, OKLAHOMA, OKLAHOMA COUNTY, ANNUALLY, 1938 - 1965

Year	Personal	Public Services	Real Estate	Total Value	Net[a] Value
1965	$1,456,685	$1,122,313	$9,054,650	$11,633,648	$9,174,538
1964	1,223,680	930,734	7,769,425	9,923,839	7,664,859
1963	926,885	897,887	6,489,995	8,314,767	6,356,862
1962	851,250	659,248	5,828,165	7,338,683	5,500,098
1961	766,905	545,781	5,258,225	6,570,911	4,875,046
1960	696,555	482,434	4,423,760	5,602,749	4,079,849
1959	611,590	329,492	4,048,970	4,990,052	3,565,917
1958	523,895	335,397	3,773,880	4,633,172	3,251,832
1957	511,905	314,233	3,625,515	4,451,653	3,111,443
1956	520,450	284,015	3,243,260	4,047,725	2,855,175
1955	502,415	259,874	2,998,545	3,760,834	2,635,074
1954	492,885	248,083	2,769,405	3,510,373	2,406,108
1953	425,280	247,692	2,727,790	3,400,762	2,314,412
1952	427,585	247,473	2,604,005	3,279,063	2,190,178
1951	410,175	237,754	2,538,755	3,186,684	2,112,884

(Continued)

TABLE 11 -- Continued

Year	Personal	Public Service	Real Estate	Total Value	Net[a] Value
1950	$ 312,305	$ 234,892	$1,961,925	$2,509,122	$1,575,032
1949	300,975	211,119	1,890,995	2,403,089	1,533,374
1948	287,380	192,184	1,813,115	2,292,679	1,446,194
1947	282,600	187,112	1,735,940	2,205,652	1,433,647
1946	223,500	188,004	1,449,415	1,860,919	1,220,304
1945	229,935	183,863	1,425,470	1,839,268	1,248,903
1944	174,840	180,803	1,223,310	1,578,953	1,060,503
1943	163,620	176,334	1,221,725	1,561,679	1,081,039
1942	N.A.	N.A.	N.A.	N.A.	N.A.
1941	114,725	164,581	1,207,720	1,487,026	1,039,806
1940	122,235	161,014	1,195,085	1,478,334	1,052,269
1939	135,280	157,838	1,168,635	1,461,753	1,066,758
1938	119,325	168,349	1,153,176	1,440,850	1,054,530

Source: Oklahoma County Tax Assessor's Office.

N.A.: Not Available

[a]Total value minus tax exempt property.

are totaled for each year from 1941 through 1965, with a net value derived when tax-exempt property is removed. The data shows that the net value of all property has grown each year for Oklahoma County from $134,236,552 in 1941 to $575,933,402 in 1965, which represents a 6 per cent average yearly rate of growth for the 25-year period. For Edmond, the growth of the net value of all property increased from $1,039,806 in 1941 to $9,174,538 in 1965, which represents, over the 25-year period, a growth rate for each year of slightly over 9 per cent.

Number of Lots

By 1941 there were 6,064 lots in Edmond, as indicated by Table 12, and in the twenty years only 872 lots were added -- an average of slightly more than 40 lots per year. The real growth pattern started in 1958 and has continued unabaited to the present. From 1960 through 1965, 1,397 lots were added to give a total of 8,333 lots currently found on the tax assessor's books -- and an additional 253 lots still to be added. The growth pattern found in the rapid development of the real estate market of the 1960's was reflected in almost all areas measured by this study.

Rural Farm Land Within the City

The amount of unplatted rural land within the city limits of Edmond prior to 1941, (Table 13), was approximately three sections of land -- or about 1,920 acres. By 1941 about 68 per cent of these three sections or 1,215 acres were platted into lots. From 1941 through

TABLE 12

NUMBER OF PLATTED LOTS IN EDMOND, OKLAHOMA, ANNUALLY, 1941 - 1965

Year	New Lots Platted	Total Number of Lots in Tax Assessment Books
1965	568[a]	8,333
1964	263[b]	7,962
1963	378[c]	7,752
1962	263	7,377
1961	27	7,114
1960	151	7,087
1959	113	6,936
1958	259	6,823
1957	18	6,564
1956	...	6,546
1955	100	6,546
1954	...	6,446
1953	6	6,446
1952	70	6,440
1951	...	6,370
1950	27	6,370
1949	...	6,343
1948	...	6,343
1947	185	6,343
1946	48	6,158
1945	46	6,110
1944	...	6,064
1943	...	6,064
1942	...	6,064
1941	19	6,064

Source: Compiled from data.

[a]197 Lots not on 1965 Tax Assessment records.

[b]53 Lots not on 1965 Tax Assessment records.

[c]3 Lots not on 1965 Tax Assessment records.

TABLE 13

NUMBER OF ACRES IN RURAL FARM LAND WITHIN CITY LIMITS OF EDMOND, OKLAHOMA, ANNUALLY, 1941 - 1965

Year	Acreage Added	Total Acreage	Total Acres[a] Platted	Total Unplatted Acres
1965	. . . .	39,259	1,667	37,592
1964	1,260	39,259	1,592	37,667
1963	8,354	37,999	1,550	36,449
1962	21,006	29,645	1,475	27,170
1961	. . . .	8,639	1,423	7,216
1960	. . . .	8,639	1,417	7,222
1959	6,466	8,639	1,387	7,252
1958	59	2,173	1,365	808
1957	18	2,114	1,313	801
1956	. . . .	2,096	1,309	787
1955	103	2,096	1,309	787
1954	10	1,993	1,289	694
1953	. . . .	1,983	1,289	694
1952	44	1,983	1,288	695
1951	. . . .	1,939	1,274	665
1950	15	1,939	1,274	665
1949	4	1,924	1,269	655
1948	. . . .	1,920	1,269	651
1947	. . . .	1,920	1,269	651
1946	. . . .	1,920	1,232	688
1945	. . . .	1,920	1,222	698
1944	. . . .	1,920	1,215	705
1943	. . . .	1,920	1,215	705
1942	. . . .	1,920	1,215	705
1941	83	1,920[b]	1,215	705

Source: Compiled from data.

[a]Divide the total number of lots platted each year in Table 12 by 5 lots per acre.

[b]Total acreage of 3 sections.

1959 an additional 150 acres were platted and only a few acres were added to the total area found within the town. However, Edmond motivated by a desire to protect itself from what appeared to be the land-hungry desires of its large neighbor from the south, Oklahoma City, increased the total acreage from 2,173 in 1958 to 39,259 in 1965 while increasing the platted land from 1,265 to 1,667 acres. This leaves slightly more than 37,000 acres of rural farm land within the city limits of Edmond, Oklahoma.

SUMMARY

From the early history of Edmond to the present, the dominating influence upon the town has been Central State College. The growth in population, retail trade, and services reflect the enrollment and expenditure of the college, and the college's growth was a reflection of the growth in the college-age population, the growth of Oklahoma City, and the opening of the northwest area by the building of the Turner Turnpike with its access roads connecting the turnpike with U. S. Highways 66 and 77. With this new transportation network, it was extremely easy to commute from anywhere in Oklahoma City to Central State College. All of these growth factors apparently created an immense increase in land value and unearned increment -- exactly as predicted by Henry George. In the next chapter this impact upon land values will be investigated.

CHAPTER IV

EDMOND REAL ESTATE SALES AND TAX ASSESSMENTS FOR 1965

In this chapter the value of the 1965 real estate sales in Edmond are compared with their 1965 tax assessments to establish a ratio between sales value and tax assessments. To determine this ratio, the total real estate sales of 1965 are divided into two groups: usable and unusable value indicators. Those sales with unusable value indicators that make it impossible to determine the actual value of the property are in-family sales or exchanges, property exchanges, sales without warranty deed stamps, or sales with a mortgage for which a meaningful value could not be estimated. Those sales which have usable value indicators are of three types: actual sales value, warranty deed revenue stamp value, and mortgage value. Comparisons are made between and among these values, and statistical estimates of their related values are used to determine the total value of all sales with usable value indicators. These values are compared to tax assessed values to establish a ratio that is used later in this study.

Real Estate Sales in 1965

There are several classifications of platted land sold in 1965: land only, land and improvements, builder's loans[1], land with non-taxed improvements, and land and improvement with an indeterminate value.[2]

In all there are 684 real estate sales involving 1,179 lots in Edmond, as shown in Table 14. One of the total sales, 257 sales of

TABLE 14

NUMBER OF REAL ESTATE SALES OF PLATTED LAND IN EDMOND, OKLAHOMA, 1965

Property by Type	Number of Sales	Number of Lots
Land and Improvements	257	444
Land	122	331
Builder's Loans	84	91
Non-Taxed Improvements	165	170
In-Family, No Warranty Stamp or Mortgage Value	56	143
Total	684	1,179

Source: Compiled from data collected from The County Clerk's Office, Oklahoma County, Oklahoma.

444 lots are with improvements and 122 sales of 331 lots are without improvements. There are eighty-four sales of ninety-one lots with

[1] Land with a mortgage on a building to be taxed but which is not on the tax rolls in 1965.

[2] Some property had neither a warranty deed stamp nor mortgage and the exchange of other property was made within a family or had a value of only "ten dollars or more" noted on the deed.

builder loans in which the deeds provide the information on the selling price of the unimproved land, but the mortgage value placed upon both the land and improvements to be built by the contractor and paid for in one year are not reflected on the tax rolls.[3] On 165 sales of 170 lots there are improvements that have been made and sold by the contractors, but the value of the improvements is not on the 1965 rolls.[4] Finally, on fifty-six sales of 143 lots, the sales are such that it is impossible to determine the value of the property. These sales include in-family sales or exchanges, sales without warranty deed stamps, or sales with a mortgage for which a value could not be estimated.

Of the 684 real estate sales, there is a total of 463 sales of 866 lots (73 per cent of all lots sold in 1965) in which sufficient information is available to enable the investigator to estimate the sale value of the lots and/or improvements by converting the warranty deed revenue stamp value and mortgage value into actual value.

Types of Value Indication in 1965 Sales

In 1965, there are 463 sales of platted property in Edmond, Oklahoma, which had a warranty deed and/or mortgage that indicated a sale value. Of these sales, 245 had warranty deed stamps; 271 sales had a mortgage value; and seventeen sales had recorded the actual value of the

---

[3]The total mortgage value of the builder's loans is $1,446,866 or $17,244 average per mortgage.

[4]The total warranty deed revenue stamp value of the non-taxed improvements is $2,635,385 or $15,915 average per sale.

sale. In 215 sales both the warranty deed stamps and the mortgage value appeared, while only five sales had the actual value and the warranty deed stamps. Only one sale had both the actual value and the mortgage value on the same deed as shown in Table 15.

TABLE 15

NUMBER OF SALES OF PLATTED REAL ESTATE BY TYPE OF VALUE INDICATOR, EDMOND, OKLAHOMA, 1965

Type of Value Indicator	No. of Sales	No. of Warranty Deed and	No. of Mortgage and	No. of Actual Value and
Warranty Deed Stamps	245	...	215	5
Mortgage	271	215	...	1
Actual Value	17	5	1	...
	463			

Source: Compiled from data collected from The County Clerk's Office, Oklahoma County, Oklahoma.

The actual value of each sale can be determined separately or in various combinations: by the actual amount of the transaction, by the Internal Revenue Stamps on the warranty deed, and/or by the indication of a mortgage or a mortgage value that had been placed upon the property at the time of the sale. This data, which appears on the warranty deed or the mortgage instrument noted on the warranty deed, is used to determine the actual value of all sales in 1965.

<u>Actual Value and Warranty Deed Revenue Stamp Value</u>

The Federal Revenue Act of 1932 requires that all deeds under which "lands, tenaments or other realty sold shall be granted, assigned, transferred or otherwise conveyed to, or vest in, the purchases or purchasers, or any other person or persons," be taxed at $.55 when the value exceeds $100 and does not exceed $500, plus $.55 for "each additional $500 or fractional part thereof." These revenue stamps, which are affixed to warranty deeds, can be used for a fairly reliable estimate of property value.[5] The Internal Revenue Stamp values found on all deeds which are guaranteed to be correct, i.e., warranty deeds, are used to determine the value of those sales.

In tracing all transactions from 1941 through 1965, of the 400 lots in the random sample, seventy-eight deeds were found with both the Internal Revenue Stamps and the actual value recorded on the deed. While the property value determined by the last $.55 unit of the revenue stamps may vary from $1 to $500, all previous $.55 units are accorded, as determined by law, the value of $500 for each unit. In Table 16, an array appears which indicates the incremental property value of the last $.55 unit of the Internal Revenue Stamps of the seventy-eight warranty deeds.

In Table 17, the data indicates that the property value, as determined by the marginal increment of the Internal Revenue Stamp, is skewed to the left. The sample of seventy-eight deeds has a mode of

---

[5]Cf. Norman Nyfroten, "Estimating Cost Consideration in Real Estate Transfers from Internal Revenue Stamps," Journal of Farm Economics, Vol. 30 (August, 1948), pp. 558-61; and Robert L. Tontz, Jeppe Kristensen, and C. Curtis Cobb, Jr., "Reliability of Deed Samples as an Indication of Land Market Activity," Land Economics, Vol. 30 (February, 1954), pp. 47-48.

TABLE 16

ARRAY IN ASCENDING ORDER OF THE MARGINAL PROPERTY VALUE BASED UPON THE MARGINAL $.55 UNIT OF THE INTERNAL REVENUE STAMP OF 78 WARRANTY DEEDS EDMOND, OKLAHOMA, 1965

The Property Value Determined by the Last $.55 Unit of Revenue Stamp on the Warranty Deed							
No.	Value	No.	Value	No.	Value	No.	Value
1	$ 50	21	$250	41	$440	61	$500
2	50	22	250	42	470	62	500
3	100	23	250	43	500	63	500
4	100	24	300	44	500	64	500
5	100	25	300	45	500	65	500
6	100	26	300	46	500	66	500
7	100	27	300	47	500	67	500
8	125	28	300	48	500	68	500
9	150	29	300	49	500	69	500
10	150	30	300	50	500	70	500
11	150	31	300	51	500	71	500
12	150	32	300	52	500	72	500
13	169	33	350	53	500	73	500
14	200	34	400	54	500	74	500
15	200	35	400	55	500	75	500
16	200	36	400	56	500	76	500
17	210	37	400	57	500	77	500
18	250	38	400	58	500	78	500
19	250	39	440	59	500		
20	250	40	440	60	500		

Source: Compiled from data.

TABLE 17

PROPERTY VALUE INCREMENT AS DETERMINED BY THE MARGINAL INCREMENT OF THE INTERNAL REVENUE STAMP, EDMOND, OKLAHOMA, 1941 - 1965

Class	Mid-Point m	Frequency f	d	fd	fd^2
25- 74	\$ 50	2	-7	-14	98
75-124	100	5	-6	-30	180
125-174	150	6	-5	-30	150
175-224	200	4	-4	-16	64
225-274	250	6	-3	-18	54
275-324	300	9	-2	-18	36
325-374	350	1	-1	- 1	1
375-424	400	5	0	...	...
425-474	450	4	1	4	4
475-524	500	36	2	72	144
		N =78		$\Sigma fd = -49$	$\Sigma fd^2 = 731$

Source: Compiled from data collected from the County Clerk's Office, Oklahoma County, Oklahoma.

Mean = \$369

Standard Deviation = \$150

Median = \$438

Standard Error of the Mean = \$17.0

Mode = \$496

$496, a median of $438, and a mean of $369 with a standard deviation of $150, and a standard error of the mean of $17.

The mean of $369 will be used as the property value of the last $.55 stamp increment. The previous $.55 units, which have a property value of $500 each, are added together to give the total property value of a deed. Examples of this total value are shown in Table 18.

The use of the sample mean of $369 may understate the true mean of the last $.55 stamp increment -- as indicated by the position of the median and mode to the right of the mean. However, since the purpose of this investigation is to examine the contention that a "single tax" on land value could support a local government, the use of data which appears to be the most adverse to the conclusion will serve to strengthen the findings of the investigation.

Warranty Deed Value and Mortgage Value

Of the 684 sales in 1965 that involved 1,179 lots in Edmond, Oklahoma, 215 sales had both the warranty deed Internal Revenue Stamps and a mortgage value. By comparing the mean of the mortgage values, which is usually lower than actual value, it is possible to establish a ratio between the two values. This data can then be used to give a meaningful estimate of the actual value of land and/or improvements when only the mortgage value is available.

In Table 19, the mean of the warranty deed values is shown to be $14,284, with a median of $14,750 and a mode of $14,250, while the

TABLE 18

SELECTED PROPERTY VALUES AS DETERMINED BY INTERNAL REVENUE STAMPS ON WARRANTY DEEDS
EDMOND, OKLAHOMA, 1941 - 1965

Total Value of Internal Revenue Stamps Appearing on Warranty Deed	Marginal $.55 Increment of Internal Revenue Stamp	Value of Remainder of Internal Revenue Stamp (Col.1-Col.2)	Marginal Increment Value of Property	Value of Remainder of Property Value (Col.4-Col.5)	Total Value of Property
$ .55	$ .55	. . .	$369	. . .	$ 369
1.10	.55	$ .55	369	$ 500	869
1.65	.55	1.10	369	1,000	1,369
2.20	.55	1.65	369	1,500	1,869
2.75	.55	2.20	369	2,000	2,369
3.30	.55	2.75	369	2,500	2,869
3.85	.55	3.30	369	3,000	3,369
4.40	.55	3.85	369	3,500	3,869
4.95	.55	4.40	369	4,000	4,369
5.50	.55	4.95	369	4,500	4,869
.	.	.	.	.	.
.	.	.	.	.	.
.	.	.	.	.	.

Source: Table 17 and data collected from the County Clerk's Office, Oklahoma County, Oklahoma.

TABLE 19

WARRANTY DEED VALUES OF ALL 1965 SALES POSSESSING BOTH WARRANTY DEED AND MORTGAGE STAMPS

Class (000)	Mid Point m(000)	Frequency f	fm(000)	$m-\bar{x}$	$(m-\bar{x})^2$	$f(m-\bar{x})^2$
0 - 5	$ 3	10	30	-11,284	127,328,656	1,273,286,560
6 - 11	9	64	576	- 5,284	27,920,656	1,786,921,984
12 - 17	15	96	1,440	716	512,656	49,214,976
18 - 23	21	40	840	6,716	45,104,656	1,804,186,240
24 - 29	27	3	84	12,716	161,696,656	485,089,968
30 - 35	33	1	33	18,716	350,288,656	350,288,656
36 - 89	68	1	68	53,716	2,885,408,656	2,885,408,656
		N = 215	Σfm = 3,071			$\Sigma f(m-\bar{x})^2$ = 8,634,397,040

Source: Compiled from data collected from the County Clerk's Office, Oklahoma County, Oklahoma.

Mean = $14,284

Standard Deviation = $6,337

Median = $14,750

Mode = $14,250

mortgage values in Table 20 show a mean of $13,242, a median of $13,750, and a mode of $13,333. Each mean value has a standard deviation of slightly over $6,000. The Spearman test of rank correlations yields a value of .828 as the coefficient of correlation. This reveals a high degree of correlation between the warranty deed stamp value and mortgage value.

By dividing the mean of warranty deed value ($14,284) into the mean of the mortgage value ($13,242), we find that the mortgage value is 92.7 per cent of the warranty deed value -- or approximately 92.7 per cent of the actual sale value.

While the use of this method of determining actual value from mortgage value gives a fairly accurate estimate of value, one must be careful when inspecting the deeds to determine whether the Internal Revenue Stamps represent the total value of the property or merely the value of the equity. This may, however, be checked by not only looking at the present deeds and previous deeds of this property closely, but by checking the tax assessment which can be used as a guideline. This is especially true if one's estimate of value appears to be significantly lower than the tax assessed value.

<u>The Value of Real Estate Sales in 1965</u>

The value of the Real Estate Sales in Edmond in 1965 was determined by three value indicators: the Internal Revenue Stamps value, the mortgage value, and the actual value of the property. If the value indicator on the warranty deed was the Internal Revenue Stamp, then the

TABLE 20

MORTGAGE VALUES OF ALL 1965 SALES POSSESSING BOTH
MORTGAGE AND WARRANTY DEED STAMPS

Class (000)	Mid Point m(000)	f	fm	$m-\bar{x}$	$(m-\bar{x})^2$	$f(m-\bar{x})^2$
0 - 5	$ 3	9	27,000	-10,242	104,898,564	944,087,076
6 - 11	9	80	720,000	- 4,242	17,994,564	1,439,565,120
12 - 17	15	104	1,560,000	1,758	3,090,564	321,418,656
18 - 23	21	20	420,000	7,758	60,186,564	1,203,731,280
24 - 95	60	2	120,000	46,758	2,180,310,564	4,372,621,128
		N = 215	Σfm = 2,847,000			$\Sigma f(m-\bar{x})^2$ = 8,281,423,260

Source: Compiled from data collected from the County Clerk's Office, Oklahoma County, Oklahoma.

Mean = $13,242

Standard Deviation = $6,207

Mode = $13,333

Median = $13,750

value would be determined by each \$.55 Internal Revenue Stamp, as shown in Table 18. When only one \$.55 stamp was placed upon the instrument, the value of the property was determined to be \$396. Any additional \$.55 stamp increments indicated an increase of \$500 in value for each \$.55 increase in stamp value. When the value indicator used was the mortgage, then the value of the mortgage would be divided by 92.7 per cent[6] and multiplied by 100 in order to determine the actual value of the property. Finally, the actual sale value, whenever known, was used as the value of the property at the time of the sale. By using all three value indicators, it was possible to check and cross-check the values given to various real estate sales which include land and improvements. However, if one is to investigage the "single tax" thesis, then the value of land must be separated from the value of improvements.

The Value of Land Sold in 1965

The 463 sales in Edmond in 1965 were placed into three classifications: Land Only, Builder's Loans and Land Improvements, and the value of the land as extracted from the total value of the sales.

"Land Only" is a sale classification in which land without taxed improvements has changed hands and in which the value of the land is determined by the sale.

"Builder's Loans" are those land sales in which the recorded deed indicates the sale of land only. Also, appearing on the warranty deed

---

[6]See Table 10 and Table 11.

is a notation of a mortgage or mortgage value which had been placed on the land, as well as the improvements that have been made within the last six months and are to be paid in one year. These improvements are not assessed or taxed for the year 1965.

"Land and Improvements" are those sales of real estate for which both land and improvements changed hands with each sale and for which the land and improvements are assessed separately and together. To determine the value of land alone, however, the ratio of assessed land value to total assessed value is used in this investigation in order to separate the land value from the total sale value of land and improvements.[7]

By adding the value of land for each sale in each of the three classifications of Land Only, Builder's Loan, and Land and Improvements, the total value of land in the 463 sales can be determined, as shown in Table 21. And the tax assessed on land value only of the 463 parcels

TABLE 21

ACTUAL VALUE OF LAND SOLD IN EDMOND, OKLAHOMA, 1965

Number of Lots Sold	866
Total Value	$1,615,150
Average Value Per Lot	$1,865

Source: Compiled from data collected from The County Clerk's Office, Oklahoma County, Oklahoma.

---

[7]Taxed assessed value of land ÷ taxed assessed value of Land Improvement X Sales Price = Value of Land.

of land can be determined as indicated in Table 22. With a comparison of the tax assessed value of land sold in 1965, a ratio between tax

TABLE 22

TAX ASSESSED VALUE OF LAND SOLD IN EDMOND, OKLAHOMA, 1965

Number of Lots Sold	866
Total Tax Assessed Value of Land Only	$136,738
Average Tax Assessment Per Lot	$158

Source: Compiled from data collected from The County Clerk's Office, Oklahoma County, Oklahoma.

assessed values and actual values can be established. The ratio between land value and tax assessed values in 1965 was $1,615, 150 to $136,738 -- or $11.81 to $1. This ratio will be used in Chapter V to establish the value of land from tax assessments in the sample survey.

SUMMARY

From the 1965 sales of land, land and improvement and builders' loans, it is possible to construct a series of values from warranty deeds possessing actual sale value or from the Internal Revenue Stamps that possessed a known value for each $.55 stamp unit. From the sample, a mean value for the last $.55 unit of the Internal Revenue Stamp found on the warranty deed was $369. This value may be somewhat lower than actual value, but, it gives an adequate approximation of the value for inclusion in this study for indicating warranty deed stamp values. A comparison with warranty deed values and mortgage values revealed that the mortgages granted in Edmond were 92.7 per cent of the actual value of the real estate. After separating the land value from the total value for land and improvements, the tax assessment was compared to the actual value to establish a ratio of actual value to tax assessment of $11.81 to $1, or the real estate in Edmond is taxed at slightly over 8 per cent of actual value rather than at the stated rate of 25 per cent.

CHAPTER V

"SINGLE TAX" APPLICATION TO EDMOND, OKLAHOMA

Introduction

To support the single tax thesis of Henry George, data will be presented to determine the changes in land value in Edmond, Oklahoma, from 1941 through 1965 and to measure the extent of the land rent and the unearned increment available to cover the total expenditures for both the city and the school district of Edmond.

The determination of the actual value of land is somewhat complicated and circuitous. The current 1965 data available on real estate sales and tax assessments, as well as the manner in which this data are kept, requires statistical manipulation in order to reach a somewhat satisfactory estimate of actual land value. Tax assessments in Oklahoma County are apparently both arbitrary and out of date. Although assessments are supposed to be made at 25 per cent of actual value, it is apparent from the sales and mortgage data of 1965 that there is extensive underassessment. If the city of Edmond is indicative of the tax assessment level in the rest of Oklahoma County and the state, much of the commercial property, older homes, and vacant lots are underassessed, while the newer homes in the newer additions appear to be carrying a higher tax value or a tax assessment more nearly in line with the required rate.

The ratio of land value to tax assessment for platted property ($11.81 to $1) which was established in the previous chapter will be applied to the statistical characteristics gained from a sample of all the available lots in Edmond and then used to establish an average lot value which will be cited as a basis for the determination of the total value for the years 1941 through 1965.

The total value for rural unplatted land within the city limits will be measured by taking the estimates of the Bureau of Agriculture on the per acre value of land in Oklahoma County and then multiplying that figure by the number of acres within the city limits. From the data gained on the total value of lots and rural land, estimates will be made of the aggregate land rent and unearned increment. These amounts will be compared with the total city and school district expenditures to determine the feasibility of a "single tax" on land rent and unearned increment in order to support the local fiscal and educational requirements of Edmond, Oklahoma.

<u>The Sampling Method</u>

All lots platted in the city of Edmond since 1890 were given consecutive numbers. There were 9,091 lots in 1965, as indicated in Table 23. Of these lots, 1,288 were unusable and were excluded. Of those excluded, 281 were lots which had been removed from the list by replatting or had been vacated to rural land; 253 were lots which had been recently platted but were not on the 1965 tax rolls (see Table 12); 184 were lots which had been exempt state, local, or Independent School

TABLE 23

LOTS LISTED IN THE OKLAHOMA COUNTY INDEX BOOKS, EDMOND, OKLAHOMA, 1965

Total Number of Lots in Edmond Listed in Oklahoma County Index Books 1965		9,091
Lots Excluded:		
No. of Lots that have been removed from the list or vacated to rural land	281	
No. of Lots that are not listed in the 1965 assessment book	253	
Lots exempt for State, Local and Independent School	184[a]	
Lots exempt for Church	40[a]	
Commercial Lots	530	
Total Number of Lots available for Sample		7,803

Source: Compiled from data collected from The County Clerk's Office, Oklahoma County, Oklahoma.

[a]Information gained from the sample data.

land; and forty were lots which had been exempt church property. An additional 530 commercial lots were removed from the list in order to reduce the bimodel characteristic of the universe which would be reflected in any sample except an extremely large one. The sample in this research reflects only the value of residential lots. This value was somewhat lower than the actual average lot value, because the value of the commercial property, which in several cases reaches as high as $12,000 to $15,000 per lot, has been removed. The commercial lots were removed from the sample in order to reduce the natural bimodel distribution obtained when commercial and residential values are compared. Although a reduction in average lot value means a reduction in land rent and unearned increment, it will make little difference in the final results -- as will be shown later in this study. Nevertheless, the natural skewness of residential land value data required an extremely large sample in order to secure results that approximate a normal curve.

From the remaining 7,803 lots, a random sample of 400 lots was taken by using a table of random numbers to make the selection.[1] The sample represents 5.1 per cent of the universe. In the random selection of the 400 lots, a combination of over 1,600 lots, or 20 per cent of the universe, were found to be a part of the original selection. When the early lot dimensions of 25 X 140 feet proved to be too small to handle

---

[1]William Addison Neiswanger, Elementary Statistical Methods (New York: The Macmillan Company, 1956), Column 6, Line 1171 through Column 7, Line 1208; p. 730-1.

most improvements, it became customary to combine two or more lots into one unit. The total tax assessed value ascribed to all lots was evenly divided among the several lots when lots were found in combination. The values of the sample lots were taken as the average value of the lots in combination. Although tax assessors have a tendency to place a higher value on a corner lot or show a readiness to place a different and higher value on the lot upon which the building was found, no attempts were made to estimate the differential value for any single lot which was found in combination with other lots. In this study it was assumed that all land with improvements found in combination was of equal value -- or that all lots assumed evenly all increases in value.

Size of Lot

When Edmond was platted after the "run", the minimum size of all lots (25' X 100') was determined by law. While few of the early lots deviated from this established norm, it soon became obvious that a lot of this size was insufficient for most building needs. The practice of platting subdivision lots with these established dimensions was to continue until the 1950's, when larger lots were platted. The size of lots had gradually grown from a twelfth of an acre (25' X 140') in the Original Townsite to a quarter of an acre (80' X 140') or more per lot in many of the newer subdivisions. With the current vogue of larger homes and the platting of irregular lots in subdivisions, it appears that the average size of lots in Edmond will become larger as newer subdivisions are built.

The average lot size in acres in Edmond, Oklahoma, is determined in Table 24. The square feet of each lot in the sample was divided by 43,560 square feet in an acre and an average lot size was calculated thereby. The arithmetic mean ($\bar{x}$) of the sample is .17 acres with a standard deviation (s) of .235, and a standard error of the mean ($\hat{\sigma}_{\bar{x}}$) of .012. The arithmetic mean within the 95 per cent confidence limits is $.1933 > \bar{x} > .1463$.

The influence of the early lot size of 25' X 140' or .080 acres is indicated by the 266 items out of 400 which fall in the class interval of .040 to .119 acres. Approximately 6,000 lots out of the 7,803 universe are about .080 acres in size -- which indicates a rather skewed universe. The skewness of the universe is reflected in the sample when Pearson's Coefficient of Skewness is used and the following value of skewness is secured:

$$\text{Skewness} = \frac{3(\text{Arithmetic Mean - Median})}{\text{Standard Deviation}} = \frac{3(.170 - .100)}{.235} = .893$$

The extreme skewness of this sample is further pointed out by Parl in his statement:

> The Pearsonean measure of skewness varies between the theoretical limits of +3 and -3. However, a value higher than +1 or lower than -1 is rarely found in most practical applications.[2]

Under ordinary circumstances, the extreme skewness of a universe reflected in the sample data could alter the effective use of any

---

[2] Boris Parl, Basic Statistics (Garden City, New York: Doubleday and Company, Inc., 1967), p. 77.

TABLE 24

LOT SIZE IN ACRES, EDMOND, OKLAHOMA, 1965

Acres	Mid-Point (m)	Number of Lots (f)	fm	$(m-\bar{x})$	$(m-\bar{x})^2$	$f(m-\bar{x})^2$
.040 to .119	.08	266	21.28	-.09	.0081	2.1546
.120 to .199	.16	45	7.20	-.01	.0001	.0045
.200 to .279	.24	48	11.52	.07	.0049	.2352
.280 to .359	.32	21	6.72	.15	.0225	.4725
.360 to .439	.40	4	1.60	.23	.0529	.2116
.440 to .519	.48	2	.96	.31	.0961	.1922
.520 to 2.14	1.33	14	18.62	1.16	1.3456	18.8384
		N = 400	Σfm = 67.90			$\Sigma f(m-\bar{x})^2$ = 22.1090

Source: Compiled from Sample Data

$\bar{x} = .17$

$s = .235$

$\hat{\sigma}_{\bar{x}} = .012$

$\pm 1.96\, \hat{\sigma}_{\bar{x}} = \pm .0235$

95% Confidence Limits

$\bar{x} = .1698 \pm .0235$

$= .1463 < \bar{x} < .1933$

Median = .100

Mode = .084

Skewness = .893

sample data gained or require that a larger sample be taken. However, the size of a city lot is not a major criterion for determining land value, for the location and use appears to have the greater impact on value unless size deviates greatly from the norm.[3] Furthermore, the value of the lot, as a lot, and not as acreage, is the basis for the study of changes in value for the time period covered by this study.

The Average Lot Value in Edmond

In 1965 there were a total of 8,333 lots platted in Edmond. Of these lots, 530 are used for commercial purposes and are removed from the list, (Table 23). The exclusion of all commercial lots from the sample will, while reducing the skewness of the sample, also reduce the mean value per lot in Edmond.[4] Nevertheless, a random sample of

---

[3] William Alonso, Location and Land Use: Toward A General Theory of Land Rent (Cambridge, Massachusetts: Harvard University Press, 1964), pp. 4-5, 6, 8-9, 14-15, 45n.

[4] A significant portion of the business property in Edmond has a tax assessed evaluation which is much less than the average ratio assessed upon the land in the newer housing developments. The Safeway store and lot, officially described as Lots 9 to 28 inclusive, Block 8, E. B. Townsend Addition, except 15 square feet in Southwest Corner of Lot 9, Block 8; and Lots 23 to 32 inclusive, Block 23 in Original Townsite of Edmond, were mortgaged December 12, 1964, and recorded in Book 3,142, page 391. Those lots had a mortgage stamp value of $539, or a mortgage value represented by stamps of $539,000, and was on the tax rolls in 1965 at $50,695 Total Value. There is reason to believe that the half million dollar mortgage is for the land only. On December 12, 1964, an additional mortgage of $278,850 was placed upon the same property described above with no indications that it was a second mortgage. It is possible that this mortgage may represent a separate mortgage on the building. This can be found in Book 3,142, page 395 in the County Courthouse, Oklahoma City, Oklahoma.

Furthermore, the Edmond Plaza, officially described as Lot 1, Block 1; Lot 1, Block 2; and Lot 1, Block 3; Southwinds Addition, which is reported to have contributed forty per cent (40%) or more of the total sales tax collection of Edmond, is on the tax rolls along with two gasoline stations at a total value of $7,950 in 1965.

400 lots was taken from the remaining 7,803 lots to determine the mean value per lot of all residential lots in Edmond. The mean value of the universe ranged from $\$1,837 > U > \$1,527$ (Table 25), and this value was used to estimate the amount of unearned increment of the land and the land rent.

In the sample, the tax assessed value of the land ranged from $5 to $560 while the actual value, which is 11.81 times the tax assessment,[5] ranged from $59 to $6,614, (Table 25). The mean value is $1,682 with a standard deviation of $1,470 and a standard error of the mean of $73.50.

The degree of skewness of the distribution is found to be a .70, which indicates the distribution is highly skewed. Although the skewness of the sample is rather large, it is merely a reflection of the skewness found within the universe and can be subjected to statistical verification.

In inspecting the tax assessed land values in Edmond, it is obvious that a significant number of the values are on the lower end of the scale. This observation can be substantiated through the use of a formula found in Balsley, Introduction to Statistical Methods,

---

[5]Derived from Tables 21 and 22.

TABLE 25

400 HOUSE LOT SAMPLE, EDMOND, OKLAHOMA, 1965

Class	Med. Point	f	d'	fd'	$f(d')^2$
\$ 0--\$ 749	\$ 375	118	-1	-118	118
750-- 1499	1125	126	0	...	...
1500-- 2249	1875	61	1	61	61
2250-- 2999	2625	32	2	64	128
3000-- 3749	3375	22	3	66	198
3750-- 4499	4125	6	4	24	96
4500-- 5240	4875	17	5	85	425
5250-- 5999	5625	11	6	66	396
6000-- 6749	6375	7	7	49	343
		N = 400		$\Sigma fd' = 297$	$\Sigma f(d')^2 = 1,765$

Source: Compiled from Sample data

$\bar{x} = \$1,682$

$s = \$1,470$

$\hat{\sigma}_{\bar{x}} = \$73.50$

Median = \$1,238

95% Confidence Limits

$\bar{x} = \bar{x} \pm (1.96)\ \hat{\sigma}_{\bar{x}}$

$= \$1,826 > \bar{x} > \$1,538$

Using the upper limits of the 95% Confidence Limits to establish an estimate of the standard error of the mean, the following value is ascertained: $(\hat{\sigma}_{\bar{x}}) = \$78.80$.

