STATE OF MISSOURI
GEOLOGICAL SURVEY AND
WATER RESOURCES

BIENNIAL REPORT *of the*

STATE GEOLOGIST

Transmitted to the
SIXTY-SECOND GENERAL ASSEMBLY

1943

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LETTER OF TRANSMITTAL

To His Excellency, Forrest C. Donnell, Governor of Missouri:

Dear Sir:—I have the honor and pleasure to submit herewith a brief outline covering the major activities of the Missouri Geological Survey and Water Resources for the biennial period 1941-1942.

The report also contains a tabulation showing the value of the mineral production during the past ten years and a brief review covering more especially the production during the past biennial period.

A number of short reports of geological investigations are also included as appendices. None of these is of sufficient length to warrant publishing as a separate volume.

Respectfully submitted,

H. A. BUEHLER,
State Geologist.

CHAPTER I.

WORK OF THE GEOLOGICAL SURVEY AND WATER RESOURCES DURING 1941 AND 1942.

The work of the Geological Survey during the past biennial period has been devoted chiefly to investigations directly connected with the war effort, and just as far as possible unrelated activities have been deferred or discontinued.

For a year prior to Pearl Harbor cantonments and war plants were being located in Missouri. Requests for information relative to strategic minerals took on a distinctly war trend. Detailed information concerning ground water supplies was needed at each plant location, and topographic maps were demanded and desired covering every part of the state. The value of the work of all three branches of the Survey namely; (1) Geology and Mining, (2) Water Resources and (3) Topographic Mapping, was proven time and again. In the war effort suitable water supplies have become a very important problem throughout the state. The fact that this Department has made the study of ground and surface water supplies one of its chief subjects of research for the past twenty years, made reliable data relative to deep water horizons available in every county, as well as the stream flow of every large river in the state. The data has been invaluable in the location of the various plants and because of past investigations the information was promptly available when needed.

In the investigations cited on the following pages it will be noted that the Survey outlined (1) possible dolomitic beds in southeast Missouri suitable for use in the manufacture of the much needed metal, magnesium; (2) that we worked in co-operation with representatives of the War Production Board on the possible production of sponge iron from Missouri iron ores; (3) that we completed an investigation of the flint, diaspore and plastic fire clay fields of east central Missouri and have produced a descriptive report of these deposits, which are so important in furnishing the raw clay needed in the manufacture of high-grade refractories for the Army and Navy;

(4) there was published a set of 6 large scale geologic maps (4″ to the mile) of the Joplin lead and zinc field in southwest Missouri. These maps have proven very valuable geological guides to prospecting throughout the district.

At the request of Army Engineers of the Seventh Corps Area, approximately 1500 square miles of topographic maps were completed in the area of Fort Leonard Wood and Camp Crowder. A part of the areas surrounding both of these camps had already been mapped in former years. There have been many other areas in the state where information was desired that were not covered by such maps.

The Survey has in past years published many reports describing various mineral resources. These reports have been in demand and have served as the basis of much prospecting and development. Members of the staff have visited the field with citizens interested in doing development work and have advised concerning the geological features of the areas in question and made suggestions regarding methods of prospecting.

In establishing the various cantonments, concentration camps, airports and ammunition dumps, an adequate ground water supply is a very important factor. In each and every case this Department has been consulted and has advised regarding deep subsurface possibilities. Members of the staff supervised the drilling of 20 wells for Army use at various points where plants were established, and at 6 additional plants were able to show that suitable water supplies could be obtained only from surface streams.

PERSONNEL.

There have been a greater number of resignations and changes in personnel in the Geologic Branch during the past two years than during any other biennial period in the past forty years.

Mr. Norman Hinchey resigned to enter the service of the Shell Oil Company. Mr. Garland Gott resigned to accept employment with the U. S. Geological Survey. Miss Mary Hundhausen resigned. Mr. Earl McCracken, part-time employee, resigned and is now employed by the Gulf Oil Corporation. Both Mr. Hinchey and Mr. Gott resigned because they received much better financial offers. With present salary restrictions specified by the Missouri law governing the Survey, it is not possible to compete financially with Federal Bureaus or private corporations. It requires a long time for a new man to get experience in Missouri geology and a knowledge of its resources, and the resignation of these men who have spent several years with the Department at this time is a distinct loss.

During the period Mr. Dan R. Stewart, Mr. Lyle McManamy and Mr. Jos. R. Clair were employed as geologists, and Mr. W. E. Davis was employed as ceramist and draftsman.

The following list indicates the full time employees of the Bureau at the present time:

Name	*Position*
H. A. Buehler	State Geologist
H. S. McQueen	Ass't State Geologist
John Grohskopf	Principal Geologist
F. C. Greene	Geologist
Kenneth Aid	Geologist
Jos. R. Clair	Geologist
Dan R. Stewart	Geologist
Lyle McManamy	Field Geologist
C. O. Reinoehl	Map Clerk
W. E. Davis	Ceramist and Draftsman
Jean McCaw	Secretary and Chief Clerk
Mary Houston	Secretary and Clerk
E. E. Hawkins	Janitor and Lab. Ass't

During the summer season it is usual to employ temporary assistants to undertake certain investigations, and during the present biennium the following persons have been so employed:

G. A. Muilenburg	Geologist, 1941-1942
Oliver R. Grawe	Geologist, 1941-1942
Edward L. Clark	Geologist, 1941
Earl J. McCracken	Geologist, 1941
Paul G. Herold	Ceramist, 1941
C. W. Dougan	Ceramist, 1942
Jas. V. Barnes	Field Ass't, 1942
R. L. Heller	Field Ass't, 1942
F. C. Farnham	Geophysist, 1942 (1 mo.)
R. T. Rolufs	Chemist, 1941-1942
Marvin Breuer	Magnetometer Operator, 1942 (2 mo.)
Jerry Higley	Magnetometer Operator, 1942 (2 mo.)

EMPLOYEES—WATER RESOURCES AND TOPOGRAPHIC MAPPING BRANCHES.

The work of these two branches is carried on in cooperation with the United States Geological Survey. The Federal Bureau matches State funds dollar for dollar in both branches and with the exception of one state employee in the Water

Resources Branch, the personnel is furnished by the Federal Bureau. Many of the engineers work only part time in Missouri each year, and therefore no endeavor has been made to publish the rather long list of Federal employees. The individual names are shown under each branch in the financial statement covering expenditures for the biennial period.

COOPERATION.

Cooperation with various government bureaus, cities, industries and citizens, has continued throughout the biennial period. The most important activities in this regard have been the extensive topographic mapping done at the request of the Army, and the determination of the available water resources at the various munitions plants, cantonments and airports, located in Missouri in connection with the war effort. In addition, cooperation has continued with the State Highway Department, U. S. Geological Survey, U. S. Bureau of Mines, State Securities Commission, Work Projects Administration, State Planning Board, County Agricultural Agents, State Conservation Commission, etc.

The Missouri Geological Survey could not undertake many of the research problems mentioned in the following pages if cooperative funds were not available for the work.

FIELD INVESTIGATIONS DURING 1941-1942

The State maintains the Geological Survey to assist in developing its mineral resources, prepare complete and accurate data on stream flow and prepare accurate topographic maps of the state. In order to comply with this mandate, surveys are made of the mineral producing districts and reports are published showing the character of ores produced and describing the geological conditions under which they occur. The reports are a guide to further developments. It is not the function of the Geological Survey to examine or report upon individual, privately owned properties or mines. That is the province of the consulting geologist.

In cooperation with the U. S. Geological Survey an accurate topographic map is being made of the state. Approximately 50% of the area has been completed and about 1500 square miles are completed each year.

Under the Water Resources Branch the State and Federal Surveys in cooperation maintain 95 gaging stations on the major streams of the state. These stations provide the data for computing the stream flow of every major drainage area in Missouri.

Citizens throughout the state submit samples of mineral and rock for identification, usually accompanied by a request for the determination of the commercial value of the material. Members of the staff determine the character and value by hand examination, and where necessary chemical tests are made. Several hundred samples are received and determined annually.

The following pages outline the chief investigations undertaken by the staff during the past biennial period.

GROUND WATER STUDIES.

For many years the Geological Survey has been engaged in the study of ground water supplies throughout the state and maintains a well-equipped laboratory to make chemical and microscopic studies of the drill cuttings. Drillers submit samples at 5-foot intervals from wells drilled. When these samples are received a small portion is treated with acid to remove all lime and magnesia. This treatment leaves an insoluble residue which is characteristic for each formation. These residues are examined under a microscope and a graphic log of the well is prepared, showing the kind of rock occurring every five feet throughout the total depth. Water horizons are shown and every geological feature determined. The depth at which openings occur in the well is indicated by this examination and the casing point, above which surface waters carrying possible contamination might enter, is decided upon. When this system is followed it is seldom that contamination occurs, provided the casing is satisfactorily sealed.

This Department has on file approximately 400,000 samples of cuttings from approximately 7,000 wells scattered throughout every county in the state. In addition we have several thousand drill records or logs covering which there are no samples.

During the past seven years we have received and examined samples from between 500 and 800 wells per year. During 1939 and 1940 we obtained 80,000 samples from 1400 wells. In 1941 we received 41,685 samples from 835 wells and in 1942 we received 28,204 samples from 547 wells. Drilling has fallen off very markedly during the latter part of 1942, due to the fact that it is almost impossible for drillers and owners to obtain pumps, casings or repairs for drill rigs.

This service covering the occurrence of water horizons, casing points and the geologic section of the wells, has been greatly appreciated on the part of the drillers and landowners. The drillers have voluntarily contributed the samples. In many instances the graphic logs submitted by this Department, being an authentic record of the well, have been made a part of the deed to the land. In case the record is lost by the driller or landowner a duplicate can always be obtained from this office.

The greater number of the samples submitted were from private wells. Practically every well drilled for municipal, public, semi-public and military purpose was supervised by this Department and the State Board of Health. The two departments cooperate very closely, and wells drilled for public water supplies are constructed according to specifications which have been jointly drawn up by the two departments.

During the past two years there has been an important construction program carried on in connection with the war effort. In the location of every type of war plant, the matter of a satisfactory water supply has been of vital consideration, and this Department has been called upon for information, not only at the points where such plants have been located, but also at many localities which were under preliminary consideration. In almost every case a number of sites were studied before the final location was decided upon. A complete report on ground water possibilities was made for all points under consideration and in many cases it was necessary to make a field study of existing geological conditions before a decision could be reached. In a number of instances it was shown that ground water supplies were not available.

During the biennium 26 deep wells were supervised at war plants alone, and in six additional instances it was definitely shown, after field studies were made, that adequate ground water supplies could not be obtained and that surface or shallow water supplies were the only sources available.

The following cities drilled wells either for new supplies or to augment existing supplies. Each well was supervised during construction by this Department.

CITY WELLS DRILLED

City	*County*
Aurora (2)	Lawrence
Birch Tree	Shannon
Cabool	Texas
Crane	Stone
Deering	Pemiscot
DeSoto	Jefferson
Lutesville	Bollinger
Mansfield	Wright
Ozark	Christian

In addition to the above listed wells, the drilling of which was supervised by this Department, a considerable number of wells were drilled under our supervision for churches, clinics, mining companies, dairies, cheese factories, laundries, beverage bottlers, etc.

Inquiries were received concerning the possibility of new supplies or the augmentation of existing supplies at the following cities: Alton, Carthage, Festus, Ironton, Lebanon, Piedmont and Richland. No doubt some of these wells will be drilled in the near future. Many railroad companies made inquiry concerning ground water supply along their lines. This information was assembled for them in order that they could direct the location of proposed large war plants to the most favorable area. This was especially true in north Missouri.

Hundreds of inquiries by individuals concerning water supply are answered by this Department each year. Such inquiries are particularly numerous from the St. Louis suburban area. In parts of this area a problem of the occurrence of mineralized water exists. An indication of the amount of drilling in this area is shown by the fact that samples from 600 wells in St. Louis County alone were examined. In many instances we were able to prevent drilling wells too deep where mineralized water would be encountered with depth. This advice has saved the cost of many wells. Frequently inquiries regarding water conditions are received from purchasers of land in rural areas where the purchaser is not familiar with the locality and consequently does not have an adequate knowledge of the ground water possibilities.

For the past several years much attention has been given to a study of the geology of the lowland region of southeastern Missouri. This study has shown the possibility of developing an entirely new water-bearing horizon for many towns in this region. In the past it has been the practice to obtain ground water supplies from shallow wells sunk in the surface gravels and sands at relatively shallow depths of from 100 to 300 feet. Such supplies, although perfectly adequate, have an undesirable amount of dissolved iron in the water which stains household fixtures. It is now possible for many such towns to obtain water from a sand which lies much deeper and which furnishes a water that is virtually free from iron and also very soft. This sand lies at a depth of 230 feet at Bloomfield and pitches to the southeast in the direction of Caruthersville, where it lies at a depth of 2200 feet. This horizon is persistent in character and thickness southeast of a line drawn from Commerce to Bloomfield to Campbell. The development of this supply will save the citizens of various communities thousands of dollars in soap costs, and also the construction and operating expense of an iron removal system. The following towns are now using this source of supply:

City	*County*
Campbell	Dunklin
Kennett	Dunklin
Bloomfield	Stoddard
Bernie	Stoddard

The recently completed well at the Government Airport at Malden, in Dunklin County, derives its water from this source. The well flows 250 gallons per minute and is the largest flowing well as to yield of which we have a record in Missouri.