The mean of the Universe (U) within 95% Confidence Limits

$$U = \bar{x} \pm (1.96)(\hat{\sigma}_{\bar{x}})$$
$$= \$1,682 \pm (1.96)(\$78.80)$$
$$= \$1,837 > U > \$1,527$$

for estimating the standard deviation of a universe[6] which is computed at \$51.90 as opposed to the \$73.50 which is the standard error of the mean. However, the figure for the standard deviation of the universe (σ) can be refined further under the following conditions:

"If the size of the universe is known, the standard error of the standard deviation is adjusted by multiplying by the square root of unity (1) minus the proportion the size of the sample bears to the universe."[7]

6

$$\sigma_\sigma = \frac{s}{\sqrt{2N}} = \frac{\$1,470}{\sqrt{2(400)}} = \frac{\$1,470}{28.3} = \$51.90$$

σ_σ = Standard error of the standard deviation.

s = Standard deviation of the sample.

N = Total number of frequencies in the sample.

Howard L. Balsley, Introduction to Statistical Methods (Paterson, New Jersey: Littlefield, Adams and Co., 1964), p. 126.

[7]When the data is applied to formula it yields the following:

Sample size (400) ÷ Universe (7,803) = proportion (r)
400/7,803 = .051

(Standard error of the standard deviation) ($\sqrt{1-r}$)

$$(\$51.9)(\sqrt{1-.051}) = (\$51.9)(.974) = \$50.55$$
$$\sigma_\sigma = \$50.6$$

and at 95% confidence limits:

$$\begin{aligned} \sigma &= s \pm (1.96)(\$50.6) \\ &= \$1,470 \pm (1.96)(\$50.6) \\ &= \$1,470 \pm \$99 \\ &\$1,569 > \sigma > \$1,371 \end{aligned}$$

Ibid., p. 127.

At 95 per cent confidence limits the standard deviation of the universe lies somewhere between \$1,569 and \$1,371. Within the 95 per cent confidence limits, the largest value for the standard deviation of the universe (σ) and the smallest mean of the universe (U) are used with the median found in the sample to establish the skewness of the universe. The degree of skewness is quite large for the universe and is reflected in a .13 difference between the degree of skewness of the sample and the universe:

$$SK = \frac{3(U-Md)}{\sigma} = \frac{3(\$1,538 - \$1,238)}{\$1,569} = .573$$

From the data in Table 25, it is possible to estimate the mean of the universe (U). We arrive at the estimate of the standard error of the mean ($\hat{\sigma}_{\bar{x}}$) by the use of the following formula:

$$\hat{\sigma}_{\bar{x}} = \frac{s}{\sqrt{N-1}} = \frac{\$1,569}{\sqrt{400-1}} = \frac{\$1,569}{19.99} = \$78.96^{8}$$

The mean of the universe (U), within 95 per cent confidence limits, is established through the use of the following formula:

$$\begin{aligned} U &= \bar{x} \pm (1.96)\,(\hat{\sigma}_{\bar{x}}) \\ &= \$1,682 \pm (1.96)\,(\$79) \\ &= \$1,682 \pm (\$154.8) \\ &= \$1,527 < U < \$1,837 \end{aligned}$$ [9]

---

[8] $\hat{\sigma}_{\bar{x}}$ = Standard error of the mean.
s = Standard deviation of the sample
N = Total number of frequencies in the sample.

Parl, Basic Statistics, pp. 144-46.

[9] U = Mean of the Universe
$\bar{x}$ = Arithmetic mean of the sample
$\hat{\sigma}_{\bar{x}}$ = Standard error of the mean.

For the purpose of this research, the range of the mean of the universe ($\$1,837 > U > \$1,527$) is selected to establish a high and low estimate or range for the mean value per lot for all platted lots found in Edmond in 1965.

The Methodology for the Determination of Land Value

The statistical study was undertaken to establish a basis for the estimation of the land value of platted and unplatted land within the city limits of Edmond, Oklahoma, from 1941 through 1965. In order to estimate the actual land value, a ratio of $11.81 to $1 was used to compare the actual sale value to the assessed value of land in 1965 through the use of a sample that yields a mean value for all residential lots of $\$1,837 > U > \$1,527$.

The mean value of the sample taken in 1965 may be used in two ways to determine the land value from 1941 through 1965: a ratio between actual sales and assessed value may be determined for 1965 and each year from 1941 through 1965 and then applied to a random sample of the lots for each year, or a ratio may be determined between the sales and the assessed value for 1965 and then applied to a sample of the lots to determine the total value of all lots in 1965. Through the use of the geometric mean, an estimate of the mean lot value for each year under investigation times the number of lots for each year equals the total lot value of Edmond for the years 1941 through 1965. The latter method was used because all the necessary information was available, while in the first case the changes in assessments of property from year to year were unavailable.

With the estimated average value for all lots for 1965 taken as an ending period value and the average value for all lots sold in 1890 taken as beginning period value, it is possible through the use of the geometric mean to establish the average value for all lots from 1890 to 1965. For the purpose of this study, the average high and low lot value within the 95 per cent confidence limits of the mean value of the universe for each year for 1941 through 1965 was multiplied by the number of platted lots (Table 12) to give the total land value for each year (Table 26).

The total land value for rural land within the city limits was determined by the total acreage within the city in 1965 (Table 12) times the estimate of the value of rural farm land per acre of Oklahoma County made by the Bureau of Agriculture for each of the years from 1941 through 1965 (Table 28).

Land Rent and Exchange Rent

In attempting to determine the amount of revenue that a "Single Tax" on land would yield, it is necessary to determine the kinds and the amount of rent return on the land. According to Henry George, under the general heading of rent, there are three kinds: exchange rent, rent actual, and rent potential.

> Rent ... is the share in the wealth produced which the exclusive right to the use of natural capabilities gives to the owner. Wherever land has an exchange value there is rent in the economic meaning of the term. Wherever land having a value is used, either by the owner or hirer, there is rent actual; wherever it is not used, but still has a value, there is rent potential.[10]

---

[10] George, *Progress and Poverty*, p. 166.

Not only does rent have several different meanings to George, but it can be determined in several different ways according to other economists. Among these alternatives is the definition that any income that accrues to land as a payment in relation to the value of the land is rent. Rent, as a factor payment, is the return to land for its contribution to the total product value; it also may be the payment derived from its marginal productivity. In the usual sense, rent is a payment based upon the value of land and the willingness of the user to pay the agreed upon amount.

The determination of rent in the aggregate under the last three conditions would be virtually impossible to determine because of the lack of adequate data.[11] Contract rent could be determined for individual cases, but an estimate of rental income to the owner-user would be difficult to separate from the other factor payments that the owner would receive. Rent as a return upon the value of land would be easier to estimate. With an estimate of land value and the establishment of an acceptable rate of return, the amount of rent as a percentage of value could be determined.

All rents, according to George, are unearned. In this study, in order to achieve a degree of clarity, rent actual and rent potential (possible return to vacant lots and unused rural land) are determined

---

[11] Keiper, et al, Theory and Measurement of Rent, p. 97.

as a percentage of land value and are called "Land Rent", while the increases each year in land value, exchange value, are called "Exchange Rent."

The formula used to determine land rent is the following:

Rent = Land Value X Rate of Return[12]

A rate of return that could be used in determining rent from land might be selected from two possible extremes. One of these would be the average business profit in 1965 of 11.8 per cent[13], while the second extreme could be the average interest of 5.31 per cent paid on all bank notes on short term business loans in eleven southern and western cities in 1965.[14] However, for this study, a value of 6 per cent is selected as a convenient but meaningful level of return for rent on land in 1965.[15]

---

[12]Harry Gunnison Brown, Basic Principles of Economics and Their Significance for Public Policy (Columbia, Missouri: Lucas Brothers, 1955), p. 428.

[13]"500 Largest Corporations in America," Fortune, Vol. LXXIV, No. 2, July 14, 1966, p. 119. Return on investment capital -- all industry -- 500 largest corporations.

[14]Federal Reserve Bulletin, Vol. 52, No. 6, June 1966, p. 855. Board of Governors of The Federal Reserve System, Washington, D. C.

[15]The above formula can be used to determine the value of certain types of property, i.e., Land Value = Income (Rent) ÷ Rate of Return. This is the income-capitalization approach as cited in Barlow's book: "Many appraisers tend to use capitalization rates of around 5 or 5.5 per cent with farm appraisals." Raleigh Barlowe, Land Resource Economics (Englewood Cliffs, N.J.: Prentice-Hall, Inc., 1958), p. 192.

The use of even a lower rate of return on Treasury bills of 3.95 per cent[16] in 1965 would not alter the final values to any great degree. Land rent would be lower by the 2 per cent difference but the unearned increment of the land would remain the same.

The formula used above to determine rent as a given percentage of land value is the basis for the income capitalization method. The value of a given piece of productive land, real estate, or business firm is the income divided by a given rate of return. The use of this method to determine value contains a major obstacle for those who wish to tax away a part of the rental income. If the tax is large enough to capture the entire rental income of the property, then the property has no value to the current owner.

$$\text{Value} = \frac{\text{Rental Income - Tax}}{\text{Rate of Return}} = \frac{\$100 - \$100}{.06} = 0$$ [17]

One could easily capture in the form of a single tax the rent actual or rent potential, but not the exchange rent. It would be easy to tax the flow value (land rent) or income from land, but it is not easy to tax the stock value (exchange rent) until the land had changed hands in the form of a sale[18] in order to determine any value that may be left, even after all income has been single-taxed away.

---

[16] Federal Reserve Bulletin, Vol. 52, No. 6, June 1966, p. 856.

[17] Through taxation the value is transferred from the owner to the State. See Gilbert M. Tucker, The Self-Supporting City (New York: Robert Schalkenbach Foundation, 1958), pp. 24-25.

[18] Ibid., p. 75.

The problem of contemporary rent theory is that it has lumped two dissimilar concepts together which made assumptions that are no longer valid in an area of the world where free land is no longer available. The first error is the attempt to equate income-producing land (farms and business) with non-income producing land (residential). The second error is the use of a theory of land rent which is determined by the margin of cultivation of no-rent land. No-rent land in the United States no longer exists, and the theory must be altered to fit this new phenomenon. Alonso, in his recent book[19], discusses the similarity of the Agricultural Rent functions and bid price curves of the urban firm in the usual micro-economic style[20], while in a later chapter on the residential bid price curves, the application of indifference analysis is made.[21] Alonso, who is considered to be a poor mathematician by at least one of his reviewers[22], attempts to consolidate the two systems into a single market equilibrium system of analysis. However, he recognizes some of the problems that confront him when he made the following statements:

---

[19]Alonso, Location and Land Use: Toward a General Theory of Land Rent.

[20]*Ibid.*, Chapter 3.

[21]*Ibid.*, Chapter 4.

[22]Herman G. Berkman, "The Game Theory of Land Use Determination," Land Economics, Vol. XLI, No. 1, 1965, p. 19.

> The classical form of solution for the individual /buyer or seller of land/ cannot be used in this case to derive the structure of demand in the market.... /I/n this case, land and distance are so intertwined that we cannot derive such a curve.... Since part of the problem of finding the market solutions consists of finding individual locations, not knowing the locations of individuals we would not know which of their demand curves to use to build up our market demand curve.
>
> There are difficult problems on the supply side as well. The principal one is that of defining the supply of land.

These problems are complicated by the need to make some further assumptions about the bid price curves for the individual resident in order to establish the indifference map for the purchasing of land. Three points are emphasized:

> The first is that a bid price curve refers to a given individual: other individuals may have differently shaped bid price curves in the same way the bid rent functions of different crops differ. The second is that a bid price curve refers to a given level of satisfaction. Since there is an infinite number of levels of satisfaction for an individual, there will be for each individual a family of bid price curves corresponding to different levels of satisfaction. The third point that requires emphasis is that a bid price bears no necessary relation to the actual price that is charged for the use of land at that location. A bid price is hypothetical, merely saying that, if the price of land were such, the individual would be satisfied to a given degree.[24]

What then is the relationship between land rent and exchange rent? Buchanan, in his article on "The Historical Approach to Rent and Price

---

[23]Alonso, Location and Land Use: Toward a General Theory of Land Rent, p. 36-37.

[24]Ibid., p. 59.

Theory",[25] comes the closest to answering this question when he points out that the debate among the classical economists over whether rent was price determined or price-determining, was a result of confusion:

> /The/ principal cause of the confusion of these two questions is that the question of rent and price properly lies in two main fields, namely exchange and distribution. In exchange it has been usual to think of the price of particular products and to suppose that the land has many competitive uses; but in distribution it was ... common to think of the group of commodities which a given class produces and to think of the land as taken from nature by one class and having no alternative but to return to nature.[26]

The confusion that existed for the classical economist apparently still exists today. Most economists, when referring to rent from land, either give examples of rent compared to no-rent agricultural land or view the value of land from an income-capitalization method -- which is a value determined by distribution. However, if viewed from the exchange relationship, land has a value which is determined in competition and not solely by income generation. This fact can be illustrated by several methods used to determine property values in the real estate market.

Real estate appraisers can use not only the income-capitalization method but the replacement-cost and the market-comparison approach. The replacement-cost approach is used primarily to determine the original cost and replacement cost of building and is not used to determine

---

[25]Daniel H. Buchanan, "The Historical Approach to Rent and Price Theory," Readings in the Theory of Income Distribution (Philadelphia: The Blakiston Company, 1951).

[26]Ibid., p. 600.

the value of raw land. However, the market-comparison approach can better explain the valuation process used for residential land value: "Unlike the income-capitalization method, the market-comparison approach does not attempt to value properties in terms of their expected future returns."[27] Furthermore, it is pointed out that in the United States the value of residents is not based upon income-capitalization:

> Although the English valuer may use the capitalization approach more frequently than his American or Canadian counterpart, this is at least partly due to his greater opportunity to do so. Generally, the method is limited to the valuation of properties which are purchased as investments rather than for occupation by the purchaser. Thus, for example, this approach would not be used in the appraisal of an owner-occupied single family home. Attempts to extend its application to cover cases where property has been bought primarily for occupation are not received favorably, and a quotation from a court decision summarizes the general attitude -- such valuations are 'polemical rather than practical exercises.[28]

This observation is given additional support in the statement that:

> The appraiser who attempts to think of valuation of the single family residence by a unity of replacement figures, by capitalization, and by sales comparison becomes entangled with the results. Capitalization of single family home rental is fallacious. They are not designed or intended for income. *The market does not judge the single family home value by its earning power.*[29]

---

[27] Barlowe, *Land Resource Economics*, p. 195.

[28] Philip H. White, "Some Aspects of the Income Approach," *The Residential Appraiser*, Vol. 26, No. 7, 1960, p. 22.

[29] Dominick Dunn, "Formula in Appraising," *The Residential Appraiser*, Vol. 27, No. 9, 1961, p. 12. The italics are in the original.

If income-capitalization is not used to determine value, while market-comparison is, what originally gives the value to the residence and the land? This, according to Ratcliff, is location: "The location characteristics of residential areas are of major concern not only to prospective home purchasers but also to lenders in the evaluation of mortgage risk."[30] Moreover, many real estate dealers and investigators feel that the value of residential land is determined by the competitive forces of supply and demand[31] and that these forces will reflect in the payment of the economic rent that any commodity receives when the supply is inelastic. Any increases in the value of land which are socially produced[32] are unearned and therefore can be subject to a single tax on unearned increment.

The locational or site value is controlled in part by its monopoly element, but the value of any residential lot is influenced significantly by the following social determining values: physical attractiveness of the neighborhood, social and economic status of the neighborhood, transportation facilities, schools, churches, recreational and cultural facilities, utilities and services, commercial centers, and protection

---

[30] Richard U. Ratcliff, Real Estate Analysis (New York: McGraw-Hill Book Company, Inc., 1961), p. 75.

[31] James L. Green, Metropolitan Economic Republics (Athens, Georgia: University of Georgia Press, 1965), p. 65.

[32] Eli Schwartz and James E. West, An Analysis of the Potential Effects of a Movement Toward a Land Value Based Property Tax (Albany, New York: Economic Education League, 1958), p. 5.

against adverse influences.[33] Under these considerations, it is apparent that residential land values are influenced by supply and demand and social amenities rather than by their income-generating potential. Thus, increases in residential land values are unearned -- as is the annual ground rent that is derived from the same source.

The unearned income that accrues to residential land and is subject to a single tax is a product of both the land rent (actual and potential) and the exchange rent (increases in site value). In this investigation land rent will be a percentage of land value that accrues to the owner annually, and exchange rent will be an increase in value of the residential land which is a product of social causation and not of income generation.

Land Value for Platted Land

The range in value from $1,527 to $1,837 for platted land indicates the possible average value per lot in 1965 within 95 per cent confidence limits (Table 25). Both values of the possible mean of the universe are used to establish a high and low estimate of land value for all lots in Edmond. With the estimate of land value for 1965 established, it is possible through the use of a geometric mean to ascertain the high and low lot and land value for each year from 1941 to 1965.

In data previously noted, it was shown that all lots sold originally in 1890 for $2.00 a lot, while their average value in 1965 was

---

[33] Ratcliff, Real Estate Analysis, pp. 76-79.

between \$1,527 and \$1,837. This increase in value took place in a period of seventy-five years. Consequently, this data can be used to determine the geometric rate of change in value when placed in the following formula:

$$\frac{\text{Log } \frac{E}{B}}{N} = \text{Log } 1 + r.$$

The values in the formula are defined as follows: B is the beginning land value of the period, E the land value at the end of the period, N the number of time periods, and r is the rate.[34] The rate of increase per year for the low estimate, which is based upon the lowest possible mean value (\$1,527) in 1965, is 9.2 per cent, and the rate of increase per year for the high estimate (\$1,837) is 9.5 per cent.

---

[34]Low estimate for land value per lot per year determined through the use of geometric means:

Land value per lot, 1965 = \$1,527
Land value per lot, 1890 = \$2
From 1890 to 1965 is 75 years

Log \$1,527 = 3.18380
-Log \$2 = 0.30103
2.88277 ÷ 75 years = Anti Log .03844 = 1.0925 = 1.092

Rate of Increase per year = 9.2%

High estimate for land value per lot per year determined through the use of geometric means:

Land value per lot, 1965 = \$1,837
Land value per lot, 1890 = \$2
From 1890 to 1965 is 75 years

Log \$1,837 = 3.26411
-Log \$2 = 0.30103
2.96308 ÷ 75 years - Anti Log 0.03951 = 1.095

Rate of Increase per year = 9.5%

Neiswanger, Elementary Statistical Methods, p. 287.

The data found in Table 26 indicates that the average land values per lot were based on the low estimate range from $184 in 1941 to $1,527 in 1965, while the range for the high estimate is $210 in 1941 to $1,837 in 1965. The total land value, which is the average value per lot per year multiplied by the number of the lots each year, varied from $1,180,544 in 1941 to $12,724,491 in 1965 for the low estimate, and $1,347,360 in 1941 to $15,307,721 for the high estimate. The data gained from Table 26 is then used to supply all or part of the data necessary to compile Tables 27 and 29, both of which deal with land rent and exchange rent on platted land.

Exchange Rent of Platted Land

The exchange rent is the difference between the exchange price (sale value) on a piece of land from year to year. In Table 26 the value per lot in 1965 $1,527, for the low estimate, while the value per lot in 1964 is $1,398, making a difference of $129 per lot in 1965 for the low estimate of Total Land Value per lot. The changes in exchange rent per lot go from a low of $18 in 1941 to a high of $149 in 1965 for the high estimate (Table 27). When the exchange rent per lot each year is multiplied by the number of lots, the Total Exchange Rent Low or High Estimate is determined. This ranges from $102,656 in 1941 to $1,074,957 in 1965 for the low estimate, to $115,488 in 1941 to $1,241,617 in 1965 for the high estimate.

TABLE 26

HIGH AND LOW ESTIMATE FOR LAND VALUE PER LOT AND TOTAL LAND VALUE FOR ALL LOTS, EDMOND, OKLAHOMA, 1941 - 1965

Year	Low Estimate For Land Value Per Lot[a] (1)	High Estimate For Land Value Per Lot[a] (2)	Number of Lots[b] (3)	Total Land Value Low Estimate (Col.1 X Col.3) (4)	Total Land Value High Estimate (Col.2 X Col.3) (5)
1965	$1,527	$1,837	8,333	$12,724,491	$15,307,721
1964	1,398	1,688	8,123	11,355,954	13,711,624
1963	1,280	1,542	7,748	9,917,440	11,947,416
1962	1,172	1,408	7,485	8,772,420	10,538,880
1961	1,073	1,288	7,458	8,002,434	9,605,905
1960	983	1,176	7,307	7,182,781	8,593,032
1959	900	1,074	7,194	6,474,600	7,726,365
1958	824	981	6,935	5,714,440	6,803,235
1957	754	897	6,917	5,215,418	6,204,549
1956	690	819	6,917	4,772,730	5,665,023
1955	632	748	6,817	4,308,344	5,099,116
1954	579	683	6,817	3,947,043	4,656,011
1953	530	624	6,811	3,609,830	4,250,064
1952	485	570	6,741	3,269,385	3,842,370
1951	444	521	6,741	2,993,004	3,512,061
1950	406	476	6,714	2,725,884	3,195,864
1949	372	435	6,714	2,497,608	2,920,590
1948	341	397	6,714	2,289,474	2,665,458
1947	312	362	6,529	2,037,048	2,363,498
1946	286	331	6,481	1,853,566	2,145,211

(Continued)

TABLE 26 -- Continued

Year	Low Estimate For Land Value Per Lot[a] (1)	High Estimate For Land Value Per Lot[a] (2)	Number of Lots[b] (3)	Total Land Value Low Estimate (Col.1 X Col.3) (4)	Total Land Value High Estimate (Col.2 X Col.3) (5)
1945	$ 262	$ 302	6,435	$1,685,970	$1,945,370
1944	240	276	6,435	1,544,400	1,776,060
1943	220	252	6,435	1,415,700	1,621,620
1942	201	230	6,435	1,293,435	1,480,050
1941	184	210	6,416	1,180,544	1,347,360

Source: Compiled from Tables 12 and 25.

[a]The low estimate for land value per lot based upon the mean of the universe within the 95 per cent confidence limit is $1,527 in 1965. Through the application of the geometric means, it is found that land value drops at the rate of 9.2 per cent per year, or from $1,527 in 1965 to $184 in 1941.

[b]The high estimate for land value per lot based upon the mean of the universe within the 95 per cent confidence limit is $1,837 in 1965. Through the application of the geometric mean, it is found that land value drops at the rate of 9.5 per cent per year, or from $1,837 in 1965 to $210 in 1941.

TABLE 27

HIGH AND LOW ESTIMATES FOR EXCHANGE RENT PER LOT AND TOTAL EXCHANGE RENT FOR ALL LOTS, EDMOND, OKLAHOMA, 1941-1965

Year	Exchange Rent Per Lot Low Estimate[a] (1)	Exchange Rent Per Lot High Estimate[a] (2)	Number of Lots (3)	Total Exchange Rent Low Estimate (Col.1 X Col.3) (4)	Total Exchange Rent High Estimate (Col.2 X Col.3) (5)
1965	$ 129	$ 149	8,333	$1,074,957	$1,241,617
1964	118	146	8,123	958,514	1,185,958
1963	108	134	7,748	836,784	1,038,232
1962	99	120	7,485	741,015	898,200
1961	90	112	7,458	671,220	835,296
1960	83	102	7,307	606,481	745,314
1959	76	92	7,194	546,744	661,848
1958	70	84	6,935	485,450	582,540
1957	64	78	6,917	442,688	539,526
1956	58	71	6,917	401,186	491,107
1955	53	65	6,817	361,301	443,105
1954	49	59	6,817	334,033	402,203
1953	45	54	6,811	306,495	367,794
1952	41	49	6,741	276,381	330,309
1951	38	45	6,741	256,158	303,345
1950	34	41	6,714	228,276	275,274
1949	31	38	6,714	208,134	255,132
1948	29	35	6,714	194,706	234,990
1947	26	31	6,529	169,754	202,399
1946	24	29	6,481	155,544	187,949

(Continued)

TABLE 27 -- Continued

Year	Exchange Rent Per Lot Low Estimate[a] (1)	Exchange Rent Per Lot High Estimate[a] (2)	Number of Lots (3)	Total Exchange Rent Low Estimate (Col.1 X Col.3) (4)	Total Exchange Rent High Estimate (Col.2 X Col.3) (5)
1945	$22	$26	6,435	$141,570	$167,310
1944	20	24	6,435	128,700	154,440
1943	19	22	6,435	122,265	141,570
1942	17	20	6,435	109,395	128,700
1941	16	18	6,416	102,656	115,488

Source: Table 26.

[a]Exchange Rent per lot is determined by finding the difference in value that has occurred to the lot each year, i.e., high estimate for land value per lot in 1965 was $1,837 and in 1964 it was $1,688. The difference is $149 which is the exchange rent per lot -- high estimate in 1965.

Total Value and Exchange Rent of Rural Land in Edmond, Oklahoma

Unearned Increment or unearned income from any factor of production may result from an inelastic supply and an increasing demand for the factor. Land supply is assumed by some to be inelastic and any increase in population will automatically increase the value of land by increasing the demand for land as a homesite and/or a base for food production. The increased value in the farm land within Edmond is reflected in Table 28.

The value of land and buildings compiled by the Bureau of Census every five years is found in Column 2 and the data for the intervening years is computed by using the geometric mean to determine the growth for each year. However, in order for the data to be usable, the value of the building must be eliminated.

The Department of Agriculture made estimates for various years to determine the value of farm buildings in relation to the value of land and buildings. Their estimates for the years 1955 (12.4 per cent), 1956 (9.4 per cent), and 1957 (12 per cent) are taken and a rough average of 12 per cent is used as the percentage value of the buildings to the value of land and buildings per acre of farm. This figure may be a little high, a possibility suggested in a publication of the Department of Agriculture:

> The downward trend in the value of farm buildings relative to bare land followed the rapid increase in size of farms, which has created a surplus of farm buildings in some areas. The economic value of buildings on farms that are combined with others is sharply reduced, even though on a cost-less-depreciation basis they have the same value as before. In some areas notably the western

TABLE 28

EXCHANGE RENT PER ACRE, TOTAL EXCHANGE RENT VALUE PER ACRE, AND TOTAL VALUE OF UNIMPROVED FARM LAND IN EDMOND, OKLAHOMA, 1941-1965

Year (1)	Value of Land and Buildings Per Acre[e] (2)	Land Value Per Acre, 88% of Land & Buildings[f] (3)	Yearly Exchange Rent Per Acre[g] (4)	Total Land Value (3) X 37,500 Acres[h] (5)	Total Exchange Rent (4) X 37,500 Acres (6)
1965	$422	$371	$31	$13,912,500	$1,162,500
1964	386[a]	340	28	12,750,000	1,050,000
1963	354	312	26	11,700,000	975,000
1962	325	286	23	10,725,000	862,500
1961	299	263	21	9,862,500	787,500
1960	275	242	19	9,075,000	712,500
1959	253[b]	223	21	8,362,500	787,500
1958	230	202	19	7,575,000	712,500
1957	208	183	18	6,862,500	675,000
1956	188	165	15	6,187,500	562,500
1955	170	150	14	5,625,000	525,000
1954	154[b]	136	6	5,100,000	225,000
1953	148	130	5	4,875,000	187,500
1952	142	125	5	4,687,500	187,500
1951	136	120	6	4,500,000	225,000
1950	130[c]	114	10	4,275,000	375,000
1949	118	104	10	3,900,000	375,000
1948	107	94	9	3,525,000	337,500
1947	97	85	8	3,187,500	300,000
1946	88	77	7	2,887,500	262,500

(Continued)

TABLE 28 -- Continued

Year (1)	Value of Land and Buildings Per Acre[e] (2)	Land Value Per Acre 88% of Land & Buildings[f] (3)	Yearly Exchange Rent Per Acre[g] (4)	Total Land Value (3) X 37,500 Acres[h] (5)	Total Exchange Rent (4) X 37,500 Acres (6)
1945	$ 80[d]	$ 70	$ 2	$2,625,000	$ 75,000
1944	77	66	3	2,550,000	112,500
1943	74	65	3	2,437,500	112,500
1942	71	62	2	2,325,000	75,000
1941	68	60	2	2,250,000	75,000

Source:

[a]U. S., Department of Commerce, Bureau of the Census, 1964 Census of Agriculture, I, 281.

[b]U. S., Department of Commerce, Bureau of the Census, 1959 Census of Agriculture, I, 160.

[c]U. S., Department of Commerce, Bureau of the Census, 1950 Census of Agriculture, I, 62.

[d]U. S., Department of Commerce, Bureau of the Census, 1945 Census of Agriculture, I, 176.

[e]Geometric mean used to establish values between Census years: 1940 to 1945, 3.9 per cent yearly income; 1945 to 1950, 10.7 per cent yearly increase; 1950 to 1954, 4.3 per cent yearly increase; 1954 to 1959, 10.4 per cent yearly increase; and 1959 to 1965, 8.8 per cent yearly increase.

[f]The percentage of value of farm land to Value of Land and Building is estimated at 88 per cent. In the U. S. Department of Agriculture publication of <u>Current Developments in the Farm Real Estate Market, May 1957: Changes in Dollar Value of Farmland</u>, page 15, states in the table "Buildings as a percentage of Land and Buildings in Oklahoma County, Oklahoma:" 12.4 per cent in 1955; 9.4 per cent in 1956; and 12.0 per cent in 1957.

(Continued)

TABLE 28 -- Continued

[g]Yearly exchange rent per acre is the difference in land value, in Column 3 of 371 in 1965 and 340 in 1964. It is equal to $31.00, which is the exchange rent in 1965.

[h]See Table 13. Number of Acres in Farm Land Within the city limits of Edmond, Oklahoma, 1941-1965. The acreage in 1965 of 37,592 was rounded to 37,500 in order to reduce any upward bias that may have resulted from estimation of lots per acre of platted land.

> Corn Belt and the Great Plains, sales prices of farmland without buildings are often nearly as high as those for farms with buildings.[35]

It appears that the use of the 12 per cent as the value for buildings, when compared to the total value of land and buildings, inflates the value of buildings and deflates the value of land. The use of an inflated value for buildings reduces the amount of exchange rent for land as well as the amount that could be subject to the "single tax."

In Column 3 the value of buildings per acre is separated from the land and buildings, leaving only the yearly value for land. The yearly change in value or the yearly exchange rent accruing to the owner of the land is determined in Column 4. In Column 5 the value of the land per acre is multiplied by the total number of acres of farm land within the city limits of Edmond in 1965. In Column 6 the exchange rent per acre for each year is multiplied by the total number of acres of farm land within the city limits as of 1955. The total unearned income rises from $75,000 in 1941 to over $1,162,500 in 1965[36] -- or approximately 11.6 per cent annual growth rate for the last 25 years.

---

[35] William H. Scofield, "How Do You Put A Value On Land?," Land: The Yearbook of Agriculture, 1958, The United States Department of Agriculture (Washington: U. S. Government Printing Office, 1958), p. 187.

[36] The use of the average land value of $371 in 1965 for Oklahoma County to establish rural land values within the city limits of Edmond is extremely low in light of the offer of sale of 280 acres to associates of the author for $1,500 per acre. Forty acres at another time had been offered at a price of $750, a month before a road bond election. When the election was successful, the price was raised to $1,000.

Land Rent for Rural and Platted Land

In Table 29 the amount of rent is determined at 6 per cent of the total land value within the city limits. The amount of Rural Land Value (Column 1) found in Table 28 is added to the Total Land Value Platted Land Low and High Estimates (Column 2 and 3) found in Table 27 to give the Total Land Value Low and High Estimate in Column 4 and 5 in Table 29. Both Column 4 and 5 are multiplied by the rate of return of 6 per cent to give the rental income each year 1941 through 1965 in Column 6 and 7. The rental income varies from $205,833 in 1941 to $1,598,219 in 1965 for the low estimate (Column 6), and from $215,842 in 1941 to $1,753,213 in 1965 for the high estimate (Column 7).

City and School Expenditures

The "Single Tax" thesis of Henry George indicates that sufficient revenue would result from a tax on land value to meet all the expenditure needs of both the government and schools in Edmond, Oklahoma. In Edmond, the expenditures of the city are inflated because they include the amount that is spent to secure and maintain electrical services. This additional cost is incurred by Edmond because the income that results from the sale of electricity represents a large share of the total revenue available to meet the needs of city government. Therefore, to give a true picture of the real expenditures, the cost of the electrical services is subtracted from the total General Fund Expenditures, leaving General Fund Expenditures Excluding Electrical Services, as shown in Table 30.

TABLE 29

LAND RENT FOR RURAL AND PLATTED LAND, HIGH AND LOW ESTIMATES, EDMOND, OKLAHOMA, 1941-1965

Year	Rural Land Value (1)	Total Land Value Platted Land (Low Estimate) (2)	Total Land Value Platted Land (High Estimate) (3)	Total Land Value Low Estimate (Col. 1 + 2) (4)	Total Land Value High Estimate (Col. 1 + 3) (5)	Land Rent Low Estimate (Col. 4 X 6%) (6)	Land Rent High Estimate (Col. 5 + 6%) (7)
1965	$13,912,500	$12,724,491	$15,307,721	$26,636,991	$29,220,221	$1,598,219	$1,753,213
1964	12,750,000	11,355,954	13,711,624	24,105,954	26,461,624	1,446,357	1,587,697
1963	11,700,000	9,917,440	11,947,416	21,617,440	23,647,416	1,297,046	1,418,845
1962	10,725,000	8,772,420	10,538,880	19,497,420	21,263,880	1,169,845	1,275,833
1961	9,862,500	8,002,434	9,605,905	17,864,934	19,468,405	1,071,896	1,168,104
1960	9,075,000	7,182,781	8,593,032	16,257,781	17,668,032	975,467	1,060,082
1959	8,362,500	6,474,600	7,726,365	14,837,100	16,088,865	890,226	965,332
1958	7,575,000	5,714,440	6,803,235	13,289,440	14,378,235	797,366	862,694
1957	6,862,500	5,215,418	6,204,549	12,077,918	13,067,049	724,675	784,023
1956	6,187,500	4,772,730	5,665,023	10,960,230	11,852,523	657,614	711,151
1955	5,625,000	4,308,344	5,099,116	9,933,344	10,724,116	596,001	643,447
1954	5,100,000	3,947,043	4,656,011	9,047,043	9,756,011	542,822	585,361
1953	4,875,000	3,609,830	4,250,064	8,484,830	9,125,064	509,090	547,504
1952	4,687,500	3,269,385	3,842,370	7,956,885	8,529,780	477,413	511,792
1951	4,500,000	2,993,004	3,512,061	7,493,004	8,012,061	449,580	480,724
1950	4,275,000	2,725,884	3,195,864	7,000,884	7,470,864	420,053	448,252
1949	3,900,000	2,497,608	2,920,590	6,307,608	6,820,590	383,856	409,235
1948	3,525,000	2,289,474	2,665,458	5,814,474	6,190,458	348,868	371,427
1947	3,187,500	2,037,048	2,363,498	5,224,548	5,550,998	313,473	333,060
1946	2,887,500	1,853,566	2,145,211	4,741,066	5,032,711	284,464	301,963

(Continued)

TABLE 29 -- Continued

Year	Rural Land Value (1)	Total Land Value Platted Land (Low Estimate) (2)	Total Land Value Platted Land (High Estimate) (3)	Total Land Value Low Estimate (Col. 1 + 2) (4)	Total Land Value High Estimate (Col. 1 + 3) (5)	Land Rent Low Estimate (Col. 4 X 6%) (6)	Land Rent High Estimate (Col. 5 X 6%) (7)
1945	$2,625,000	$ 1,685,970	$ 1,945,370	$ 4,310,970	$ 4,570,370	$ 258,656	$274,222
1944	2,550.000	1,544,400	1,776,060	4,094,400	4,326,060	245,664	259,564
1943	2,437,500	1,415,700	1,621,620	3,853,200	4,059,120	231,192	243,547
1942	2,325,000	1,293,435	1,480,050	3,618,435	3,805,050	217,106	228,303
1941	2,250,000	1,180,544	1,347,360	3,430,544	3,597,360	205,833	215,842

Source: Tables 27, 28, and 29.

TABLE 30

CITY EXPENDITURES EXCLUDING COST OF ELECTRICITY AND ELECTRIC SERVICES, 1941-1965

Year	Cost of Electricity Current	Supplies for Electric Department	Salaries for Electric Department	Total Cost of Electric Service	General Fund Expenditure	General Fund Expenditure Excluding Electric Service
1965	$259,469	$134,096	$35,355	$428,920	$987,792	$558,872
1964	236,810	134,398	27,066	398,274	871,231	472,957
1963	189,677	80,016	23,251	292,944	761,899	468,955
1962	150,394	47,977	18,984	217,355	640,756	423,401
1961	140,118	55,166	21,538	216,822	557,685	340,863
1960	116,033	68,924	19,386	204,343	508,232	303,889
1959	118,017	56,603	16,226	190,846	522,417	331,571
1958	108,388	38,449	16,236	163,073	453,826	290,753
1957	104,774	35,914	12,875	153,563	387,374	233,811
1956	91,030	46,975	15,002	153,007	385,150	232,143
1955	84,482	119,364	18,873	222,719	448,986	226,267
1954	76,048	29,758	18,239	124,045	357,747	233,702
1953	64,541	26,456	14,656	105,653	312,138	206,485
1952	53,987	13,040	12,460	79,487	241,721	162,234
1951	53,450	15,896	10,772	80,118	227,261	147,143
1950	50,500	14,520	11,698	76,718	227,698	150,980
1949	47,907	14,638	10,388	72,933	209,838	136,905
1948	42,000	28,728	11,130	81,858	187,476	105,618
1947	37,849	9,130	9,014	55,993	185,469	129,476
1946	NA	NA	NA	NA	NA	95,271[a]

(Continued)

TABLE 30 -- Continued

Year	Cost of Electricity Current	Supplies for Electric Department	Salaries for Electric Department	Total Cost of Electric Service	General Fund Expenditure	General Fund Expenditure Excluding Electric Service
1945	$ 30,320	$ 7,000	$ 7,050	$ 44,370	$114,578	$ 70,208
1944	27,401	2,234	4,616	34,251	93,462	59,211
1943	25,740	1,632	3,963	31,335	83,279	51,944
1942	21,221	. . .	. . .	21,221	85,319	64,098
1941	23,337	. . .	. . .	23,337	97,296	73,959

Source: Audit Report, City of Edmond, Oklahoma, 1941-1965.

NA: Not Available

[a]Geometric mean used: Percentage change = 35.7 per cent.

Part of the total expenditures to be covered by the "Single Tax" is educational expense on the elementary and secondary level. General education, upkeep, and construction compose the total cost of operating the school system. No attempt is made to prorate the construction costs in any one year over the estimated life of the structure. This method of cost determination reduces construction cost in any one year to about five per cent of the total cost, but it is not necessary to be that specific in cost determination for this study because the amount of unearned increment is more than sufficient to meet the needs in any one year.

The accounting method used by the school district was altered in 1958 to give a more comprehensive breakdown into the various areas. However, for our use in Table 31, the total expenditures for each year was all that was needed. Figures on total expenditures from 1941 to 1952 were unavailable[37]; however, they were estimated through the use of a rate of change determined by using an average based upon the percentage change for each year from 1954 to 1957. The average rate of increase for these years was 9.1 per cent, and this figure was used to determine the declining rate of change for each year from 1953 to 1941.

The method used has given an upward bias to the total expenditures for the school district and will more than likely make these

---

[37]The state school district records were stored in a disorganized fashion in an area that also contained many other state records. There was hope on the part of some officials that the records would be catalogued at some future date and they were reluctant to have the material disturbed at this time.

TABLE 31

CITY AND SCHOOL TOTAL EXPENDITURES, EDMOND, OKLAHOMA
1941-1965

Year	City Expenditures	Edmond School District Expenditures	Total of City and School Expenditures
1965	$558,872	$1,163,723	$1,722,595
1964	472,957	1,225,008	1,697,965
1963	468,955	936,212	1,405,167
1962	423,401	838,345	1,261,746
1961	340,863	765,981	1,106,844
1960	303,889	910,899	1,214,788
1959	331,571	511,526	843,097
1958	290,753	527,874	818,627
1957	233,811	370,897	604,708
1956	232,143	333,916	566,059
1955	226,267	317,274	543,541
1954	233,702	282,938	516,640
1953	206,485	261,916	468,401
1952	162,234	240,070[a]	402,304
1951	147,143	220,046[a]	367,189
1950	150,980	201,692[a]	352,672
1949	136,905	184,869[a]	321,774
1948	105,618	169,449[a]	275,067
1947	129,476	155,315[a]	284,791
1946	95,271[b]	142,360[a]	237,631
1945	70,208	130,486[a]	200,694
1944	59,211	119,602[a]	178,813
1943	51,944	109,626[a]	161,570
1942	64,098	100,482[a]	164,580
1941	73,959	92,101[a]	166,060

Source: Table 30. Annual Financial Reports of Oklahoma School Districts, 1953-1965.

[a]An estimate was used for 1941 to 1952. A per cent change was found for the years 1954 (8.0 per cent), 1955 (12.1 per cent), 1956 (5.2 per cent), and 1957 (11.1 per cent) and an average of 9.1 per cent was found. This average was used to establish the declining rate of change in school expenditures from 1953 to 1941.

[b]Geometric mean used: Percentage change = 35.7 per cent.

expenditures greater than they normally would be. However, the use of this method creates a disadvantage to anyone who is attempting to prove that a "single tax" would be sufficient to meet both city and school expenditures.

In the final Column in Table 31, the total of city and school district expenditures are shown for each year from 1941 through 1965.

SUMMARY

To test the validity of Henry George's "Single Tax" hypothesis, the total land rent and the total exchange rent must be greater than the expenditures required to finance governmental and educational activities. In Table 32 the land rent and exchange rent from the platted and rural land (Tables 27, 28, and 29) are added together for both a high and low estimate (Column 1 and 2) and then compared to the city and school expenditures (Column 3) for the same time period. In each and every year the unearned increment (total land rent and exchange rent either high or low estimate) is two and sometimes three times greater than the total expenditure for the city and schools. For the years 1941 through 1965, the unearned increment range is from $383,489 (1941) to $3,835,676 (1965) for the low estimate to $406,330 (1941) to $4,157,330 (1965) for the high estimate. During the same time period, the total expenditures for the city and schools ranged from $166,060 (1941) to $1,722,595 (1965). In all the years studied, the exchange rent (Tables 27 and 28), which ranged from $180,488 (1941) to $2,404,117 (1965), is greater than the yearly total city and school expenditures, while land rent ($205,833 in 1941 to $1,598,219 in 1965 for the low estimate and $215,842 in 1941 to

TABLE 32

LAND RENT, EXCHANGE RENT (HIGH AND LOW ESTIMATE) AND TOTAL CITY AND SCHOOL EXPENDITURES, EDMOND, OKLAHOMA, 1941-1965

Year	Total Land Rent and Exchange Rent (Low Estimate)[a] (1)	Total Land Rent and Exchange Rent (High Estimate)[a] (2)	Total City and School Expenditures[b] (3)
1965	$3,835,676	$4,157,330	$1,722,595
1964	3,454,871	3,823,655	1,697,965
1963	3,108,830	3,432,077	1,404,167
1962	2,773,360	3,036,533	1,261,746
1961	2,530,616	2,790,900	1,106,844
1960	2,294,448	2,517,896	1,214,788
1959	2,224,470	2,414,680	843,097
1958	1,995,316	2,157,734	818,627
1957	1,842,363	1,998,546	604,708
1956	1,621,300	1,764,758	566,059
1955	1,482,302	1,611,552	543,541
1954	1,101,855	1,212,564	516,640
1953	1,003,085	1,102,798	468,401
1952	941,294	1,029,601	402,304
1951	930,738	1,009,069	367,189
1950	1,023,320	1,098,526	352,672
1949	966,990	1,039,367	321,774
1948	881,074	943,917	275,067
1947	783,227	835,459	284.791
1946	702,508	752,412	237,631
1945	475,228	516,532	200,694
1944	486,864	526,504	178,813
1943	465,957	497,617	161,570
1942	401,501	432,003	164,580
1941	383,489	406,330	166,060

Source: [a]Tables 27, 28, and 29.

[b]Table 31.

$1,753,213 in 1965 for the high estimate) is about equal to it. Therefore, as Table 32 indicates, there is available for taxation via a single tax on the unearned increment arising from land, a sufficient income in the form of land rent and exchange rent to amply support the expenditure needs of Edmond, Oklahoma.

CHAPTER VI

SUMMARY AND CONCLUSION

This study was divided into three major parts: the economic background and theoretical development of Henry George, the theoretical structure that was built around the unearned increment of land and the single tax, and the statistical study of a possible application of a single tax to a local community. While others wished to rely upon "the invisible hand", George searched for another immutable law which would give the world progress without poverty. As a "flash of lightening" on a hillside in California, the problem dawned on him: with the growth of population, land grows in value, and the men who work it must pay more for the privilege. The solution to this problem, then, was not one of an invisible hand, instead, it involved another far-reaching panacea, the single tax.

The single tax provided the perfect solution. The increase in land value was socially produced, it rightfully belonged to no one, and to tax it away would not alter the existing distribution of income, but simply would allow each individual to receive the fruits of his own labor free from taxation. Thus, the government, or any government, would be free to assist in the productive efforts of society without interfering in the allocative process in order to redress the economic ills of poverty. All of the given social needs would be provided for by taxing the socially-created income (unearned increment), and society would continue to grow and prosper rather than experiencing progress and decay. The single tax would also eliminate land speculation, reduce the cost of production, increase wages and interest, increase employment, and remove permanently the spectre of poverty.

George, however, was not as clear in the measurement of his unearned increment as he was in defining it. He defined unearned increment as the income generated by the effort and growth of society in the form of rent (rent actual, rent potential and exchange rent) from land and suggested that it be taxed. He expressed a desire to tax all the rent while still acknowledging the fact that it was impossible to determine just how much of the unearned increment was generated in any given time period. This, of course, led to the debate between the limited vs. the unlimited single tax advocates.

Edmond, Oklahoma, was selected as the area for the research project. It had all the desirable factors necessary for the investigation: the availability of data, the size of the city, the economic impact of social forces, a fast growing state college, and good roads that would create unearned increment. The data gathered on Edmond indicated that the growth of Edmond coincided with the growth of the college, the population shift in Oklahoma City, and the development of a better road system in and near Edmond. Most of the growth of Edmond has been a result of external social forces with very little growth resulting from the internal growth or leadership of the local community. In fact, until Mayor Charles Johnson took office, the town's leadership had been characterized by some of the younger leaders as "a bunch of old moss-backs."

In attempting to gather the necessary data to determine the value of land in Edmond, it was essential to reconstruct some of the raw data into a more usable form. The real estate sales were recorded on warranty deeds that held information about the sales in various forms. On some of the deeds there were Internal Revenue stamps and/or mortgage values and/or actual values, while some deeds had little or no information that could lead the investigator to the reconstruction of a statistical determined value. However, it was possible to establish a relationship between the stamp value or mortgage value of the real estate transactions and the sale price. This data were used to determine a relationship between the sale price and the tax assessed value of the land under investigation. When the actual sale value was compared to the tax assessment, a ratio of $11.81 to $1 was established for 1965. In Edmond, property was taxed, on the average, at slightly over 8 per cent of actual value rather than at the stated rate of 25 per cent. With the reconstruction of the necessary data and the establishment of a ratio between assessed value and actual value, it was possible to determine the total value of all land within the city limits of Edmond and the changes in land value for each year from 1941 through 1965.

These values were ascertained through the use of a sample of 400 lots taken from a universe in which 14 per cent of the original items were eliminated before a random sample was taken. Out of 9,091 original lots, 1,288 lots were removed from the universe. Some of the lots were removed because information about assessment values was unavailable. Commercial lots which were slightly less than half of all the lots removed in order to keep the sample from reflecting the bimodal nature of land value that would occur if the value of residential and commercial property were taken together.

The mean of the universe within 95 per cent confidence limits was established for 1965. The upper and lower limits were used to establish a high and low estimation of average land value. Through use of geometric mean, values were established for the year 1941 to 1965. Each value was multiplied by the number of lots found in that year by the lot values for that year in order to determine the total value of platted land.

An estimate of the annual rural land value per acre for Oklahoma County made by the Bureau of Census was accepted. This value was multiplied by the number of acres of land within the city limits to determine the total rural land value. The value of platted land and rural land was added together to give the total value of land for each year from 1941 through 1965 for Edmond, Oklahoma. Land rent was determined at 6 per cent of total value and exchange rent was the difference between the value of land from year to year, while unearned increment or unearned income was land rent added to exchange rent for any particular given time period.

All the evidence indicated that unearned increment on land, if fully taxed, would be sufficient to meet all the expenditure needs of Edmond, Oklahoma, and its school district. This was made abundantly clear by the selection of data at all times, statistic or parameter, which would prove the most disadvantageous in any attempt to substantiate the "single tax" thesis of Henry George. The mean of the Internal Revenue stamp of $369 was considerably below the mode of $500 or the median of $400, while the mortgage ratio of 92.7 per cent of actual value may be a little low in view of the fact that the leading home builder advertised a closing cost of less than $500 on homes of $13,000 to $15,000 or more. The lowest value for the mean of the universe within 95 per cent confidence limit was used to establish the value per lot because it would yield the lowest average. The low estimate of rural land value for Oklahoma County made by the Bureau of Census was accepted even though there was strong evidence to indicate that unplatted land within the city limits of Edmond was of a much higher value. The acceptance of land value at 88 per cent of the Bureau's estimate of the value of land and improvements was also rather low. No attempt was made to prorate school construction costs over a twenty year period or longer, a procedure which would have somewhat reduced the expenditure needs of the schools in the last five or ten years when school construction was at its heaviest. Furthermore, the exchange rent which reflects the increase in value that results from the change of land from rural to platted land and the demand for it can be figured in two ways. The exchange rent, when figured from total value, was $1,369,537 or the difference between Total Value of $12,724,491 in 1965 and $11,354,954 in 1964 (Table 29), but when figured as the increase in value per lot each year multiplied by the number of lots ($129 X 8,333), the figure was a somewhat lower value of $1,074,957 for exchange rent (Table 27). The lower figure was used as the exchange rent in this investigation for 1965. Finally, the most significant feature to have an impact on the average value of land, commercial property, was left out of the study in order to reduce the bimodal impact upon the sample data. Thus, the amount of unearned increment available must be greater than, or at least equal to, the amount estimated in the investigation. The unearned increment exceeded the total expenditures in each year of the study even with the lowest possible estimates, there was still an excess of receipts over expenditures and for each year from 1941 to 1965. Actually, the unearned increment was from two to three times greater than what was needed to meet local city and school expenditures.

Therefore, I conclude that a single tax placed upon the unearned increment from land in Edmond, Oklahoma, would yield a revenue sufficient to meet the expenditure needs of both the city and the school district, with additional revenue available for the county, state, or national needs.

Additional research is needed to determine the extent of unearned income generated in a large city (Oklahoma City), a poor county

(McCurtain), and a rich county (Washington), in order to properly test the potential of a tax on unearned increment from land. With the use of proper statistical methods, it is possible to determine unearned increment for the state. However, this should be a team project and not the efforts of one man. Furthermore, I feel that the whole question of rent as well as economic rent needs investigation in some cases and reinvestigation in others in order to make clear some of the questions which were raised in the early 1900's and never answered. Those questions appear to have been glossed over by time, new interests, and a new methodology that has minimized the problems associated with distribution, value, and ethical and social economics. Of course, as Henry George prophetically pointed out in his criticism of the classical economists, none of whom had gone far enough in their investigation of the economic laws that control man, further investigation would reveal facts which may be contrary to the desires of vested interests.

BIBLIOGRAPHY

Primary Sources

The primary sources of data pertaining to the tax, sale, and value of real estate in Edmond, Oklahoma, were the records of the County Clerk's Office and the County Treasurer's Office, Oklahoma County, Oklahoma.

Enrollment data for Central State College, Edmond, Oklahoma, for selected years from 1898 through 1965 were supplied by the Office of Admissions and Records.

Secondary Sources

Public Documents

Central State College, General Catalog. Edmond, Oklahoma, 1963-66.

Edmond, Oklahoma. Annual Audit Report, City of Edmond, 1941-1965.

Federal Reserve Bulletin. Vol. 52, No. 6, June 1966. Board of Governors of The Federal Reserve System, Washington, D.C.

Oklahoma State Regents for Higher Education, First Biennial Report of the Oklahoma State Regents for Higher Education, Oklahoma City, Oklahoma, 1941-42.

______. Second Biennial Report of the Oklahoma State Regents for Higher Education, Oklahoma City, Oklahoma, 1943-44.

______. Third Biennial Report of the Oklahoma State Regents for Higher Education, Oklahoma City, Oklahoma, 1945-46.

______. Fourth Biennial Report of the Oklahoma State Regents for Higher Education, Oklahoma City, Oklahoma, 1947-48.

______. Fifth Biennial Report of the Oklahoma State Regents for Higher Education, Oklahoma City, Oklahoma, 1949-50.

______. Sixth Biennial Report of the Oklahoma State Regents for Higher Education, Oklahoma City, Oklahoma, 1951-52.

______. Seventh Biennial Report of the Oklahoma State Regents for Higher Education, Oklahoma City, Oklahoma, 1953-54.

______. Eighth Biennial Report of the Oklahoma State Regents for Higher Education, Oklahoma City, Oklahoma, 1955-56.

______. Ninth Biennial Report of the Oklahoma State Regents for Higher Education, Oklahoma City, Oklahoma, 1957-58.

______. Tenth Biennial Report of the Oklahoma State Regents for Higher Education, Oklahoma City, Oklahoma, 1959-60.

______. Eleventh Biennial Report of the Oklahoma State Regents for Higher Education, Oklahoma City, Oklahoma, 1961-62.

______. Twelfth Biennial Report of the Oklahoma State Regents for Higher Education, Oklahoma City, Oklahoma, 1963-64.

______. Thirteenth Biennial Report of the Oklahoma State Regents for Higher Education, Oklahoma City, Oklahoma, 1965-66.

Scofield, William H. "How Do You Put A Value On Land?," Land: The Yearbook of Agriculture, 1958, U.S., Department of Agriculture, Washington: U.S. Government Printing Office, 1958.

The State Board of Education. Annual Financial Reports of Oklahoma School Districts, Vol. V, Oklahoma City, Oklahoma, 1953-1965.

U.S. Bureau of the Census. Thirteenth Census of the United States: 1910. Population, Vol. II.

______. Fourteenth Census of the United States: 1920. Population, Vol. II.

______. Fifteenth Census of the United States: 1930. Population, Vol. II.

______. Sixteenth Census of the United States: 1940. Population, Vol. II.

______. Seventeenth Census of the United States: 1950. Population, Vol. II.

______. Eighteenth Census of the United States: 1960. Characteristics of Population, Vol. II.

U.S., Bureau of The Census, 1948 Census of Business. Retail Trade-Area Statistics. Part 2, Counties; Cities of 2,500 Inhabitants or More--1948. Vol. II.

______. 1954 Census of Business. Retail Trade-Area Statistics. Part 2, Counties; Cities of 2,500 Inhabitants or More--1954. Vol. II.

______. 1958 Census of Business. Retail Trade-Area Statistics. Part 2, Counties; Cities of 2,500 Inhabitants or More--1958. Vol. II.

______. 1963 Census of Business. Retail Trade-Area Statistics. Part 3, Counties; Cities of 2,500 Inhabitants or More: 1963. Vol. II.

U.S., Bureau of The Census. 1948 Census of Business. Selected Service Trade-Area Statistics. Part 2, Selected Services: 1948--Counties; Cities of 2,500 Inhabitants or More. Vol. VI.

______. 1954 Census of Business. Selected Service Trades-Area Statistics. Part 2, Selected Services: 1954 - Counties; Cities of 2,500 Inhabitants or More. Vol. VI.

______. 1958 Census of Business. Selected Services-Area Statistics. Part 2, Selected Services: 1958, Counties; Cities of 2,500 Inhabitants or More. Vol. VI.

______. 1963 Census of Business. Selected Services-Area Statistics. Part 3, Selected Services: 1963, Counties; Cities of 2,500 In habitants or More. Vol. VII.

U.S., Bureau of The Census. Census of Government: 1957. Vol. V.

U.S., Department of Agriculture. Current Developments in the Farm Real Estate Market, May 1957: Changes in Dollar Value of Farmland. (1957).

U.S., Department of Commerce. Bureau of The Census. 1945 Census of Agriculture. Vol. I.

______. Bureau of The Census. 1950 Census of Agriculture. Vol. I.

______. Bureau of The Census. 1959 Census of Agriculture. Vol. I.

______. Bureau of The Census. 1964 Census of Agriculture. Vol. I.

Books

Alonso, William. Location and Land Use: Toward A General Theory of Land Rent. Cambridge, Massachusetts: Harvard University Press, 1964.

Alper, Noah P. The Way Ahead in Jamaica (Pamphlet). Circa. 1960.

Alyea, Paul E. and Blanche R. Fairhope, 1894-1954. Birmingham, Alabama: University of Alabama Press, 1958.

Balsley, Howard L. Introduction to Statistical Methods. Paterson, New Jersey: Littlefield, Adams and Co., 1964.

Barker, Charles Albro. Henry George. New York: Oxford University Press, 1955.

Barlowe, Raleigh. Land Resource Economics. Englewood Cliffs, N.J.: Prentice-Hall, Inc., 1958.

Blaug, Mark. Ricardian Economics: A Historical Study. New Haven: Yale University Press, 1958.

Brown, Harry Gunnison. Basic Principles of Economics and Their Significance for Public Policy. Columbia, Missouri: Lucas Brothers, 1955.

_____., and Others. Land Value Taxation Around the World. New York: Robert Schalkenbach Foundation, 1955.

Buchanan, Daniel H. "The Historical Approach to Rent and Price Theory," Readings in the Theory of Income Distribution. ed. William Fellner and Bernard Haley, Philadelphia: The Blakeston Company, 1951.

Cord, Steven B. Henry George: Dreamer or Realist? Philadelphia: University of Pennsylvania Press, 1965.

Cowan, H. Bronson. Municipal Improvement and Finance: As Affected by the Untaxing of Improvements and the Taxation of Land Values. New York: Harper & Brothers, 1958.

DeMille, Anna George. Henry George, World Citizen. New York: Robert Schalkenbach Foundation, 1944.

Doane, Robert R. The Anatomy of American Wealth. New York: Harper & Brothers, 1940.

Due, John F. Government Finance: Economics of the Public Sector. Homewood, Illinois: Richard D. Irwin, Inc., 1968.

Galbraith, John Kenneth, The Affluent Society. Boston: Houghton-Mifflin Company, 1958.

Geiger, George R. The Philosophy of Henry George. New York: The Macmillan Company, 1933.

George, Henry. "Land and Taxation: A Conversation Between David Dudley Field and Henry George," The Complete Works of Henry George, Our Land and Land Policy, Vol. VIII, Garden City, New York: Doubleday, Page and Company, 1911.

______. Progress and Poverty. New York: Robert Schalkenbach Foundation, 1960.

______. The Science of Political Economy. (1962 Reprint) New York: Robert Schalkenbach Foundation, 1897.

______. The Single Tax: What It Is and Why We Urge It. New York: Robert Schalkenbach Foundation, No date.

George, Jr., Henry. The Life of Henry George. New York: Robert Schalkenbach Foundation, 1960.

Gide, Charles and Rist, Charles. A History of Economic Doctrines. trans. R. Richards. Boston: D.C. Heath and Company, 1913.

Gittinger, Roy. The Formation of the State of Oklahoma. Norman, Oklahoma Press, 1939.

Goldsmith, Raymond W. A Study of Savings in The United States. Princeton, N.J.: Princeton University Press, 1955.

Green, James L. Metropolitan Economic Republics. Athens, Georgia: University of Georgia Press, 1965.

Gwartney, Ted. The Southfield Story: A Lesson in Creative Taxation. Great Britain, Wrexham, Denbigshire: Cambrian Press (Wrexham) Ltd., 1968.

Hill, Luther B. A History of The State of Oklahoma. Chicago: The Lewis Publishing Company, 1908.

Keiper, Joseph S., and Others. Theory and Measurement of Rent. New York: Chilton Company, 1961.

Keller, Edward A. A Study of Physical Assets, Sometimes Called Wealth of The United States, 1922-1933. Notre Dame, Indiana: University of Notre Dame, 1938.

Kuznets, Simon. National Income and Its Composition, 1913-1938. New York: National Bureau of Economics Research, 1941.

______, National Product Since 1869. New York: National Bureau of Economic Research, 1946.

Lawrence, Elwood P. Henry George in the British Isles. East Lansing: The Michigan State University Press, 1957.

Liebhafsky, Herbert H. The Nature of Price Theory. Homewood, Illinois: The Dorsey Press, Inc., 1963.

Meek, Ronald L. The Economics of Physiocracy. Cambridge, Massachusetts: Harvard University Press, 1963.

Neiswanger, William Addison. Elementary Statistical Methods. New York: The Macmillan Company, 1956.

Netzer, Dick. Economics of The Property Tax. Washington, D.C.: The Brookings Institution, 1966.

Parl, Boris. Basic Statistics. Garden City, New York: Doubleday and Company, Inc., 1967.

Ratcliff, Richard U. Real Estate Analysis. New York: McGraw-Hill Book Company, Inc., 1961.

Reisman, David. Thorstein Veblen. New York: Charles Scribner's & Sons, 1953.

Richards, W. B. (compiled by). The Oklahoma Red Book. Vol. II. Oklahoma City, Oklahoma, 1912.

Rock, Marion Tuttle. Illustrated History of Oklahoma. Topeka, Kansas: C. B. Hamilton and Sons, 1890.

Roll, Eric. A History of Economic Thought, 3d ed. Englewood Cliffs, N.J.: Prentice-Hall, Inc., 1957.

Schwartz, Eli. and West, James E. An Analysis of the Potential Effects of a Movement Toward a Land Value Based Property Tax. Albany, New York: Economic Education League, 1958.

Seligman, Edwin R. A. The Shifting and Incidence of Taxation. New York: The Macmillan Company, 1902.

Shirk, George H. Oklahoma Place Names. Norman, Oklahoma: University of Oklahoma Press, 1965.

Smith, Adam. The Wealth of Nations. New York: The Modern Library, 1937.

Stern, Philip M. The Great Treasury Raid. New York: The New American Library, 1965.

Teilhac, Ernest. Pioneers of American Economic Thought in the Nineteenth Century. New York: The Macmillan Company, 1936.

Tucker, Gilbert M. The Self-Supporting City. New York: Robert Schalkenbach Foundation, 1958.

Articles and Periodicals

Berkman, Herman G. "The Game Theory of Land Use Determination," Land Economics, Vol. XLI, No. 1 (February 1965), pp. 11-19.

Chapman, Berlin B. "The Legal Sooners of 1889 in Oklahoma," The Chronicles of Oklahoma, Vol. XXXV, No. 4 (Winter 1957-1958), pp. 405-9.

Dunn, Dominick. "Formula in Appraising," The Residential Appraiser, Vol. XXVII, No. 9 (September 1961), pp. 8,12.

"The 500: A Decade of Growth," Fortune. Vol. LXXIV, No. 2 (July 15, 1966), pp. 213-15, 268-278.

George, Henry. "A Single Tax on Land Values," The Century Magazine, Vol. XL (July 1890), pp. 394-403.

Nyfroten, Norman. "Estimating Cost Consideration in Real Estate Transfers from Internal Revenue Stamps," Journal of Farm Economics, Vol. XXX (August, 1948), pp. 556-61.

Price, L. L. "Some Aspects of The Theory of Rent" Economic Journal, Vol. 1 (March 1891), pp. 122-44.

Tontz, Robert L., Kristensen, Jeppe., and Cobb, Jr., C. Curtis. "Reliability of Deed Samples as an Indication of Land Market Activity," Land Economics, Vol. XXX (February, 1954), pp. 44-51.

Ware, Norman J. "The Physiocrats: A Study in Economic Rationalization," American Economic Review, Vol. XXI, No. 4 (December 1931), pp. 607-619.

White, Philip H. "Some Aspects of The Income Approach," The Residential Appraiser, Vol. XXVI, No. 7 (July 1960), pp. 16-23.

Whitmore, H. "Real Estate Value in Boston," American Statistical Association Journal, Vol. V (March 1896), pp. 1-17.

Unpublished Material

Fordice, Stella Barton. "History of Edmond, Oklahoma." Unpublished Master's thesis, Department of History, University of Oklahoma, 1927.

Other Sources

University of Oklahoma, Norman, Oklahoma. Bureau of Business Research. Personal interview with Director of the Bureau in November, 1965.

70-2297

BUCKE, Jr., David Perry, 1937-
EFFECT OF DIAGENESIS UPON CLAY MINERAL CONTENT OF INTERLAMINATED DESMOINESIAN SANDSTONES AND SHALES IN OKLAHOMA.

The University of Oklahoma, Ph.D., 1969
Geology

University Microfilms, Inc., Ann Arbor, Michigan

THE UNIVERSITY OF OKLAHOMA

GRADUATE COLLEGE

EFFECT OF DIAGENESIS UPON CLAY MINERAL CONTENT OF INTERLAMINATED DESMOINESIAN SANDSTONES AND SHALES IN OKLAHOMA

A DISSERTATION

SUBMITTED TO THE GRADUATE FACULTY

in partial fulfillment of the requirements for the

degree of

DOCTOR OF PHILOSOPHY

BY

DAVID P. BUCKE, JR.

Norman, Oklahoma

1969

EFFECT OF DIAGENESIS UPON CLAY MINERAL CONTENT OF INTERLAMINATED

DESMOINESIAN SANDSTONES AND SHALES IN OKLAHOMA

APPROVED BY

Charles J. Mankin

David B. Kitts

Harvey Blatt

Arthur J. Myers

Stanley C. Rich

DISSERTATION COMMITTEE

ABSTRACT

EFFECT OF DIAGENESIS UPON CLAY MINERAL CONTENT OF INTERLAMINATED DESMOINESIAN SANDSTONES AND SHALES IN OKLAHOMA

Closely interlaminated sandstones and shales from Desmoinesian deltaic strata have been investigated to determine the relative importance of diagenetic and detrital crigin of constituent clay minerals. Close association of the two lithologic types eliminates many parameters which could otherwise have varying effects upon mineral content. Subsurface samples were studied using various x-ray diffraction and x-ray fluorescence techniques in addition to thin-section observation.

Authigenic mineral formation is quantitatively unimportant. Bulk chemical analyses show little variance between sands and shales other than those associated with expected detrital differences. Permeability is the basic factor controlling the amount of diagenesis that occurs.

Consistent differences in relative amounts of chlorite, illite, and kaolinite are present between sands and shales. Illite and chlorite are of detrital origin whereas a significant portion of the kaolinite has been formed diagenetically. Illite is the dominant clay mineral in all shales and most sands investigated, but is relatively more abundant in shales and in finer size fractions of both sands and shales. Chlorite distribution is variable, not being directly related to grain size, because this mineral is present both as clay and in metamorphic rock fragments. Kaolinite is a much more important constituent in sands, a difference attributed to authigenic formation of this mineral in the more permeable sands.

Authigenic kaolinite formation was possible because four coexisting factors were present: organic material to help maintain a low pH through bacterial activity, potassium feldspars as a source of aluminum and silicon, partly degraded illite as an efficient "sink" for potassium released during feldspar decomposition, and water-filled pore space allowing aqueous solution chemistry to proceed and to provide growth space for the kaolinite. The formation of authigenic kaolinite did not require long-distance transport of necessary ions, all ingredients being present in situ.

Additional minerals were formed during diagenesis, especially in the sands. The sequence of formation of these authigenic components being: quartz overgrowths, kaolinite, calcite, dolomite, and finally pyrite-siderite. An additional initial authigenic mineral, "hydrotroilite," is proposed.

ACKNOWLEDGMENTS

The writer expresses his sincere appreciation to Dr. Charles J. Mankin for his guidance throughout this study; to Dr. Harvey Blatt, Dr. David B. Kitts, Dr. Arthur J. Myers, and Dr. Stanley C. Neely who read the manuscript and offered helpful suggestions; to Dr. George C. Huffman and Dr. Clifford A. Merritt with whom valuable discussions were held relative to petrography and regional stratigraphy; and to William H. Bellis and Clayton R. Nichols for assistance in laboratory investigations.

Special thanks are extended to my family for their patience.

Financial assistance was provided by the School of Geology and Geophysics and through an N.D.E.A. Title IV Fellowship.

CONTENTS

ILLUSTRATIONS

EFFECT OF DIAGENESIS UPON CLAY MINERAL CONTENT OF INTERLAMINATED DESMOINESIAN SANDSTONES AND SHALES IN OKLAHOMA

INTRODUCTION

Literature dealing with the clay-mineral content of sediments and rocks is abundant. An unsolved problem frequently discussed is the origin of the clay-mineral suites present in the various lithologies. Most investigators have agreed that both detrital and diagenetic processes are operative, but the problem of which is more effective within a given environment is met with little accord.

Support for Detrital Origin

One of the leading proponents for a dominant detrital or allogenic origin of clay minerals is C. E. Weaver who concludes (1958a, p. 254) ". . . that the great majority of clay minerals in sedimentary rocks are detrital in origin, strongly reflect the character of their source material, and are only slightly modified in their depositional environments." The same writer (Weaver, 1959) gives an excellent review of clay petrology in both modern and ancient sediments, again emphasizing detrital control of the clay minerals. The European literature has been surveyed by Riviere (1953, *in* Weaver, 1959) with the same conclusions being reached. Some Russian investigators have also supported the detrital origin of clays. An example is the conclusion reached by

Yurevich (1961, p. 821) from his studies of the Akchagylian deposits of the Pribalkhan region; "The clear connection that exists between the granulometry of the sediment and the composition of the clay minerals and the tectonic situation . . . enables us to assume that . . . the clay minerals did not undergo any significant changes during the stages of sedimentogenesis and diagenesis."

After study of cores taken from the North Pacific, Griffin and Goldberg (1963, p. 739) conclude ". . . the homogeneous distribution of clay minerals with depth in any given core emphasizes the stability of clay minerals in the marine environment at least over periods of hundreds of thousands of years." Hurley et al. (1959, 1963) found potassium-argon ages of illites from the same area to be on the order of hundreds of millions of years, clearly suggesting a continental source for these clay minerals.

Garrels and Christ (1965, p. 364) suggest on the basis of theoretical studies, ". . . the composition of sea water may be so slightly removed from that required for stability of a great many phases that there is little chemical potential available for equilibration, hence rates of change of unstable species may well be vanishingly low."

The results of many additional investigations are published in which it is clearly demonstrated that the clay-mineral distribution in modern sediments may be explained in terms of source area or segregation of different clay minerals due to size differences and selective flocculation; Biscaye (1964), Griffin (1962), Johns and Grim (1958), Keller (1964), Milne and Earley (1958), Muller (1967), Pryor and Glass (1961), Van Andel and Postma (1954).

Diagenesis Defined

Before citing published evidence for the diagenetic origin of clays, the definition of the term "diagenesis" should be clarified. Gumbel coined the term in 1888 (in Schuchert, 1920, p. 425) and defined it as ". . . the chemical and physical changes that sediments undergo during and after their accumulation, but before consolidation takes place." Recent usage has expanded the definition to include changes taking place after consolidation up to the beginnings of metamorphism, the latter boundary being gradational and therefore controversial. Most current writers approximately follow the definition in the A. G. I. Glossary of Geology and Related Sciences (1960, p. 17 of supplement); "Process involving physical and chemical changes in sediment after deposition that converts it to solid rock, includes compaction, cementation, recrystallization and perhaps replacement as in the development of dolomite." The following writers state some of the varying interpretations of "diagenesis"; Bayly (1968, p. 157), Holmes (1965, p. 92), Krumbein and Sloss (1963, Chap. 7), Mason (1966, p. 248), Pettijohn (1957, p. 648), Read and Watson (1962, p. 255), and Weller (1960, p. 78).

Within the limiting boundaries of depositional and the onset of metamorphism, a number of further subdivisions have been proposed and are discussed in Müller (1967). In the same publication, Müller expands the scope of diagenesis to include preburial physiocochemical processes in both "fresh" water (aquatolysis) and the marine environment (halmyrolysis).