It is believed that the Survey reaches more people directly and indirectly through this phase of its work than in any other way. It is certain that public health in urban communities is dependant upon a satisfactory water supply, and the proper supervision of the construction of wells is a vital factor in assuring a water supply that is free from contamination.

OIL AND GAS.

The most important oil and gas development in the biennial period just closed was the discovery of oil on Thanksgiving Day, November 26, 1942, in the Cities Service Company's No. 1 Jim Cook well, SW¼ NW¼ NW¼ Sec. 32, T. 65 N., R. 39 W., near Tarkio, Atchison County.

The Geological Survey has followed closely the drilling of other oil and gas tests in the state during the past biennium. This work consisted of visiting certain wells and observing the drilling of important formational contacts. In some instances Survey geologists were at certain wells during the drilling of the entire section. In either instance advice was given regarding various phases of the geology. Arrangements were made by Survey geologists for samples of cuttings from nearly all the wells drilled and from all of the deep wildcats. Other records pertaining to these wells were obtained also. Advice has been given in conferences by Survey geologists relative to various areas, and many inquiries have been answered. During the present period two reports, The Geology of the Polo Gas Field, Caldwell County, and The Oil and Gas Resources of Jackson and Cass Counties, have been prepared and are now being printed.

The Polo gas fields, located west of Polo, in Caldwell County, discovered and drilled out in 1940 and 1941, is the most northeasternly pool yet discovered in Missouri. During the present biennial period Mr. Greene and Mr. McQueen studied this pool in considerable detail, and have determined the possible capacity of the field and the general structural and sand conditions of the area. Twenty productive wells having a combined open flow capacity of 33,000,000 cubic feet have been drilled. The rock pressure is 86 pounds and the depth to the gas sand is approximately 400 feet.

It is possible that the adjacent region may produce additional pools in the Knobtown or Polo sands of the Pleasanton and Henrietta formations. The Cherokee formation also offers possibilities where the sand bodies in it are well developed. It will be necessary to detail the structure as determined by surface outcrops and probably supplement such surface geological work by shallow test holes in areas where surface outcrops indicate structural highs but fail to furnish complete information due to glacial covering. After favorable structural conditions have been found, several holes should be drilled in the event the first tests are dry. The erratic distribution of dry and productive holes in the Polo field with reference to structure makes this necessary to really prove the area. The field is described in Appendix I of this report.

Additional data have been considered and tabulated in connection with a new report on northwest Missouri. Completion of that report has been delayed, however, because of other demands for work created by the war.

MAGNESIUM METAL.

One of the outstanding developments of the present war is the production of magnesium metal, which is lighter than aluminum and is in demand for the building of airplanes.

During the early part of 1942, inquiry was made of the Survey as to the suitability of the dolomitic beds of the Ozark region for this use. The principal stipulations were that the rock should be a practically pure dolomite with only small quantities of impurities, especially silica, which was restricted to 2% or less.

Practically all of the lime-bearing strata of the Ozark region are dolomitic in character, but not all are true dolomites. Some do not carry sufficient magnesium to meet the requirements. Many of the formations show a high percentage of chert, which makes it difficult to quarry the formation and not include percentages of silica above the restrictions.

Practically all of the dolomitic formations throughout the region were visited, old analyses were consulted and old records in the Survey were examined. Apparently the Eminence and Potosi formations of southeast Missouri were satisfactory. Samples of the Eminence formation obtained west of Potosi, however, carried too much silica. In the Bonneterre formation south of Fredericktown, drill records of wells drilled for water showed a very white, coarsely crystalline dolomite, approximately 150 feet thick. The area was mapped and samples analyzed which showed that this dolomite carried less than 2% silica. There is an unlimited supply of satisfactory rock available. This occurrence is described in Appendix II of this report.

BAUXITIC CLAYS.

Under a W. P. A. project which this Department has sponsored during the past few years, an extensive prospecting campaign for clays that might prove commercial possibilities was undertaken, in southeast Missouri. Auger holes were put down throughout Scott, Stoddard and Mississippi counties, and tests of the clays encountered have been described in the following reports:

Appendix I, 58th Biennial Report, The Geology and Bleaching Clays of Southeast Missouri.

Appendix VI, 59th Biennial Report, The Geology of Stoddard County, Missouri.

Appendix I, 61st. Biennial Report, Further Investigations of Southeastern Missouri Clays.

Extensive deposits of Fuller's Earth were found to comprise the larger part of the Porter's Creek formation, and during the past year, clay having the appearance of bauxite has been found near Ardeola at the Wilcox-Midway contact. This clay, which has much of the coarse pisolitic texture of bauxite, occurs in boulders embedded in the basal portion of the Ackerman. The geological horizon at which these boulders are found is the same as that at which most of the bauxite occurs in the coastal plain region including the states of Arkansas, Georgia, Mississippi and Alabama. An X-ray examination of the clay by Prof. P. G. Herold indicates that the mineral composing the pisolitic particles which analyze 35% alumina is Kaolinite. To date these boulders have been found over an area of more than five acres.

Samples supposed to be bauxite have been submitted by citizens from different areas in the state, but on detailed investigation were found to be ordinary or refractory clays. Up to the present time no true bauxite has been found. A general description of this bauxitic clay is given in Appendix III of this report.

REFRACTORY CLAYS.

Refractory clays are a No. 1 essential in the present war effort. Super refractory brick are a Navy requirement, and the refractories industry of Missouri is operating at full capacity. The use of flint and diaspore clays is essential to the highest grade refractory brick. The district yielding these clays is located in the north central part of the Ozark region, where the clay occurs in sink deposits which vary in size, but no individual deposit is of sufficient size to support a large plant for any considerable time. There is a continual search for new deposits.

One of the main research problems undertaken by the Survey during the biennium has been the re-mapping and locating of all known deposits in the diaspore and plastic clay fields. Structural conditions have been studied, cross-sections made and new factors bearing on the geologic relations determined. The results of this work have been embodied in a report which is now in the hands of the State Printer for publication. It is believed that this study will assist in the development of new deposits.

IRON ORES.

Taking the Granite City furnace out of blast in 1932 closed the only local market for Missouri iron ores, and the production during recent years has been restricted largely to shipments to Ohio and Alabama. Freight rates to these points absorbed much of the profits of the operations in both the red and the brown ore districts, and there were only one or two operators who continued activity. In 1928 and 1929 the M. A. Hanna Company discovered, through diamond drilling, additional ore deposits at Iron Mountain.

In 1941 the blast furnace at Granite City was purchased by the Koppers United Company and one cupola placed in operation. The need for pig iron to furnish war plants became acute and there has developed a strong demand for Missouri iron ore.

In order to assist in opening up properties and in increasing Missouri production, members of the staff visited the districts, advised operators and encouraged prospecting for new deposits and the reopening of deposits that were former producers. The report of the Survey, Volume X, 2d. Series, on Iron Ores, has been in recent demand but unfortunately is now completely out of print.

Considerable effort was directed to the possibility of using Missouri iron ore in the manufacture of sponge iron, and considerable time has been spent on this problem. It is believed that ore from many or all of the various districts in Missouri can furnish a suitable feed for the manufacture of sponge iron.

So-called sponge iron is metallic iron obtained by heating finely ground iron ore in a reducing atmosphere. At the right temperature the oxygen of the ore is abstracted, leaving a porous mass of metallic iron which is not melted during the process. This metal is then briquetted and is suitable for melting in open-hearth or cupola furnaces. Much of the mechanical impurities such as chert or sand can be seperated before briquetting by passing the iron through a magnetic field.

Sponge iron can be used as a substitute for scrap, or can be melted direct to wrought iron in the furnace. The steel plants in the St. Louis and Kansas City areas could utilize the output of a large plant making sponge iron from Missouri ores.

TUNGSTEN ORE.

One of the strategic metals in the present war is tungsten, which is needed in the manufacture of certain types of steel.

The quartz veins of the Silver Mine area, located approximately twelve miles west of Fredericktown, on the St. Francois River, have long been known to carry tungsten ore (Wolframite). The property was first worked for lead ore, which in this area carries from 20 to 30 ounces of silver to the ton of concentrates. During World War I (1918) the old dumps were re-worked for tungsten ore, but with the recession of price after the war all operations ceased. In 1940 Mr. Joseph Hahn and Mr. C. T. Smith worked the property and shipped some 14,000 pounds of concentrates to New York.

The tungsten ore has been produced from three quartz veins having a northeast-southwest course. In order to show the workings in detail a large scale map of the area was made by the Geological Survey in 1942. A description of the district was published as Appendix I of the 57th Biennial Report.

GEOPHYSICAL INVESTIGATIONS.

In comparatively recent years various types of geophysical prospecting have been employed, with very important commercial results. This is especially true of oil and gas development. Structural and stratigraphic subsurface conditions are ascertainable by the use of magnetic, gravimetric, electrical conductivity or seismographic methods, all of which have been used in locating mineral deposits and the structural conditions favorable for the formation of oil and gas pools.

For a number of years the Missouri Geological Survey has carried on geophysical studies, in order if possible to supplement with subsurface data the results of surface geological observations. The first work was undertaken at the request of the St. Louis Industrial Club, which club purchased the necessary instruments and paid the field expenses of parties in making a magnetic survey of the iron ore deposits of the central Ozark region. Electrical conductivity work was undertaken in the sink hole area of the northern Ozarks, and during the past biennial period, gravimetric work has been done on a statewide plan. Because of the prohibitive expense, seismographic work has not been undertaken.

With the assistance of the W.P.A. magnetic observations have been extended to cover the entire state and, as noted under publications, the results have been published in a state magnetic map. With the exception of the central and southern Ozark regions, where observations were made along the main highways, the observations were made at one-mile intervals. Quite striking magnetic anomalies have been found. At Bourbon, in Crawford County, an area of magnetic high intensity of some 6,150 gammas exceeds all other phenomena except the values over the iron ore deposits at Iron Mountain. The Bourbon results are higher than any attributable to rock formation. It is believed that such values could only be brought about by the occurrence of magnetic iron ore, probably 2,000 feet or more in depth.

Based upon the magnetic work done by the Missouri Geological Survey, the U. S. Bureau of Mines made further investigation of the area by making a resistivity survey during the month of December, 1942.

GRAVIMETRIC INVESTIGATIONS.

During the summer of 1942, through the courtesy of the American Geophysical Union, the Missouri Survey was again able to obtain the use of a gravimeter and transportation equipment. This work was started in 1940, as mentioned in the 61st Biennial Report of the State Geologist.

In the two months that this equipment was available a sufficient number of additional observations were made to make possible the preparation of a state map showing the general outline of gravity anomalies throughout the state. A map of the state is now being published showing the general gravity picture of Missouri. In addition to making observations along the principal highways, an area was detailed in the western portion of Iron Mountain, and the general area of the iron ore deposits on the west flank of the mountain showed a greater attraction than the surrounding area. Small areas known to be underlain by bodies of disseminated lead ore in St. Francois County did not show any noticeable increase in attraction. There was added gravimetric attraction in the area of the Bourbon magnetic high, in Crawford County. One of the most pronounced differences was found in detailing the Joplin lead zinc area, although no direct relation has been found to the ore bodies of the area. It is probable that the difference is due to a regional influence rather than to the effect of the individual ore bodies.

QUARRY LOCATIONS.

Considerable field work was carried on in northwest Missouri, locating and describing the various limestone quarries, and sand and gravel deposits. Much of the area of the northwest portion of the state is underlain by shale and sandstone with comparatively thin limestone beds. Usually these limestones are persistent and outcrop over long distances. If suitable for quarrying in one locality they are usually suitable for the same purpose at some considerable distance even though on the outcrop the horizon may be partially or completely covered by soil or glacial drift. While the need for this information is especially desired for northwest Missouri, it is the intention to compile a complete list of quarries throughout the state.

MANGANESE

Deposits of manganese associated with the Pre-Cambrian igneous rocks of southeast Missouri, as well as with the residual cherty clays overlying dolomitic formations in the same general area, have been known for many years.

The national need for high-grade manganese for war purposes has drawn attention to the outcrops known to occur in Missouri, and since 1940 greater activity has been shown in prospecting than at any time since World War I.

In 1941 the Survey undertook a detailed survey of the manganese deposits of the state. Mr. O. R. Grawe was employed during the summer of 1941 for this purpose and he is now preparing a report on the occurrence of the various deposits in the state.

MAP SHOWING MINERAL DEPOSITS.

For some time members of the staff have been contributing information and observations on the various mineral deposits of the state, especially with regard to the location, limits and extent of the various districts. The wide distribution and great variety of the mineral deposits of Missouri make the preparation of such a map of importance at this time when mineral deposits are so important in the war effort.

AGRICULTURAL LIMESTONE.

During the former biennial period this Department assisted many County Agents, especially in the northern Ozark region, in determining the lime rock strata that were most suitable for crushing to agricultural lime. This service was so successful that during the present biennium many analyses were made for the same purpose, and this type of work has been continued throughout the entire period.

OFFICE EXAMINATION OF SPECIMENS.

Citizens throughout the state are continually looking for minerals of value, this is especially true in the Ozark region where the wide range of mineral deposits lends credence to the fact that many strange looking rocks may be valuable mineral. Hundreds of samples are mailed to the Survey for determination. Each sample is examined and chemically tested if necessary, and the result forwarded to the sender as soon as possible after receiving the sample. Good ore samples are frequently received in this manner, and in many cases a member of the Survey visits the area and advises with the landowner on the best way to develop the property if favorable indications are found. Citizens also often ask for advice without sending in samples and hundreds of letters are received describing the occurrence of mineral or supposedly mineral deposits. These requests are answered to the best of our ability, and frequently a member of the staff will visit the property to discourage spending money on something that has no possibility of success. This is especially true in advising with regard to drilling for oil and gas in areas where it is known that conditions are not favorable to the occurrence of either fuel. We have saved many investors and landowners thousands of dollars by just such advice.

WORK OF THE FEDERAL WORKS AGENCY-WORK PROJECTS ADMINISTRATION, OFFICIAL PROJECT 165-1-55-217

During the past two years opportunities for employment in private industry greatly increased and, as a result, many of our project employees obtained other employment. As replacements were not available it was necessary to continue certain phases of the work with limited personnel. The work undertaken and some of the results accomplished during this period are briefly described herein.

Groundwater Studies.—Project employees have assisted materially in studies of the ground water resources of the state by performing necessary office and laboratory work. Workers employed in the sub-surface laboratory have prepared numerous samples of drill cuttings for microscopic examination. Other workers have prepared permanent records of data resulting from laboratory studies for property owners, drillers, and files of the sponsoring agency. These records serve to provide information essential to locating adequate supplies of fresh water for towns and cities, military establishments, and plants producing war materials.

Geological Prospecting.—Prospecting by means of earth augers and other hand drilling methods has been continued in Stoddard County during this period. Considerable drilling was done along the east face of Crowleys Ridge in connection studies of the stratigraphy in this area. During the past year most of the drilling was confined to the exploration for bauxite near Ardeola, Stoddard County, where a small deposit of bauxitic clay was discovered in connection with field work. Although considerable exploration has been done in this area, no commercial deposit of bauxite has been found to date. During the biennial period 128 holes were drilled representing a total depth of 10,598 feet.

Clay Investigation.—In order to revise a map of the flint fire clay district of Central Missouri, one geologist was engaged during the summer of 1941 in contacting clay producers of that district. Studies were made of the production of flint, burley, and diaspore clay and of the occurrence of the deposits. The information collected during the course of this study is now being used extensively in prospecting for new deposits of these clays, and will be incorporated in a report to be published in the near future.

Magnetometer Surveys.—As project workers engaged in magnetometer mapping resigned to accept other employment, it was necessary that the sponsor employ field men in order to complete this work. During the current period magnetometer surveys were completed of forty-one counties in the southern part of Missouri. This accomplishment served to complete a survey of the state and has resulted in the compilation of a magnetometer map which is being published. In connection with this work office employees made the necessary computations of field notes and prepared county magnetometer maps from the resulting data.

Other Investigations.—One field party and two draftsmen were employed during the first six months of the biennial period in preparing topographic maps. During this time seventy-six miles of third order level lines were established and sixty-two square miles of topography were mapped. Approximately 273 square miles of topography were repenciled and inked on field sheets preparatory to engraving.

Project workers have also assisted in the stream-flow measurement program conducted by the sponsor. During the first half of this period three persons were engaged in making computations of river charts and preparing permanent discharge records of the principal streams and larger springs of the state.

In connection with geological studies, draftsmen employed on the project have also prepared numerous areal maps and cross-sections from data collected during the course of field work.

TOPOGRAPHIC MAPPING

Topographic mapping was continued throughout the biennial period in cooperation with the United States Geological Survey and the State Highway Department. The Federal Bureau matched Missouri funds on a fifty-fifty basis.

Early in 1941 the need for topographic maps in the Fort Leonard Wood area concentrated our work in that vicinity, and 939 square miles were mapped on a scale of approximately one inch equals one mile. The quadrangles included are the Lebanon, Drynob, Richland, Big Piney, Manes, and Bado. These quadrangles together with the Edgar Springs, Rolla, and Waynesville, which were completed several years ago, surround the camp with an area of completed topographic maps which can be used in all maneuvers.

Upon the established location of Camp Crowder near Neosho, requests were made for maps of areas to the south and east that had not been mapped, and 553 square miles were completed covering the Rocky Comfort, Ritchey, Monett and Elsey quadrangles. The areas to the west and north had already been mapped.

A total of 1522 square miles were mapped during the biennium in the vicinity of cantonment areas at the request of the Army. In addition 1811 square miles were mapped in other parts of the state. The following indicates the quadrangles mapped and the various counties in which they are located:

Mountain
Ritchey
Monett
Big Piney
Drynob
Richland
Manes
Bado
Elsey
Lebanon
Stone Hill
Salem

Troy
Farber
New Florence
Mokane
Bellflower
Warrenton
Boss
Redford
Ruble
Valhalla
Lowry City

After field mapping is completed the field sheets are sent to the U. S. Geological Survey at Washington, D. C. for lithographing or engraving.

The following sheets comprising an area of 3,314 square miles have been received from the Government Printing Office during the biennial period:

Farragut	Jefferson City
Hamburg	Harwood
Tarkio	Arnica
Sweet Springs	El Dorado Springs, North
Gatewood	Caplinger Mills
Elsberry	Deerfield
Topaz	Hume
Skidmore	Moundville
Nebo	El Dorado Springs, South
Fordland	Sprague
Wellsville	Richards
Filley	

WATER RESOURCES BRANCH

The work of the Missouri Geological Survey and Water Resources during the biennial period relating to the surface water resources of the State has consisted principally of a continuation of the stream-flow investigations for use in flood-control, drainage, water-power, and water-supply developments. These investigations have been carried on, as in the past, in cooperation with the Water Resources Branch of the United States Geological Survey, which organization furnished trained personnel to carry on the work, and during the biennial period contributed $30,500 to its cost. One new gaging station was established; seven were discontinued. At this time 89 gaging stations are being maintained on the principal streams of the State. At 34 stations a local resident reads a gage once or twice a day to determine the height of the water and at 55 stations a continuous height record is obtained by means of recording gages. The engineers make measurements of the flow, or discharge, of the streams in terms of cubic feet per second, prepare rating curves and tables showing the flow for any gage height, and then compute from the daily gage heights the flow for each day of the year.

During the biennial period, the Geological Survey received many requests for stream-flow records for use in planning military establishments, defense industries, and civilian works of various types, some of the more important of which will be enumerated here.

The United States Army during the biennial period constructed two large military cantonments in Missouri—Fort

Leonard Wood about 35 miles southwest of Rolla and Camp Crowder near Neosho—at a cost of about $50,000,000, where about 50,000 troops are being trained. The stream-flow records collected by the Geological Survey and Water Resources were used by the Army officials and their consulting engineers in selecting the sites for these camps and in obtaining the water supplies for them. The records were also used in planning some phases of the small arms ammunition plant at Lake City, the TNT plant at Weldon Springs, and a number of other defense industries.

During the biennial period the United States Army Engineers completed the construction of a dam on the St. Francis River at Wappapello and started one on the Black River at Clearwater (near Piedmont and Leeper); and will later improve the levees along the St. Francis River, in order to protect many thousand acres of fertile farm land in Southeastern Missouri and Northeastern Arkansas, and also the low parts of the city of Poplar Bluff, from the devastating floods that have visited these regions so frequently in the past. The estimated cost of these projects is about $30,000,000. The stream-flow records collected by the Geological Survey and Water Resources were used in planning these important projects.

Many important flood-control and water-power projects in Missouri are now being studied for post-war construction. Several of these are included in the $375,000,000 plan authorized by Congress in the "omnibus" flood-control bill of 1938. This bill makes it mandatory to install penstocks for the development of power in flood-control dams when so recommended by the Chief of Engineers, U. S. Army, and the Federal Power Commission. In all flood-control reservoirs it is also planned to maintain a minimum pool level, below which the water will not be drawn, in order to provide a permanent conservation lake which may be used for recreation.

Other sites are also being studied by the Federal Government and private agencies for the development of power. Some of these sites may be used for multiple-purpose dams, such as for combinations of flood control, power, and water conservation.

Besides these proposed reservoir projects, several agencies of the Federal Government have made or are now making preliminary investigations for channel improvements, levees, and water-retardation and soil-conservation measures, at many other places, including the Grand, Chariton, Fox, Wyaconda, Fabius, Salt, Cuivre, Meramec, St. Francis, and White River Basins.

The estimated total cost of these reservoirs and other projects is more than $150,000,000. Their construction would confer very substantial benefits upon the State of Missouri. The stream-flow records being collected by the Missouri Geological Survey and Water Resources constitute the basic information upon which all these projects are being planned.

The stream-flow records so collected have also been used during the biennial period by consulting engineers, city officials, and the State Board of Health, in studies relating to municipal and industrial water supplies, sewage disposal, and stream pollution. The Geological Survey and Water Resources is cooperating with the cities of Springfield and Kansas City in collecting records of flow of nearby streams for such purposes.

The State Highway Department has made frequent use of the stream-flow records in designing new bridges for the State highway system. In order to obtain more complete information, the Highway Department cooperated with the Geological Survey in maintaining nine gaging stations by furnishing the services of maintenance men or nearby residents to read the gages.

A wide public interest is being shown in the large springs of the State, and many requests are received for information regarding their flow. In order to be able to supply this information, the Geological Survey and Water Resources makes occasional measurements of the flow of all the larger springs. The Survey also cooperates with the State Park Department in determining the daily flow of Big Spring in the Big Spring State Park. The Geological Survey and Water Resources is issuing a special publication entitled "The Large Springs of Missouri", which gives much useful and interesting information upon the springs of the State.

The United States Army Engineers are making extensive improvements on the Mississippi and Missouri Rivers within the State of Missouri to provide navigation and to stabilize the river banks, and they are also making many studies for flood control and the development of water power in the State. In planning this work, they make frequent and thorough use of the stream-flow records. In order to provide for the collection of additional records needed in their studies, the Army Engineers furnished funds to the United States Geological Survey (with whom the State Survey cooperates) to assist in maintaining forty-five gaging stations on the Mississippi, Missouri, and other rivers in the State. During the biennial period they contributed $41,325 for the operation of these gaging stations.

The Flood Control Advisory Committee, United States Department of Agriculture, made studies for the reduction of floods and the prevention of soil erosion in many parts of the State and in this work they made extensive use of the streamflow records.

During the biennial period, the State Geologist served as Chairman of the Water Resources Committee of the State Planning Board. This committee made general studies of the merit and feasibility of the proposed flood-control and waterpower developments in the State, especially for those in the Meramec River Basin. The Geological Survey also made some preliminary silt investigations for the Meramec study.

The widespread interest throughout the State in the streamgaging work of the Geological Survey and Water Resources is evidenced by the large number of requests for the records, and also by the amount of cooperation furnished by private and public agencies interested in developing the streams for flood control, drainage, water power, water supply, bridge design, soil conservation, and other purposes. These agencies contributed $4,800 during the biennial period in order to assist in the expansion of the work—this being exclusive of the funds contributed by the United States Geological Survey, the United States Army Engineers, and of the services furnished by the State Highway Department and the State Park Department, as noted above. The following list gives the names of those who cooperated in the work and the number of gaging stations each helped to maintain during a part, or the whole, of the biennial period:

Missouri Highway Department	9
Missouri Park Department	2
United States Army Engineers	45
United States Weather Bureau	5
Little River Drainage District	7
Empire District Electric Company	3
Union Electric Company of Missouri	5
Missouri Electric Power Company	1
City of Kansas City	1
City of Springfield	1
Total	79

PUBLICATIONS

Joplin Maps. In order to expedite the search for additional deposits of lead and zinc, a series of 6 geologic maps was published covering the principal productive areas of the Missouri portion of the Joplin district. These maps are on a scale of 4 inches equals 1 mile. They show all cultural features including cities and towns, school houses, churches, roads and drainage. The surface relief on a 10 foot scale interval is also indicated. River alluvium is shown in yellow, the area underlain by the Pennsylvanian formations in blue, and the area underlain by the Mississippian limestone is left uncolored. The mineralized areas are shown in red. The deep solid color shows shallow mines where maps were available, and red cross-hatch lines show mineralized areas in which there may have been deep or shallow mines, but no maps of the old workings are available. Sheet ground mines are shown in double red cross-hatch. All silicified and dolomitized areas (with which the ore is associated) are shown in black cross-hatch.