The present writer prefers to limit the definition to the more widely accepted post-deposition usage. An understanding of preburial processes is, of course, important because most of them are continued or reversed after deposition. Of particular significance are ion exchange "reconstitution" and selective flocculation processes which affect clay minerals upon entering a marine environment. For a further discussion of this aspect, the reader is referred to Fairbridge (1967).

Larsen and Chilingar (1967, p. 524) aptly summarize diagenesis as follows:

> Regardless of how the phenomena may be defined or named, diagenetic transformation may be characterized collectively as the reaction of the sediment or sedimentary rock to its physico-chemical environment. The most important factors here are the pH and Eh of the environment, the concentration of various cations and anions, as well as pressure and temperature.

Support for Diagenetic Origin

Illite

The overall evidence suggests illite is present in all geologic periods but is more abundant in older sediments, particularly those older than Upper Mississippian age. Weaver (1959), among others, explains this variance by non-diagenetic mechanisms. However, the dominance of illite in the older Paleozoic shales is so pronounced that many experienced geologists lean toward diagenesis as being their most probable origin. A change of montmorillonite to illite was first proposed in 1941 by Dietz (in Whitehouse and McCarter, 1958). Grim (1953, 1958) agrees that illite may have formed at the expense of other clay minerals. Even Weaver admits, after a study of Late Cretaceous rocks in Wyoming, that montmorillonite gradually changes to illite via mixed-layer montmorillonite-illite with depth until (1961, p. 154) ". . . at a depth approximately 10,000 feet no discreet montmorillonite remains." Others have made similar observations in both recent and older sediments; Burst (1959, 1969), Hurley et al. (1960), Murray and Harrison (1957), and Powers (1959). Grim et al. (1949), based on studies of recent sediments, concluded that little montmorillonite was lost during marine diagenesis but instead illite and possibly chlorite form from kaolinite. However, the same writer (Grim and Johns, 1954) later states that montmorillonite in the Mississippi River Delta possibly does alter to illite and chlorite-kaolinite. More recently Grim reports authigenic illite in Sidney Harbor, Australia (Grim and Loughnan, 1962). These examples can all be explained by a reconstitution mechanism. Müller (1967), who has extensively surveyed the literature, believes it is well documented that degraded three-layer minerals take up potassium to form reconstituted illite, and magnesium to form chlorite and chlorite-like minerals. The formation of glacuonite, a dioctahedral ferric illite, is generally accepted as authigenic, and is probably a true "neogenesis" (as opposed to reconstitution), although there is little agreement about the mechanism of formation. Illite that has almost certainly crystallized directly from solution has been identified from several mid-continent sandstones by Rex (1966).

Kaolinite

Kaolinite of unquestioned authigenic origin was reported as early as 1936 by Tarr and Keller, the clay having crystallized from solution in quartz geodes in the Mississippian Warsaw Shale of Iowa. Keller (1967) cites several similar occurrences from the same area and from southeastern Kansas. Bayliss et al. (1965) report nonhydrothermal dickite from sandstones of the Sidney Basin of Australia. Authigenic kaolinite from deltaic Pennsylvanian sands in southern Illinois has been identified by Potter and Glass (1958). The crystallization of kaolinite from solution has found support in laboratory work with silica and alumina gels by DeKimpe et al. (1961), Murray and Gravenor (1953), and Roy (1954). In a 1963 publication, Fuchtbauer and Goldschmidt conclude that kaolinite commonly forms during shallow burial of argillaceous rocks and is followed below a depth of several hundred meters by a kaolinite-to-chlorite transformation.

Chlorite

Most literature supporting a diagenetic origin for chlorite cites mechanisms involving ion exchange coupled with interlayer brucite precipitation. For instance, Grim and Johns (1954) conclude that detrital calcium-montmorillonite undergoes this process in the Gulf of Mexico, resulting in a montmorillonite--mixed-layer montmorillonite-chlorite--sequence. Powers (1954) cites chlorite of similar origin in the Chesapeake Bay and still more is reported by Pinsak and Murray (1960) in the Gulf of Mexico. Weaver (1959) suggests the sequence volcanic ash--dioctahedral montmorillonite--chlorite. A less severe change is indicated in the work of Murray and Harrison (1957) who found simply an increase in chlorite crystallinity with depth. Biotite as a parent material for chlorite has been reported by Kossouskaya et al. (1965). References to chlorite growing interstitially directly from solution are rare. However, Eckhardt (1958, in Muller, 1967) has found chlorite

chlorite crystals of this type in argillaceous sediments. Blatt (personal communication, 1969) has seen similar chlorite in unmetamorphosed sandstone of the Franciscan Formation (Jurassic) from California. No reports of direct growth of chlorite crystals in the laboratory have been found, although Whitehouse and McCarter (1958) did produce chloritic clay in the laboratory from montmorillonite after a three-year exposure to artificial sea water.

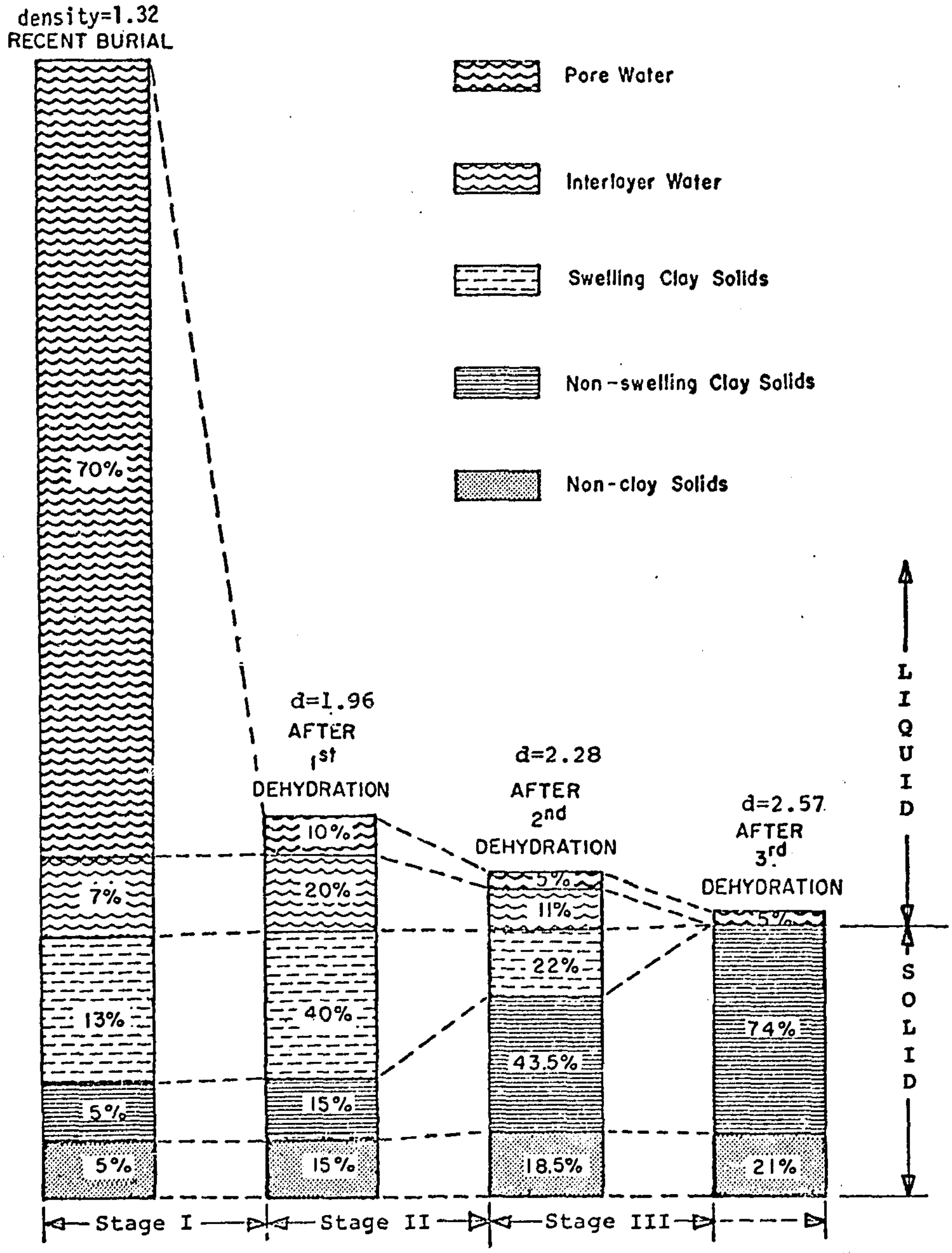
Summary

Referring to clay minerals in general, Keller (1967, p. WK-6) does ". . . not hesitate a bit accepting the geologic occurrence of authigenic clay minerals crystallizing from cold aqueous fresh-water solution." For further discussion, the reader is referred to this same publication in which Keller gives an excellent overview of clay mineral occurrence and modes of genesis.

The present writer believes in any discussion of clay-mineral diagenesis, it should be emphasized that two general types of diagenetic mechanisms are involved. The first, and less drastic, may be termed "exchange diagenesis" during which little, if any, change is undergone by the basic crystal structure. This is markedly different from the second, "structural diagenesis," during which an entirely new tetrahedral-octahedral framework may be created.

Most instances cited in support of diagenesis involve only various ion-exchange and hydration-dehydration mechanisms. Degens (1965, p. 39) states: "It should be emphasized that this [geochemical adjustment to environment of deposition] is mainly on an . . . ion exchange level unaccompanied by marked structural and chemical changes in detrital clay composition." Garrels and Christ (1965) agree that clay minerals are classic examples of solid substances which, when placed with an aqueous solution, show marked tendency to lose certain components while retaining others and gaining still others, all while the basic structure of the original material is preserved.

Many of the "montmorillonite"-to-illite or chlorite alterations are most likely ion-exchange and dehydration phenomena. In 1952, Emery and Rittenberg noted the most important change with depth is water decrease. Burst (1969) presents strong evidence indicating that the numerous reports of montmorillonite altering via mixed-layer montmorillonite-illite phase with depth can be explained by a three-step dehydration mechanism which is largely a function of increasing pressure (overburden) and temperature with depth (see Fig. 1). Stage I involves expulsion of all pore water except a two-layer coordinated water packet between clay sheets, by the action of overburden. Further increase of pressure inhibits the removal of this remaining water. The double interlayer water packet has a higher density than the surrounding pore water, therefore the water tends to expand when expelled into the pores, a process directly opposed by increased overburden pressure. Thus heat energy is needed to assist in the removal of one of the remaining water interlayers in stage II. The final stage III is reached when still additional pressure and heat energy become sufficient to expel the remaining water interlayer. This final stage is slow, even in a geologic sense, probably requiring at least tens of millions of years.



SHALE BULK COMPOSITION DURING DEHYDRATION
(from Burst, 1969, p 81)

Figure 1

Thus a non-expanding illite has been formed from a fully expanding montmorillonite.

Structural diagenesis is also documented, but not nearly as often as the less severe exchange diagenesis. Zen considers physico-chemical relationships among many minerals in sediments and sedimentary rocks stressing the concept of equilibrium among sedimentary mineral assemblages (1959, p. 41); "Existing petrographic evidence is compatible with the hypothesis of equilibrium . . . which carries with it the implication that phase transformations may take place even at near-surface conditions in a reasonably short time. Such transformations include major structural changes of the clay-mineral lattices."

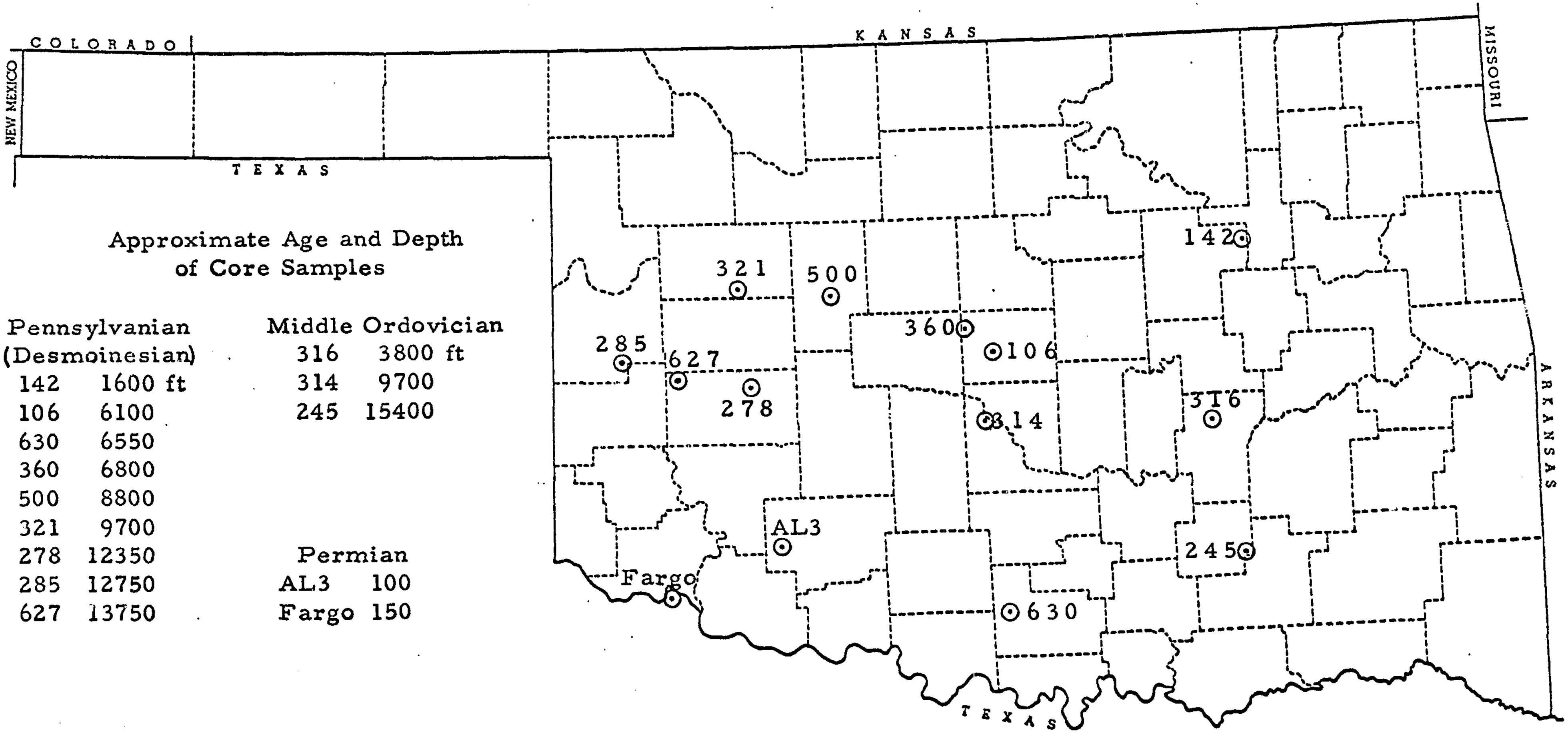
Purpose and Method of Investigation

The present study is designed to provide further definitive information in the attempt to ascertain the relative importance of diagenetic and detrital origin of clays in closely associated shales and sandstones. The two lithologic types in the samples chosen were interlaminated with an individual lamina having a thickness on the order of one or two centimeters and frequently as small as one or two millimeters. By limiting the detailed study to such close associations some parameters which could affect clay-mineral content may be assumed essentially invarient. Among these factors which therefore are not determinants of differences of clay-mineral components in the sands and shales studied are pressure (burial depth), temperature, time, tectonics, source rock, general depositional environment, and major climatic variations.

Some major differences do exist, however, which are possible contributors to differences in clay types present in the two lithologies. Particle size variation is the most obvious and most important difference. This, in turn, is controlled by slight differences in energy of transporting media, particularly at the site of deposition. The sorting of detritus in the depositional environment would cause partitioning of mineral types according to size, shape and specific gravity. For instance, among the clay minerals illite commonly occurs in the finest fraction whereas detrital chlorite and kaolinite tend to be larger. Thus it is to be expected when comparing shales and sands that the former should contain a relatively higher percentage of illite. It is also reasonable to expect a higher percentage of non-clay minerals in the sands, thus contributing to an overall difference in bulk chemistry between the sand and shale.

Other important direct results of size differentiation are differences in porosity and, more important, permeability. Initially porosity is higher in argillaceous sediments, being as much as 80 percent in some cases (Müller, 1967). This is reduced rapidly by overburden pressure to approximately 30 percent at a depth of about 150 feet. Krumbein and Sloss (1963) report that most sandstones have porosities less than 30 percent. Thus, at least at shallow depths, shales contain more interstitial water. Migration of this contained water is more important in promoting changes in chemistry than simple static containment. This permeability is strongly affected by grain size, rocks containing larger particles having larger interparticulate connections and less tortuosity. As a result more fluid migration takes place through sands than shales and sands then have a much greater opportunity to experience intra- and inter-formational transfer of chemical constituents than do shales. On this basis, diagenetic changes are expected to be greater in the coarser sediments.

Samples for study were selected from cores on file at the University of Oklahoma Core and Sample Library in order to eliminate the effect of present-day weathering modifications. The samples were cut from the centers of the cores as a precaution against contamination by drilling fluids and muds. A total of 14 cores from depths of 100 to 15,440 feet and from geographically dispersed locations in Oklahoma (see Fig. 2) were selected for study. From these more than 125 samples were thoroughly examined by various x-ray diffraction techniques, 26 representative thin sections were prepared for detailed petrographic study, and 28 samples were subjected to bulk chemical analysis by x-ray fluorescence. Nine of the cores were from strata of Middle Pennsylvanian (Desmoinesian) age, three from Middle Ordovician rocks, and two from rocks of Permian age. The Desmoinesian samples were subjected to more intensive investigation because they represented the best examples of close shale-sand interlamination. Detailed descriptions of samples and investigation procedures are included in the appropriate appendices.



INDEX MAP OF CORE LOCATIONS

Figure 2

RELATIVE AMOUNTS OF CLAY MINERALS IN SANDS AND SHALES

Procedure

Semiquantitative determinations of amounts of illite, chlorite, and kaolinite were made for 30 shales and 35 sands. The selection of samples studied in this portion of the investigation was governed by the clarity and separation of the (004)-chlorite and (002)-kaolinite peaks at approximately 25° 2θ.

The area under the peak was used as a measure of the intensity of the reflection. This area, in cm^2, was approximated by multiplying the peak height by the peak width at one-half the height. The intensities were then weighted relative to the (001)-kaolinite reflection as suggested by Weaver (1958a) and Murray (1954). When equal amounts of chlorite, illite, and kaolinite are present, their (001)-reflection intensities are 1:1:3, respectively. The intensity of the (001)-kaolinite reflection could not be measured directly due to the superposition of the (002)-chlorite reflection. Therefore the (002)-kaolinite reflection which is about 0.8 as intense as the (001)-kaolinite reflection was measured and adjusted to an (001) equivalence by multiplying by 1.25. The (001) intensities of chlorite and illite were each increased threefold to allow direct comparison among the three clays on each diffractogram.

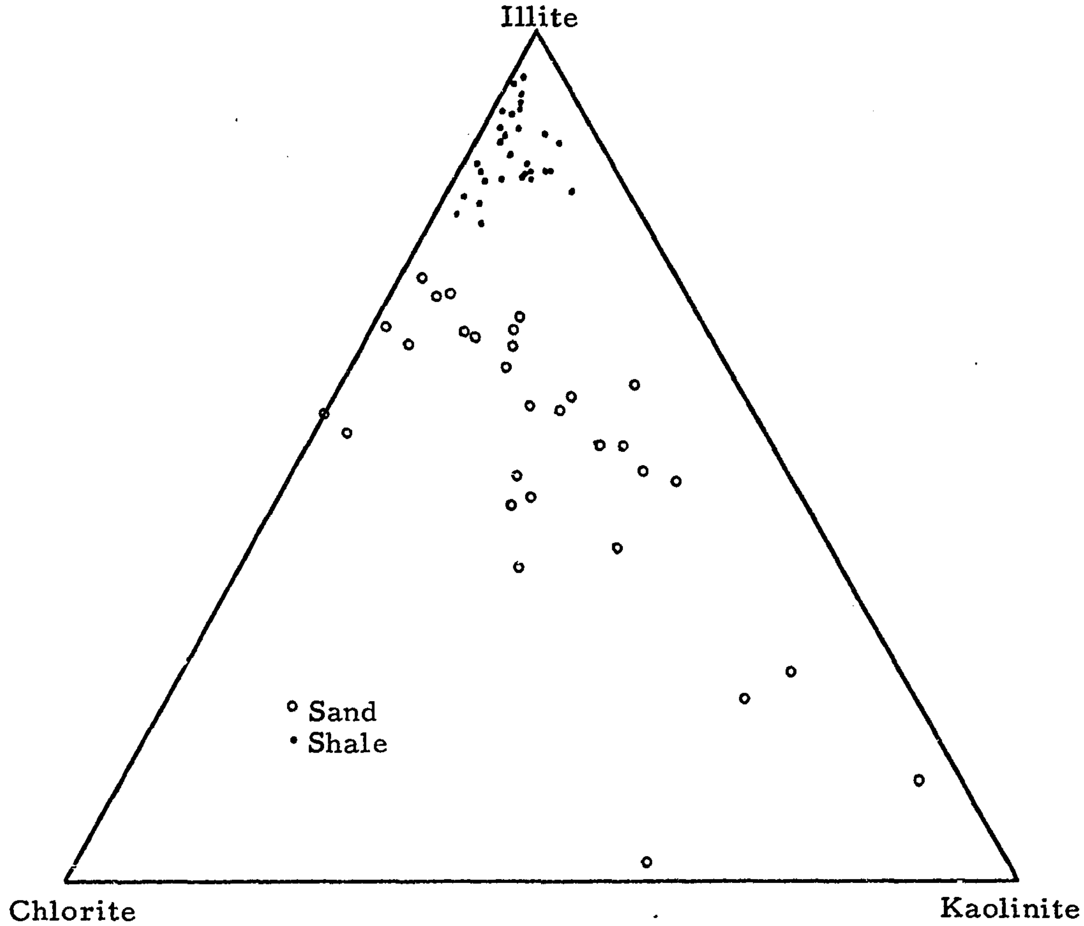
The diffractograms were obtained from both North American Phillips (Norelco) and Siemens-Halske diffraction units at various appropriate scale factors making direct comparisons between diffractograms impossible. An overall comparison was made possible by expressing the amounts of chlorite, illite, and kaolinite as percentages of the total clay fraction in each sample. The results are shown on Fig. 3.

Validity of Semiquantitative Determinations

Sources of Error

Inaccurate measure of actual area. Indistinct peaks were not used. Repeated measurements of the same diffractogram and of subsequent diffractograms of the same sample resulted in close agreement, indicating good precision. The peaks measured closely approximate triangles, any irregularities being smoothed to straight-line averages. Thus the standard mensuration formula for the area of a triangle, $a = \frac{1}{2}bh$, is a valid close approximation. In view of these factors, the measured areas are considered valid.

Inaccurate weighting of measured peak areas. The assumption has been made that the (001)-reflection intensities of chlorite, illite, and kaolinite are 1:1:3, respectively and the intensities of the (002)- and (001)-kaolinite reflections are 0.8:1, respectively. These values are close approximations according to the work of previous investigators (see above). The major objective in this investigation is to determine a semiquantitative comparison between shale clays and sand clays. Because the same procedure has been used in all cases, any consistent differences



RELATIVE CLAY MINERAL CONTENT
OF DESMOINESIAN SANDS AND SHALES
Less Than Four Micron Fraction

Figure 3

are real but not necessarily quantitatively accurate--semiquantitative accuracy is claimed.

Variability of chlorite basal reflection intensities. Intensities of x-ray reflections are related to the atomic scattering factors of ions forming the structure. Ions of similar structure and which are iso-electronic such as Si^{+4}, Al^{+3}, and Mg^{+2} have similar scattering factors. Transition elements of the same period such as Fe, Cr, and Mn also have similar scattering factors, but the factors are about twice that of the first group. In consequence, any substitution of Fe for Mg in the chlorite structure appreciably changes the absolute intensities of the x-ray reflection. In addition, the relative basal intensities are changed (Brindley,1961), as discussed below.

Two important variables to be considered are: (1) the amount of iron in octahedral sites, and (2) the distribution of iron between the "talc" and "brucite" layers. If the iron is equally distributed between the two octahedral locations the intensity of the odd-order reflections is independent of the amount of iron substitution. This is due to the octahedral layer spacing of d(001)/2, resulting in a scattering of waves exactly out of phase for the odd-order reflections, thus making no contribution to these reflections.

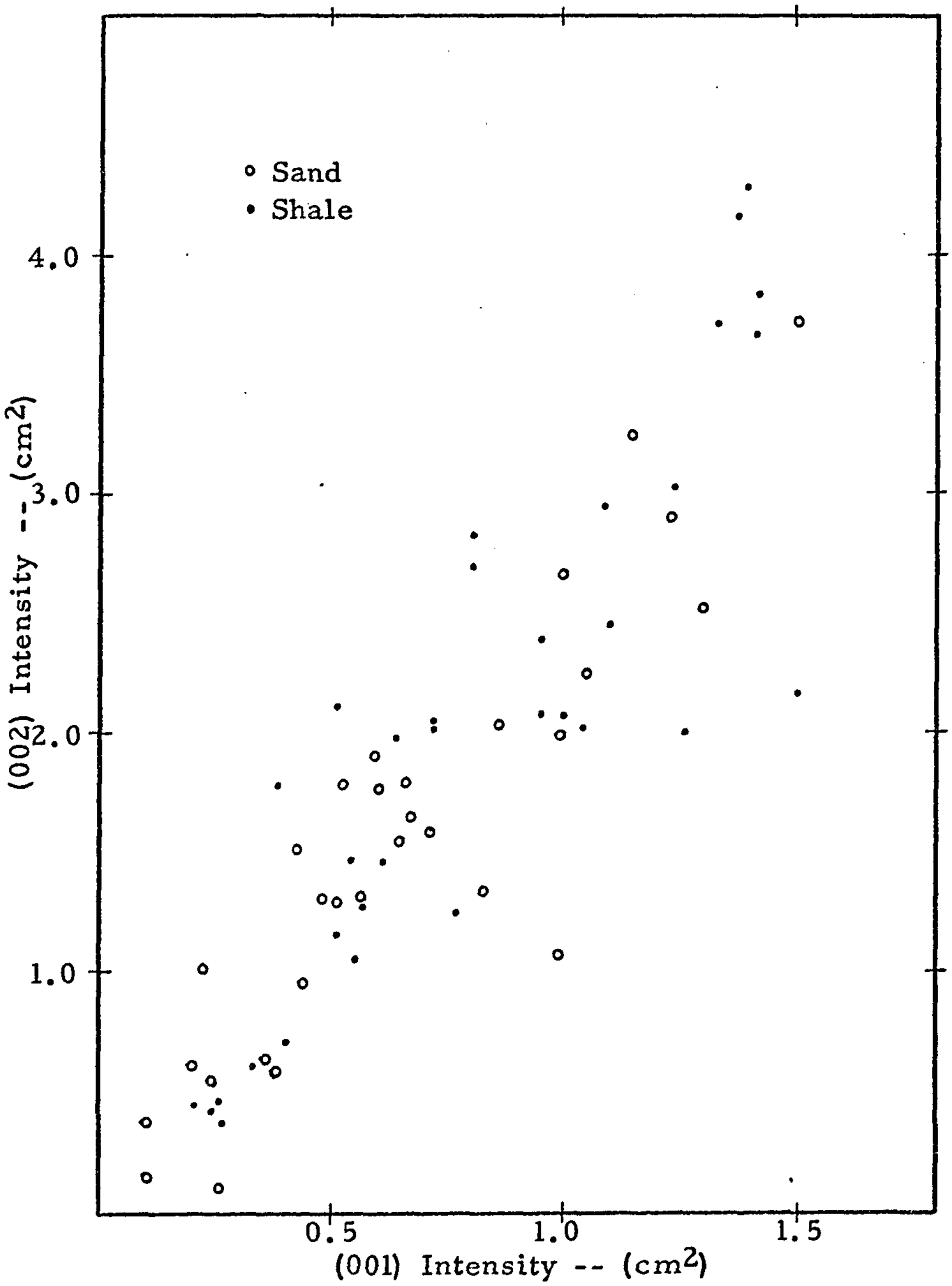
If, however, the iron substitution is not evenly distributed, the result is varying odd-order intensities. For the (001) reflection, the intensity increases (relative to iron-free chlorite) with more iron in the talc layer and decreases with more iron in the brucite layer.

For even-order basal reflections, the two octahedral layers scatter waves that are exactly in phase and therefore the intensity of the (002) reflection is independent of the distribution of iron substitution.

In order to determine if variances in (001) intensities measured in the current investigation are due to varying iron amounts or to actual variations in the amount of chlorite present, a comparison of (002) and (001) intensities was made. If all chlorites are approximately the same, the ratio of these intensities should remain approximately constant in all samples. Figure 4 shows a definite linear trend indicating a constant ratio of (002):(001) intensities thus supporting the validity of assuming variations in (001) intensity are principally due to varying amounts of chlorite. Further support is given by the fact that the variation in iron content of the bulk samples is independent of the (001)-chlorite intensities. From petrographic and x-ray diffraction investigations of the samples, other iron-bearing minerals, notably pyrite, siderite, and various iron oxides, are the iron-determining constituents rather than chlorite.

A problem in determining the (002)-chlorite intensities for the above comparisons was encountered because the (001)-kaolinite reflection is superimposed upon the (002)-chlorite reflection. The following method was devised to surmount this difficulty.

According to Murray (1954), when equal amounts of chlorite and kaolinite are present, the (002)-chlorite intensity is one-half that of the (001)-kaolinite intensity. Thus, with equal amounts of the two clays, one-third of the 7 Å intensity is due to chlorite. For other chlorite-



CHLORITE (002) INTENSITY vs (001) INTENSITY

Figure 4

kaolinite mixtures a proportionate relationship was developed using the following symbolism:

c = portion of 7 Å peak area due to chlorite (002)

k = portion of 7 Å peak area due to kaolinite (001)

T = total area of 7 Å peak

C = actual amount of chlorite

K = actual amount of kaolinite

The relationship is devised by assuming that the variation in (001)-chlorite intensity results only from varying amounts of chlorite. If this is true, the (002)-chlorite intensity, "c", should vary directly with the adjusted (001)-chlorite intensity, "C". If the (001) intensity variation is due to differing amounts of iron, a non-linear plot of (001) vs (002) intensities will result.

The (001) intensity of chlorite is 1/3 as great as the (001) intensity of kaolinite, and the (002) intensity of kaolinite is 0.8 as intense as the (001) intensity of kaolinite:

C = 3 x (001)-chlorite-area

K = 1.25 x (002)-kaolinite-area

The (001)-kaolinite reflection is twice as strong as the (002)-chlorite reflection:

$C \propto 2c$ and $K \propto k$ thus $C/K \propto 2c/k$ or $2c \propto k(C/K)$

If $R = C/K$, then $2c \propto kR$

by definition $k \propto T-c$ and $2c \propto (T-c)R$

thus $c \propto TR/(2+R)$

and finally, since the proportionality factor is constant

$c = TR/2 + R)$.

General Statement

Amounts of illite, chlorite, and kaolinite in Desmoinesian sandstones and shales are compared in Figures 3, 5, 6, and 7. An obvious consistent difference is present between the sands and shales. The shales have a limited range of composition, illite dominating in all cases. Compositional variation is prevalent among sands although illite is still the major constituent in most samples. The percentages plotted are relative to the amount of clay in each sample. As expected, the absolute amount of clay is much higher in the shales than in the sands.

Degraded Clays

The amount of mixed-layer or degraded clay could not be quantitatively measured and is not included in the clay mineral composition as shown in Figures 3, 5, 6, and 7. A semiquantitative estimate of the amount of degraded clay was possible, however, by observing the sharpness of the (001) peaks of illite and chlorite, particularly with respect to the amount of basal broadening of these peaks on the low-angle side as shown on diffractograms of oriented samples. In addition, the amount of shift of this low-angle broadening upon solvation with ethylene glycol was noted. Typical results of this treatment upon a sand-shale pair are illustrated in Appendix C.