When joined together these maps give an exceptionally clear picture of the producing area of the Missouri portion of the Joplin lead and zinc district. They should be a distinct aid in future prospecting.

Magnetic Map. For a number of years the Survey in cooperation with the W.P.A. has been making observations on magnetic variation in the state and has finally completed the entire area. In the greater part of the state the observations were taken at about one mile intervals. In the south central Ozark area the observations were taken mainly along the highways and not on one mile intervals, because of the difficulty of getting over the ground. The map is on a scale of 1 inch equals 8 miles. The magnetic values are contoured on 100 gamma intervals. The map shows some very striking anomalies among which the Bourbon area, with a maximum anomaly of 6,200 gammas, shows the highest value in the state other than observations directly over the slightly magnetic iron ore deposits at Iron Mountain. From horizontal measurements it would seem that the cause of the attraction is located some 2,000 feet beneath the surface. The so-called Malden high, in the lowland area of southeast Missouri, shows a very strongly polarized area over a distance of 8 miles in length. It is the only place where this type of phenomenon has been noted. The Joplin district also shows distinct high anomalies. The striking feature in this region is that no ore bodies of consequence have been found in areas of high magnetic attraction.

Gravity Map. During the Biennial period, gravimetric observations were completed over a state-wide network that was started in 1940. The map, drawn on intervals of 100 units, shows the general gravimetric features of the state. Observations were made about every 5 miles, along the principal highways of the state. The most striking anomaly is noted in the Joplin district.

Refractory Clay Report. The manufacture of highly refractory clay products from plastic and semi-plastic fire clays is one of the most important mineral industries in Missouri. Through the combined use of flint and diaspore non-plastic clays found in the northern Ozark region, and high-grade plastic clays found in east central Missouri, the plants in this state produce super refractories that have no equal in the country.

These clays do not occur uniformly over extensive areas. In fact the best grade clays are restricted in their extent, and the need for ever greater supplies makes the discovery of additional deposits necessary. In order to assist in this development of new deposits, during the biennium the Geological Survey revised the old clay map and, after additional field work, has prepared a report on the occurrence and nature of both the plastic and non-plastic clays. Special attention has been given to the probable origin of these clays and the geological factors which have played an important role in restricting their occurrence. It is believed that this report, which is now in press, will clarify many geologic features and assist in the development of new deposits so badly needed to keep up an adequate reserve for the refractory industry.

Bauxitic Clay. In searching for clays under a W.P.A. project in southeast Missouri, bauxitic clay boulders were discovered south of Ardeola, in Stoddard County. At first, because of the similarity in character, this clay was thought to be bauxite. Auger holes were put down over a considerable area and the occurrence of the boulders outlined. Chemical composition was determined and the results of this field work are given in Appendix III of this Biennial Report.

Structural Report on Cass and Jackson Counties. More small shoe string and shallow gas fields have been discovered and drilled out in Jackson and Cass counties than in any other counties in the state. In order to determine the character of the structures, a detailed geologic study was made and maps prepared of each county, showing the location of all holes and productive areas. The report is now in the hands of the State Printer for publication.

Magnesium Metal. In this biennial report, a short appendix is devoted to the description of an area of dolomite south and east of Fredericktown that is suitable for use in the manufacture of magnesium metal. In doing this work all of the dolomitic formations of the Ozark region were considered, but this particular area of Bonneterre dolomite was found to be the most satisfactory insofar as the Survey was able to determine in a hurried examination.

Polo Gas Field. A new natural gas field has recently been discovered in Missouri. It is the so-called Polo Gas Field, located approximately 4 miles west of Polo, in Caldwell County. In order to show the geological features and character of this pool, a brief report is being published as Appendix I of this Biennial Report.

Lexington Coal Bed of Northwest Missouri. In 1910 this Department published a coal report in which was shown the areas where the Lexington coal bed was being mined. Since that time, operations have been extended to new areas which are shown on an outline map, accompanied by a brief description of the geologic sections in the new areas.

APPROPRIATION FOR 1941-1942

The following appropriation was made by the Sixty-first General Assembly for the Geological Survey and Water Resources for the years 1941-1942:

Personal Service	$ 97,500.00
Additions	2,000.00
Repairs and Replacement	5,000.00
Operation	61,500.00
Total	$166,000.00

These funds were expended on the investigations undertaken by the three branches of the Survey work as outlined in the preceding pages.

APPROPRIATION REQUESTED FOR 1943-1944

The following items have been requested of the Budget Commissioner to cover the work and activities of the three branches of the Geological Survey and Water Resources for the coming biennium:

Personal Service		$112,600.00
Additions		2,000.00
Repairs and Replacement		5,000.00
Operation		57,800.00
		$177,400.00
PERSONAL SERVICE:		
Geology and Mining	$ 62,600.00	
Water Resources	30,000.00	
Topographic Mapping	20,000.00	
		112,600.00
ADDITIONS:		
Office equipment	$ 400.00	
Field equipment	1,000.00	
Laboratory equipment	600.00	
		2,000.00
REPAIRS AND REPLACEMENT:		
Office equipment	$ 400.00	
Transportation equipment	2,800.00	
Field equipment	1,200.00	
Laboratory equipment	600.00	
		5,000.00
OPERATION:		
Rent	$ 600.00	
Railroad fare	1,400.00	
State cars	10,000.00	
Personal cars	1,000.00	
Hotels and meals	18,000.00	
Freight, express and drayage	1,000.00	
Printing and binding	8,000.00	
Postage	1,000.00	
Telephone and telegraph	800.00	
Laboratory and field supplies	6,000.00	
		57,800.00
Total		$177,400.00

The total request is $11,400.00 over the amount granted by the Sixty-first General Assembly. The importance of making additional topographic maps and gauging our major streams, and the need for additional mineral production for the war effort would justify a largely increased request in the amount of funds for this department, but the fact that it is impossible to obtain additional trained and experienced personnel is, in our judgment, a limiting factor in the work that can be done and therefore in the possible judicious expenditure of funds.

The proposed budget provides for the expenditure, during the biennium of $15,000.00 per year on topographic mapping and $10,000.00 per year on Water Resources. In both of these branches the U. S. Geological Survey will match State expenditures dollar for dollar. In the Mining and Geology branch special attention will be directed to ground water resources and to a study of the geological factors which may be helpful in the search for additional mineral resources.

The major portion of the expenditures of this Department fall under Personal Service and Operations. The Missouri University owns and maintains the building occupied by the Survey and this Department has no expenditures for upkeep of buildings or grounds.

The small amounts requested for Additions and for Repairs and Replacement are the same as for the last biennial period.

The amount requested under Personal Services is greater than for the last biennial period and the request for Operation is less. This change is made in an endeavor to adjust the ratio of expenditures under the items of Personal Services and Operation, especially in the Topographic and Water Resources branches, where it is found much more convenient to pay certain items of expense from Federal funds.

VALUE OF MINERAL PRODUCTION OF MISSOURI, 1932-1940

Commodity	*1932*	*1933*	*1934*	*1935*	*1936*	*1937*	*1938*	*1939*	*1940*
Lead concentrates	$4,932,306	$4,135,573	$4,548,519	$5,667,955	$7,403,159	$14,736,662	$9,253,451	$12,539,245	$14,430,602
Zinc concentrates	30,728	264,951	363,362	392,541	1,098,233	1,655,289	578,020	961,344	990,321
Coal	6,654,000	6,175,000	6,278,000	6,923,917	7,559,000	7,978,000	6,814,000	6,154,274	6,317,352
Clay products	3,897,558	5,572,752	6,323,896	7,443,931	10,795,047	14,383,035	9,369,683	12,023,348	13,758,734
Cement	3,666,220	4,722,441	5,449,606	4,940,713	7,134,240	7,041,016	6,871,120	7,420,013	7,616,247
Limestone	3,223,507	3,194,792	2,660,428	2,452,036	3,732,753	4,209,079	4,018,311	3,973,934	5,667,491
Marble	402,939	248,822	170,419	179,812	380,825	461,152	392,460	556,014	392,762
Sand and gravel	2,114,400	1,668,048	1,462,740	1,889,787	2,402,304	2,481,464	1,919,146	2,310,995	2,311,221
Lime	526,488	597,180	907,338	1,046,243	1,283,175	1,557,528	1,121,668	2,023,400	2,305,772
Lime, hydrated	508,362	524,115	631,562	713,675	764,014	769,400	602,472	776,977	878,521
Clay	504,403	713,127	961,854	1,006,862	1,336,382	1,529,239	904,766	1,172,029	1,400,932
Chats	260,000	232,870	484,350	275,372	458,575	160,377	95,445	124,774	353,007
Barytes	463,347	510,551	581,889	727,888	1,008,528	1,430,397	1,150,630	1,163,870	1,216,069
Copper	(*b*)	(*b*)	(*a*)	5,616	35,144	65,098	(*b*)	(*b*)	154,810
Iron ore	72,144	(*a*)	13,271	8,764	16,566	57,687	45,279	59,185	134,411
Granite	6,544	12,480	33,905	40,303	29,372	38,965	28,661	23,513	26,647
Silver	318	(*b*)	40,770	79,459	126,801	138,999	188,768	144,853	185,112
Sandstone	112,337	21,477	48,663	(*a*)	(*b*)	(*a*)	(*b*)	(*a*)	(*a*)
Natural gas	82,016	59,224	47,000	282,000	196,000	38,000	122,000	48,420	29,846
Pyrites	(*a*)	50,161	51,640	77,263	77,660	50,070	71,956	68,369	74,088
Miscellaneous (*a*)	131,159	221,357	180,429	266,889	278,870	301,922	223,866	327,606	301,939
Totals	$27,588,816	$28,924,921	$31,239,641	$34,421,026	$46,116,648	$59,083,379	$43,771,702	$51,872,163	$58,545,884

(*a*) Miscellaneous includes, in addition to items noted: Tripoli, silica, miscellaneous stone, asphaltic sandstone, and tungsten.

(*b*) No production reported.

CHAPTER II

MINERAL PRODUCTION OF MISSOURI

The mineral industries of Missouri in 1941 show a decided increase in value over 1940 and reached a higher total value than at any time during the past ten years. While figures are not available for 1942, they will no doubt show a still greater increase, since the demand for every type of mineral resource has been greatly activated by war requirements. The increased over all production is more than 110% between 1932 and 1940, and in 1941 approximately 125%.

The tabulation on the opposite page shows the yearly variation in value of each mineral produced. Clay products, cement, lead concentrates, coal, limestone and lime are the most important mineral resources in the order of their importance. Missouri stands first in the production of lead concentrates and barytes, first in super grade refractories, third in lime and ninth in cement.

Statistical data given in this chapter are collected in cooperation with the Economics and Statistics Division of the U. S. Bureau of Mines. The Federal Bureau publishes the totals for the United States as well as the separate state productions of all minerals produced in the United States, also a discussion of world-wide mineral production throughout the world in the Minerals Year Book which is published annually.

ASPHALTIC SANDSTONE

Asphaltic sandstone outcrops in 13 counties in the west and southwest portion of Missouri. The chief operations in the past have been confined to Barton and Vernon Counties, although exposures are known to occur in Bates, Cass, Caldwell, Ray, Carroll, Lafayette, Johnson, Cedar, Barry, Hickory and St. Clair Counties. In Jackson, Cass and Caldwell Counties, asphaltic sandstone deposits are known but only the westline deposits in Cass County have been quarried and these have not been worked for many years.

A. Stockpile, asphaltic sandstone, Iantha, Missouri

B. Quarry, asphaltic sandstone, Iantha, Missouri

Occasional small outcrop areas of bituminous limestone are found in the Boone formation in southwest Missouri, chiefly in Jasper, Cedar and Hickory Counties. These have not been worked.

Various endeavors have been made to work the asphaltic sandstone deposits, especially in Vernon and Barton Counties. The State Highway Department carried on an extensive series of tests on Highway 54, east of Nevada. Many combinations were and varying from raw stone as quarried to mixtures of raw rock and different percentages and types of Oklahoma asphalt.

The Geological Survey has analyses of some of the stone quarried in Vernon County. The total percentage of bitumen in three specimens varied from 6.16% to 6.87%, of which approximately 75% was petrolene (no binding power) and 25% or less was asphaltine. In some instances the stone will run 10% or more in total bitumen.

While most of the stone has a brown to black "organic" color it does not carry sufficient asphalt content to provide a good cement and asphalt must be added to the raw rock to make a satisfactory road metal.

At the present time the Barton County Rock Asphalt Company is operating a quarry and mixing plant near Iantha, Missouri. This company has been producing and shipping a mixture of the raw rock and asphalt for twelve years. They report that the rock as quarried from a 12 foot ledge carries from 4% to 7% native bitumen, to which is added approximately 4% of 50 to 60 penetration asphalt as the rock passes through the plant. The trade name of the product is Bar-Co-Roc.