Few samples contained appreciable amounts of degraded clays and those that did are not included in the graphical representations. The amount of degraded clay shows a very slight, but inconsistent decrease with depth. The amount of degraded clay varies much more

CLAY MINERAL COMPARISON OF INTERLAMINATED
SAND-SHALE PAIRS
(LESS-THAN-4-MICRON FRACTION)

Figure 5

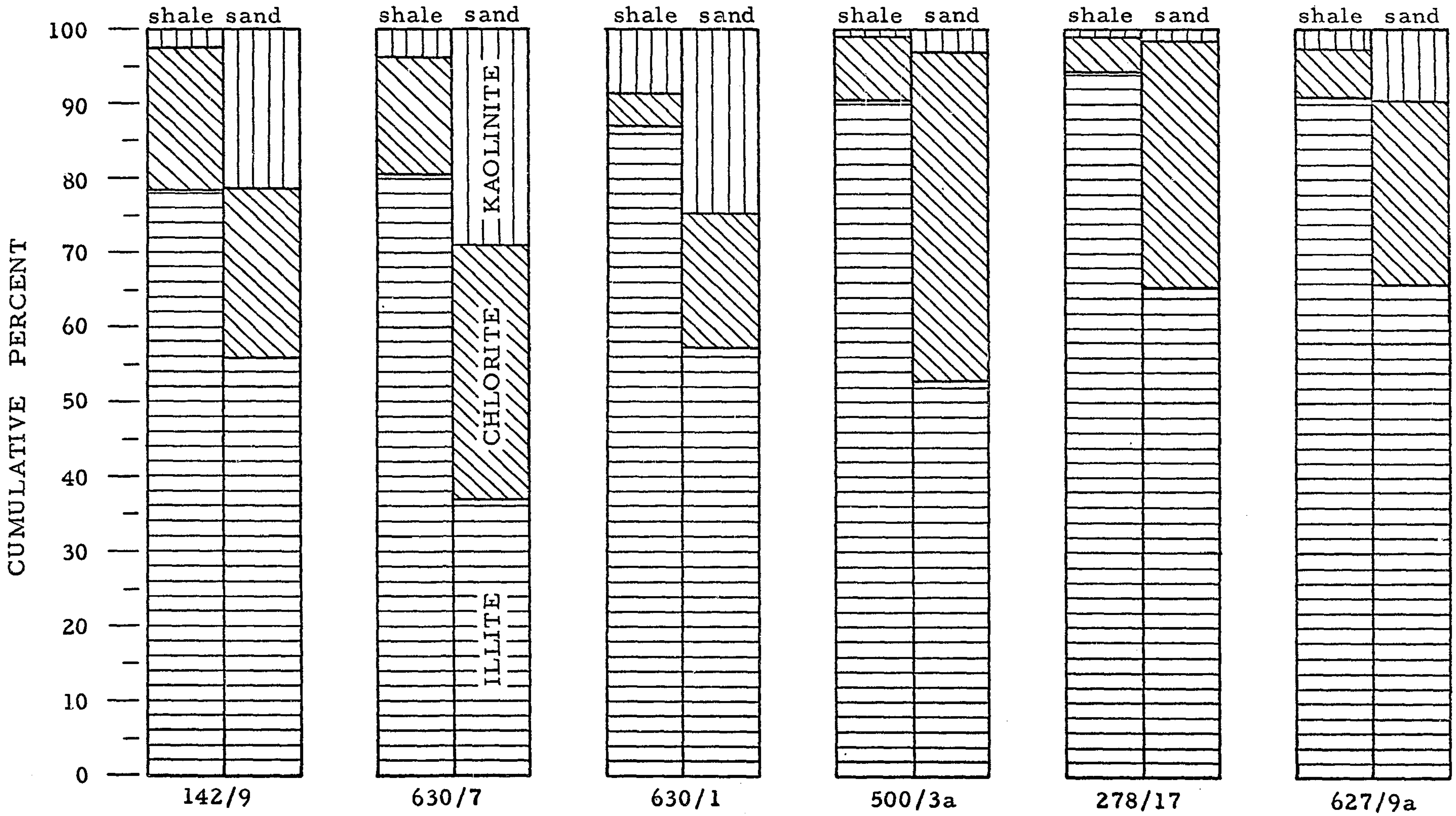


Figure 6

CLAY CONTENT VARIATION WITH SIZE FRACTION

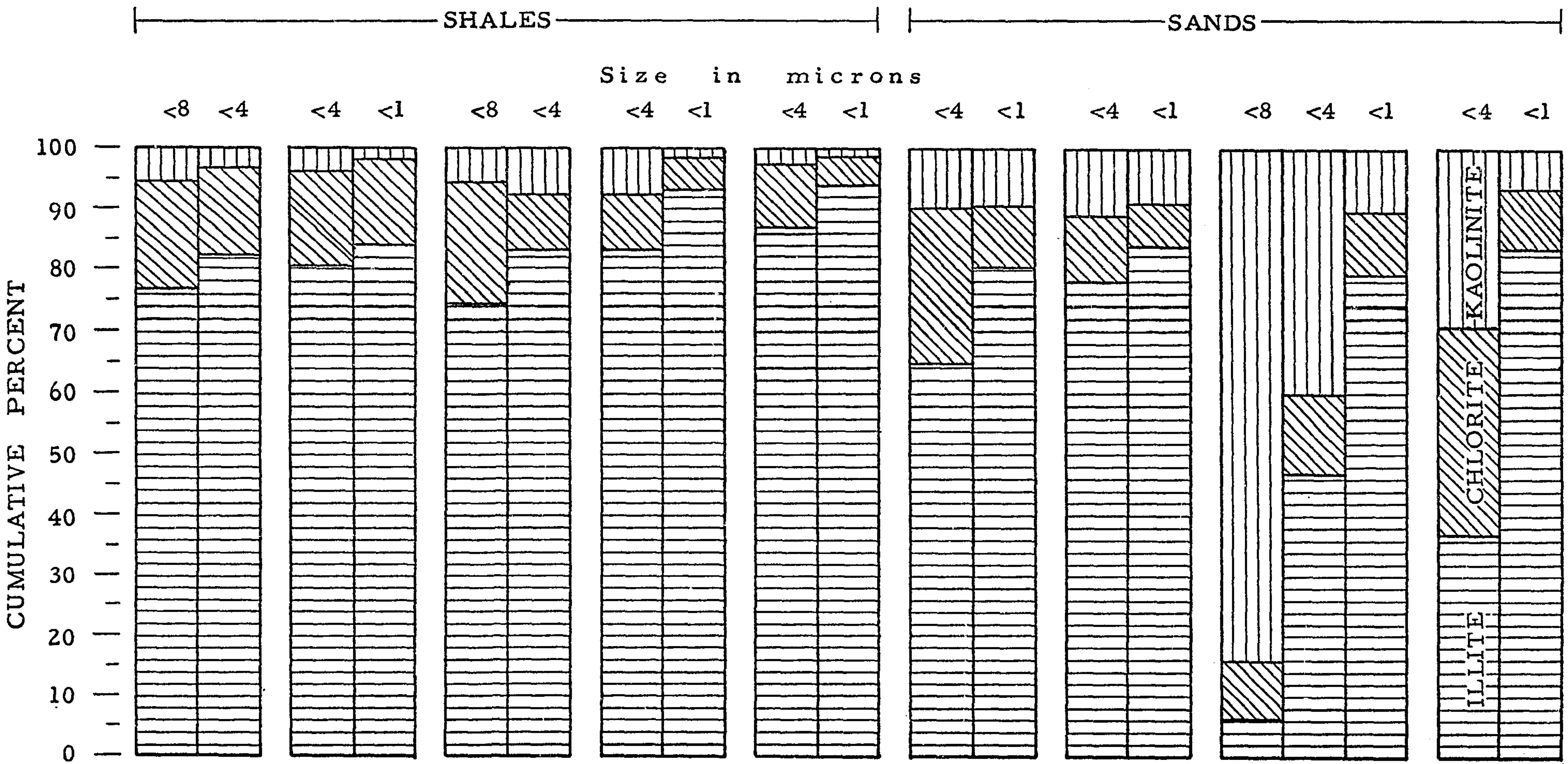
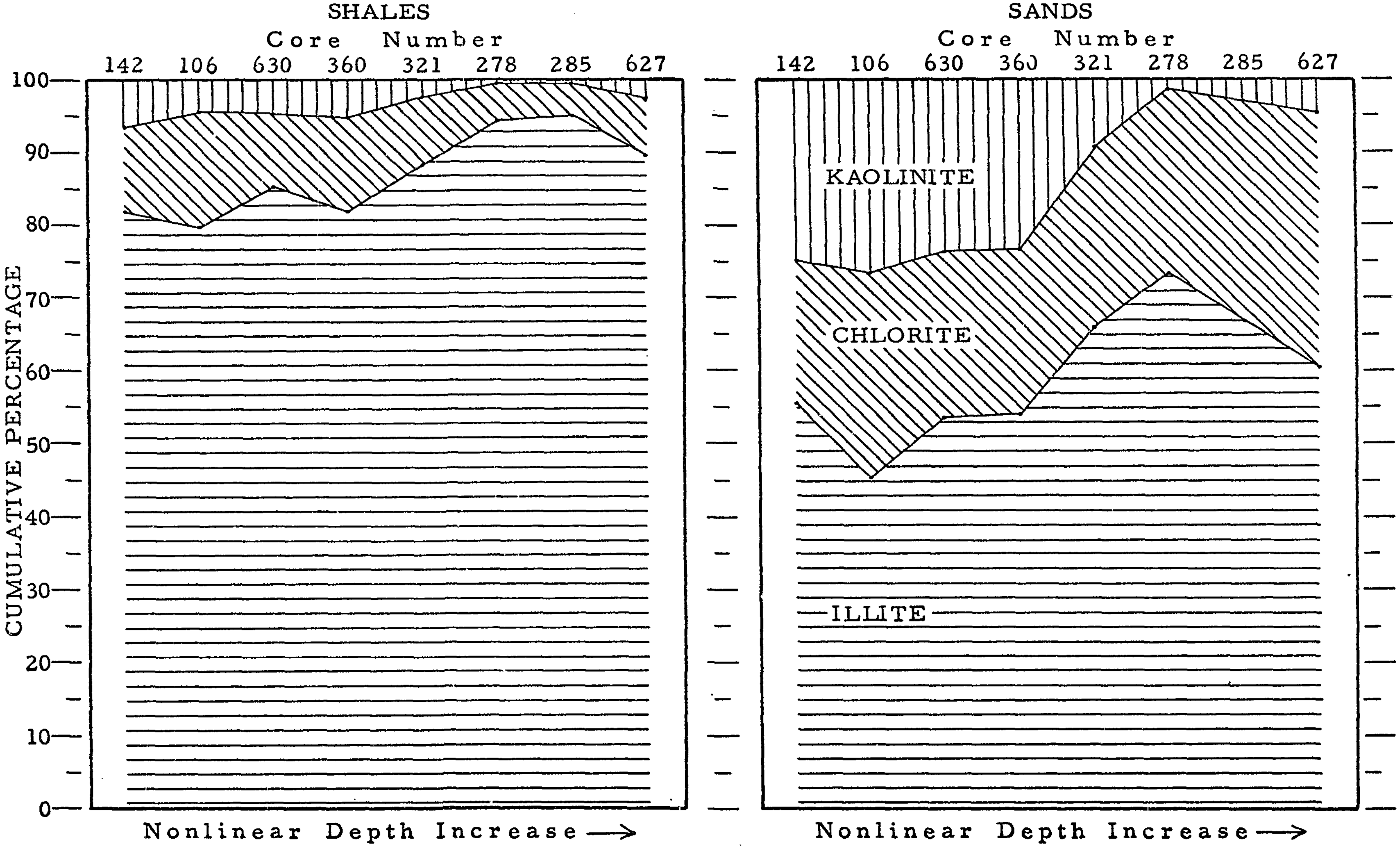


Figure 7

AVERAGE CLAY CONTENT OF DESMOINESIAN CORES



between adjacent sand-shale pairs than between samples taken from different depths. The better crystalline clays are almost invariably associated with sands regardless of the clay mineral in question.

Several inferences can be drawn from these observations. The illite and chlorite were probably brought to the site of deposition in varying states of disrepair imposed by weathering. The great majority of samples studied were deposited in fluvial or deltaic environments and were thus not exposed to high concentrations of dissolved ions. This fresh or brackish water environment severely limited the amount of ion absorption and exchange that took place prior to and during deposition. Those clays deposited as shales or mudstones have been preserved with only minor reconstitution by ion absorption and exchange. Any changes that may have occurred were probably physical changes, notably water expulsion during compaction as described by Burst (1969). Those weathered illites and chlorites deposited in minor amounts along with coarser material were in a post-depositional environment with continued relatively high porosity and permeability even after compaction. These clays had prolonged access to the required ions, notably potassium and magnesium, brought by circulating interstitial water and thereby some weathering effects have been reversed.

Chlorite-Illite

Chlorite and illite are discussed concurrently because they are both interpreted by the writer as being detrital clays. The following evidence is presented in support of this hypothesis.

Illite

As noted above, the clay mineral content of the shales has only limited variability whereas the clay mineral content of the sands shows a relatively broad variation. Although illite is the major constituent in both rock types, it invariably dominates the shale and displays a rather wide variation in relative quantity within the sands. Size fractionation is the most reasonable mechanism controlling this distribution. All samples studied for clay mineral identification were divided into two size groups: less than four microns, and less than one micron. Numerous samples were more extensively fractioned to include sizes from less than eight microns to as fine as less than one-fourth micron. In every case the relative proportion of illite increases with decreasing grain size. Figure 6 illustrates some typical results of this size fractioning. Although relative amounts of clays shown on Figures 5 and 7 are all for less than four micron fractions, there are lesser amounts of illite in the sands than in the finer-grained shales.

The variability of illite amounts in the sands as illustrated in Figure 3 is also related to grain size. The term "sand" is used rather loosely in this investigation and includes mean grain sizes from medium silt through some coarse sand. Most sands are, however, fine to medium. With few exceptions, the coarser sands contain less clay, as expected, but of the clay present, the relative amount of illite becomes less with larger sand size. The general observation that illite tends to be concentrated in finer grain size is not unique, having been noted in previous investigations by this writer and by many other investigators.

Chlorite

The chlorite recorded as clay has been found by thin-section investigation (see Appendix B) to be present both in phyllite rock fragments and as "clay matrix". (The latter is the only form in which illite has been found optically.) This is true particularly in the sand samples because the phyllite fragments constitute part of the sand-size fraction. Figures 6 and 7 show that the major variations in the clay types within the sand samples are accounted for by illite and kaolinite with chlorite variation being relatively small. The illite content varies inversely with increasing sand size as noted above because it is concentrated in the fine clay matrix. The proportion of chlorite remains relatively stable because as the chloritic matrix decreases, the chloritic phyllite increases. The variance in relative amounts of chlorite between sands and shales as shown in Figures 3, 5, and 7 is also largely attributed to the phyllite content of the sands.

Kaolinite

Kaolinite is interpreted as being almost entirely authigenic in origin, probably having formed directly from solution and also by reconstruction diagenesis of some detrital clay material. The major evidence for this comes from thin-section investigations, although x-ray diffraction data supports the idea.

Optically identified kaolinite is always in pore spaces in the form of clusters of granules (see Plate II). The size of the clusters varies and ranges from much smaller to much larger than the average detrital grain size. This observation by itself suggests the clusters are not detrital. The clusters commonly conform to spaces interstitial to sand grains but do not display any elongation parallel to bedding in those samples where alignment of clay, mica, and organic debris is present. In addition, the boundaries of the kaolinite clusters commonly attack adjacent quartz or potassium feldspars which strongly suggests authigenic growth.

As shown in Figures 5, 6, and 7 the sand intervals consistently have a higher relative kaolinite content than do associated shales. Similar findings have been reported by Glass (1958) and Smoot and Narain (1960) from investigations of Pennsylvanian sediments in Illinois which closely resemble those studied in this investigation. This unequal kaolinite distribution has been attributed by them to the higher permeability of the sands allowing post-depositional kaolinite formation. If the kaolinite is authigenic, it is reasonable to expect that interstitial fluids and their ability to migrate should play an important role in its formation. Weaver (1961, p. 153) states in general: "In recent sediments, kaolinite does not appear to be strongly concentrated in sands rather than muds." Thus the conclusion reached by Glass, Smoot and Narain and independently concurred by this writer gains further support. Confirmation that these clusters are in fact kaolinite is offered by the direct correlation between kaolinite amounts seen optically and recorded by x-ray diffraction analysis.

Thus a combination of optical and x-ray diffraction investigations and comparison with recent sediments strongly suggest that most of the kaolinite is authigenic whereas illite and chlorite are detrital in origin. The latter two clays have been subjected only to some "repair work" in the sands rather than true authigenic formation.

PROVINANCE AND DEPOSITIONAL ENVIRONMENT

Most of the sands and shales subjected to detailed study during the present investigation are of Desmoinesian age. This age assignment is based upon information supplied by those who donated the cores to the University of Oklahoma (see Appendix A). Although the accuracy of individual unit name identification is open to some question, the Desmoinesian designation is assumed correct. The samples chosen are all similar in megascopic appearance (see Plate I). This writer concludes all the closely interlaminated sands and shales to have delta-associated origins. Sand-shale intervals of striking similarity are found in modern deltaic environments and in ancient units identified as deltaic. The more thickly bedded Desmoinesian sands and shales which were studied are similar petrographically, in clay mineral content and in diagenetic history to the closely interlaminated samples. It is suggested their genesis was not greatly different from the closely interlaminated sequences.

The Pennsylvanian System in Oklahoma is divided into five series which are, in ascending order; Morrowan, Atokan, Desmoinesian, Missourian, and Virgilian. The reader is referred to Branson (1962), Ham and Wilson (1967), Huffman (1959), Tomlinson and McBee (1962), and Visher (1968) for detailed discussions of the overall Pennsylvanian and Desmoinesian

PLATE I

DESMOINESIAN CORE SAMPLES

All samples were photographed in reflected light and are oriented with tops up. The line above each photograph represents one centimeter. These samples closely resemble modern deltaic sediments. Compare with Potter and Glass, 1967, plates 7 and 8, pages 34a and 34b.

A Sample 142/1, Creek Co., depth 1572 ft., X2.

B Sample 142/10, Creek Co., depth 1611 ft., X1.4.

C Sample 500/3b, Blaine Co., depth 8779 ft., X2.

D Sample 321/14, Dewey Co., depth 9725 ft., X0.9.

E Sample 106/4, Oklahoma Co., depth 6096 ft., X 1.4.

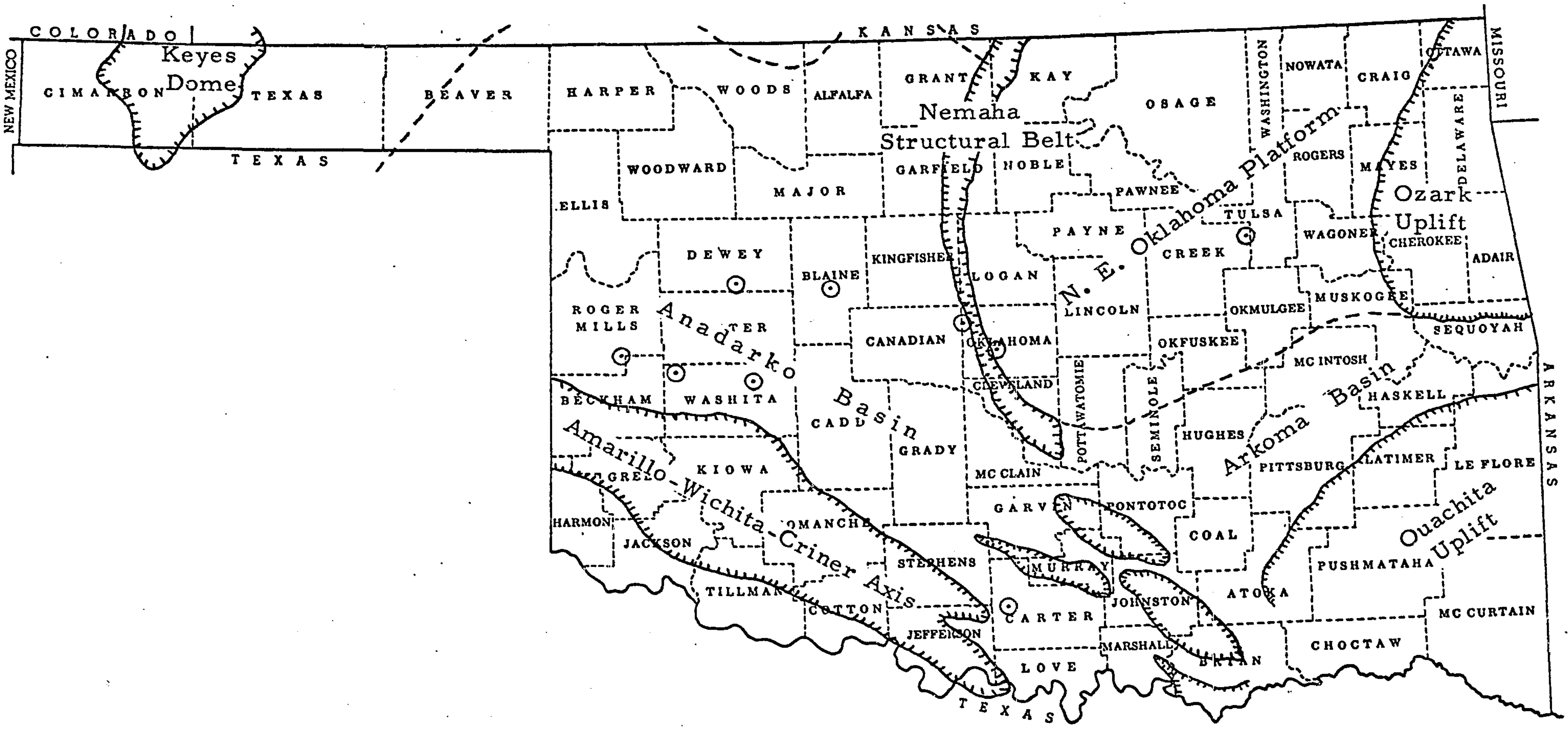
F Sample 360/19, Oklahoma Co., depth 6791 ft., X 1.4.

G Sample 630/2, Carter Co., depth 6548 ft., X 2.

sequence of Oklahoma. Figure 8 is a schematic compilation of various structural elements and emergent areas of Oklahoma during Desmoinesian time. As a general description, the Desmoinesian sea spread northward across an eroded and irregular surface causing sediments to be deposited over strata ranging in age from Precambrian to Atokan. The late Desmoinesian sea subsequently withdrew to the south, a widespread regional disconformity resulting after deposition of the overlying Missourian sequence.

In late Morrowan time southern Oklahoma underwent extensive folding and faulting during the Wichita Orogeny (Huffman, 1959). The Ouachita geosyncline was uplifted as were the Amarillo-Wichita-Criner Hills arch, the Nemaha Ridge, and the Hunton-Tishomingo arch. The principal uplift of the Arbuckle Mountains was post-Missourian but earlier movements are indicated (Huffman, 1959). In addition, the Ozark and Central Kansas uplifts experienced renewed epirogenic elevation (Ham and Wilson, 1967). These and other emergent areas supplied sediments from various directions.

Deltas extended northward into the Anadarko basin from the Wichita Mountain area and westward into the basin from the Nemaha Ridge. The latter area was one of only low relief in Desmoinesian time and thus served as an avenue for transportation of sediments from the north rather than as a primary detrital source in itself (G. G. Huffman, personal communication, 1969). Graphic quartz-K-feldspar intergrowths are present within the cores from the Anadarko basin in Roger Mills, Washita, and Dewey Counties. These "micropegmatites" are identical to those found in the Middle-to-Upper Cambrian Wichita and Lugert granites of the Wichita



MAJOR STRUCTURAL FEATURES AND EMERGENT AREAS
IN EARLY DESMOINESIAN TIME
after Branson (1962), Huffman (1959), Jordan and
Vosburg (1963), and Tomlinson and McBee (1962).

Figure 8

Mountains (C. L. Merritt, personal communication, 1969) supporting a northward deltaic development. Fragments of polycrystalline quartz and phyllite in these same cores probably originated in members of the Late Precambrian or Early Cambrian Tillman Metasedimentary Group. Volcanic rock fragments, probably from the Late Cambrian Carlton Rhyolite, are also common as are limestone and chert fragments which likely came from Cambro-Ordovician Arbuckle carbonates.

It is interesting to note that graphic intergrowths similar to those mentioned above are present in the core from extreme eastern Creek County, across the Nemaha Structural Belt and 150 miles northeast of the Wichita Mountains. A petrographic study of the Spavinaw granite of Mayes and Delaware Counties, by Merritt (1960), has shown the presence of graphic quartz-K-feldspar in this granite also. In addition, during their study of the basement rocks of the continental interior of the United States, Muehlberger, Denison, and Lidiak (1967) state that micrographic granites are common, if not characteristic, of much of the Precambrian basement through northeastern Oklahoma, southeastern Kansas, and southwestern Missouri. However, essentially all of this basement with the exception of portions of the Nemaha Structural Belt and portions of the Ozark Uplift were covered by pre-Desmoinesian sediments, The source of the Creek County Desmoinesian sediments probably lay to the northeast in the nearby Ozark Uplift. Muehlberger et al. (1967) state that abundant metasediments and rhyolites are associated with the Nemaha and Spavinaw granites in the present subsurface thus accounting for the numerous volcanic and metamorphic rock fragments in this core.

Visher (1968) and Busch (1959) both postulate major Desmoinesian deltaic complexes covering the Northeast Oklahoma Platform. The source area for these distributaries lay to the east and northeast in the Ozark Uplift, to the north in the Central Kansas Uplift, and to the west and northwest in the Nemaha Structural Belt. As stated earlier, the Nemaha Structural Belt was of low relief and not a significant sediment source during Desmoinesian time.

Thus the majority of samples studied during the course of this investigation were deposited in Desmoinesian deltaic complexes with varied igneous, metamorphic, and sedimentary sources in the Wichita Mountains and Ozark Uplift providing the bulk of the detritus.

ORIGIN OF DESMOINESIAN AUTHIGENIC COMPONENTS

Through x-ray identification and petrographic relationships, six authigenic minerals have been identified and the presence of a seventh is implied within the Desmoinesian sands and shales. These include "hydrotroilite," quartz overgrowths, kaolinite, calcite, dolomite, pyrite, and siderite. Each of these is discussed in the following paragraphs in the inferred order of their appearance.

"Hydrotroilite"

The presence of amorphous iron sulfide is suggested by several lines of supporting evidence. By x-ray fluorescence analysis it is clear that the weight percent of both iron and sulfur in the average shale is higher than that of the sands (shale average--5.05% Fe, 3.02% S; sand average--2.65%, Fe, 0.66% S). However, both optical and x-ray diffraction investigations indicate essentially no pyrite in the shales, this mineral being confined to the sands, albeit commonly in small amounts.

The pyrite within the sands is definitely authigenic, invariably being in the form of either individual euhedral crystals or clusters of these crystals. Those who have investigated the formation of authigenic pyrite agree that it is secondary, having been derived from initially-formed hydrotroilite, $FeS \cdot nH_2O$ (Berner, 1964; Degens, 1965; Goldschmidt, 1954; Kaplan et al., 1963). The formation of hydrotroilite is favored by an environment with negative Eh, a probable condition during essentially the entire post-depositional history of the Desmoinesian sand-shales sequence. This condition is suggested by the abundant carbonaceous remains, especially within the shales. Within the more permeable sands alteration to pyrite was accomplished probably through loss of iron or possibly by the addition of sulfur. The hydrotroilite trapped within the shales has not had access to percolating water and therefore has been unable to achieve the required iron or sulfur transfer.

The initial formation of hydrotroilite probably occurred early in the diagenetic history of the sediments, possibly concurrently with deposition. The sulfur source may have been dissolved sulfates and/or organic sulfur. In any case the availability of sulfur is directly related to bacterial activity (Degens, 1965). Bacteria also tend to concentrate iron within their systems. The initial iron source, however, was most likely various iron-bearing detrital minerals such as chlorite and biotite.

In summary, it is suggested that during or shortly after deposition iron sulfide, as hydrotroilite, was formed within the sediments, particularly the shales with their greater organic content. Later in the diagenetic history, hydrotroilite was altered to pyrite within the more permeable sands, but has remained in essentially its original state within the confines of the shales.

Quartz Overgrowths

Many investigations of solution-precipitation relations of various silica forms have been conducted theoretically and empirically both in the laboratory and in the field. A few recent references are: Blatt, 1966; Hess, 1966; MacKenzie, 1967; Shcherban, 1967; Siever, 1962; and Swett, 1965.

At 25° C the solubility of amorphous silica is in the range of 100-140 ppm, whereas quartz has a solubility of only 6-14 ppm. The solubility of both forms is independent of Eh and of pH values of less than about 9. Beyond pH = 9.5 the solubility of both quartz and amorphous silica increases sharply reaching about 500 ppm for amorphous silica at approximately pH = 10.5. The same solubility is reached by quartz at about pH = 11.5. Temperature changes also markedly affect silica solubility. Within the temperature range of most diagenesis, 20-200° C, Sievers (1962) using data from numerous investigators finds a solubility increase from 120 to 800 ppm for amorphous silica and from 9 to 270 ppm for quartz.

The silica concentration in soil waters, streams, lakes, and underground waters varies from 5 to 40 ppm with one writer (Livingstone, 1963) suggesting some concentrations as high as 300 ppm. River water commonly is in the interval of 5 to 30 ppm with an overall average value of about 13 ppm. Rivers in tropical areas such as the Amazon have higher averages, those draining temperate areas such as the Mississippi have lower average silica contents. Emery and Rittenberg (1952) have determined a silica concentration of about 40 ppm for pore water.

Early investigators expressed varying opinions concerning the form in which silica is present in water. Although numerous forms are theoretically possible, from colloids to various true solution forms, the consensus now is that the silica is present as a true solution in the form H_4SiO_4 with ionized forms not being significant until pH values exceed 9 or 9.5. The ionization of H_4SiO_4 at these higher pH values allows the sharp increase in silica solubilities noted above.

Shcherban (1967) states that the overall solubility of silica increases markedly in the presence of dissolved NaCl, dissolved carbonates and "some other salts." These observations are disputed by others however (e.g., Dapples, 1959 and Meents et al., 1952). Better agreement is found with respect to the role of dissolved aluminum ions, the amount of silica in solution decreasing in their presence.

Because the amount of silica in most natural solutions is intermediate between the solubilities of quartz and amorphous silica it is apparent that neither of these species controls the amount of dissolved silica. In the fresh water environment silica is probably supplied through chemical weathering of feldspars and other silicate minerals.

It is clear from these data that the general fresh water conditions are those of supersaturation with respect to quartz and undersaturation with respect to amorphous silica. The standard free energy change for the reaction $H_4SiO_{4aq} \longrightarrow 2H_2O + SiO_{2qtz}$ involves a release of 5.1 kcal/mole of quartz produced (free energy values from Krauskopf, 1967) and, therefore quartz should precipitate from average fresh water. The thermodynamic feasibility, of course, does not reflect kinetics nor does it consider intermediate energy barriers that may be present. These factors apparently do affect quartz precipitation and solubility because neither has been accomplished in the laboratory under normal pH and temperature conditions. Nevertheless given time enough, quartz should precipitate from interstitial water, and geologic evidence in the form of commonplace quartz overgrowths shows that it does. Dapples (1959) and Siever (1959) both present evidence suggesting quartz overgrowths are characteristic of early burial, being the first diagenetic precipitate--the latter observation is supported in the present investigation. However, syngenetic quartz overgrowths have never been identified in modern sediments (Blatt, personal communication, 1969) thus the definition of "early" burial is open to question.

Quartz overgrowths are common within the Desmoinesian sands although the volumetric percentage is low. None have been observed on quartz grains within the shale intervals. Thin sections in which a diagenetic sequence can be established show quartz overgrowths to be the first-formed authigenic component. The overgrowths commonly have straight euhedral outlines, apparently having grown into pore spaces. Several thin sections clearly contain overgrowths which were present at least before the present state of compaction was accomplished. Clay matrix and phyllite fragments are bent around the overgrowths and in one instance a detrital chlorite flake has been broken by compaction against the sharp euhedral corners of a quartz overgrowth. The sands, being of the arkose-graywacke type have a minimal number of quartz-quartz contacts and therefore interlocking overgrowths do not form a major portion of the cement.

The conditions present at the time of quartz overgrowth formation include a pH less than 9 and a negative Eh environment perpetuated by abundant organic matter. Most quartz overgrowths occurred before compaction was completed; perhaps the expulsion of pore water from the adjacent shales during compaction provided a continuous replenishment of silica as it was gradually withdrawn by precipitation.

Kaolinite

Evidence has been cited previously (p. 27) supporting the presence of authigenic kaolinite in the Desmoinesian samples studied. Conditions necessary for the formation of kaolinite have been investigated by numerous writers both from geologic occurrences and attempts at laboratory synthesis.

Conditions apparently conducive to kaolinite formation at the surface of the earth are well summarized by Keller (1964). The presence of kaolinite as a weathering product implies: 1) high Al:Si ratio, 2) acid environment, and 3) Na, Ca, K, Mg, Fe absent or "out of circulation." In other words, kaolinite is formed in a climate and terrain where leaching is dominant and low pH conditions prevail, most commonly because of organic activity.

The fact that kaolinite is formed by alteration of aluminum silicates in weathering and diagenetic environments is obvious from geologic relationships, but details of the alteration process(es) remain obscure. Three major paths of formation have been suggested and these are reviewed by Degens (1965). The most basic approach involves interaction between isolated species of monomeric silica and alumina with OH^- and H^+ resulting in the necessary octahedral and tetrahedral units. A second mechanism inserts an intermediate colloidal phase from which crystallization proceeds. The third invokes structural rearrangement of alumina-silica residue left from selective leaching of parent materials such as feldspars.

Attempts to solve the mechanism problem through laboratory experimentation encounter the usual low-temperature geochemistry pitfall--reaction rates are extremely slow under conditions simulating those found in nature. Although low temperature experiments yield disappointing results with respect to growing kaolinite, these attempts do indicate that aluminum and silicon dissolve separately (Krauskopf, 1967) casting doubt upon the third mechanism listed above. At higher temperatures, leaching reactions are relatively easy to attain in the laboratory. However, the extrapolation back to weathering or diagenetic conditions obviously inserts an element of doubt.

Some promising high-temperature and pressure results have been attained. Hemley and Jones (1964, p. 548) have experimentally determined the stability field for kaolinite for the system $K_2O - Al_2O_3 - SiO_2 - H_2O$ at P_{H_2O} = 1000 atmospheres in a temperature range of approximately 259° C to 500° C. Although extrapolation to low temperature and pressure is tenuous, such a projection of the kaolinite stability field places it within ground and surface water that has been in prolonged contact with feldspar-bearing rocks (Krauskopf, 1967). From thermodynamic considerations, Garrels and Christ (1965, p. 361) have determined the kaolinite stability field in the same system at 25° C and 1 atmosphere. Their conclusion is essentially the same, ". . . most ground and stream waters fall into the kaolinite field of stability." Work by Hess (1966) and Feth, Roberson and Polzer (1964, in Hess, 1966) adds still further conformation.

The empirical and theoretical evidence does not solve the mechanism problem but it does support the geologic findings of the present investigation, and those of others, that authigenic kaolinite does form during diagenesis. Petrographic indications (see Plate II) that kaolinite is replacing or attacking quartz suggests that the Desmoinesian kaolinite is probably precipitated from solution.

It is important to note that the ingredients necessary for formation of authigenic kaolinite in the Desmoinesian sands are present in situ. Feldspars, particularly orthoclase, microcline, and perthite are present as a source for aluminum and silicon and additional silicon can be provided by various other silicates. A key for release of aluminum and silicon by orthoclase is the presence of partly degraded illite which acts as a K^+ acceptor. Investigations of the K_2O-Al_2O_3-SiO_2-H_2O system (Hemley and Jones, 1964) show that a low KCl/HCl mole ratio is necessary for kaolinite to form from K-feldspar, otherwise the formation of authigenic illite is favored. The presence of this mechanism is supported by the anomalous presence of plagioclase in essentially unaltered form as opposed to severely deteriorated K-feldspars. This difference is even noted within perthite where the K-feldspar portions are selectively attacked. Apparently the interstitial water was saturated with Na^+ and Ca^{++} preserving the plagioclase feldspars, but K^+ was being removed by reconstitution of partly degraded illite thus promoting the breakdown of K-feldspars. Further support is offered by the fact that the illites within the sands are commonly better crystallized than their counterparts in the adjacent shales.

PLATE II

SELECTED PHOTOMICROGRAPHS

A. Subarkose: Authigenic kaolinite (center) attacking quartz (left), perthite (below), and metamorphic rock fragments (right and lower left); quartz overgrowths; calcite replacing quartz (left edge) and kaolinite (upper center). Thin section 2133, sample 142/18a, depth 1640 ft., Creek Co., Crossed nicols, X 75.

B. Feldspathic Subgraywacke: Authigenic kaolinite (center) replacing quartz; "pressure solution" contacts between quartz grains, some overgrowths; phyllite grain (bottom) distorted by compaction. Thin section 2127, sample 142/1, depth 1537 ft., Creek Co. Crossed nicols, X 75.

C. Subgraywacke: Authigenic kaolinite (center) replacing quartz on three sides, being replaced by calcite (right); quartz overgrowths; metamorphic rock fragments. Thin section 2123, sample 360/17, depth 6787 ft., Oklahoma Co. Crossed nicols, X 75.

D. Argillaceous Subarkose: Fresh plagioclase (center) attacked by calcite; limestone fragment (top); quartz overgrowths (upper right); composite quartz (lower center); siderite grains throughout. Thin section 2341, sample 285/104, depth 12754 ft., Roger Mills Co. Crossed nicols, X 75.

E. Feldspathic Subgraywacke: "Diapiric" intrusion of silt into shale lamina. Thin section 2342, sample 500/3b, depth 8779 ft., Blaine Co., Open nicols, X 15.

F. Arkose: Quartz overgrowth (top center); several varieties of graphic intergrowths of quartz and feldspar. Thin section 2343, sample 278/19, depth 12349 ft., Washita Co. Crossed nicols, X 75.

In summary, the formation of authigenic kaolinite in the Desmoinesian sands was possible by the interplay of four major factors;

1) porosity and permeability allowing migration of interstitial water,
2) presence of K-feldspars as a source of Al and Si,
3) presence of partly degraded illite as a K^+ acceptor,
4) presence of organic material to maintain a low pH.

Authigenic kaolinite is not present in Desmoinesian shales because factors 1 and 2 are severely limited.

Authigenic kaolinite is not present in the Ordovician orthoquartzites investigated because factors 2 and 4 are absent.

Authigenic kaolinite is not present in the Permian "granite wash" investigated because factors 3 and 4 are absent.

Calcite and Dolomite

Calcite and, to a lesser extent, dolomite have been introduced in varying amounts as authigenic cement. In all instances where the diagenetic sequence could be determined, the carbonate cement definitely postdates quartz overgrowths and authigenic kaolinite. This diagenetic order is commonly reported in the literature: Dapples, 1959; Krauskopf, 1964; Potter and Glass, 1958; Siever, 1959; Sujkowski, 1958; and Von Englehardt, 1967. In the Desmoinesian sands of the present study the carbonate cement is rarely present as a passive pore filling, rather it is replacing all detrital grains to varying extents and also is replacing authigenic kaolinite.

The conditions and mechanisms necessary for precipitation of calcite in this environment are frequently discussed but as yet no firm answers are available. Of course, a single answer cannot be found for all sediments due to to the wide variety of parameters involved. However, some general lines of evidence are being uncovered. The precipitation of calcite cement in the pores of sandstone depends largely upon increasing the $[Ca^{++}][CO_3^{=}]$ product in interstitial waters. The most obvious way to accomplish this is to raise the pH of the environment. The common antipathetic relationship between quartz and calcite has been attributed by Correns (1950) to the inverse relationship of their solubulities with increasing pH. As stated earlier, the solubility of quartz is virtually independent of pH for values less than about 9. Although values this high have been shown theoretically possible and have been produced in the laboratory under diagenetic conditions (Garrels, 1960; Krauskopf, 1967), the circumstances necessary are rather unique. Siever (1962), among others therefore suggests that temperature increase with depth likely plays a more important role in the precipitation of calcite and concurrent dissolution of silica. Miller (1962) has demonstrated the decrease in calcite solubility with increasing temperature in a closed system with constant P_{CO_2}. Similar results should occur in an open system because increasing temperature decreases the solubility of CO_2 thereby encouraging calcite precipitation.

Increasing temperature with increasing depth is accompanied by increasing pressure. Higher pressure favors dissolution of both quartz and calcite, but Degens (1965) indicates the solubilities of the two increase at about the same rate and effects of temperature increase overshadow those of pressure increase.