The product of this plant has been used almost exclusively for street paving in cities in the states of Missouri, Iowa, Illinois, Indiana, Nebraska and Kansas. The material is giving good results in city work and the output of the plant has shown a continual increase during recent years.

The following publications of the State Geological Survey mention the natural asphaltic rock deposits of the State:

Volume XV, The Sand and Gravel Resources of Missouri.
Volume XVI, The Occurrence of Oil and Gas in Missouri.
Volume XIX, The Geology of Vernon County.

BARITE.

BARITE PRODUCTION AND VALUE, 1930-1941

Year	*United States Production* Tons	Price per ton	*Missouri Production* Tons	% of total	Value	Price per ton
1930	234,932	$6.55	132,640	56	$ 938,812	$7.08
1931	174,520	5.70	93,417	54	539,152	5.77
1932	129,854	5.74	85,458	66	463,347	5.42
1933	167,880	5.08	112,335	67	510,551	4.54
1934	209,850	5.29	118,836	57	581,889	4.90
1935	225,111	5.56	131,921	59	727,888	5.52
1936	283,160	5.91	160,866	57	1,008,528	6.27
1937	355,888	6.25	198,101	56	1,430,397	7.24
1938	309,663	6.47	156,539	51	1,150,630	7.35
1939	383,609	6.11	171,642	45	1,163,870	6.78
1940	390,462	6.34	179,455	43	1,216,069	6.78
1941			212,781		1,337,756	6.29

As shown by the above table the production of barytes in Missouri in 1941 reached an all time high with a production of 212,781 tons valued at $1,337,756. The price per ton averaged $6.29 which was 95 cents less than the price per ton in 1937 when a production of only 198,101 tons brought a value of $1,430,397.

During 1942 there was some recession in demand. The restrictions on oil and gas developments specifying only one hole to 40 acres materially reduced wildcat drilling and consequently the use of barium in heavy drilling mud. This has, in recent years, been one of the important uses of barytes.

While the last three years has shown a steady increase in the production of barytes, the production of the United States has increased at even a greater rate. In 1940 Missouri produced 43 percent of the total barytes mined in the United States; in 1939 it was 45 percent; in 1938, 51 percent, and in the years prior to 1938 it varied from 56 percent to as high as 67 percent. In recent years even though Missouri production has increased rapidly the percentage compared to the United States production has shown a marked decline.

The construction of new washers continued througout the Washington County district in both 1941 and 1942. The percentage of mechanical mined tiff has continued to increase rapidly in the last few years until now but little tiff is being produced by old hand methods.

Practically no new districts have been opened. The deposit near Houston, Texas County, which was partially developed in 1940 has been worked rather extensively during the past two years.

The Washington-Jefferson County district continues to produce 80% or more of the baryte mined in the State. The central district including Benton, Camden, Cole, Cooper, Miller, Moniteau, Morgan, Pettis, and St. Clair Counties only produced 18.34% of the State total in 1939; 19.39% in 1940, and 12.05% in 1941.

The following washers in the state were operated either a part or all of 1941 and 1942.

Name of Operator	*Address*	*Location of mine*	*County*
W. C. Wolf, Pres., Superior Mineral Co.	Potosi	Cadet	Washington
Midwest Mining Co., Subsidiary Geo. S. Mepham & Co.	E. St. Louis, Ill.	Richwoods	Washington
Henry Hartzell	Potosi	Old Mines	Washington
De Soto Mining Co., J. Marshall Thompson	De Soto	Richwoods	Washington
Hornsey Bros.	Potosi	Potosi	Washington
M & B Mining Co., Lynn McMillen, R. A. Blount	Potosi	Old Mines	Washington
Ozark Products Co., Ernest Pearce, Pres.	Cadet, R. F. D.	Belfountain	Washington
Scott & Whaley	De Soto	Richwoods	Washington
Cadet Mining Co., A. H. Long, Mgr.	Cadet	Cadet	Washington
Haynes and Bone	Richwoods	Richwoods	Washington
Carter Mining Co	Potosi	Richwoods	Washington
John Adams et al., c/o Harry Blount	Potosi	Potosi	Washington
Healy Boyer et al.	Potosi	Mineral Point	Washington
Wilson Davis	Potosi	Cannon Mines	Washington
R. E. Johnson	De Soto, Star Rt.	Frumet	Jefferson
Harrison Knapp	Grubville	6 Miles N. Fletcher	Jefferson
O. S. Reavis	Versailles	South of Versailles	Morgan.
O. S. Reavis	Versailles	Henley	Cole
O. S. Reavis	Versailles	Bagnell	Miller
Osage-Ozark Mining Co.	Versailles	Versailles	Morgan
W. C. Irwin, Mgr.	Versailles	Bagnell	Miller
McDonald Mining and Engineering Co., O. D. Lantz, Sec. 6217 Wabash Ave., Kansas City		Lupus	Moniteau
Honey Mine	Blackwater	Lupus	Moniteau

Name of Operator	*Address*	*Location of mine*	*County*
Ozark Mining and Smelting Co., Geo. M. Bellairs	Coffeyville	Lupus	Moniteau
Sub. Sherwin Williams Co.	Kansas		
Blackwater Mining Co., J. W. Creech and Geo. M. Bellairs	Blackwater	8 miles from Blackwater	Cooper
Elliot Mining Co., J. P. Willis, Jefferson City		Henley	Cole
Baroid Sales Co., Los Angeles, Calif.			
J. W. Steenbergen	Henley	Henley	Cole
Campbell Brothers	Russellville	Cole Camp	Benton
B. N. Walker	Gravois Mill	Gravois Mill	Morgan
Benton County Mining Co., Warmer M. White		Cole Camp	Benton
G. H. Bates	Jefferson City	Cole Camp	Benton
Murphy Mining Co	Houston	Houston	Texas

CEMENT (Portland).

The manufacture and sale of Portland cement in Missouri reached an all time high in 1941. The total sales were 6,516,-345 barrels valued at $10,272,509 or an average price of $1.58 per barrel.

The above value was $2,656,262 greater than the value of sales in 1940, the second most important yearly output in the history of the State. There was sold 4,867,799 barrels valued at $7,616,247 or $1.56 per barrel.

While figures are not available it is certain that the output of cement in 1942 will be greater than 1941 as the industry has been much more active on war contracts than even in 1941 or 1940.

There is at present very strong demand for Portland cement and, with an annual capacity of 11,770,000 barrels, the Missouri plants can materially increase production to almost any needs.

The Portland cement industry requires an enormous tonnage of raw materials and produces a relatively bulky, cheap product. Cement must therefore be produced in large plants of large capacity to be manufactured at a low cost.

There has been no change in the location of plants in Missouri during the biennial period. The following five plants manufactured the above output: Marquette Cement Manufacturing Company, located south of Cape Girardeau, Missouri, uses the Plattin limestone and alluvial clay from flood plains of the Mississippi River. Universal Atlas Cement Company, located at Ilasco Station south of Hannibal in Ralls County uses the Burlington limestone and Grassy Creek shale. Missouri Portland Cement Company located at Prospect Hill, St. Louis County uses Ste. Genevieve limestone of Mississippian age and shale of Pennsylvanian age. Alpha Portland Cement Company located at Alpha in the southeastern part of St. Louis County, uses Mississippian limestone and Cherokee shales and loess. Missouri Portland Cement Company located at Sugar Creek, north of Independence, Jackson County uses Pennsylvanian limestones and shaley limestone from the Kansas City formation.

The wide distribution of the above plants indicates that Missouri is well supplied with raw materials suitable for the manufacture of Portland cement. The fact that there are not more plants in Missouri is in no way dependent upon the lack of raw materials, but is limited by demand. There are few industries that are more vitally effected by the financial conditions of the country at large; any condition which curtails construction curtails the demand for Portland cement. On the other hand an active construction season denotes an unusually strong demand for cement.

CLAY AND CLAY PRODUCTS.

For years Missouri has maintained an eminent position among the states in the manufacture of super refractories.

In 1942 the A. P. Green Fire Brick Company of Mexico, Missouri received the highly coveted "M" award of merit from the United States Maritime Commission for outstanding achievement in War Production.

Missouri maintains her position as the premier state in the manufacture of super refractories because of the occurrence of two different high-grade clay districts, the clay from both of which is used in the manufacture of refractories. In the northern Ozark region, centering in the counties of Franklin, Osage, Gasconade, Crawford, and Phelps, occur irregular pockets of so-called flint-diaspore clay which is highly refractory. The deposits vary greatly in size but are usually quite small, yielding only a few thousand tons of suitable clay.

The flint clay is hard, non-plastic, and breaks with a conchoidal fracture. It contains approximately 40% alumina, 40% silica, 12 to 15% water, and is very low in fluxing impurities.

The diaspore clay is a monohydrated oxide of alumina and is not a silicate. It is usually found in irregular beds or restricted areas within the flint pits and has been derived from the flint clay through leaching. High-grade diaspore will assay 75% alumina and 6% or less silica. The so-called burley clay found in these pits is an intermediate product, oolitic in character, which is partly altered flint clay. The amount of alumina in the burley or rough clay varies from 50% to 65%, depending on the amount of alteration.

North of the Missouri River in Audrain, Callaway and adjoining counties and in St. Louis County the so-called Cheltenham clay seam has been utilized for many years in the manufacture of refractories. These deposits produce a plastic clay which makes an excellent refractory and which can be used as a binder for the flint-diaspore clay.

The Cheltenham seam, being blanket-like in character, provides deposits giving large tonnages. The manufacturing plants are all located in the area producing the plastic clay since no individual or group of deposits in the flint diaspore field is large enough to provide raw clay for a large plant.

High-grade diaspore is not abundant and there is a continual search for new deposits to keep an adequate reserve, and at present there is intensive activity in prospecting for flint-diaspore clay. Practically every nationally known refractory company in the country has plants in Missouri.

COAL.

The table at the beginning of this chapter shows the value of the coal production in Missouri since 1932. During this ten year period the value of production has varied from $6,175,000 in 1933 to $7,978,000 in 1937. In 1940 the value was $6,317,352 and in 1941 it increased to $7,391,560, which does not equal the value of either 1936 or 1937. Coal and sand and gravel are the mineral products that during the past ten years have not shown any material increase in value of the output. The usual production varies between 3,000,000 and 4,000,000 tons and only in

1932 with a production of 4,069,000 and in 1937 with a production of 4,091,000 tons did the output exceed the 4,000,000 figure.

The effect of one very important change in the method of mining is shown by the very decided increase in the percentage of coal mined by strip methods since 1926. During that year 41.3% of the coal produced in Missouri was mined by strip methods, while in 1938 a total of 67.4% was so produced.

New developments in the coal mining industry, aside from mines and pits largely devoted to supplying local trade, have been in the southwestern part of the State during the biennial period 1941-42.

The Windsor Coal Company began operations at the New Castle plant three miles east of Leeton, Johnson County. The tipple and washery are located at New Castle siding on the Chicago Rock Island and Pacific Railroad in Sec. 25, T. 44 N., R. 25 W.

The stripping is done with a 15-yard Marion electric powered shovel and in the present operations the overburden averages 30 feet. An average section is as follows:

	Thickness	
Material	*Feet*	*Inches*
Soil and clay	8	
Limestone, dark gray, thin-bedded, softer than next lower bed	3-3½	
Limestone, a single bed, dark gray hard	1½-2	
Shale, hard, black, slaty	2-2½	
Limestone, a concretionary layer, hard, black	½-1	
Shale, gray, homogenous	14	
Coal		18-24

Shot holes are drilled horizontally into the gray shale above the coal before the stripping and after the overburden is removed a pinning machine loosens the coal. Ten-ton trucks convey the coal to the tipple. Lumps over six inches are hand picked and those under six inches are washed. The loss from washing is estimated to be less than 10%. In the washery 240 gallons of water per minute are used and can be supplied from a deep well, but a reservoir of 1,000,000 gallons is also available.

The output is shipped both by railroad and truck and at present averages about 25,000 tons per month.

The Pioneer Coal Company began preliminary operations for large scale stripping two miles northeast of Walker, Vernon County. A section measured in a test pit in the NE¼ SE¼, Sec. 3, T. 36 N., R. 30 W., is as follows:

SECTION IN TEST PIT NORTHEAST OF WALKER

Material	*Thickness* *Feet*	*Inches*
Surface soil, clay and gravel	6-8	
Shale, black, soft	2	4
Shale, black, fissile, hard	1	2
Shale, black, blocky, hard	1	6
Coal	2	2
Shale, black, with lenses of pyrite and thin streaks of coal		3
Clay	....	

ANALYSES OF COAL FROM TEST PIT NORTHEAST OF WALKER*

	Air-dry loss 6.3	Coal (air-dried)	Coal (as rec'd)
	Moisture	2.1	8.3
Proximate	Volatile matter	48.1	45.3
Analysis	Fixed carbon	44.5	41.7
	Ash	5.0	4.7
		100.0	100.0
	Hydrogen	6.1	6.4
	Carbon	75.8	71.0
Ultimate	Nitrogen	1.3	1.2
Analysis	Oxygen	8.5	13.6
	Sulphur	3.3	3.1
	Ash	5.0	4.7
		100.0	100.0

British Thermal Units 14080

Prospecting by core drill has been carried on over a large area in Bates County, but the results have not yet been made available.