The temperature effect lessens the amount of pH variation needed but does not eliminate the necessity of some pH increase. The change in conditions from at least weakly acid during early diagenesis to basic during carbonate precipitation must still be accounted for. A simple answer is to call on percolating waters to come from lower temperature environments and precipitate the carbonate cement in the sands in question. These solutions could themselves bring a pH rise. An essentially in situ mechanism could also be operative. Natural chromatography has been demonstrated by Bredehoeft et al. (1963), Chave (1960), and Nagy (1960) to effectively increase the ion concentration in the sands. The interlaminated shales act as physical and chemical filters allowing water molecules to pass through but stopping most dissolved ions at the sand-shale interface. Von Englehardt and Giada (1963) have demonstrated that an additional mechanism is operative between interlaminated sands and shales. As water is mechanically squeezed from the shales, the solution left behind in the shales is less concentrated than that expelled into the sands. Thus the passage of water both into and out of sands tends to increase the ion concentration in the sands.

Any or all of these processes could have played a role in the development of the calcite cement in the Desmoinesian sands. There is a general, although inconsistent, tendency for the sands from greater depths to contain more calcite suggesting that the temperature effect may have played a significant role. In any case it is clear that the precipitation of calcite followed the formation of kaolinite and thus at least a minor effective increase in pH occurred.

Dolomite precipitation requires conditions similar to those needed for calcite precipitation, and as with calcium ions, magnesium ions are probably present in adequate supply for dolomite formation (Blatt, 1966). However the highly ordered placement of calcium and magnesium ions within the dolomite structure causes a lower nucleation rate than that of calcite. Although it is not petrographically clear that calcite precipitation preceded that of dolomite in the Desmoinesian sands, this order is probable.

Pyrite and Siderite

The latest diagenetic products, as shown by petrographic relationships, are pyrite and siderite. Most authors who discuss the diagenetic formation of pyrite agree that the initial form is hydrotroilite, $FeS \cdot nH_2O$. Alteration of hydrotroilite to FeS_2 can lead to either of the dimorphs, pyrite or marcasite, depending to a major extent upon the pH of the environment (Degens, 1965), pyrite formation being favored by alkaline and marcasite by acid environments. In order to accomplish this change there must be a relative enrichment in sulfur. This can be accomplished either by loss of iron or gain of sulfur, both mechanisms having been suggested. Kaplan et al. (1963) suggests addition of sulfur whereas Goldschmidt (1954) supports the loss of iron.

The writer suggests the following sequence for pyrite formation in Desmoinesian samples. Early in the diagenetic history, perhaps concurrent with deposition, hydrotroilite was formed. Bacterial decay of organic matter was the major sulfur source while iron came from iron-bearing detrital minerals. The hydrotroilite remained in this form until conditions developed favoring the precipitation of calcite cement. These alkaline conditions favored the formation of pyrite rather than marcasite and allowed removal of iron which subsequently was incorporated with carbonate to form siderite.

Evidence supporting this sequence of events includes the close association of calcite, siderite, and pyrite, the pyrite being preferentially associated with organic debris. Lesser amounts of either calcite or organic remains corresponds with less pyrite, and pyrite is never found without associated siderite. The pyrite is present almost exclusively within the sands indicating the presence of interstitial water played an important role in its formation. The dark color invariably associated with the shales may be due in part to remaining hydrotroilite. From thermodynamic considerations, the formation of pyrite and siderite from hydrotroilite and dissolved carbonate is favored by a standard free energy release of 49.8 kcal for the reaction:

$FeS + CO_3^{=} \longrightarrow FeS_2 + FeCO_3$ (Standard free energy values from Krauskopf, 1967).

Formation of quartz overgrowths and authigenic kaolinite is seen petrographically to have preceded calcite introduction and siderite postdates calcite. Early diagenetic conditions were acid, kaolinite having an abrasion pH of 5 to 7 (Degens, 1965). If transformation of hydrotroilite were to have occurred during this phase of diagenesis, marcasite would have formed. None has been identified optically nor through x-ray investigation and the pyrite is invariably euhedral, commonly as octahedra or cubes with no indication of pseudomorphic replacement of orthohombic marcasite. Thus an overall trend toward higher pH conditions during diagenesis is suggested.

CHEMICAL ANALYSES

Twenty-eight samples were chemically analyzed by x-ray fluorescence. Of these, five were from Permian strata, three from Ordovician strata, and the remaining twenty were from ten sand-shale pairs from Desmoinesian strata. The analyses of nine samples have been rejected because of questionable total percentages. Most of these rejected analyses indicated unusually high amounts of carbonate (calcite, dolomite, siderite) and/or high amounts of sulfur. The totals for these samples were well over 100 percent due to an appreciable difference in matrix effect between the samples and the standards used causing less fluorescence radiation to be absorbed in these samples than in the standards.

Because monomineralic separations were impossible, analyses were necessarily made of bulk sand and shale samples resulting in data of limited value to the present study. Several items of interest can nevertheless be extracted.

Expected differences between the sands and shales are evident. The average SiO_2 content of the sands is higher than that of the shales (73.35% vs 55.50%) reflecting the higher quartz content of the sands. Average Al_2O_3, MgO, and K_2O amounts are higher in the shales because of more clay in these samples (Al_2O_3, 21.13% vs 9.42%; MgO, 2.65% vs 1.57%; K_2O, 4.06% vs 1.32%). The higher weight loss by the shales upon ignition

(7.20% vs 3.88%) is attributable to their same higher clay content and the concomitant combined water.

Other differences in average composition occur in FeO, TiO_2 and S, all of which are present in more abundance within the shales (FeO, 6.67% vs 3.98%; TiO_2, 1.19% vs 0.68%; S, 1.53% vs 0.26%). These differences, particularly in iron and titanium, probably indicate a higher percentage of heavy minerals within the shales. The relative scarcity of these minerals in the sands may be a function of higher porosity and permeability in the coarser sediments allowing them to be selectively leached from the sands. The higher sulfur content of the shales is accounted for, at least in part, by their higher organic content. Higher CaO within the sands (3.89% vs 1.07%) is almost certainly due to the selective introduction of calcite cement into the more permeable sands.

In general, the lack of major unexpected differences in bulk chemical composition between the Desmoinesian sands and shales supports the hypothesis that authigenic mineral formation is quantitatively unimportant.

Refer to Appendix C for tabulation of analyses and procedural details.

CONCLUSIONS

Diagenesis, especially with reference to clay minerals, should be viewed at two levels of "intensity." The first involves a relatively simple rebuilding or reconstitution process by ion exchange, the basic structural framework of the mineral remaining intact. The presence of this process within the Desmoinesian samples is evident on x-ray diffraction patterns. Comparison of the amount of degraded character of illite and chlorite in sand-shale pairs almost always shows better crystallinity in the sands and never better crystallinity in the shales. The reasonable conclusion is the clays in the shales more nearly represent the condition of the clays as they were supplied to the depositional site, whereas those in the sands have undergone more reconstitution diagenesis.

True authigenic mineral formation is quantitatively unimportant with the possible exception in a few instances of abundant carbonate cements in sands. Chemical analyses show little compositional variance between sands and shales other than those associated with expected detrital differences.

Permeability and porosity are the basic factors controlling the amount of diagenesis that occurs. Coarser-grained sediments naturally have more water-filled pore space after compaction allowing the aqueous chemistry of diagenesis to proceed. Authigenic mineralization such as quartz overgrowths, kaolinite clusters, and pyrite crystals are present in sands up to the shale-sand interface, but apparently are essentially absent in the shales.

The distribution of illite, chlorite, and kaolinite between the Desmoinesian sand-shale pairs is a function of several factors. Illite is the dominant clay in all shales and most sands reflecting the mineralogy of the source area, however it is relatively more abundant in the shales and in the finer size fractions of both sands and shales. Thus, its distribution is controlled by fine grain size. Chlorite distribution is variable, not being directly related to grain size, because this mineral is present both as clay and in the silt-sand-size fraction as metamorphic rock fragments. Kaolinite is a much more important constituent in the sands for diagenetic reasons listed below and is present in decreasing amounts in finer size fractions because of the large (for clay) size of the authigenic kaolinite crystals and aggregates.

Authigenic kaolinite formation was possible because four coexisting factors were present: organic material to help maintain a low pH through bacterial activity, potassium feldspars as a source of aluminum and silicon, partly degraded illite as an efficient "sink" for potassium released during feldspar decomposition, and water-filled pore space allowing aqueous solution chemistry to proceed and to provide growth space for the kaolinite. Authigenic kaolinite is absent or nearly so in Desmoinesian shales, Ordovician orthoquartzites, and Permian shales and arkoses because one or more of these four factors was absent. The formation of authigenic kaolinite in the Desmoinesian sands did not require long-distance transport of necessary ions, all ingredients being present in situ.

The sequence of authigenic mineral formation as observed in thin section is: quartz overgrowths, kaolinite, calcite, dolomite, and finally pyrite-siderite. An additional initial authigenic mineral, "hydrotroilite," is proposed.

Negative Eh conditions, at least in the macroenvironment, were present throughout the diagenetic history as attested by abundant carbonaceous organic remains. There was a general trend toward a higher effective pH as diagenesis progressed. The actual change in pH may have been minor because increasing temperature (increasing burial depth) has much the same effect on solubilities, especially of quartz and calcite, as an increase in pH.

SELECTED REFERENCES

Alexander, G.B., Heston, W.M., and Iler, R.K., 1954, The solubility of amorphous silica in water: Jour. Phys. Chemistry, v 58, p 453-455.

Bailey, S.W., 1963, Polymorphism of the kaolin minerals: Amer. Mineralogist, v 48, p 1196-1209.

Bass, A.W., Leatherock, C., Dillard, W.R., and Kennedy, L.E., 1937, Origin and distribution of Bartlesville and Burbank shoestring oil sands in parts of Oklahoma and Kansas: Amer. Assoc. Petroleum Geologists Bull., v 21, p 30-66.

Bates, T.F., 1960, Rock weathering and clay formation in Hawaii: Mineral Industries, Penna. State Univ., v 29, n 8, p 1.

________ 1962, Halloysite and gibbsite formation in Hawaii: Clays and Clay Minerals, v 9, p 315-328, New York, Pergamon Press.

Bayliss, P., Loughnan, F.C., and Standard, J.C., 1965, Dickite in the Hawkesbury Sandstone of the Sydney basin, Australia: Amer. Mineralogist, v 50, p 418-426.

Bayly, Brian, 1968, Introduction to petrology: Englewood Cliffs, New Jersey, Prentice-Hall, Inc., 371 p.

Beavers, A.H., and Marshall, C.E., 1951, The cataphoresis of clay minerals and factors affecting their separation: Soil Sciences Soc. Amer. Proc., v 15, p 142-145.

Berner, R.A., 1964, Iron sulfides formed from aqueous solution at low temperatures and atmospheric pressure: Jour. Geology, v 72, p 293-306.

Biscaye, P.E., 1964a, Mineralogy and sedimentation of the deep sea sediment fine fraction in the Atlantic Ocean and adjacent seas and oceans: Yale Univ., Dept. Geol., Geochem. Tech. Rep. 8, 86 p.

________ 1964b, Distinction between kaolinite and chlorite in recent sediments by x-ray diffraction: Amer. Mineralogist, v 49, p 1281-1289.

Blatt, Harvey, 1966, Diagenesis of sandstones: processes and problems, in Symposium on recently developed geologic principles and sedimentation of the Permo-Pennsylvanian of the Rocky Mountains: 12th Ann. Conf., Wyo. Geol. Assoc., p 63-65o.

Branson, C.C., 1962, Pennsylvanian System of the Mid-Continent, in Pennsylvanian System in the United States: Amer. Assoc. Petroleum Geologists Symposium, p 431-460.

Bredehoeft, J.D., Blyth, C.R., White, W.A., and Maxey, G.B., 1963, Possible mechanism for concentration of brines in subsurface formations: Amer. Assoc. Petroleum Geologists Bull., v 47, p 257-269.

Brindley, G.W., 1961, Chlorite minerals, in The x-ray identification and crystal structures of clay minerals (ed. Brown, G.): Mineralog. Soc., London, p 242-296.

Brindley, G.W., and Gillery, F.H., 1956, X-ray identification of chlorite species: Amer. Mineralogist, v 41, p 169-186.

Brindley, G.W., Santos, P., and Souza, H., 1963, Mineralogical studies of kaolinite-halloysite clays: Part I. Identification problems: Amer. Mineralogist, v 48, p 897-910.

Brown, George, ed., 1961, The x-ray identification and crystal structures of clay minerals: London, Mineralog. Soc., 544 p.

Burst, J.F., 1959, Postdiagenetic clay mineral environmental relationships in the Gulf Coast Eocene: Clays and Clay Minerals, v 6, p 327-341, New York, Pergamon Press.

________ 1969, Diagenesis of Gulf Coast clayey sediments and its possible relation to petroleum migration: Amer. Assoc. Petroleum Geologists Bull., v 53, p 73-93.

Busch, D.A., 1959, Prospecting for stratigraphic traps: Amer. Assoc. Petroleum Geologists Bull., v 43, p 2829-2843.

Chave, K.E., 1960, Evidence on history of sea water from chemistry of deeper subsurface waters of ancient basins: Amer. Assoc. Petroleum Geologists Bull., v 44, p 357-370.

Clark, F.W., 1924, The data of geochemistry: U.S. Geol. Survey Bull. 770.

Coleman, J.M., and Gagliano, S.M., 1965, Sedimentary structures: Mississippi River deltaic plain, in Primary sedimentary structures and their hydrodynamic interpretation: Soc. Econ. Paleontologists Spec. Pub. 12, p 133-148.

Correns, C.W., 1950, On the geochemistry of diagenesis, I. The behavior of $CaCO_3$ and SiO_2: Geochim. et Cosmochim. Acta, v 1, p 49-54.

________ 1963, Experiments on the decomposition of silicates and discussion of chemical weathering: Clays and Clay Minerals, v 10, p 443-459, New York, Pergamon Press.

Dapples, E.C., 1959, The behavior of silica in diagenesis, in Silica in sediments: Soc. Econ. Paleontologists and Mineralogists Spec. Pub. 7, p 36-54.

________ 1962, Stages of diagenesis in the development of sandstones: Geol. Soc. America Bull., v 73, p 913-934.

________ 1967, Diagenesis of sandstones, in Diagenesis in sediments: p 91-125, Amsterdam, Elsevier.

Degens, E.T., 1965, Geochemistry of sediments: Englewood Cliffs, N. J., Prentice-Hall, Inc., 342 p.

DeKimpe, C., Gastuche, M.C., and Brindley, S.W., 1961, Ionic coordination in alumino-silicic gels in relation to clay mineral formation: Amer. Mineralogist, v 46, p 1370-1382.

________ 1964, Low temperature synthesis of kaolin minerals: Amer. Mineralogist, v 49, p 1-16.

Eggleton, R.A., and Bailey, S.W., 1967, Structural aspects of dioctahedral chlorite: Amer. Mineralogist, v 52, p 673-698.

Emery, K.O., and Rittenberg, S.C., 1952, Early diagenesis of California basin sediments in relation to origin of oil: Amer. Assoc. Petroleum Geologists Bull., v 36, p 735-806.

Fairbridge, R.W., 1967, Phases of diagenesis and authigenesis, in Diagenesis in sediments: Amsterdam, Elsevier, p 19-89.

Flawn, P.T., 1959, The Ouachita structural belt, in The geology of the Ouachita Mountains, a symposium: Dallas Geol. Soc. and Ardmore Geol. Soc., p 20-29.

Frazer, H.L., 1935, Experimental study of the porosity and permeability of clastic sediments: Jour. Geology, v 43, p 910-1010.

Fuchtbauer, H., and Goldschmidt, H., 1963, Beobachtungen zur Tonmineral-Diagenese: Internatl. Conf. Clay, 1st, Stockholm, Proc., p 99-111.

Garrels, R.M., 1960, Mineral equilibria: New York, Harper and Bros., 254 p.

Garrels, R.M., and Christ, C.L., 1965, Solutions, minerals and equilibria: New York, Harper and Row, 450 p.

Gibbs, R.J., 1965, Error due to segregation in quantitative clay mineral x-ray diffraction mounting techniques: Amer. Mineralogist, v 50, p 741-751.

Glass, H.D., 1958, Clay mineralogy of Pennsylvanian sediments in southern Illinois: Clays and Clay Minerals, v 5, p 227-241, Natl. Acad. Science--Natl. Research Council Pub. 566.

Glass, H.D., Potter, P.E., and Siever, R., 1956, The clay mineralogy of some basal Pennsylvanian sandstones, clays, and shales: Amer. Assoc. Petroleum Geologists Bull., v 40, p 750-754.

Goddard, E.N. (chmn.), 1963, Rock-color chart: New York, Geol. Soc. America.

Goldschmidt, V.M., 1954, Geochemistry: Oxford, Clarendon Press, 730 p.

Goldstein, A., and Hendricks, T.A., 1962, Mississippian and Pennsylvanian of the Ouachita facies, in Pennsylvanian System in the United States, a symposium: Tulsa, Amer. Assoc. Petroleum Geologists, p 385-430.

Goldston, W.L., Jr., 1922, Differentiation and structure of the Glenn Formation: Amer. Assoc. Petroleum Geologists Bull., v 6, p 5-23.

Goodyear, J., and Duffin, W.J., 1961, An x-ray examination of an exceptionally well crystallized kaolinite: Mineralog. Mag., v 32, p 902-907.

Griffin, G.M., 1962, Regional clay-mineral facies--products of weathering intensity and current distribution in the northeastern Gulf of Mexico: Geol. Soc. America Bull., v 73, p 737-768.

Griffin, G.M., and Ingram, R.L., 1955, Clay minerals of the Neuse River estuary: Jour. Sed. Petrology, v 25, p 194-200.

Griffin, J.J., and Goldberg, E.D., 1963, Clay-mineral distribution in the Pacific Ocean, in The sea, ideas and observations in progress in the study of the seas. 3. The earth beneath the sea: New York, Interscience, p 728-741.

Griffiths, J.C., Bates, T.F., and Shadle, H.W., 1956, Guide to field trip of 4th National Clay Conference--clay minerals in sedimentary rocks: Clays and Clay Minerals, v 4, p 1-20, Natl. Acad. Science --Natl. Research Council Pub. 456.

Grim, R.E., 1951, The depositional environment of red and green shales: Jour. Sed. Petrology, v 21, p 226-232.

________ 1953, Clay mineralogy: New York, McGraw-Hill, 384 p.

________ 1958, Concept of diagenesis in argillaceous sediments: Amer. Assoc. Petroleum Geologists Bull., v 42, p 246-254.

Grim, R.E., Bradley, W.F., and White, W.A., 1957, Petrology of the Paleozoic shales of Illinois: Report of Investigations 203, Ill. State Geol. Survey, 35 p.

Grim, R.E., Dietz, R.S., and Bradley, W.F., 1937, Mica in argillaceous sediments: Amer. Mineralogist, v 22, p 813-829.

_______ 1949, Clay mineral composition of some sediments from the Pacific Ocean off the California coast and the Gulf of California: Geol. Soc. America Bull., v 60, p 1785-1808.

Grim, R.E., and Johns, W.D., 1954, Clay-mineral investigation of sediments in the northern Gulf of Mexico: Clays and Clay Minerals, v 2, p 81-103, Natl. Acad. Science--Natl. Research Council Pub. 327.

Grim, R.E., and Loughnan, F.C., 1962, Clay minerals in sediments from Sidney Harbour, Australia: Jour. Sed. Petrology, v 32, p 240-248.

Grim, R.E., and Rowland, R.A., 1942, DTA analysis of clay minerals and other hydrous materials: Amer. Mineralogist, v 27, p 746-761, 801-818.

Ham, W.E., and Wilson, J.L., 1967, Paleozoic epeirogeny and orogeny in the central United States: Amer. Jour. Science, v 256, p 332-407.

Heald, M.T., 1956, Cementation of Simpson and St. Peter sandstones in parts of Oklahoma, Arkansas and Missouri: Jour. Geology, v 64, p 16-30.

Hemley, J.J., 1959, Some mineralogical equilibria in the system K_2O-Al_2O_3-SiO_2-H_2O: Amer. Jour. Science, v 257, p 241-270.

Hemley, J.J., and Jones, W.R., 1964, Chemical aspects of hydrothermal alteration with emphasis on hydrogen metasomatism: Econ. Geology, v 59, p 538-569.

Hess, P.C., 1966, Phase equilibria of some minerals in the K_2O-Na_2O-Al_2O_3-SiO_2-H_2O system at 25° C and 1 atmosphere: Amer. Jour. Science, v 264, p 289-309.

Holmes, Arthur, 1965, Principles of physical geology: New York, Ronald Press Co., 1288 p.

Hsi, H.R., and Clifton, D.F., 1962, Flocculation of selected clays by various electrolytes: Clays and Clay Minerals, v 9, p 269-275, New York, Pergamon Press.

Huffman, G.G., 1959, Pre-Desmoinesian isopachous and paleogeologic studies in central Mid-Continent region: Amer. Assoc. Petroleum Geologists Bull., v 43, p 2541-2574.

Hurley, P.M., Cormier, R.F., Hower, J., and Fairbairn, H.W., Jr., 1960, Reliability of glauconite for age measurement of K-Ar and Rb-Sr methods: Amer. Assoc. Petroleum Geologists Bull., v 44, p 1793-1808.

Hurley, P.M., Hart, S.R., Pinson, W.W., and Fairbairn, H.W., Jr., 1959, Authigenic versus detrital illite in sediments (abs.): Geol. Soc. America Bull., v 70, p 1622.

Hurley, P.M., Heezen, B.C., Pinson, W.H., and Fairbairn, H.W., Jr., 1963, K-Ar age values in pelagic sediments of the North Atlantic: Geochim. et Cosmochim. Acta, v 27, p 393-399.

Ireland, H.A., 1955, Pre-Cambrian surface in northeastern Oklahoma and parts of adjacent states: Amer. Assoc. Petroleum Geologists Bull., v 39, p 468-483.

________ (ed.), 1959, Silica in sediments: Soc. Econ. Paleontologists and Mineralogists Spec. Pub. 7, 185 p.

Johns, W.D., and Grim, R.E., 1958, Clay-mineral composition of Recent sediments from the Mississippi River delta: Jour. Sed. Petrology, v 28, p 186-199.

Johns, W.D., Grim, R.E., and Bradley, W.F., 1954, Quantitative estimation of clay minerals by diffraction methods: Jour. Sed. Petrology, v 24, p 242-251.

Jordan, Louise, and Vosburg, D.L., 1963, Permian salt and associated evaporites in the Anadarko basin of western Oklahoma-Texas Panhandle region: Okla. Geol. Survey Bull. 102, 76 p.

Kaplan, I.R., and Rittenberg, S.C., 1963, Basin sedimentation and diagenesis, in The sea, ideas and observations in progress in the study of the seas, v 3, the earth beneath the sea: New York, Interscience, p 583-619.

Kaplan, I.R., Emery, K.O., and Rittenberg, S.C., 1963, The distribution and isotopic abundance of sulfur in recent marine sediments off southern California: Geochim. et Cosmochim. Acta, v 27, p 297-331.

Keller, W.D., 1936, Clay mineral colloids as a cause of bedding in sedimentary rocks: Jour. Geology, v 44, p 52-59.

________ 1956, Clay minerals as influenced by environments of their formation: Amer. Assoc. Petroleum Geologists Bull., v 40, p 2689-2710.

________ 1958, Argillation and direct bauxitization in terms of concentration of hydrogen and metal cations at surface of hydrolyzing aluminum silicates: Amer. Assoc. Petroleum Geologists Bull., v 42, p 233-245.

________ 1963, Diagenesis in clay minerals--a review: Clays and Clay Minerals, v 11, p 136-157, New York, Pargamon Press.

_______ 1964, Processes of origin and alteration of clay minerals, in Soil and clay mineralogy: Chapel Hill, Univ. N. Car. Press.

_______ 1967, Geologic occurrences of clay-mineral layer silicates, in Short course lecture notes, layer silicates: Washington, D.C., Amer. Geol. Institute, p WK-1--WK-105.

Kossovskaya, A.G., Drits, V.A., and Alexandrova, V.A., 1965, Trioctahedral micas in sedimentary rocks: Internatl. Clay Conference Proc., Stockholm, p 147-169.

Krasukopf, Konrad, 1959, The geochemistry of silica in sediments: Soc. Econ. Paleontologists and Mineralogists Spec. Pub. 7, p 4-20.

_______ 1967, Introduction to geochemistry: New York, McGraw-Hill Book Co., 721 p.

Krumbein, W.C., and Sloss, L.L., 1963, Stratigraphy and sedimentation: San Francisco, W.H. Freeman and Co., 660 p.

Kullerud, G., and Yoder, H.S., 1959, Pyrite stability relations in the Fe-S system: Econ. Geology, v 54, p 533-572.

Larsen, G., and Chilingar, G.V., (eds.), 1967, Diagenesis in sediments: Amsterdam, Elsevier, 524 p.

Livingstone, D.A., 1963, Chemical composition of rivers and lakes, in Data of geochemistry, 6th ed.: U.S. Geol. Survey Prof. Paper 440G, 64 p.

Lovering, T.S., 1959, Significance of accumulation of plants in rock weathering: Geol. Soc. America Bull., v 70, p 781-800.

MacKenzie, F.T., 1967, Silica in sea water: control by silica minerals: Science, v 155, p 1404-1405.

Mason, Brian, 1966, Principles of geochemistry, 3rd ed.: New York, John Wiley and Sons, 329 p.

McElroy, M.N., 1962, Isopach and lithofacies study of the Desmoinesian Series of north-central Oklahoma: Shale Shaker Digest, v XII, p 1-18.

McLaughlin, R.J.W., 1955, Effects of grinding dickite: Clay Minerals Bull., v 2, p 309-317.

Meade, R.H., 1964, Removal of water and rearrangement of particles during compaction of clayey sediments: U.S. Geol. Survey Prof. Paper 497B, 23 p.

Meents, W.F., Bell, A.H., Reese, O.W., and Tilbury, W.G., 1952, Illinois oil field brines: Ill. State Geol. Survey, Ill. Petroleum, v 66, p 5-38.

Mellon, G.B., 1964, Discriminatory analysis of calcite and silica-cemented phases of the Mountain Park Sandstone: Jour. Geology, v 72, p 786-809.

Merritt, C.A., 1960, Petrography of the Spavinaw Granite: Okla. Geol. Survey, Okla. Geol. Notes, v 20, p 224-228.

Miller, J.P., 1952, A portion of the system calcium carbonate-carbon dioxide-water with geological implications: Amer. Jour. Science, v 250, p 161-203.

Milne, I.H., and Earley, J.W., 1958, Effect of source and environment on clay minerals: Amer. Assoc. Petroleum Geologists Bull., v 42 p 328-338.

Moore, J.R., 1968, Recent sedimentation in northern Cardigan Bay, Wales: British Museum (Nat. History) Bull., Mineralogy, v 2, n 2, London, 131 p.

Muehlberger, W.R., Denison, R.E., and Lidiak, E.G., 1967, Basement rocks in continental interior of United States: Amer. Assoc. Petroleum Geologists, v 51, p 2351-2380.

Müller, German, 1967, Diagenesis in argillaceous sediments, in Diagenesis in sediments: Amsterdam, Elsevier, p 127-177.

Murray, H.H., 1954, Genesis of clay minerals in some Pennsylvanian shales of Indiana and Illinois: Clays and Clay Minerals, v 2, p 47-67, Natl. Acad. Science--Natl. Research Council Pub. 327.

Murray, H.H., and Gravenor, C., 1953, Colloidal size silica in sediments: Science, v 118, p 25-28.

Murray, H.H., and Harrison, J.L., 1957, Clay mineral composition of recent sediments from the Sigsbee Deep: Jour. Sed. Petrology, v 26, p 363-368.

Murray, H.H., and Sayyab, A.S., 1955, Clay mineral studies of some recent marine sediments off the North Carolina coast: Clays and Clay Minerals, v 3, p 430-441, Natl. Acad. Science--Natl. Research Council Pub. 395.

Nagy, B., 1960, Review of the chromatographic "plate" theory with reference to fluid flow in rocks and sediments: Geochim. et Cosmochim. Acta, v 19, p 289-296.

Nelson, B.W., 1960, Clay mineralogy of the bottom sediments, Rappahannock River, Virginia: Clays and Clay Minerals, v 7, p 135-147, New York, Pergamon Press.

Newnham, R.E., 1961, A refinement of the dickite structure and some remarks on polymorphism in kaolin minerals: Mineral. Mag., v 23, p 683.

Okamoto, G., Okura, T., and Goto, K., 1947, Properties of silica in water: Geochim. et Cosmochim. Acta, v 12, p 123-132.

Packham, G.H., and Crook, K.A.W., 1960, The principle of diagenetic facies and some of its implications: Jour. Geology, v 68, p 392-407.

Pauling, L.B., 1960, Nature of the chemical bond: Ithica, N.Y., Cornell Univ. Press, 644 p.

Pettijohn, F.J., 1957, Sedimentary rocks: New York, Harper and Bros., chap. 14.

Pinsak, A.P., and Murray, H.H., 1960, Regional clay-mineral patterns in the Gulf of Mexico: Clays and Clay Minerals, v 7, p 162-177, New York, Pergamon Press.

Potter, P.E., and Glass, H.D., 1958, Petrology and sedimentation of the Pennsylvanian sediments in southern Illinois: a vertical profile: Ill. State Geol. Survey, Rep. Inv. 204, 60 p.

Powers, M.C., 1954, Clay diagenesis in the Chesapeake Bay area: Clays and Clay Minerals, v 2, p 68-80, Natl. Acad. Science--Natl. Research Council Pub. 327.

________ 1957, Adjustment of land-derived clays to the marine environment: Jour. Sed. Petrology, v 27, p 355-372.

________ 1959, Adjustment of clays to chemical change and the concept of the equivalence level: Clays and Clay Minerals, v 6, p 309-326, New York, Pergamon Press.

Pryor, W.A., and Glass, H.D., 1961, Cretaceous-Tertiary clay mineralogy of the upper Mississippi embayment: Jour. Sed. Petrology, v 31, p 38-51.

Radoslovich, E.W., 1963, The cell dimensions and symmetry of layer-lattice silicates. IV. Intermolecular forces: Amer. Mineralogist, v 48, p 76-99.

Read, H.H., and Watson, J., 1963, An introduction to geology: London, MacMillan, 693 p.

Rex, R.W., 1966, Authigenic kaolinite and mica as evidence for phase equilibria at low temperatures: Clays and Clay Minerals, v 13, p 95-104, New York, Pergamon Press.

Rex, R.W., and Martin, B.D., 1966, Clay mineral formation in sea water by submarine weathering of K-feldspar: Clays and Clay Minerals, v 14, p 235-240, New York, Pargamon Press.

Rich, J.L., 1951, Three critical environments of deposition, and criteria for recognition of rocks deposited in each of them: Amer. Assoc. Petroleum Geologists Bull., v 62, p 1-20.

Roy, R., 1954, The application of phase equilibrium data to certain aspects of clay mineralogy: Clays and Clay Minerals, v 2, p 124-140, Natl. Acad. Science--Natl. Research Council Pub. 327.

Sand, L.B., 1956, On the genesis of residual kaolins: Amer. Mineralogist, v 41, p 28-40.

Schroeder, R.J., and Hayes, J.B., 1968, Dickite and kaolinite in Pennsylvainian limestones of southeastern Kansas: Clays and Clay Minerals, v 16, p 41-49, New York, Pergamon Press.

Schuchert, C., 1920, Diagenesis in sedimentation: Geol. Soc. America Bull., v 31, p 425-432.

Shcherban, I.P., 1967, Some possible forms of migration of silicon in aqueous solution and the mode of origin of silica: Doklady of the Acad. Science, U.S.S.R., v 177, p 241-243.

Shepard, F.P., 1960, Mississippi delta: marginal environments, sediments and growth, in Recent sediments, northeast Gulf of Mexico: Amer. Assoc. Petroleum Geologists, Tulsa, p 56-81.

Shepard, F.P., and Moore, D.G., 1955, Central Texas coast sedimentation: characteristics of sedimentary environments, recent history and diagenesis: Amer. Assoc. Petroleum Geologists Bull., v 39, p 1463-1593.

Sherman, D.G., and Ikawa, H., 1959, Occurrence of gibbsite amygdules in Haiku bauxite area of Maui: Pacific Science, v 13, p 291-294.

Siever, Raymond, 1959, Petrology and geochemistry of silica cementation in some Pennsylvanian sandstones, in Silica in sediments: Soc. Econ. Paleontologists and Mineralogists, Spec. Pub. 7, p 55-79.

________ 1962, Silica solubility, 0^{o}-200^{o} C, and the diagenesis of siliceous sediments: Jour. Geology, v 70, p 127-150.

Siever, Raymond, Beck, K.C., and Berner, R.A., 1965, Composition of interstitial waters of modern sediments: Jour. Geology, v 73, p 39-73.

Smoot, T.W., and Narian, K., 1960, Clay mineralogy of pre-Pennsylvanian sandstones and shales of the Illinois Basin: Ill. State Geol. Survey Circ. 287, 14 p.

Sujkowski, Zb.L., 1958, Diagenesis: Amer. Assoc. Petroleum Geologists Bull., v 42, p 2692-2727.

Swett, Keene, 1965, Dolomitization, silicification and calcitization patterns in Cambro-Ordovician oolites from northwest Scotland; Jour. Sed. Petrology, v 35, p 928-938.

Tarr, W.A., and Keller, W.D., 1936, Dickite in Missouri: Amer. Mineralogist, v 21, p 109-114.

________ 1937, Some occurrences of kaolinite deposited from soultion: Amer. Mineralogist, v 22, p 9333-935.

Thompson, Allan, 1959, Pressure solution and porosity, in Silica in sediments: Soc. Econ. Paleontologists and Mineralogists Spec. Pub. 7, p 92-110.

Tomlinson, C.W., and McBee, W., Jr., 1962, Pennsylvanian System in the United States: Amer. Assoc. Petroleum Geologists Symposium, p 461-500.

Towe, K.M., 1962, Clay mineral diagenesis as a possible source of silica cement in sedimentary rocks: Jour. Sed. Petrology, v 32, p 26-28.

Trowbridge, A.C. (ed.), 1960, Glossary of geology and related sciences: Washington, D.C., Amer. Geol. Institute.

Verhoogen, John, 1958, Physical properties and bond type in Mg-Al oxides and silicates: Amer. Mineralogist, v 43, p 552.

Visher, Glenn S. (ed.), 1968, A guidebook to the geology of the Bluejacket-Bartlesville Sandstone, Oklahoma: Oklahoma City, Okla. City Geol. Soc., 72 p.

Von Engelhardt, Wolf, 1967, Interstitial solution and diagenesis in sediments, in Diagenesis in sediments: Amsterdam, Elsevier, p 503-521.

Von Engelhardt, Wolf, and Gaida, K.H., 1963, Concentration changes of pore solutions during the compaction of clay sediments: Jour. Sed. Petrology, v 33, p 919-930.

Walker, T.R., 1962, Reversible nature of chert-carbonate replacement in sedimentary rocks: Geol. Soc. America Bull., v 73, p 237-242.

Weaver, C.E., 1953, A lath-shaped non-expanding dioctahedral 2:1 clay mineral: Amer. Mineralogist, v 38, p 279-289.

________ 1958a, Geologic interpretation of argillaceous sediments: Amer. Assoc. Petroleum Geologists Bull., v 42, p 254-310.

________ 1958b, A discussion on the origin of clay minerals in sedimentary rocks: Clays and Clay Minerals, v 5, p 159-173, Natl. Acad. Science--Natl. Research Council Pub. 566.

________ 1959, The clay petrology of sediments: Clays and Clay Minerals, v 6, p 154-187, New York, Pergamon Press.

________ 1960, Possible uses of clay minerals in search for oil: Amer. Assoc. Petroleum Geologists Bull., v 44, p 1505-1518.

________ 1961, Clay mineralogy of the Late Cretaceous rocks of the Washakie Basin: Guide Book, Wyo. Geol. Assn. 16th Ann. Conf., p 148-154.

Weller, J.M., 1960, Stratigraphic principles and practice: New York, Harper and Bros., p 292-318.

White, D.E., 1965, Saline waters of sedimentary rocks, in Fluids in subsurface environments: Amer. Assoc. Petroleum Geologists Mem. 4, p 342-366.