*Made by U. S. Bureau of Mines, Department of the Interior.

The following tabulation shows the coal production in Missouri in 1941 by Counties.*

County	*Tons Produced*
Adair	136,471
Audrain	3,243
Barton	232,485
Bates	114,286
Boone	18,642
Callaway	160,230
Cedar	469
Carroll	727
Chariton	5,442
Clay	141,560
Cole	1,262
Dade	9,017
Daviess	20,000
Grundy	3,485
Harrison	22,426
Henry	584,441
Howard	838
Jasper	9,880
Johnson	5,426
Lafayette	252,188
Lincoln	1,417
Linn	52,366
Macon	443,956
Moniteau	1,317
Monroe	9,011
Montgomery	211
Morgan	3,236
Putnam	38,897
Ralls	11,956
Randolph	572,688
Ray	148,383
St. Clair	7,472
Schuyler	302
Vernon	69,828
Warren	655
Total	3,085,551

COBALT-NICKEL AND COPPER.

The lead ore occurring in the southern part of the disseminated lead district of southeast Missouri, especially the area in the vicinity of Mine LaMotte at Fredericktown carries cobalt, nickel, copper, and iron minerals. These metals were recognized in the deposits at Mine LaMotte during the early years

*From 54th Annual Report, Missouri Department of Mines and Mining.

of mining and the Mine LaMotte Company between the years 1899 and 1908 mined cobalt and nickel ore, the products of which were valued at more than $600,000.

The most extensive known deposit, carrying these metals, occurs on the property of the Missouri Cobalt Company, located about one mile east of Fredericktown. During the years 1918 to 1920 inclusive active mining was carried on and the ore was treated in a very large mill. Lead, copper, cobalt, nickel, and sulphur were recovered from the ore. The property has not been operated since 1920. It is owned by M. J. O'Brien interests of Ottawa, Canada. The following information submitted by the company indicates the grade and quantity of ore mined and the possible reserves drilled out with additional territory still to be prospected.

"During the years 1918, 1919 and 1920 a total of 163,027 tons of ore were mined and showed an average grade of 1.16% lead, 2.04% copper, 0.49% cobalt, 0.619% nickel and 0.506 ounces per ton silver. The average daily tonnage treated was 223 tons. The principal minerals in the ore are galena, chalcopyrite, siegenite (cobalt-nickel sulphide) and marcasite. Research and laboratory tests during 1928 to 1932 indicated that the cobalt-nickel and the copper minerals can be practically liberated by grinding to 150 mesh, and that flotation concentration which was not used in the 1918 to 1920 period would be feasible.

The mine workings were never systematically sampled and accurate data on remaining ore is not therefore available, but from the old mine records and diamond drill hole data we have been able to arrive at what we feel is a conservative estimate of ore still in place.

In the main ore zone adjacent to Nos. 2 and 3 shafts, there is at least 300,000 tons with additional possibilities for developing considerable tonnage north of No. 3 shaft and northeast of No. 2 shaft. In the absence of any mine assays a grade equal to the average of the ore mined in the 1918 to 1920 period may reasonably be assumed, i. e., Pb 1.17%; Cu 2.04%; Co 0.49%; Ni 0.61%, and these grades are borne out by surface diamond drill holes which have intersected the ground in question. In addition to the above, diamond drilling on an eastern section of the property known as the Rhodes tract has indicated 170,000 tons assaying Pb 1.62%; Cu 1.83%; Co 0.40%; Ni 0.53%, and the ground between this and the main ore zone is very imperfectly explored."

Total reserves therefore, are:

			Per Cent		
	Tons	*Pb*	*Cu*	*Co*	*Ni*
Main Ore Zone	300,000	1.17	2.04	0.49	0.61
Rhodes tract	170,000	1.62	1.83	0.40	0.53
	470,000	1.33	1.96	0.46	0.58

Some years ago the St. Louis Smelting and Refining Company encountered similar ore southeast of Fredericktown while drilling for lead ore. A substantial tonnage was developed although no mining developments were made at the time.

Due to the strategic position of cobalt and nickel and the need of greater output of copper and lead for war purposes, the St. Louis Smelting and Refining Company has leased the Cobalt property, checked old drill holes and have sunk a shaft to the ore body on the Rhodes tract. During 1943 this area will again be producing cobalt, nickel, and copper as well as lead.

All of these metals occur in lesser quantities in the northern portion of the disseminated lead district and some copper is recovered as a by-product obtained in milling the lead ore. In 1940 this value amounted to $154,810 a part of which was probably produced but not sold in 1938 and 1939 as no sales were reported during those years. In 1941 the recovered copper was valued at $330,400 by far the largest amount ever reported for this metal in any one year.

There was no production from the copper deposits in Ste. Genevieve, Shannon or Franklin Counties during the biennial period.

The following volumes by the Missouri Geological Survey discuss the copper deposits occurring in the respective areas covered by the reports.

Volume XXII, Second Series, The Geology of Ste. Genevieve County.

Volume XXIV, The Geology of the Eminence and Cardareva Quadrangles.

GOLD AND SILVER.

There are no known commercial gold deposits in Missouri. The glacial drift which covers a large part of the northern portion of the State carries a little gold in some areas, especially in the sands and gravel. The drift in part is composed of ground up rock powder and boulders derived from gold bearing formations in regions of Canada. It however does not carry a sufficient quantity of the precious metal to be commercial.

At the Einstein Silver mine about twelve miles west of Fredericktown in Madison County argentiferous galena occurs with tungsten ore in quartz veins. The galena assays approximately 30 ounces of silver to the ton of lead concentrates. This is the only occurrence in the State that might be termed a silver ore. The property was first worked for the silver bearing galena and the richest deposit was apparently worked out at about 200 feet in depth and there is not enough galena showing at present to warrant mining for the lead and silver alone.

The lead concentrates of the southeast lead district contain about one-half ounce of silver per ton and when smelted this silver is concentrated in the lead metal. It is not sufficient to warrant treating the lead for the recovery of silver, but in the purification process where the metal is used in the production of lead paints the silver is removed. This silver is then recovered and in 1941 was valued at $261,467; the largest amount ever recovered in one year. In 1940 the recovery was valued at $185,112 and in 1939 it was valued at $144,853.

IRON ORES.

The production of iron ore in Missouri for 1940 increased somewhat over that of 1939. In 1940 a total of 53,420 tons of ore were sold for $134,411. Of this total 3,203 tons were sold for $11,177 to paint manufacturers. The remaining 50,217 tons were sold to iron furnaces for $123,234 with the exception of a small tonnage which was sold to non-ferrous smelters as flux. The ore mined was of two varieties, hematite known as red ore, and limonite called brown ore. The production of limonite was 39,660 tons which sold for an average price of $2.50 per ton. The production of hematite was 13,760 tons which sold for an average price of $2.50 per ton.

Production figures for 1941 show that 18,473 tons of ore were sold for $59,192. Paint manufacturers purchased 5,063 tons for $23,649, the remainder being sold to iron furnaces with the exception of a small tonnage which was used as flux at non-ferrous smelters. The production of limonite was 6,206 tons which sold for $18,223 and the production of hematite was

A. Fox Den, brown ore iron mine near Taskee, Missouri

B. Christy, red ore iron mine east of Steelville, Missouri

7,204 tons which sold for $17,320. The drop in production as compared to 1940 was chiefly in the southeastern portion of the state which produces limonite ore.

The hematite ores were mined chiefly in Crawford, Miller, Dent, and Franklin counties in what is known as the central or filled sink district. Here the ore occurs in sink holes that vary in size from 50 feet to as much as 1000 feet in diameter. Their average depth is less than 100 feet although in a few instances some pits have attained depths up to 300 feet. The largest production recorded from any one pit is about 750,000 with the average being between 50,000 and 150,000 tons for the medium sized deposits. The ore consists chiefly of soft red hematite and hard blue or specular hematite. The deposits are usually mined by open pit methods and hand sorting of the ore is necessary.

The limonite or brown ores are mined chiefly in Butler, Carter, Wayne, Bollinger, and Washington counties in the southeastern part of the state. The brown ores occur in the surface clays and as a general rule are tabular in shape. They are mined by open pit methods and hand sorting is necessary. As a general rule the individual brown ore deposits are not as large as the hematite deposits, however, a few have produced from 50,000 to 150,000 tons of ore. In total tonnage there is probably more brown ore available than there is hematite from the filled sinks, because of the greater number of occurrences.

The war effort has caused an increase in demand for pig iron. In the latter part of 1941 the Koppers Company bought the furnace at Granite City which had been out of blast for 9 years. However, no market was offered for Missouri ore until the early part of 1942. This market aroused increased interest in iron mining in Missouri especially in the limonite district. At this time the Missouri Cliffs Company which is a subsidiary of the Cleveland Cliffs Company entered the field. They purchased the interests of Chapman and Doane of Poplar Bluff and continued to mine the existing operations. Notable among these was the Fox Den mine near Taskee from which approximately 140,000 tons of ore have been mined. Other properties are being worked and considerable prospecting has been done. A washing plant was operated until midsummer of 1942, but has been discontinued. One of the newer properties, known as the Wells and located about 12 miles west of Williamsville, has developed a sizable ore body. The so-called Barnes mine near Sam A. Baker State Park produced a few carloads but is not now in operation. In the summer of 1942 Chapman and Doane again became active in iron mining. They began shipping ore from West Plains and Doniphan to the Missouri Cliffs Company.

The central or filled sink district was also stimulated by the opening of the Granite City smelter. The K.W.D. (Kerruish, Williams and Davis) Mining Company acquired leases on several properties. Some prospecting was done at Copper Mountain near Sullivan but an ore body has not yet been located. They also have done considerable development work at Silver Hollow near Sullivan. It is anticipated that they will soon begin shipping considerable ore from the latter.

At the Cherry Valley mine located near Steelville a washing plant to recover ore from the dumps has been erected by the Superior Minerals Company of Potosi. This plant consists of a Diesel electric power unit, large capacity pumps for taking water from the old open pit, several small power shovels, and trucks for moving the ore. The washer itself contains a log washer, a small jaw crusher, a large gyratory crusher, a revolving screen, two jigs of 3 cells each, and 2 drag classifiers or driers. The washer has a capacity of approximately 6 cars of ore per day. Some prospecting has been done at Cherry Valley No. 1 and indications are that some ore still exists below the old open pit. Additional prospecting is being done, and if sufficient ore is developed to warrant, an attempt may be made to mine underground.

At the Christy mine in Crawford County, M. E. Richards is mining ore by a series of inclines from the bottom of the old open pit. A shaft is also being sunk to approximately 125 feet along the west side of the open cut. This shaft will encounter the ore body as revealed by drilling and underground mining is contemplated.

J. E. Moore is doing prospecting by means of test pits and shafts on the Coleman property near Scotia Post Office. Dr. Brandt has purchased the Benton Creek mine located in southern Crawford County near Bangert and is prospecting it by means of deep shafts. W. Wolf is prospecting the McKindsey mine located in northern Washington County near Anthonies Mill by churn drilling. This deposit exhibits a good sink structure and it is believed will contain a sizable ore body. E. F. Krewinghaus and J. F. McDermott are doing some stripping at the Tirell mine which is located in northern Washington County near Richwoods. C. Peterson is sinking a shaft in the bottom of the open pit at the Reuppele Mine near Stanton in Franklin County and intends to mine the ore body remaining by underground methods. Some attempts were made to mine the Powell property which is located on the Meramec River near the Steelville ford on Highway 8. The ore contains considerable lime in the face which lies above river level and very little is known as to the character of the ore under the river. The river channel was partially diverted but because of a defense plant contract the operator removed his equipment before anything definite could be determined concerning the size and character of the ore body.

In 1928 and 1929 the M. A. Hanna Company drilled out exceptionally large ore bodies near Hayes cut at Iron Mountain. Magnetic iron ores at these localities are indicated on old magnetic maps which show observations made during a survey done in 1873. No development work was carried out subsequent to 1929 until 1942, when additional drilling extended the developed area very materially.

Some prospecting has been done by C. Maughs about 1½ miles east of New Bloomfield, Callaway County in the NW¼ Sec. 4, T. 45 N., R. 10 W. The ore is exposed at the mouth of an old mine tunnel, the entrance to which is located in a small draw about 10 feet below the general upland surface. The tunnel is now caved in but some ore is visible at its entrance. The ore occurs as a bedded deposit and is reported to be from 4 to 6 feet in thickness. A dump just east of the draw from the tunnel shows considerable red hematite which has definite bedding. Approximately 400 feet northwest of the tunnel and just across the township line in Sec. 32, T. 45 N., R. 10 W., is an old shaft which is now filled. It was reported to have encountered 13 feet of soil and boulders and then 7 feet of ore. In 1942 Maughs sank a shaft along a line between the main tunnel and this shaft. The Maughs shaft is about 100 feet northwest of the mine tunnel and is 14 feet deep. The first 9 feet in this shaft was clay and boulders below which 3 feet of red shale was encountered and a few boulders of blue specular iron occurred at 13 feet. It would appear from this that the ore is lenticular in nature and the red shale in the Maughs shaft might represent the ore zone encountered in the other workings. An analysis of the ore shows it to be of commercial grade and acceptable as furnace ore.