White, D.E., Hem, J.D., and Waring, G.A., 1963, Data of geochemistry, chemical composition of waters: U.S. Geol. Survey Prof. Paper 440F, 67p.

Whitehouse, V.G., and McCarter, R.S., 1958, Diagenetic modification of clay mineral types in artificial sea water: Clays and Clay Minerals, v 5, p 81-119, Natl. Acad. Science--Natl. Research Council Pub. 566.

Yaalon, D.H., 1959, Weathering reactions: Jour. Chem. Education, v 36, p 73-76.

Yoder, H.S., Jr., 1959, Experimental studies on micas: a synthesis: Clays and Clay Minerals, v 6, p 42-60, New York, Pargamon Press.

Yurevich, A.L., 1961, The clay minerals of the Akchagylian deposits of the Pribalkhan region: Doklady of the Academy of Sciences of U.S.S.R., v 139, p 819-823.

Zen, E-An, 1959, Clay mineral-carbonate relations in sedimentary rocks: Amer. Jour. Science, v 257, p 29-43.

________ 1961, The zeolite facies; an interpretation: Amer. Jour. Science, v 259, p 401-409.

ZoBell, C.E., 1946, Studies on redox potential of marine sediments: Amer. Assoc. Petroleum Geologists Bull., v 30, p 477-513.

APPENDICES

APPENDIX A

SAMPLE DESCRIPTIONS

Desmoinesian, Ordovician, and/or Permian stratigraphic intervals of 36 core were examined. Fourteen of these were investigated in detail. Representative samples of lithologic variations were selected for further laboratory study. These representative samples are herein described.

Accession numbers are those by which the cores are cataloged in the University of Oklahoma Core and Sample Library. Sample numbers correspond with box numbers from which the samples were taken. For example, sample 245/3 was taken from box 3 of the core with accession number 245. Identification of the units is based on information supplied by the operators. Colors have been assigned by comparison with the G. S. A. Rock-Color Chart.

Acc. no.: 106. Location; SW-SE, sec. 17, T13N, R3W, Oklahoma Co. Operator: Gulf Oil Co., #1 Jesse, 4 in. core. Sample depths: 6089-6098 ft., Desmoinesian (Bartlesville), 6663 ft., Ordovocian (Simpson).

Sample Number	Depth (ft.)	
1	6087	Shale, brownish black (5 YR 2/1), silty, well indurated, subparallel parting along bedding, fine (<1 mm.) lenses of medium light gray (N 6) silt account for 5% of sample.
2	6089	Shale and silt, similar to sample 1, silt accounts for 50% of sample, disrupted bedding.
4	6094	Shale and silt, similar to sample 2, bedding more regular, "diapiric intrusions" of silt into shale.
6	6098	Silt and shale, similar to sample 4, silt accounts for 75% of sample.
9	6663	Silt, light olive gray (5 Y 7/1), calcareous, uniform, some diffuse irregular thin (0.5 mm.) red brown stringers.

Acc. no.: 142 (new no. 942). Location; SE-SW-NE, Sec. 29, T18N, R12E Creek Co. Operator: Gulf Oil Corp., #2-C-9W, 4 in core. Sample depths: 1572-1652 ft., Desmoinesian (Glenn Sand of Bartlesville).

Sample Number	Depth (ft.)	
1	1572	Sand, uniform light gray (N 7) with irregular clay laminae, light olive gray (5Y 6/1), thin section 2127.
2	1573	Sand, similar to sample 1, numerous randomly spaced carbonaceous flecks.
3	1583	Sand, uniform greenish gray (5 GY 6/1), well indurated.
6	1594	Sand, uniform light olive gray (5 Y 6/1), well indurated, thin section 2128.
8	1605	Sand, uniform light brownish gray (5 YR 6/1), fine black laminae.
9	1608	Sand, uniform light olive gray (5 Y 6/1), fine black laminae, thin section 2129.
10	1611	Sand, similar to sample 9, small-scale disrupted cross bedding, slumping, channeling.
14	1622	Sand, dark medium gray (N 4), well indurated, grades rapidly to claystone, pale yellowish brown (10 YR 6/2), silty, sideritic, well indurated.
15a	1623	Calcarenite, dark greenish gray (5 GY 4/1), fossiliferous.
15b	1624	Calcarenite, similar to sample 15a, irregular diffuse black areas, thin section 2131.
15c	1625	Shale, greenish black (5 G 2/1), well indurated, fissile, sharp contact with overlying calcarenite, thin section 2131.
16	1631	Shale, similar to sample 15c, less fissile.
17	1637	Sandstone, light olive gray (5 Y 6/1), dark micaceous films.

Acc. no.: 142 (new no. 942)--Continued.

Sample Number	Depth (ft.)	
18a	1640	Sandstone, light olive gray (5 Y 6/1) to light brownish gray (5 YR 6/1), gray portion contains well crystalline kaolinite (x-ray), brownish portion is sideritic, thin section 2133
18b	1641	Sandstone, light gray (N 7), friable, dark carbonaceous flecks.
18c	1642	Shale, dark gray (N 3), well indurated, fissile.
19a	1643	Shale, similar to sample 18c.
19b	1644	Mudstone, greenish black (5 G 2/1), shiny, not fissile, coaly, thin section 2132.
19c	1644½	Mudstone, similar to 19b, contains hard siderite concretion, pale yellowish brown (10 YR 6/2), 2 in. diameter, thin section 2344.
20	1645	Siltstone, light gray (N 7), numerous fine irregular coaly veinlets.
21a	1649	Siltstone, similar to sample 20, additional shaly laminae.
21b	1652	Siltstone, similar to sample 21a, shale, dark gray (N 3) accounts for 50% of sample, thin section 2130.

Acc. No.: 245. Location: C-SE-SW, Sec. 26, T1N, R11E, Coal Co.
Operator: Pasotex Petroleum Co., #1-A Underhill Unit, 4 in. core.
Sample Depths: 15429-15447 ft., Ordovician (Simpson).

Sample Number	Depth (ft.)	
1a	15429	Shale, medium dark gray (N 4), well indurated, no bedding visible, irregular fracture, minor fossil debris, irregular calcareous blotches, light gray (N 7).
1b	15431	Limestone, dark greenish gray (5 G 4/1), abundant fossil debris, coarsely crystalline, subparallel alignment of fossil fragments,
1c	15433	Shale, brownish black (5 YR 2/1), shiny, irregular bedding and parting, calcareous intraclasts, thin section 2126.
2a	15434	Shale, similar to sample 1c.
2b	15436	Limestone and shale, limestone as in 1b with dull medium dark gray (N 4) shale irregularly interspersed accounting for 20% of sample.
2c	15440	Shale, medium dark gray (N 4), dull, irregular parting, uniform, well indurated, thin section 2125.
3	15444	Shale and limestone, similar to sample 2b, limestone accounts for 30% of sample as randomly oriented intraclasts.
4	15447	Shale and limestone, shale brownish black (5 YR 2/1), shiny accounts for 70% of sample, limestone is dark greenish gray (5 G 4/1), fossiliferous.

Acc. No.: 278. Location: C-SW-NW, Sec. 34, T11N, R16W, Washita Co. Operator: Gulf Oil Corp., #1 Fletcher, 4 in. core. Sample Depths: 12345-12349 ft., Desmoinesian.

Sample Number	Depth (ft.)	
17	12345	Shale, greenish black (5 G 2/1) and sand, greenish gray (5 G5/1), disrupted, interlaminated, sand fine to medium grain, slickensides in shale, petroliferous, 50% shale.
19	12349	Sand, medium gray (N 5) and shale, dark gray (N 3), calcareous sand with thin (1 mm.) dark micaceous shale layer, dark organic (?) subparallel flecks throughout sand, cement in shale is dolomite (x-ray), thin section 2343.

Acc. No.: 285. Location: C-SE-NE, Sec. 14, T12N, R23W, Roger Mills Co. Operator: Gulf Oil Corp., #1 Taylor, 4 in. core. Sample Depth: 12754 ft., Desmoinesian.

Sample Number	Depth (ft.)	
104	12754	S nd, dark greenish gray (5 G 5/1), and shale, greenish black (5 G 2/1), calcareous, dolomitic, very fine sand, thick (2 cm.) shale irregularly interlayered, sand contains numerous thin (< 1 mm.) black disrupted discontinuous lenses and films, shiny irregular fracture surfaces in shale, dolomite dominant carbonate in sand, calcite dominant in shale, thin section 2341.

Acc. No.: 314. Location: C-NE-NW Sec. 31, T9N, R3W, McClain Co. Operator: Petroleum, Inc., #1 Kunkel, 4 in. core. Sample Depths: 9676-9701 ft., Ordovician (Simpson).

Sample Number	Depth (ft.)	
90a	9676	Limestone, dusky yellowish green (10 GY 3/2) to olive gray (5 Y 4/1), dolomitic, fossiliferous, irregular pale yellowish green (10 GY 7/2) intraclasts, dolomite and calcite in approximately equal amounts, widely distributed quartz sand and shale.
90b	9678	Limestone, similar to sample 90a, contains 4 cm. shale layer, olive black (5 Y 2/1), irregularly laminated.
91	9680	Limestone, grayish green (10 GY 5/2), intraclastic, fossiliferous, intraclasts are light gray (N 7) and display lineation parallel to "bedding," intraclasts rimmed by narrow band, olive gray (5 Y 4/1), minor sand and clay content, thin section 2120.
93	9685	Limestone, medium gray (N $5\frac{1}{2}$), coarsely grained, irregular fine-grained laminations, olive gray ((5 Y 4/1), soft-sediment deformations common, minor sand.
94a	9688	Limestone, dolomite, shale. Lower half is limestone, grayish green (5 G 5/2), coarsely crystalline; upper half is dolomite, light brownish gray (5 YR 6/1), fine-grained carbonates separated by 2 mm. shale, olive black (5 Y 2/1).
94b	9689	Limestone, similar to that of 94a.
95	9690	Limestone, grayish green (10 GY 5/2), disrupted, intraclastic.
96	9694	Mudstone, dark greenish gray (5 GY 3/1), blocky fracture.
97a	9696	Dolomite, medium dark gray (N 4), corasely crystalline, as intraclasts, contains carbonaceous flecks, shale, dark greenish gray (5 GY 3/1), shiny, irregularly engulfs dolomite.

Acc. No.: 314--Continued.

Sample Number	Depth (ft.)	
97b	9698	Shale, medium dark gray (N 4), shiny along partings, irregularly silty.
97c	9699	Dolomite, medium gray (N $5\frac{1}{2}$), fractures filled with coarse spar, red-brown stains along other non-spar-filled fractures.
98a	9700	Dolomite, similar to 97c, disrupted, intraclastic.
98b	9701	Shale, dusky blue green (5 BG 3/2), well indurated, calcite and dolomite cement.

Acc. No.: 316. Location: C Sec. 17, T8N, R10E, Hughes Co.
Operator: Pan American Petroleum Corp., #4 Perryman C, 4 in. core.
Sample Depths: 3710-3860 ft., Ordovician (2nd Wilcox Sand of Simpson).

Sample Number	Depth (ft.)	
1a	3710	Sandstone, olive gray (5 Y 4/1), well indurated, irregular dark banding, well rounded sand, bimodal size, medium sand and coarse silt, dolomite and calcite cement, minor clay, thin section 2348.
1b	3712	Sandstone, similar to 1a, dark bands have finer grain size.
1c	3715	Sandstone, pale green (5 G 7/2), friable, clean, bimodal very well rounded medium sand and coarse silt, grains appear frosted, thin section 2347.
3b	3724	Sandstone, grayish yellow green (5 GY 7/2), friable, grades into well indurated (calcite cement) light brownish gray (5 YR 6/1), sand, minor clay in friable portion.
4b	3732	Sandstone, average color olive gray (5 Y 4/1), uneven banding, blotchy color, lighter areas less indurated.
5b	3736	Sandstone, light olive gray (5 Y 6/1), friable, some irregular well indurated petroliferous laminations, dark gray (n 3), calcite cement.
7	3745	Sandstone, light grayish green (10 GY 6/2), very well indurated, ferroan dolomite cement.
9	3757	Sandstone, light grayish green (10 GY 6/2), friable, grades into indurated moderate yellowish green (10 GY 6/4) sand, dolomite cement.
10	3761	Sandstone, light greenish gray (5 G 8/1), dolomitic, very well indurated, crystals line cavities, grades into well indurated moderate yellowish green (10 GY 6/4) sand, no cavities, calcite cement.
13	3786	Sandstone, light olive gray (5 Y 6/1), well indurated, white splotches surrounded by thin dark gray rims.

Acc. No.: 316--Continued.

Sample Number	Depth (ft.)	
19	3786	Sandstone, drak grayish olive green (5 GY 2/2), very well indurated, salty, irregular petroliferous areas, calcite cement.
21	3817	Sandstone, average color light olive gray (5 Y 6/1), poorly indurated to friable, petroliferous along fractures.
22	3821	Sandstone, dark grayish olive (10 Y 3/2), friable, petroliferous.
24	3842	Sandstone, similar to sample 22, some irregular white blotches capped by irregular silty laminations.
28	3858	Sandstone, medium gray (N 5), silty, argillaceous, fissile.
29	3860	Sandstone, light to medium grayish olive (10 Y 4/2), irregularly banded.

Acc. No.: 321. Location: SE-NW Sec. 19, T16N, R16W, Dewey Co., Operator: Sunray DX, #1 Richardson, 4 in. core. Sample Depths: 9719-9726 ft., Desmoinesian (Oswego).

Sample Number	Depth (ft.)	
12	9719	Shale, black (N 1), dull, uniform, petroliferous.
14a	9725	Shale, dark greenish gray (5 G 4/1), silty, irregular calcareous areas, fine oriented mica on subparallel bedding planes.
14b	9726	Shale, medium dark gray (N 4), subparallel bedding, good parting, fine oriented mica flakes common on bedding planes, petroliferous, medium light gray (N 6) silt as fine discontinuous stringers accounts for 10% of sample, thin section 2346

Acc. No.: 360. Location: SW-SW-SE Sec. 30, T14N, R4W, Oklahoma Co. Operator: Sohio Oil Co., #B-3 Cargill, 3 in. core. Sample Depths: 6752-6791 ft., Desmoinesian (Bartlesville).

Sample Number	Depth (ft.)	
1	6752	Shale, medium gray (N 5), crinoidal, disrupted bedding, some scattered silt lenses, thin section 2121.
2	6755	Shale, similar to sample 1, fossil hash abundant, calcareous silt, light gray (N 7), accounts for 30% of sample.
4	6759	Silt and shale, similar to sample 2, thick bedding ($2\frac{1}{2}$ cm.) badly contorted, shale accounts for 40% of sample.
5	6761	Silt, similar to sample 4, shale accounts for 5% of sample, less fossil debris.
6	6763	Shale, black (N 1), shiny to dull, irregular partings, no bedding visible, pyritiferous shell fragments, thin section 2122.
7	6765	Silt, similar to sample 5, shale more diffuse, no clear bedding contacts, no fossils.
8	6767	Silt, pale yellowish brown (10 YR 6/2), uniform, some irregular dark films.
9	6769	Sand, pale brown (5 YR 5/2), fine grained, subparallel diffuse banding (1 mm.), partings at bandings have oriented mica flakes.
12	6775	Sand, dark yellowish brown (10 YR 4/2), fine grained, uniform, no partings, scattered black organic (?) debris.
14	6779	Sand, similar to sample 12, black debris aligned.
16	6783	Sand, same as sample 14.
17	6787	Silt and shale, silt light gray (N 7), shale medium dark gray (N 4), sharp contact with overlying sand, some gentle crossbedding and flow structures, 50% shale, thin section 2123.

Acc. No.: 360--Continued.

Sample Number	Depth (ft.)	
18	6789	Shale and silt, similar to sample 17, 80% shale, silt in fine laminae, thin section 2124.
19	6791	Sand, same as sample 14.

Acc. No.: 500. Location: C-SE-NE Sec. 31, T16N, R11W, Blaine Co. Operator: Texaco Oil Co., #1 V. Jones, 4 inc. core. Sample Depths: 8779-8780 ft., Desmoinesian (Marmaton).

Sample Number	Depth (ft.)	
3b	8779	Sandstone, light gray (N $6\frac{1}{2}$), fine to very fine grained, and shale, dark greenish gray (5 G 5/1), disrupted, interlaminated, oblate spheroidal sand lenses within shale, slumping and differential compaction, 50% shale, thin section 2342.
3a	8780	Sand, similar to sample 3b, 5% of interval occupied by slightly distorted dark micaceous shale, dark greenish gray (5 G 5/2).

Acc. No.: 627. Location: SW-SW-NE Sec. 10, T11N, R20W, Washita Co.
Operator: Glover, Heffner, and Kennedy, McAlpine #1-10, 3 in. core.
Sample Depths: 13750-13776 ft., Desmoinesian.

Sample Number	Depth (ft.)	
3a	13750	Shale, grayish green (10 GA 1/2) and sand, medium light gray (N $6\frac{1}{2}$), very fine grained, finely interlaminated, 70% shale, disrupted bedding, differential compaction, mica flakes common on surface of shale laminae.
3b	13751	Sandstone, medium light gray (N $6\frac{1}{2}$), very fine grained, scattered very fine discontinuous subparallel dark clay films and laminae make up 5% of sample, bedding disrupted, mica flakes common on bedding planes, thin section 2340.
9a	13775	Shale and sand similar to sample 3a, finely interlaminated but better segregation, top 6 in. 95% shale, lower 6 in. 90% sand.
9b	13776	Sandstone, light gray (N 7), scattered diffuse dark shale laminae account for 5% of sample, partings at shale, aligned mica flakes on shale partings.

Acc. No.: 630. Location: C Sec. 14, T3S, R3W, Carter Co.
Operator: King Resources, Inc., Stewart #1-14, 4 in. core.
Sample Depths: 6542-6575 ft., Desmoinesian (Deese).

Sample Number	Depth (ft.)	
1a	6542	Shale, dark grayish green (10 G 4/2), 2 mm. layers, irregular sandy stringers, greenish gray (5 G 6/1), less than 1 mm. thick.
1b	6545	Sandstone, moderate yellowish green (10 GY 6/4), with irregular fine (0.1 mm.) shale laminae, grayish green (10 G 4/2).
2	6548	Sandstone, light brownish gray (5 YR 5/1), with irregularly interlayered shale, greenish black (5 GY 2/1), disrupted slump and flow structures, 40% shale.
4	6556	Sandstone, light brownish gray (5 YR 5/1), minor lenses and films of shale, moderate olive brown (5 Y 4/4), 10% shale.
5	6558	Sandstone, similar to sample 4, 2% shale.
6	6561	Sandstone and shale, similar to sample 5, 50% shale, subparallel organic flecks in shale.
7	6571	Shale and sandstone, similar to sample 7, 20% sand.
9	6575	Shale, grayish black (N 2), obscure bedding, shiny glassy partings at various angles.

Acc. No.: AL3. Location: 1200 ft. N, 800 Ft. W of SE corner of Sec. 14, T2N, R15W, Comanche Co. Operator: U. S. Army Corps of Engineers. Sample Depths: 172-193 ft., Permian.

Sample Number	Depth (ft.)	
45	172	Claystone, grayish green of varying hue (10 GY 5/2 to 5 G 5/2), irregular fracture, indistinct disrupted bedding.
46a	173	Claystone, similar to sample 45 but more homogeneous.
46b	175	Claystone, similar to sample 45, silty.
46c	178	Sandstone, grayish yellow green (5 GY 7/2), medium grained, angular, feldspathic, clay intraclasts, friable.
50	193	Arkose, grayish orange pink (5 YR 6/2), poorly sorted, coarse to very fine sand, clay intraclasts, friable, thin section 2345.

Acc. No.: Fargo. Location: 1200 ft. S, 2360 ft. W of intersection of U. S. 283 and Texas 91, NE $\frac{1}{4}$, Sec. 29, Blk. 29, H2TC, Reg. Co. Survey, Wilbarger Co., Texas. Operator: U. S. Army Corps of Engineers. Sample Depths: 120-207 ft., Permian.

Sample Number	Depth (ft.)	
23	120	Sandstone, very light gray green (5 G 7/3), very fine sand, common light-colored rounded clay intraclasts, sharp contact with similar but moderate red (5 R 5/4), mineralogies similar, more dolomite in light portion.
25	180	Sandstone, pale green (5 G 7/2), fine, friable, arbillaceous.
32	207	Shale, moderate red (5 R 4/6), irregular blocky fracture, small spherical "reduction spots."

APPENDIX B

THIN SECTION DESCRIPTIONS

General Statement

A total of 24 thin sections were prepared from representative lithologies and were examined in detail. Seventeen, representative of these, are described on the following pages. The thin sections were studied to determine mineral composition, texture, and if possible, the sequence of diagenetic changes. The nomenclature used is modified from Folk (1965). Color assignments were made by comparison with the G. S. A. Rock Color Chart (1963). Percentages cited are based upon a count of at least 200 points. Grain sizes were measured with a calibrated occular micrometer. All thin sections are on file by accession number at the School of Geology and Geophysics X-ray Laboratory.

Format

I. ACCESSION NUMBER AND SAMPLE IDENTIFICATION

II. ROCK NAME AND GENERAL DESCRIPTION.

III. STRUCTURES AND TEXTURE.

IV. CHEMICAL CONSTITUENTS. Authigenic and diagenetic components.

V. TERRIGENOUS CONSTITUENTS.

VI. ADDITIONAL COMMENTS.

I. 2121, core 360, sample 1, depth 6,752 ft.

II. Poorly washed biosparite; quartzose, disrupted "bedding."

III. Disorganized mixture of calcite-replaced fossils, irregular concentrations of medium-sized silt, contorted bands of iron-oxide-stained illitic clay.

IV. Calcite, 75%; approximately one-half micritic and one-half recrystallized larger grains (to 0.1 mm), coarser grains completely filling fractures and cavities and as fossil debris replacement.

Siderite, 1%; isolated scattered grains replacing calcite.

Pyrite, 1%; widely scattered euhedral grains and aggregates, more abundant in shaley portion.

V. Quartz, 13%; angular to subangular, medium silt, embayed by calcite, commonly confined in irregular concentrations.

Illite, 5%; finely divided, ferric-oxide stain common, concentrated in contorted laminations.

Chlorite, 2%; elongate mica laths, more numerous in shaley portions, parallel to laminations.

Muscovite, 2%; laths scattered through silt and clay, more abundant in shale, parallel to laminations.

Volcanic Rock Fragments, trace; fine-grained granular assemblages, rounded, coarse silt size.

Collophane, trace; silt-size, rounded grains, confined to calcitic areas.

I. 2122, core 360, sample 6, depth 6,763 ft.

II. Shale; shiny to dull black, pyritiferous shell and woody fragments, irregular megascopic partings.

III. Dark red-brown stain (organic?) makes identification difficult. Elongate grains of mica and organic debris randomly oriented.

IV. Kaolinite, 4%; fine crystalline aggregates, indistinct boundaries.

Calcite, 4%; irregular areas of optically continuous cement almost obscured by clay and silt.

Pyrite, 3%; clusters of euhedral crystals replacing floral and faunal debris.

Siderite, 2%; small clusters of fine granules superimposed upon all mineral types except pyrite.

V. Clay Matrix, 49%; evenly distributed, illite, chlorite, mixed-layer illite-montmorillonite from x-ray.

Quartz, 15%; very fine to fine silt, scattered grains to 0.1 mm, commonly display strong undulatory extinction, subangular to angular.

Organic opaques, 9%; widely and randomly distributed elongate indistinct areas, petroliferous.

Metamorphic Rock Fragments, 5%; silt size, phyllitic and composite quartz grains.

Collophane, 4%; rounded, clear, wide size range, very fine sand through very fine silt.

Muscovite, 3%; fresh, undisturbed, randomly oriented laths.

Chlorite, 2%; undistorted, fresh, randomly oriented laths, average size of all mica 0.07 mm x 0.01 mm.

I. 2123, core 360, sample 17, depth 6,787 ft.

II. Subgraywacke; fine to very fine sand, medium dark gray with carbonaceous flecks and in places clay films.

III. Silt displays no particular orientation, continuous clay film is slightly undulose indicating only minor distortion by compaction.

IV. Calcite, 6%; sparry optically continuous cement engulfing and replacing quartz and feldspars.

Kaolinite, 5%; crystalline aggregates adjacent to and in places replacing quartz grains. Also replacing clay matrix and rarely orthoclase.

Pyrite, 2%; randomly scattered, most commonly associated with iron-oxide-stained clay matrix. Excellent octahedral crystals to 0.02 mm.

Siderite, 2%; small anhedral granules, commonly in large aggregates, commonly associated with pyrite, replaces all minerals but pyrite.

V. Quartz, 57%; overgrowths common, formed before appreciable compaction since clay and mica are bent around overgrowths, common crenulated contacts between adjacent quartz grains, extinction sharp to composite, bubble trains and crystalline inclusions common, grains attacked by calcite, siderite, kaolinite.

Clay matrix, 8%; illitic, some recrystallization, bent around detrital grains, commonly iron-oxide stained.

Orthoclase, 6%; commonly sericitized.

Chlorite, 5%; as mica laths, bent and broken by compaction, pyrite inclusions common.

Metamorphic Rock Fragments, 4%; chloritic phyllite fragments, some composite quartz aggregates.

Plagioclase, 3%; elongate grains, altered, pyrite common along twin boundaries.

Muscovite, 1%; laths bent around quartz and feldspar.

Also trace amounts of pyroxene (?), leucoxene, magnetite-ilmenite, collophane, apatite, zircon, limestone fragments, volcanic rock fragments, rutile.

2123 -- Continued.

VI. Diagenetic sequence evident in part; quartz overgrowths developed early before compaction; pyrite formed after compaction, localized commonly by compaction-caused breaks in chlorite mica; calcite replaces quartz, sericitized feldspars and illite; relationship between calcite and kaolinite uncertain, kaolinite aggregates not affected by compaction thus post-compaction formation, always associated with quartz and commonly sericitized orthoclase.

I. 2124, core 360, sample 18, depth 6,789 ft.

II. Interlayered mudstone and graywacke; dark mudstone with discontinuous coarse silt laminations.

III. Mudstone portion shows excellent alignment of clays via common extinction position, accentuated by elongate carbonaceous areas, clay and mica bent around silt grains in graywacke portion.

IV. Silt

Siderite, 4%; composite granules.

Pyrite, 2%; randomly distributed and in elongate veins associated with organic debris.

Chlorite, 2%; coarse flaring areas of fibrous grains growing from fine-grained detrital areas.

Calcite, 2%; scattered areas of cement, attacking quartz.

Kaolinite, 1%; granular aggregates.

Mudstone

Calcite, 3%; small scattered areas of cement.

Pyrite, 1%; individual scattered euhedral crystals.

V. Silt

Quartz, 44%; angular to subangular grains, minor inclusions, commonly strained, attacked where adjacent to calcite.

Metamorphic Rock Fragments, 18%; chloritic-phyllite and chlorite-composite-quartz aggregates.

Clay Matrix, 18%; illitic, areas of probable recrystallization.

Muscovite, 3%; deformed laths.

Chlorite, 3%; deformed laths.

Orthoclase, 2%; commonly altered to clay.

Limestone Fragments, 1%; rounded grains.

Plus trace amounts of tourmaline, zircon, rutile, leucoxene, magmetite-ilmenite.

V. Mudstone

Illitic Clay, 69%; excellent orientation shown by common extinction.

Quartz, 8%; angular clay-size fragments.

Carbonaceous Opaques, 8%; elongate areas parallel to bedding.

Muscovite, 7%; aligned, undisturbed laths.

Chlorite, 2%; aligned, undisturbed laths.

Phyllite Fragments, 1%; chloritic, rounded, elongate.

Collophane, 1%; widely scattered, clear, rounded grains.

VI. Authigenic components comprise at least 11% of silty portion but only 4% of clay-rich portion clearly reflecting better permeability in coarser material. Fine grain size and iron-oxide stain obscure diagenetic sequence. Calcite replaces quartz and orthoclase in silt, and siderite replaces calcite. Kaolinite always adjacent to one or more quartz grains suggesting direct source of silica. Some replacement of quartz by kaolinite is present in silt.

I. 2127, core 142, sample 1, depth 1,537 ft.

II. Feldspathic Subgraywacke; megascopically uniform, light gray with irregular light olive gray very-fine-grained laminae.

III. Medium to fine sand, some medium silt, finer grained laminae mostly micritic siderite, sand-micrite contact sharp, no distinct laminations within sand or micrite.

IV. Siderite, 7%; very fine grained aggregates surrounding and attacking most detrital grains, some phyllite fragments almost entirely consumed.

Kaolinite, 3%; granular aggregates between clastic grains, commonly replacing quartz or phyllite fragments.

Calcite, 1%; widely scattered isolated patches of cement.

V. Quartz, 51%; angular, medium to fine sand, commonly attacked by siderite, sharp extinction common, vacuoles rare, variable crystalline inclusions, overgrowths common.

Metamorphic Rock Fragments, 20%; mostly elongate chloritic phyllite grains, some composite quartz, phyllite attacked by carbonates and kaolinite.

Orthoclase, 8%; fine sand to medium silt, grains altered to clay, attacked by siderite.

Volcanic Rock Fragments, 5%; fine polycrystalline fragments.

Clay Matrix, 2%; illitic, good orientation shown by common extinction, mostly replaced by siderite.

Plutonic Rock Fragments, 1%; coarse quartz-feldspar aggregates and graphic intergrowths.

Plagioclase, 1%; only minor alteration, some attack by siderite.

Also trace amounts of altered perthite and microcline, distorted randomly oriented muscovite.

VI. Percentages cited above are for sand portion. Carbonate laminae are more than 70% siderite with very fine silt clastics widely scattered. Siderite obscures much detail in sand,however diagenetic sequence is quartz overgrowths first, kaolinite next, and siderite last.

I. 2128, core 142, sample 6, depth 1,594 ft.

II. Feldspathic Subgraywacke; megascopically uniform light olive gray sand.

III. No lineations visible, fine sand grains angular to subrounded in places, average grain size 0.17 mm.

IV. Kaolinite, 5%; granular aggregates, attacking quartz, phyllite fragments, plagioclase, orthoclase and especially clay matrix.

Siderite, 3%; anhedral granular clusters, commonly along grain boundaries.

Calcite, trace; diffuse, throughout clay matrix.

Pyrite, trace; euhedral crystals, commonly associated with leucoxene.

Chlorite and Illite, trace; fibrous clusters replacing clay matrix.

V. Quartz, 44%; subangular to subrounded, overgrowths common, some crenulated "pressure solution" contacts, attacked by siderite and kaolinite, minor inclusions, extinction commonly sharp.

Metamorphic Rock Fragments, 19%; one-fourth are composite quartz, remainder phyllite fragments, scattered phyllite replaced by kaolinite, chlorite or illite.

Volcanic Rock Fragments, 2%; fine-grained polycrystalline aggregates of quartz and feldspar.

Orthoclase, 8%; commonly altered.

Clay Matrix, 8%; illite and chlorite with scattered carbonate, some areas of recrystallization.

Chert, 2%; rounded grains, attacked by kaolinite.

Plagioclase, 1%; less alteration than in orthoclase.

Also traces of plutonic rock fragments, magnetite-ilmenite, leucoxene, chlorite, muscovite, and biotite micas.

VI. All clay types appear well crystalline on x-ray diffractograms. This is supported optically by frequent areas of recrystallization and authigenic keolinite. The apparent order of diagenetic change is quartz overgrowths first and siderite last. Recrystallization of clays, formation of kaolinite, introduction of calcite, and growth of pyrite are intermediate in undetermined order. Anomalously fresh plagioclase relative to potassium feldspars is common.

I. 2131, core 142, sample 15c, depth 1,624 ft.

II. Argillaceous Pelmatazoan Calcarenite; numerous fossil fragments in fine petroliferous groundmass.

III. Completely disrupted bedding although excellent alignment within contorted laminations is shown by organic debris, micas, and clays.

IV. Calcite, 60%; most as shell fragment replacement, remainder as micritic and coarsely recrystallized sparry cement.

Pyrite, 10%; replacing fossil debris partly or completely.

V. Clay Matrix, 19%; stained by petroliferous organic residue, x-ray shows degraded illite and chlorite, concentrated in laminae.

Quartz, 6%; fine to very fine silt, unevenly distributed.

Organic Opaques, 5%; elongate areas, commonly within shaley portions, petroliferous odor.

Muscovite and Chlorite, trace; fine laths within quartz silt areas.

VI. Diagenetic changes limited to calcite recrystallization and pyrite formation. Petroliferous stain makes detailed description difficult. Fossil debris in order of decreasing abundance includes fragments from pelmatazoans, gastropods, pelecypods, bryzoans, brachiopods, crinoids, and trilobites. Permeability has probably remained low since clays remain in degraded condition.

I. 2133, core 142, sample 18a, depth 1,640 ft.

II. Subarkose; medium to fine sand, light olive gray to light brownish gray, brownish areas due to high concentration of siderite, texture magascopically uniform.

III. Subangular to subrounded medium and fine sand with some intergranular fine and medium silt, grains cemented by large optically continuous areas of calcite, abundant siderite, and some clay.

IV. Siderite, 9%: scattered throughout but highly concentrated in a 0.5 cm. zone parallel to bedding, granular clusters along grain boundaries and fractures, rarely within plagioclase grains, replacing calcite, feldspars, quartz, kaolinite, and rock fragments.

Calcite, 7%: sparry cement, optically continuous areas engulfing numerous sand grains, attacks all types of clastic grains--especially feldspars.

Kaolinite, 5%: polycrystalline aggregates between sand grains, replacing quartz and feldspars.

Pyrite, trace: randomly scattered individual and polycrystalline grains.

V. Quartz, 51%: subangular to subrounded, angularity magnified by overgrowths and calcite attack, some replacement by siderite and kaolinite, grains commonly strained, vacuoles common, scattered zircon and rutile inclusions.

Metamorphic Rock Fragments, 8%: chlorite schists and quartz aggregates with crenulated contacts.

Orthoclase, 6%: altered to clay to varying extents, edges corroded by calcite and kaolinite.

Volcanic Rock Fragments, 4%: very fine crystalline aggregates.

Plutonic Rock Fragments, 3%: coarsely crystalline quartz-feldspar aggregates and intergrowths.

Microcline, 2%: commonly severely altered.

Perthite, 2%: commonly severely altered.

Clay (Illite?), 2%: fine widely disseminated matrix.

Also traces of zircon, rutile, chert.

2133--(Continued).

VI. In addition to authigenic kaolinite, some recrystallization of chlorite within schist fragments and of "muscovite" within clay is present, order of authigenic growth chronologically is quartz overgrowths, kaolinite formation, calcite cement, siderite. No clear evidence for relative position of pyrite or recrystallized chlorite and illite is present.

I. 2340, core 627, sample 3b, depth 13,751 ft.

II. Argillaceous Subarkose: very fine grained, disrupted irregular subparallel clay laminations, iron-oxide stain irregularly distributed.

III. Disrupted irregular bedding defined by argillaceous concentrations suggests slumping of unconsolidated material. Detrital muscovite and chlorite parallel to bedding, and fine grain size suggest low energy depositional environment. Average grain size 0.08 mm.

IV. Siderite, 2%: widely scattered aggregates of fine silt-size anhedral grains replacing calcite.

Calcite, 2%: sparry to cloudy cement, replacing quartz.

Kaolinite, 1%: fine-grained clusters, commonly adjacent to altered feldspars.

V. Quartz, 61%: subrounded to subangular, grains commonly interlock with scattered feldspars included suggesting plutonic rock fragments, commonly etched by calcite, variable extinction.

Clay Matrix, 14%: illite(?), scattered throughout sand and concentrated in thin discontinuous layers, commonly iron-oxide stained.

Orthoclase, 8%: subrounded grains, commonly altered to clay.

Chlorite, 4%: as individual mica laths.

Metamorphic Rock Fragments, 1%: chloritic phyllite and composite quartz.

Volcanic Rock Fragments, 1%: composite quartz-feldspar, fine-grained aggregates.

Muscovite, 1%: laths, commonly bent.

Plagioclase, 1%: altered subangular grains, some closely associated with quartz.

Leucoxene, 1%: widely scattered subrounded grains.

Magnetite-ilmenite, 1%: widely scattered subrounded grains.

Limestone Rock Fragments, 1%: widely scattered, subrounded to rounded, micritic.

Organic Opaques, trace: carbonaceous plant fragments.

2340--(Continued).