The Geological Survey has been in constant touch with iron mining activities especially during the recurrence of interest due to creation of the market at Granite City. We have advised prospective miners and others from information in our files and by frequent visits of inspection to various properties. In view of present conditions it is anticipated that considerable time will be devoted to this mineral resource during the coming biennium.

LEAD ORE*

With a production of lead concentrates valued at $15,534,-335 in 1941, Missouri continues to maintain first place among the states in the production of this metal. The total output of lead concentrates in 1941 was 230,746 tons; all but a small percentage of the galena was produced in southeast Missouri. The output from the disseminated lead district of St. Francois and adjoining counties continues to lead in quantity and value the output of any other lead producing district in the United States. The ore is produced from the Bonneterre dolomite of Cambrian age. The galena is disseminated through the country rock in small crystals. The ore is practically free from other impurities which are chiefly iron sulphide and a small quantity of copper pyrites. The content of the formation as mined averages 3% lead. The Missouri production is approximately one-third of the total output of the United States.

The St. Joseph Lead Company is the principal producer in southeast Missouri.

The following major developments have been inaugurated during the present biennial period.

In 1941 the Fredericktown Lead Company reopened the old Catherine mine northwest of Fredericktown. Several headings are being worked and stope is being taken in part of the old drifts on the 100 foot level. After the lower ground is dewatered, much of the present floor will be mined in prepara-

*Statistics compiled by the U. S. Bureau of Mines and published in the Minerals Year Book for 1941.

tion of the establishment of a new grade for haulage. A 400 tons mill on the property concentrates the ore.

The St. Louis Smelting and Refining Company is sinking a shaft on the property of the Missouri Cobalt Company southeast of Fredericktown. Other shafts are proposed for the purpose of further prospecting the character of the deposit. A complex lead-nickel-cobalt ore is indicated in the drilling. Plans for a concentration mill are awaiting for additional information concerning the deposit.

The Park City Consolidated Mining Company of Park City, Utah, is sinking the Ruth shaft on a tract of land four miles south of Fredericktown. This area has been extensively prospected with the churn drill.

The long abandoned open pits of old Mine La Motte have been reopened. Some of the pillars have been removed and in places the ore has been stoped to the surface. This ore is trucked to the Mine La Motte Company mill northeast of Fredericktown.

LIME.

In common with a number of other mineral resources the total production of lime, amounting to 736,200 tons valued at $4,106,468, exceeded the output and value of any previous year. In the case of lime this increase is approximately $1,000,000 and is 300% greater than 10 years ago, at which time the production was valued at $1,034,850.

The most important center of production is near Ste. Genevieve in Ste. Genevieve County, where the burning of oolitic Spergen limestone produces the whitest and highest grade lime in the State. Most of this output is used in the chemical industry.

Other Mississippian formations are burned at Hannibal, Ash Grove, Pierce City, Gallaway, Neosho, and Springfield.

All of the plants enumerated produce high calcium limes. The following table indicates the uses of Missouri lime in the order of their importance:

Use	*Production*	*Value*
Chemical Lime	341,142 T.	$1,709,125
Metallurgy	237,234	1,453,585
Water Purification	102,265	563,629
Building Materials	55,559	380,129
State Total	736,200	$4,106,468

Missouri stood third among the states in the value of lime production in 1941. The wide range of uses reported for Missouri lime is shown in the following tabulation:

Paper	Sand lime brick
Paints	Alkalies
Petroleum	Minor uses include the manufacture of:
Insecticides	
Tanneries	Soap and fats
Food Products	Glue
Sewage	Alcohol
Calcium Carbide	Varnish
Bleaching liquid and powder	Rubber
Sugar	Salt Rfg.
Coke and gas	Grease
Silica Brick	Asphalts

MANGANESE.

The increased need for manganese in the production of steel for war purposes has renewed interest in the possible development of manganese ore from known Missouri deposits. During the biennial period considerable prospecting has been done in southeast Missouri.

The major portion of the development work was done in Shannon, Reynolds, and Madison counties. In Shannon County 6 carloads of ore were shipped from The Thorny Mountain mine, located on the west slope of Thorny Mountain, in Sec. 8, T. 28 N., R. 2 W. This property is about 10 miles southeast of Eminence, on the property of Mrs. M. S. Akers.

The manganese is exposed in narrow veins which were opened up by surface blasting in 1937, by J. C. Benson and F. B. Greene of Eminence. In 1940 Mr. W. M. Nash sunk a pit 20 feet long by 6 feet wide by 10 feet deep, but shipped no ore. In November 1941 the property was leased by the Shannon County Mining & Ore Company. A shaft was sunk in the bottom of the old pit to a depth of approximately 40 feet, and 2 carloads of ore were shipped. During 1942 a second shaft was sunk along the strike of the vein, 138 feet south of Shaft No. 1. In October 1942 this shaft was also about 40 feet deep and had produced 4 carloads of ore.

The ore which is largely dense, hard, black Braunite, occurs in veins in rhyolite porphyry country rock. It is partly fissure vein filling and partly replacement of the porphyry. With depth the vein has widened and more replacement of the porphyry has been shown. The ore must be thoroughly hand-picked and sorted to eliminate unreplaced country rock. A sample collected by O. R. Grawe of the Department and analyzed by the Survey chemist ran 21.34% insoluble and 38.99% manganese. Evidently the silica had not been entirely replaced in this sample.

During the biennial period Mr. W. M. Nash and Mrs. Blanche S. McCaw started prospecting on the Oliver Tucker farm, in Sec. 11, Twp. 29 N., R. 1 W., approximately 4 miles west of Ellington, at the head of a tributary ravine to Christian Hollow. The manganese ore in this area consists chiefly of Psilomelane and occurs in the surface clay, cementing boulders of chert derived from the weathering of the underlying dolomite in this particular area. Some 55 pits were sunk, many of which showed cemented breccia. A sufficient showing was developed to interest the U. S. Bureau of Mines, which department did some development work, sinking some 20 odd pits in addition to those sunk by the owners. The Government Bureau did not continue development of the property to production.

One interesting feature of the occurrence is the presence of cobalt in the ore. Analyses for this metal have shown that different ores vary in content from a very slight amount to as high as 1% cobalt. Samples of the ore analyzed by R. T. Rolufs, chemist for the Geological Survey, shows insoluble 31.41%, manganese 27.61% and cobalt 0.47%.

During the latter part of 1941 development work had stopped on this property and no production has been marketed.

In Madison County, during World War I, considerable prospecting was done on the Harry Clover property, located in Sec. 30, Twp. 33 N., R. 8 E., adjacent to the Belmont branch of the Missouri Pacific Railroad, about one mile north of the town of Cornwall. In about 1890 this property was opened for the production of brown iron ore, which was used as flux at Mine La Motte. In 1917 the property was leased by G. L. Barnes who produced some 80 tons of manganese ore and manganiferous iron ore. Some 40 tons of this material was shipped. In 1940 approximately 12 pits were dug in the vicinity of the old workings by Mr. Ernest Pearce of Cadet, Missouri. Considerable manganese ore was encountered. Late in 1942 Mr. Pearce expected to have the property in production. The ore occurs in residual clays overlying the Potosi and Eminence formations, and apparently consists largely of the oxides, Psilomelane and Pyrolusite.

In Iron County manganese has also been found in fractures in the Pre-Cambrian porphyry and has partial replacement by porphyry adjacent to the fractures. In some instances there has been replacement of volcanic tuff. The principal developments in Iron County have been made at the so-called Cuthbertson mine, in Sec. 19, Twp. 33 N., R. 4 E., approximately 3½ miles southwest of Arcadia, on the south slope of Cuthbertson Mountain. The original openings made on this property were developed as early as 1874. Some work was done in 1916 and 1917, but the ore produced at that time was considered too siliceous for use. In 1939 Dr. J. H. Martin of Arcadia and associates did some prospecting and piled up several tons of ore. In 1941 Mr. Ernest Pearce of Cadet took over the property and did sufficient work to produce about 30 tons of ore, which was shipped.

At the present time the pits show poor exposures, but it is evident that the manganese has been concentrated chiefly in beds of altered volcanic tuff from 3 to 6 feet in thickness. No work is being done on this property at the present time. The ore consists of soft wad and hard nodules of Psilomelane and Pyrolusite.

Very little development work has been done outside of the above mentioned localities. They have shown the most encouraging results, but to date only one of them has produced commercial shipments. There are other areas showing similar ores in both the porphyry and sedimentary rocks in the above counties.

OIL AND GAS.

The most important oil and gas development in the Biennial period just closed was the discovery of oil on November 26, Thanksgiving Day, 1942, in the Cities Service Oil Company No. 1 Jim Cook well, SW¼ NW¼ NW¼ Sec. 32, T. 65 N., R. 39 W., Atchison County. The well is located approximately 2 miles southeast of the city of Tarkio. The oil producing sand, tentatively correlated with the "Bartlesville" sand of the Cherokee formation of the Pennsylvanian system was topped at 1440 feet, and drilled into to a depth of 1442 feet. 7 inch O. D. pipe was cemented at that depth.

The well was drilled to the depth mentioned with rotary tools. Operations were then continued with cable tools and the sand was drilled from 1442 to 1450 feet. Although the well has not been completed at the time this report is written, December 12, 1942, tests would indicate a small well of 15 to 25 barrels of black oil, the gravity of which is reported by the Cities Service Company to be 25.7°. Some water is being obtained with the oil and tests are also being made to determine the source.

The drilling of this well was preceded by the drilling of a dry hole one location north, Cities Service Oil Company, No. 1 Glen Gray, SW¼ SW¼ SW¼ Sec. 29, T. 65 N., R. 29 W., which was completed as a dry hole in Devonian (Hunton) dolomite at a total depth of 2426 feet. This well was drilled with rotary tools. An examination of the rotary samples showed oil stains in the "Bartlesville" sand from 1460 to 1487 feet. The company attempted to develop the well but was unsuccessful as water intruded.

Although the present well does not appear at this time to represent a major discovery, it is nevertheless a most significant one. Insofar as available records are concerned it is the first show of oil in the Bartlesville sand, in the Missouri portion of the Forest City basin with one possible exception, McCain et al, No. 1 Bermond, SW¼ SE¼ SW¼ Sec. 26, T. 58 N., R. 34 W., Buchanan County, Missouri, where dead oil was noted in sand at 1030 feet which possibly corresponds to the producing sand at Tarkio. In the Buchanan County well a show of oil was also found in a lower sand, but no attempts were made to develop it. Oil and gas are being produced from a Pennsylvanian sand in the McLouth pool, Ts, 9 and 10 S., R. 20 E., Jefferson and Leavenworth Counties, Kansas, about 80 miles due south of the present discovery at Tarkio. The sand, however, is possibly lower in the Cherokee section than the sand at Tarkio.

The nearest pool to the Tarkio well producing from sands also in the Cherokee is the north Plattsburg pool, Sec. 18, T. 55 N., R. 31 W., and Sec. 13, T. 55 N., R. 32 W., Clinton County, Missouri. In relation to the oil being produced from the Devonian (Hunton) dolomite, in Richardson County, southeastern Nebraska, the well near Tarkio is 20 miles northeast of the Barada pool, Sec. 36, T. 3 N., R. 16 E., and 30 miles northeast of the Falls City pool, Secs. 7, 17, 18, and 20, T. 1 N., R. 16 E.

Including the discovery well, only seven wells of record have been drilled in Atchison County into or through the present producing sand. A large area is therefore open to development. Because of the comparatively shallow depth, an exploration program of some extent would take place under more normal conditions, and despite them the drilling of additional tests in this area is anticipated.

Drilling was carried on in other portions of the State during 1941 and 1942 in an attempt to develop production. There was considerable activity in 1941 when 69 wells were completed, but 1942 was marked by the lowest number of completions, 24, since the exploration program following the Forest City basin oil and gas lease play, was started.

With the exception of the Tarkio well there were no outstanding events in northwestern part of the State. The record total depth for this area was established by the Skelly Oil Company, No. 1 Mutual Benefit Life Insurance Company well, SE¼ SE¼ Sec. 32, T. 60 N., R. 37 W., Holt County which was completed at a total depth of 3513 feet in the "Arbuckle" dolomite. Several shows were reported in this well.

A number of wells were drilled in shallow gas fields during 1941 and 1942. The Polo field, Caldwell County saw considerable activity, and a number of wells were drilled in the Prairie Point gas field, Platte County.