VI. Varied source area--igneous, metamorphic, sedimentary. No clear evidence of quartz overgrowths, calcite replaces quartz and feldspar, siderite replaces calcite, chronologic relationship between carbonates and authigenic kaolinite not clear. Other alterations are argillization of feldspars and formation of leucoxene.

I. 2341, core 285, sample 104, depth 12,754 ft.

II. Argillaceous Subarkose: medium light gray coarse silt with subparallel dark shaly lenses and laminae (less than 1.0 mm) showing small-scale crossbedding and disruptions.

III. Majority of thin section occupied by a close mixture of fine clay (illite from x-ray) and carbonate. An accurate point count is difficult due to strong masking by carbonate replacement. Dark laminae consist of iron-oxide stained aligned clay with abundant polycrystalline pyrite masses and some carbonaceous material.

IV. Calcite and Dolomite, 24%: anhedral "groundmass" with some sparry crystals and dolomite rhombs, replacing all detrital material. Rhombs are 0.04 mm and smaller.

Pyrite, 14%: as polycrystalline masses, commonly 0.10 mm, widely distributed but more common in argillaceous carbonaceous laminae. apparently replacing organic debris.

V. Illite, 30%: abundant throughout slide but concentrated in thin iron-oxide-stained laminae. Obscured by carbonates, good alignment.

Quartz, 15%: angular to subrounded grains, strongly etched by carbonates, 0.04 mm common size, percentage is minimal.

Plagioclase, 6%: angular coarse silt grains, most grains fresh except for peripheral carbonate attack.

Orthoclase, 5%: grains angular to subrounded, attacked by carbonate, altering to clay.

Perthite, 2%: angular to subrounded, attacked by carbonate, altering to clay.

Organic Opaques, 1%: carbonaceous, elongate, commonly surrounded or being replaced by pyrite, more common in shaly laminae.

Micas, 1%: muscovite with some chlorite and biotite, subparallel alignment, minor distortion, attacked by carbonates.

Leucoxene, 1%: subrounded, widely distributed, coarse silt.

Also traces of maghematite, magnetite-ilmenite, apatite, graphic quartz-feldspar plutonic grains, metamorphic rock fragments, limestone fragments.

I. 2342, core 500, sample 3b, depth 8,779 ft.

II. Feldspathic subgraywacke: fine to very fine light colored (N 6.5) sand interlaminated with iron-oxide-stained, organic-rich, micaceous shale layers.

III. Subparallel laminations with oblate fine sand lenses within shale laminations, sand grains angular to subrounded, mica and clay shows excellent alignment, sand-shale contacts sharp except in vicinity of sand "intraclasts."

IV. Carbonate, 4%: as calcite cement and some widely scattered siderite granules.

Kaolinite, 3%: clusters of fine (less than 0.002 mm) granules, commonly bordering and intruding into argillized feldspars and phyllite fragments.

Pyrite, trace: very fine aggregates, rarely in shale.

V. Quartz, 44%: fine sand, coarse silt in shaly laminae, angular to subrounded, etched by calcite, grains commonly severely strained.

Clay Matrix, 13%: chlorite and illite, secondary crystallization suggested at places by coarse fibrous appearance, bent around sand grains, excellent alignment within shale laminae.

Metamorphic Rock Fragments, 12%: composite quartz grains, chloritic phyllite and schist grains.

Orthoclase, 7%: subangular to subrounded grains, mostly in sand portion, grains attacked by authigenic kaolinite and in places by illitic and chloritic recrystallization.

Mica, 5%: approximately equal amounts of chlorite, biotite and muscovite as distorted laths in sand portion, gently warped in shale portion.

Volcanic Rock Fragments, 3%: fine-grained aggregates of quartz and feldspar.

Plagioclase, 2%: scattered angular laths, selectively argillized along twin boundaries.

Organic Opaques, 2%: elongate carbonaceous particles, almost exclusively within shale.

2342--(Continued)

V. (Continued).

Magnetite-ilmenite, 2G: coarse silt, subrounded, scattered throughout sand and shale.

Hematite, 1%: fine sand, subrounded in sand portion, as stain in shale.

Limestone Fragments, 1%: rounded fine sand grains, micritic.

Also trace amounts of leucoxene, collophane, staurolite, epidote, and zircon.

VI. Varied source area, metamorphic fragments predominate, some suggestions of recrystallization and grain growth among chlorite and illite, kaolinite new mineral growth most commonly associated with chlorite rock fragments or potassium feldspar. Concentration of organic debris and little, if any diagenesis in shale suggests intrastratal fluid movement confined to sands with little sand-shale interchange.

I. 2343, core 278, sample 19, depth 12,349 ft.

II. Calcareous Arkose: medium gray, medium sand, thin laminations and films of dark gray micaceous shale, megascopic black carbonaceous flakes throughout sand.

III. Randomly oriented, poorly sorted, subangular grains, size range from 0.01 mm to 0.60 mm (average 0.30 mm) in addition to clay, organic flakes display subparallel alignment megascopically but no alignment is noted in micrscopic investigation.

IV. Calcite, 43%: cement throughout sample, attacking quartz and feldspars, x-ray shows minor dolomite.

Pyrite, 1%: commonly associated with organic material.

Kaolinite, trace: polycrystalline patches, commonly associated with orthoclase.

V. Quartz, 16%: subangular grains, vacuoles common, few grains have abundant crystalline inclusions, attacked by calcite.

Perthite, 8%: varying amounts of alteration, scattered grains show highly altered sodic portion, nearly fresh potash.

Orthoclase, 8%: wide size range, from largest to smallest in slide (0.6 mm--0.01 mm), commonly intensively altered to clay.

Graphic Intergrowths, 8%: variety of geometric patterns of quartz in orthoclase and microcline, scattered square euhedral beta quartz in orthoclase, feldspar portion commonly sericitized.

Chert, 4%: subrounded to rounded grains, some carbonate attack.

Limestone Fragments, 4%: rounded micritic grains.

Volcanic Rock Fragments, 4%: fine-grained aggregates, tridymite(?) needles common.

Clay, 2%: illite as unevenly distributed matrix.

Plagioclase, 1%: altered but commonly less intense than orthoclase.

Microcline, 1%: commonly intensely altered, attacked by carbonate.

Also traces of magnetite-ilmenite, leucoxene, zircon, muscovite, biotite, chlorite micas.

2343--(Continued)

VI. Calcite overwhelms nearly everything, plagioclase not as strongly altered as K-feldspar. From x-ray investigation, shale associated with this sand contains dolomite and minor calcite as opposed to calcite and minor dolomite in sands. Local derivation of Mg from clays of shale probable. Graphic intergrowths similar to Wichita Mountain granites, especially Lugert Granite.

I. 2344, core 142, sample 19c, depth 1,537 ft.

II. Siderite Concretion: micritic siderite with irregularly scattered very fine sand and pyrite.

III. Randomly oriented mica laths and randomly-shaped areas of clastic concentration suggest post-depositional distortion. Large (to 0.38 mm) elongate carbonaceous areas randomly distributed, commonly replaced by fine polycrystalline pyrite.

IV. Siderite, 91%: micritic, attacking detrital quartz and feldspar, void fillings are coarser grains (0.004 mm). Percentage a maximum, some detrital material probably obscured.

Pyrite, 3%: as euhedral crystals (0.008 mm) and fine-grained polycrystalline aggregates, the latter confined to carbonaceous areas.

Kaolinite, 2%: irregular polycrystalline patches, 0.2 mm and smaller.

V. Quartz, 2%: subangular to subrounded, irregular outlines due to siderite attack, sharp extinction common, minor rutile inclusions, grains widely scattered but commonly concentrated in poorly-defined areas.

Collophane, 1%: randomly distributed, rounded, somewhat larger than quartz grains.

Also traces of muscovite, biotite, metamorphic rock fragments, volcanic rock fragments, orthoclase, chert, carbonaceous material. (The latter was probably initially present in higher percentage but now replaced by pyrite).

VI. Micritic size of siderite suggests "primary" formation. Siderite attacking essentially all detrital grains. Pyrite replacing organic material suggests reducing environment near organic debris with sulfur from organics and iron from siderite. Authigenic kaolinite clusters have shapes suggesting void fillings, some clusters appear to be replacing feldspars.

I. 2345, core AL3, sample 50, depth 100 ft.

II. Graphic Arkose: medium to coarse sand, megascopically homogeneous.

III. Plutonic graphic intergrowth fragments dominate as angular to subangular grains 0.9 mm to 0.2 mm, averaging 0.4 mm. Widely distributed individual quartz scattered as subrounded to rounded grains 0.1 to 0.2 mm diameter. Clay present commonly as coating on grains, commonly iron-oxide stained.

IV. Kaolinite and "Illite," 8%: as coating around grains and in cleavage planes, attacking feldspars, well crystalline elongate plates and vermicular tablets.

Calcite, 2%: as sporadic cement, attacks feldspar.

Pyrite, trace: replacing magnetite(?).

V. Plutonic Graphic Rock Fragments, 36%: majority are graphic intergrowths of quartz and perthite or quartz and orthoclase, feldspars argillized to varying extent.

Quartz, 18%: majority as composite grains, some rounded grains apparently recycled sedimentary grains.

Perthite, 10%: sodic feldspar commonly more altered.

Volcanic Rock Fragments, 10%: fine-grained polycrystalline fragments.

Orthoclase, 9%: commonly argillized and rimmed by authigenic clay.

Microcline, 6%: commonly argillized and rimmed by authigenic clay.

Also traces of biotite, muscovite, magnetite-ilmenite, leucoxene, rutile, zircon, tourmaline.

VI. Micas bent around other grains. Coarsely crystalline clay around grains and along fractures commonly iron-oxide stained and slightly pleochroic thus not optically a typical kaolinite. X-ray patterns show very-well crystalline kaolinite accounting for nearly all the clay mineral content, slight pleochroism suggests dickite.

I. 2346, core 321, sample 14b, depth 9.726.

II. Pyritiferous Feldspathic Subgraywacke: subparallel interlaminated dark greenish gray coarse silt and very fine sand and greenish black shale, disrupted laminations.

III. Subparallel, in places disrupted laminations defined by concentration of clay, laminations distinct megascopically but gradational in thin section, alignment of platy and elongate minerals in shaly portion is good, moderate in coarser portion.

IV. Calcite, 16%: cement, almost totally confined to sand-silt portion.

Pyrite, 8%: polycrystalline aggregates in silt and edges of shale, commonly associated with organic debris.

Chlorite, 1%: fibrous masses, commonly within detrital fine-grained clay and fractures of feldspars.

Siderite, 1%: individual anhedral grains (0.005 mm) replacing calcite.

Kaolinite, trace: polycrystalline aggregates, in silt, commonly adjacent to orthoclase and perthite.

V. Quartz, 40%: angular to subrounded coarse silt and very fine sand, vacuoles common, undulose to sharp extinction, replacement by calcite common.

Orthoclase, 8%: altered to varying extent, attacked by calcite.

Metamorphic Rock Fragments, 7%: subrounded composite quartz and phyllite fragments.

Muscovite, 4%: laths in silty areas, undisturbed to bent to broken depending upon proximity to silt grains.

Clay Matrix, 4%: illite (x-ray), good alignment in shaly laminations only.

Chlorite, 2%: laths similar to muscovite.

Biotite, 2%: laths similar to muscovite.

Plagioclase, 2%: less altered than orthoclase.

Perthite, 1%: selectively attacked.

Volcanic Rock Fragments, 1%: polycrystalline fine-grained aggregates.

2346--(Continued).

V. (Continued).

Limestone Fragments, 1%: well-rounded coarse silt and very fine sand, micritic.

Also traces of plutonic rock fragments (orthoclase-quartz aggregates and some graphic intergrowths), chert, leucoxene, organic carbonaceous debris, tourmaline, magnetite-ilmenite.

VI. Calcite attacking quartz and feldspar and replacing matrix clay. Authigenic and recrystallized clay not attacked by calcite, thus probably postdates calcite. Siderite confined to calcite. Organic material pyritized in silt portion but only rarely in argillaceous areas. K-feldspars more altered than plagioclase.

I. 2347, core 316, sample 1c, depth 3,715 ft.

II. Orthoquartzite: friable, magascopically uniform olive gray sand.

III. Very-well-rounded medium quartz sand (average 0.4 mm) with interstitial subrounded to subangular coarse quartz silt (average 0.05 mm) very weakly "cemented" with clay matrix.

IV. No authigenic components optically identified.

V. Quartz Sand, 71%: very well rounded, high sphericity, some interpenetration of grains, wavy extinction, most grains clear, some with abundant vacuoles, oriented rutile needles, scattered tourmaline and zircon inclusions,no overgrowths.

Quartz Silt, 19%: subrounded to subangular, minor inclusions.

Clay Matrix, 10%: illite (by x-ray).

Chert, trace: silt size.

VI. Quartz probably originally of plutonic origin. Small amount of orthoclase and dolomite are indicated by x-ray investigation, not identified optically. Lack of cement and authigenic components suggest little fluid movement through sands, despite friability porosity and permeability are low due to interstitial clay. Compare with thin section 2348.

I. 2348, core 316, sample 1a, depth 3,710 ft.

II. Orthoquartzite: megascopically uniform olive gray sand with scattered irregular dark laminations, well indurated.

III. Very-well-rounded medium quartz sand (average 0.4 mm) with interstititial subrounded to subangular coarse quartz silt (average 0.05 mm), tightly cemented with calcite and dolomite and quartz overgrowths.

IV. Dolomite, 10%: abundant rhombs, replacing calcite, attacking quartz.

Quartz overgrowths, 8%: on all grain sizes, commonly interlocks grains.

Calcite, 4%: as optically continuous areas, attacking quartz, being replaced by dolomite.

V. Quartz Sand, 60%: very well rounded grains, common overgrowths, undulose to composite extinction, some vacuoles, abundant zircon, some rutile needles and grains.

Quartz Silt, 16%: angular to subrounded, abuncant overgrowths.

Clay (illite), 2%: interstitial matrix, being attacked by carbonates.

VI. Compare with thin section 2347. The clay in this interval of the core is largely segregated intc shale laminae (none in this thin section) allowing much higher permeability and porosity. Quartz overgrowths occur first, "pressure solution" second, calcite third, dolomite most recently.

APPENDIX C

ANALYTIC PROCEDURES

General Statement

Samples for study were selected from cores on file at the University of Oklahoma Core and Sample Library. A total of 14 cores from varying depths and geographically dispersed locations (see Fig. 2) were chosen for detailed investigation. From these cores, more than 125 samples were thoroughly examined by various x-ray diffraction techniques. Twenty-eight of the samples were subjected to x-ray fluorescence analysis. The location of the cores and descriptions of the samples are given in Appendix A.

X-Ray Diffraction

Representative samples from each lithologic unit were separated and ground in an agate mortar until all material passed an 80-mesh dry sieve. A split fraction of each was sieved onto a glass slide coated with a film of petroleum jelly which serves as an inert adhesive. X-ray analyses were made of these randomly-oriented bulk powder samples to determine overall mineral composition and to locate "edge" reflections of the clay minerals.

A second split fraction of each was dispersed in distilled water by an ultrasonic transducer (Branson Sonifier, model S125). The samples were variously size-fractioned (spherical equivalent) by settling techniques based upon Stokes' Law (Folk, 1965, p. 40). Flocculation was encountered in a few samples and was eliminated by repeated washings with distilled water. Suspensions of these size fractions were allowed to settle and dry at 60° C on glass slides in order to enhance basal reflections of the clay minerals. Duplicate oriented slides were prepared of the less-than-4-micron fraction for each sample. One slide was x-rayed before and after heating to temperatures varying from 100° C to 700° C. The other slide was x-rayed after a minimum of 3 hours exposure to a saturated ethylene glycol atmosphere at 60° C.

A third split sample of approximately one-fourth of the samples was treated with warm 10% HCl for 12 hours and then sedimented on glass slides. This procedure was used to confirm the presence of kaolinite by removing the interference of chlorite.

Both North American Phillips (Norelco) and Siemens-Halske diffraction units were employed in these investigations. Nickel-filtered Cu (K-alpha) radiation generated at 40 KV and 20 ma on the former and 35 KV and 18 ma on the latter was used. The diffracted radiation was detected with scintillation counters. A scanning rate of 1° 2θ/min was used with scale factor and multiplier values varied to obtain optimum resolution on the diffractogram strip charts. Diffractograms were obtained from 2° to 65° 2θ for powder samples and from 3° to 30° 2θ for oriented samples.

Examples of diffractograms of a typical sand-shale pair are shown on the following four pages.

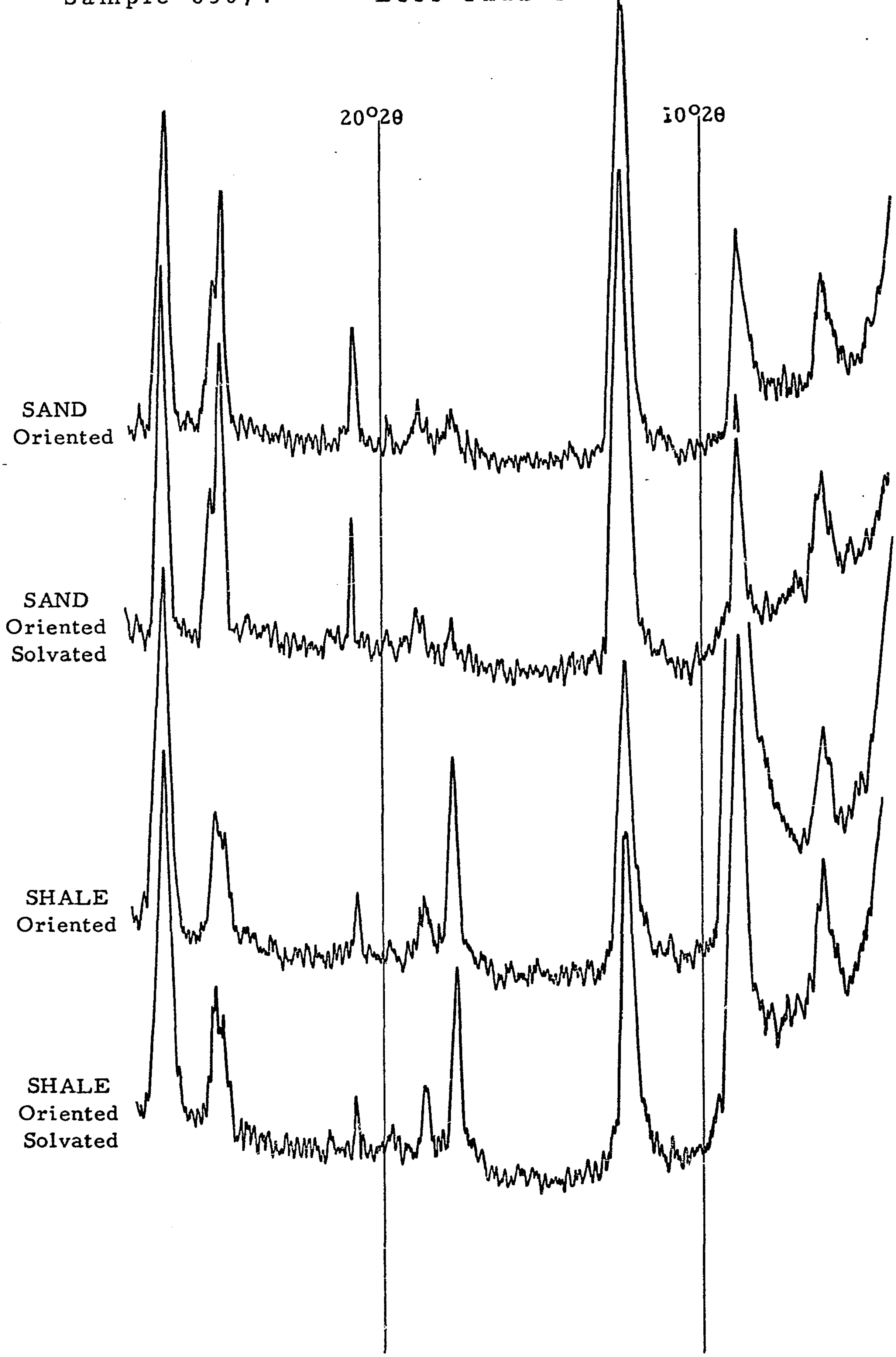
X-Ray Fluorescence

A total of 28 samples were selected for bulk chemical analysis by x-ray fluorescence. Of these, 5 are from Permian strata, 3 from Ordovician strata, and the remaining 20 represent 10 sand-shale pairs from Desmoinesian strata. The analyses of 9 samples have been rejected because of questionable total percentages. Most of these rejected analyses indicated unusually high amounts of carbonate and/or sulfur. The totals for these samples are well over 100% due to an appreciable difference in matrix effect between the samples and the standards used causing less fluorescence radiation to be absorbed in the samples than in the standards.

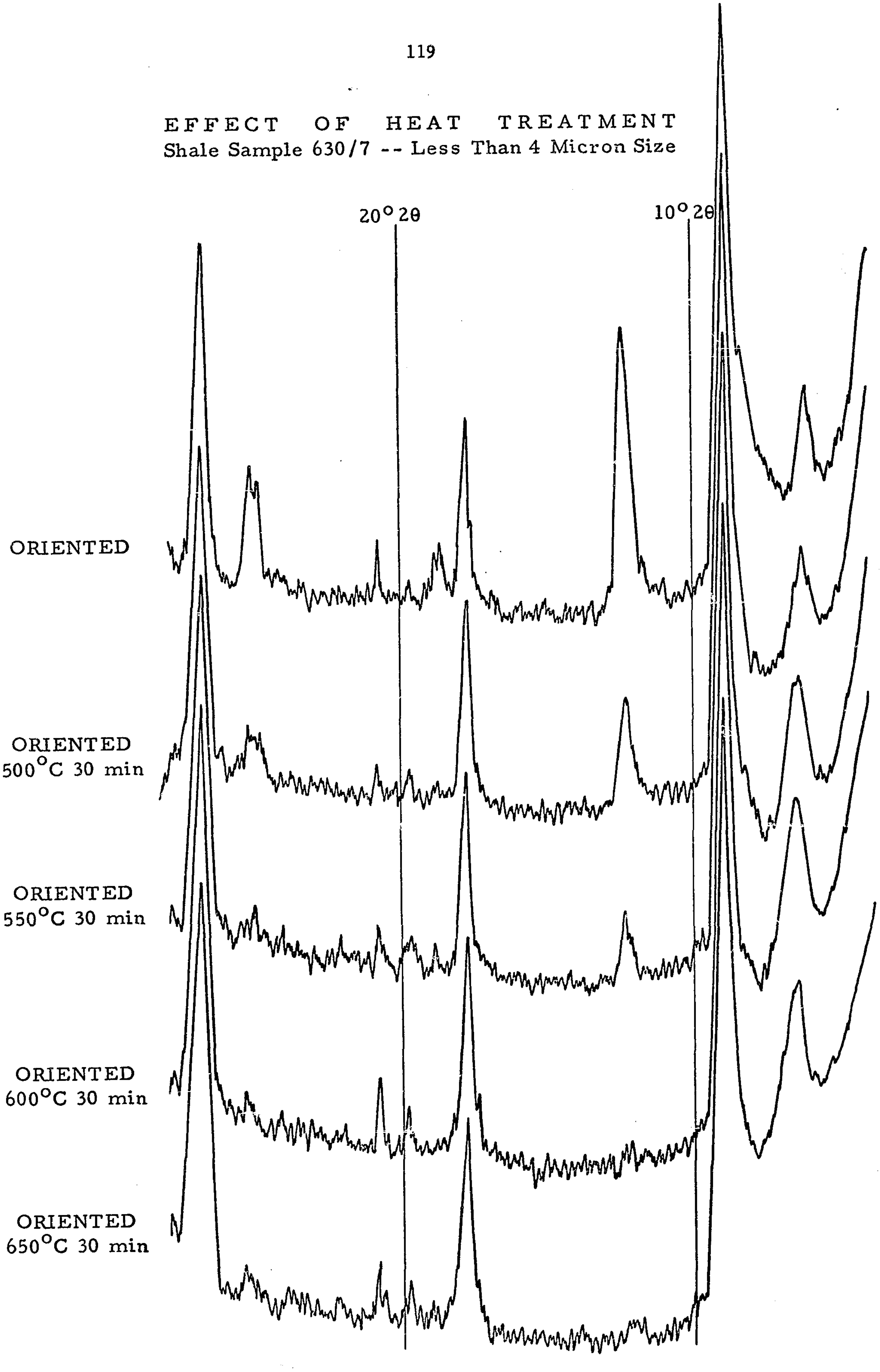
Samples were prepared by grinding in an agate mortar until all material passed a 200-mesh sieve. Each sample was then combined with sufficient binder (polyvinyl alcohol) to achieve a mixture containing 80% sample. These mixtures were then pressed into discs at approximately 15 tons/in.^{2} pressure. Standard samples had previously been prepared in a similar manner. These samples were obtained from the U. S. Geological Survey silicate rock standards and the U. S. Bureau of Standards.

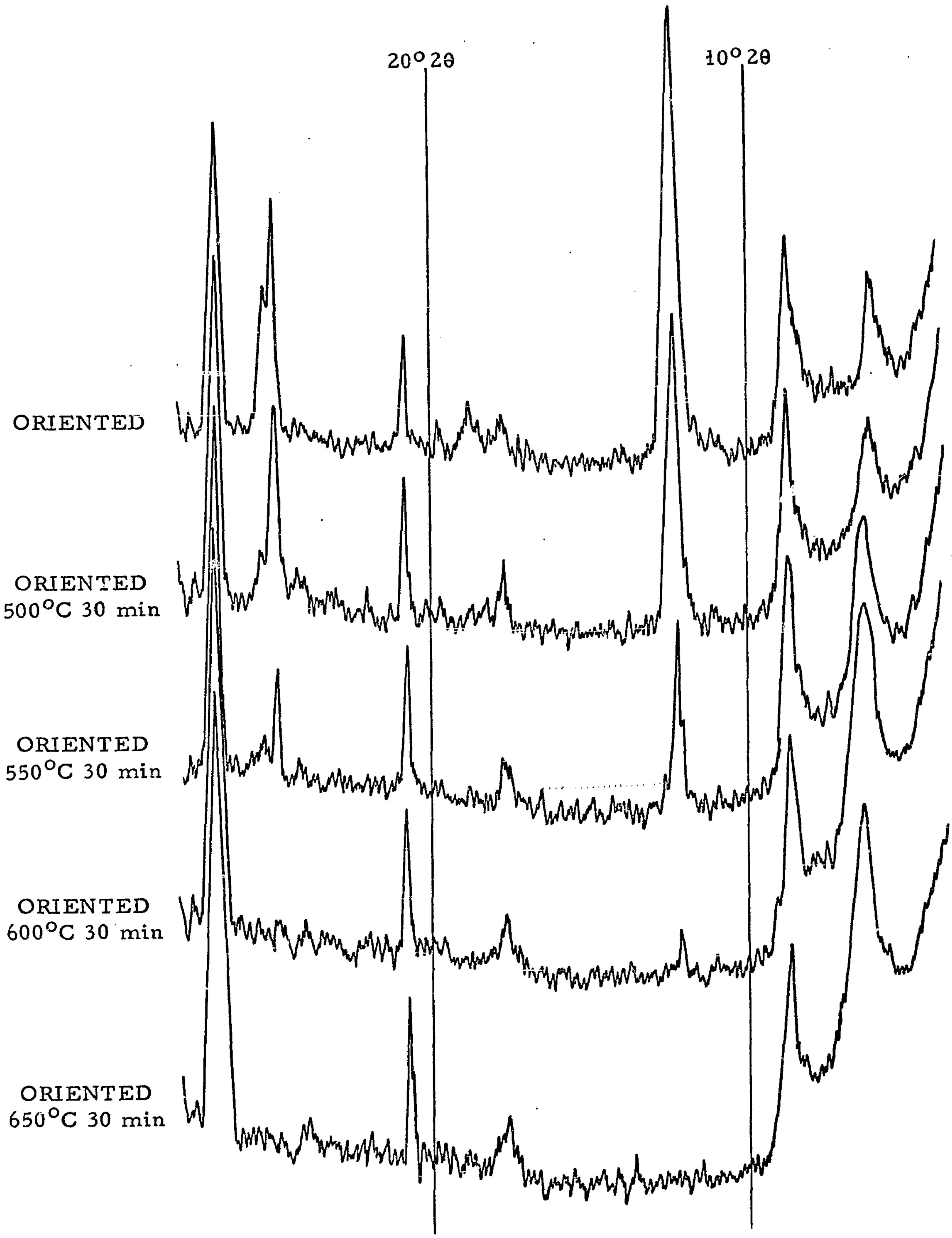
Analyses were run on a Siemens-Halske sequential x-ray fluorescence spectrometer, model SRS-1. For calcium and lighter elements, a vacuum of less-than-100 microns was kept on the system. A chromium tube and gas-flow detector were used for all elements except manganese and iron for which a tungsten tube and scintillation counter were

EFFECT OF ETHYLENE GLYCOL SOLVATION
Sample 630/7 -- Less Than 4 Micron Size



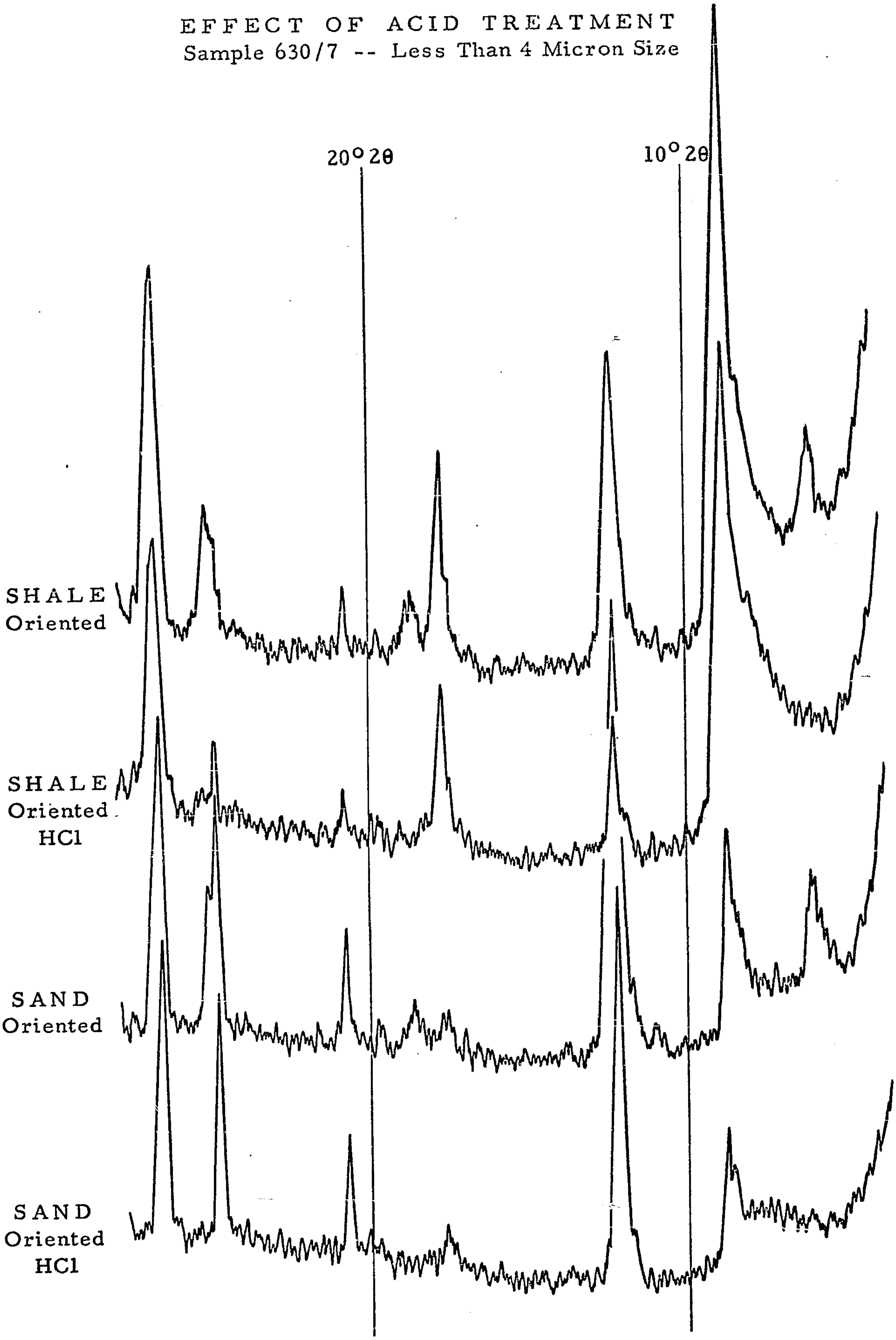
EFFECT OF HEAT TREATMENT
Shale Sample 630/7 -- Less Than 4 Micron Size





EFFECT OF HEAT TREATMENT
Sand Sample 630/7 -- Less Than 4 Micron Size

EFFECT OF ACID TREATMENT
Sample 630/7 -- Less Than 4 Micron Size



employed. Diffraction crystals and electronic controls were varied as necessary for each element.

Results of the chemical analyses, by weight percent, are recorded on the following page.

CHEMICAL ANALYSES

	SiO_2	Al_2O_3	FeO	MgO	K_2O	CaO	P_2O_5	Na_2O	MnO	TiO_2	S	Cl[a]	Ig.Loss[b]	Total
Desmoinesian Shale														
142/9	56.1	19.6	7.93	2.82	4.01	0.28	0.16	1.42	0.14	1.31	0.11	0.18	5.87	99.75
142/15c	53.0	21.9	6.14	1.18	2.58	1.41	0.10	0.74	0.04	1.19	7.21	0.09	9.85	105.34
142/19c	47.8	23.7	9.82	2.17	4.96	0.64	0.27	1.08	0.18	1.08	2.99	0.17	6.97	101.66
106/1	58.4	19.7	8.30	2.97	3.63	0.38	0.16	0.98	0.18	1.04	0.19	0.11	6.78	102.71
630/7	60.5	19.0	5.81	3.47	3.57	0.20	0.13	1.38	0.03	1.28	0.38	0.12	4.76	100.51
360/6	52.8	23.6	7.05	2.60	4.34	0.34	0.15	0.99	0.08	1.06	0.97	0.09	8.23	102.21
278/17	57.8	18.3	3.77	3.77	4.76	5.11	0.18	0.99	0.03	1.16	0.25	0.01	8.93	105.05
627/3a	57.6	23.2	4.50	2.18	4.59	0.18	0.14	1.18	0.04	1.41	0.15	0.01	6.22	101.39
Desmoinesian Sand														
142/9	73.0	12.5	4.12	1.50	1.75	0.18	0.11	1.69	0.04	0.72	0.10	0.23	2.00	97.71
106/6	74.1	7.0	3.44	1.11	0.70	7.96	0.14	0.73	0.15	0.48	0.17	0.08	5.40	101.38
630/7	75.1	11.3	3.92	1.23	1.17	0.91	0.10	1.26	0.03	0.36	0.25	0.05	2.65	98.28
500/3a	76.2	7.6	4.64	1.25	0.73	3.53	0.18	1.11	0.12	1.41	0.52	0.03	2.38	99.67
278/17	55.8	10.6	4.29	3.49	2.74	10.42	0.23	1.40	0.04	0.60	0.51	0.01	9.19	99.31
627/3b	85.9	7.4	3.45	0.83	0.80	0.33	0.10	1.24	0.07	0.54	0.04	0.02	1.66	102.36
Permian Shale														
Fargo/32	51.6	16.7	8.49	8.71	4.81	2.44	0.19	0.92	0.13	0.82	0.03	0.02	8.53	103.37
Permian Sand														
AL3/50	65.0	14.9	5.18	1.65	3.91	0.02	0.06	2.81	0.01	0.32	0.00	0.01	2.66	96.52
Ordovician Shale														
245/1c	52.4	17.3	3.86	5.20	7.64	5.80	0.21	0.62	0.04	0.72	1.64	0.01	7.06	102.49
Ordovician Sand														
316/3a	91.0	3.85	0.00	0.67	0.86	0.00	0.05	0.75	0.00	0.12	0.17	0.23	0.53	98.00
316/24	89.1	3.90	0.00	0.45	1.12	1.01	0.59	0.75	0.00	0.12	0.46	0.27	2.72	100.22

[a]The Cl is not included in the total because it is present as a negative ion.

[b]Ignition losses are determined by heating to 1000° C for 1 hr, the amount recorded is adjusted for the amount of S present.