A number of deep tests were completed in the embayment area of southeastern Missouri, and one, the Strake Petroleum Company's No. 1 T. Russell, Sec. 24, T. 19 N., R. 11 E., Pemiscot County, was completed at a total depth of 4740 feet and thus established a new total depth record for the State. It was abandoned as a dry hole in Cambrian quartzite. This well drilled a thick section of upper Cambrian dolomite, shale, and quartzite which have no lithologic counterparts in the Cambrian section exposed to the northwest in the St. Francis Mountain area.

Similar rocks were encountered in the O. W. Killam, No. 1 Pattinson well, SE¼ SW¼ Sec. 33, T. 18 N., R. 13 E. Pemiscot County. In this well, the upper Cretaceous rocks were in contact with these Upper Cambrian rocks, and thus an unconformity of great magnitude is indicated in portions of the embayment.

The following statistics covering oil and gas developments in 1941 and for the period January to October, 1942 will be of interest.

DRILLING OPERATIONS IN MISSOURI, 1941 (REVISED).

County	*Oil*	*Gas*	*Dry*	*Initial open flow of gas (cu. ft.)*
Atchison	..	..	2	....
Bates	..	..	1	....
Buchanan	..	..	1	....
Caldwell	..	9	10	4,000,000
Cass	..	1	8	550,000
Clinton	..	..	3	....
DeKalb	..	..	4	....
Holt	..	..	3	....
Jackson	..	4	9	240,000
Knox	..	..	4	....
Lewis	..	..	1	....
New Madrid	..	..	2	....
Pemiscot	..	..	2	....
Platte	..	5	10	7,859,000
Ray	..	..	5	....
St. Clair	..	..	1	....
Shelby	..	..	1	....
Vernon	..	..	2	....
Totals	..	19	69	12,649,000

Drilled by various types of rotary rigs.....................27 holes 31,135 feet
Drilled by cable tools.....................................61 holes 30,156 feet
Drilled below base of Pennsylvanian.......................20 holes

DRILLING OPERATIONS IN MISSOURI, JANUARY-OCTOBER, 1942.

County	*Oil*	*Gas*	*Dry*	*Initial open flow of gas (cu. ft.)*
Andrew	..	..	1	....
Atchison	..	..	1	....
Bates	..	2	5	550,000
Caldwell	..	1	2	200,000
Cass	..	..	1	....
Clinton	..	..	2	....
Holt	..	..	1	....
Jackson	1	..	1	....
Nodaway	..	..	1	....
Platte	..	1	4	100,000
Ray	..	..	5	....
Totals	1	4	24	850,000

Drilled by various types of rotary rigs..................... 8 holes 10,726 feet
Drilled by cable tools.....................................21 holes 10,236 feet
Drilled below base of Pennsylvanian.......................10 holes

PYRITES.

For a number of years Missouri produced from 20,000 to 35,000 tons of pyrite which was used in the manufacture of sulphuric acid by chemical plants in St. Louis. All of the production came from deposits located in the "filled sink" iron ore area of Phelps, Crawford and adjoining counties in the northern portion of the Ozarks.

Many of the iron ore bodies contain iron sulphide in the lower portion of the deposits although the chief producer was Moselle No. 10 mine in Phelps County which property had a total output of approximately 150,000 tons.

With the depletion of Moselle No. 10, mine production ceased and the acid plants in St. Louis changed equipment to burn pure sulphur from Louisiana and Texas. There is now no market for Missouri pyrite and there is no production.

The past history of pyrite production is well summarized in the 60th Biennial Report.

SAND AND GRAVEL.

The value of sand and gravel output in common with most of the mineral production of the State showed a material increase in 1941 over that of 1939 or 1940. As shown on the tabulation of yearly production this increase was slightly over 25% and no doubt is a reflection of the extensive construction of defense plants in the State. While figures are not as yet available, the sand and gravel plants have been extremely active during 1942 and this year will probably show a materially larger output, even though the State Highway Department has virtually ceased using gravel in the construction of concrete pavement. The chief use of gravel by the Highway Department in recent years has been for the surfacing of farm-to-market roads.

Practically all of the sand and gravel used in highway work, in concrete construction and for railroad ballast, is produced from extensive deposits found along the major streams of the Ozark region. The various dolomitic limestone and sandstone formations of the southern half of the State, when weathered, leave a very heavy cherty, sandy, clay residuum which, when sorted by stream action, furnish an inexhaustable supply of chert gravel and sand. In the northern part of the State the underlying geological formations do not leave a cherty residuum and there are no extensive chert gravel deposits except in those counties bordering the Mississippi River. Glacial deposits in the northern part of the State have furnished important quantities of sand and gravel, especially near Chillicothe, Livingston County and LaGrange, in Lewis County. Over most of the area covered by glacial debris there is little sand or gravel.

The St. Peter sandstone, which outcrops in a comparatively narrow belt from north of the Missouri River to Scott County, furnishes an inexhaustible supply of high silica, pure white sand, used extensively in the manufacture of plate, bottle and window glass, grinding and polishing sand, abrasives, etc. The Pittsburgh Plate Glass Company mines this sand at Herculaneum, Jefferson County, for the manufacture of plate glass. At Pacific the Pioneer Sand Company and the Hardstone Brick Company produce various grades of sand and sand lime brick. This sandstone is also quarried at Klondike, on the Missouri River in St. Charles County. Small production has been made along the line of outcrop south of St. Louis, in Jefferson County.

STONE.

The use of stone constitutes the most important basic mineral industry in the state. Not only does the use of limestone as such constitute one of the most important mineral industries, but limestone used in the Portland cement industry and the lime industry furnishes the basic raw material for two additional mineral industries that are among the most important in Missouri.

The following tabulation shows the production and value of limestone for 1940 and 1941:

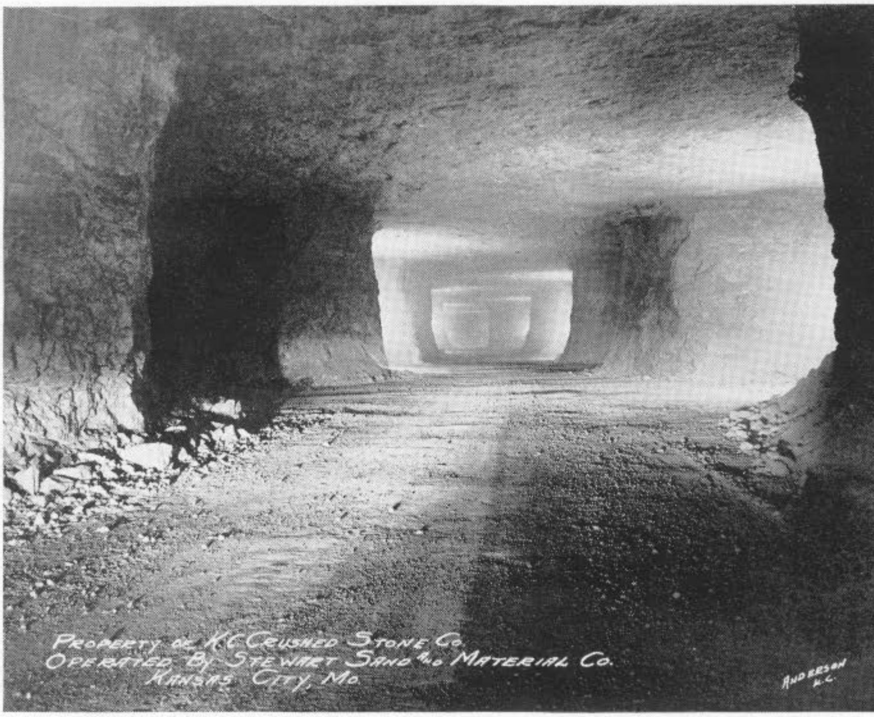
LIMESTONE PRODUCTION FOR 1940 AND 1941.

	1940		1941	
	Production (Tons)	Value	Production (Tons)	Value
CRUSHED LIMESTONE:				
Concrete and Road Metal....	4,101,510	$3,923,765	5,016,480	$5,398,413
Agriculture................	599,130	577,922	649,010	619,132
Railroad Ballast...........	5,800	6,699	173,910	129,075
Riprap.....................	864,710	815,566	102,590	103,059
Flux.......................	10,860	13,833	14,760	21,011
*Other Uses................	131,370	230,258	172,450	300,299
Total, Crushed Limestone..	5,713,380	$5,568,043	6,129,200	$6,570,989
DIMENSION LIMESTONE:				
Building Stone.............	64,550	$96,858	46,080	$71,088
Curbing and Flagging.......	710	2,590	450	2,492
Total, Dimension Limestone	65,260	$99,448	46,530	$73,580
Grand Total.............	5,778,640	$5,667,491	6,175,730	$6,644,569

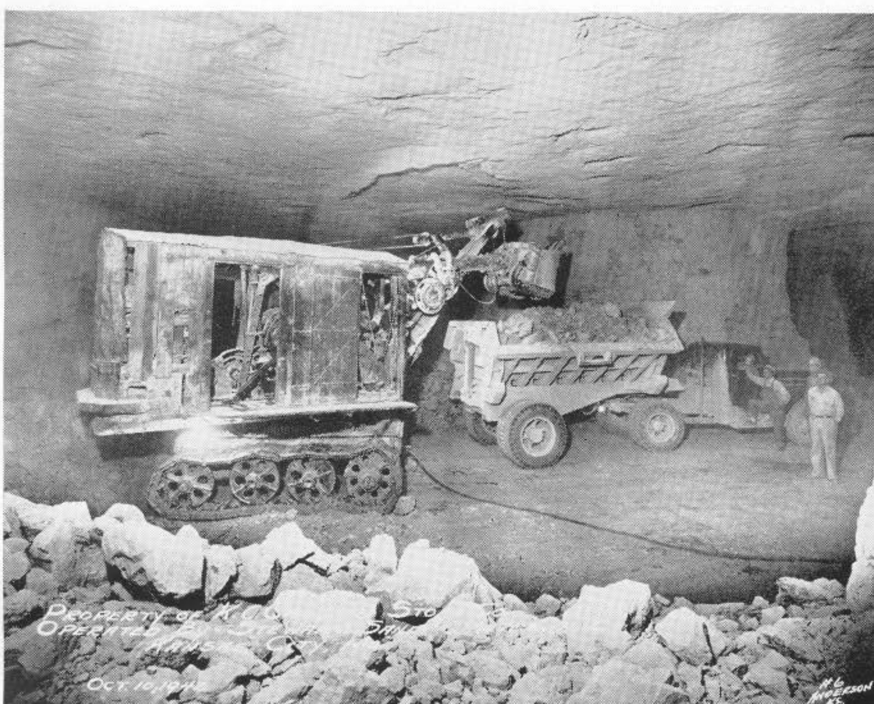
*Other uses include, mineral food, glass, sugar, fertilizer filler, other filler, whiting, filter beds, and poultry grit.

The figures, namely, 6,175,730 tons, valued at $6,644,569 in 1941 constitute an all time high both in tonnage and value. The year 1940 with a production of 5,758,640 tons valued at $5,-667,491 stands as the second highest output and value. These figures no doubt reflect the influence of a structural building program as the value of rock used in concrete and as road metal was practically 1,000,000 tons greater in 1941 than in 1940. With the exception of riprap the output of other uses does not show a very large difference in the two years. Riprap, however, shows almost an 88% decrease, which is probably due to a very decided reduction in river improvement work during the past year. Most of the riprap used in this state is used on the Mississippi and Missouri rivers.

Missouri probably has a greater variety of limestone and dolomitic formations suitable for commercial use than any other state in the Upper Mississippi Valley. In composition they vary from the very pure oolitic Spergen limestone of Ste. Genevieve County, which has a composition of approximately 99% calcium carbonate which is burned to chemical lime, to



A. Underground quarry, Jackson County, Missouri.



B. Method of loading and underground haulage, Jackson County, Missouri

the very impure argillaceous dolomitic, soft Sedalia limestone used for the manufacture of rock wool at Easley, in Boone County.

At the beginning of the century this Bureau prepared a report on the Quarrying Industry of the state. In 1900 the value of production was only $1,079,303. The 1941 production shows an increase of more than 600%.

Chats.—The lead and zinc mining industry of Missouri produces millions of tons of waste in milling both the southeast Missouri lead ores and the zinc-lead ores of the Joplin district in southwest Missouri. This waste material is known as "chats".

The chats produced in the Joplin district is chiefly flint of chert. It is used chiefly as railroad ballast, for road metal and for concrete aggregate. The refuse or chats of the southeast Missouri disseminated lead mines is composed chiefly of magnesium limestone or dolomite. It is used for railroad ballast, and in concrete work. It is too soft to be used as a highway surfacing material. In recent years this material has been extensively used as agricultural limestone and is trucked from the mining area throughout adjoining counties.

Except where the shipper designates a selling price this material has been given an arbitrary value of 25 cents per ton.

TONS USED IN 1941

	Company	*Commercial*	*Total*
Southwest Missouri	1,308,221	470,172	1,778,393
Southeast Missouri	311,902	70,634	382,536
Total	1,620,123	540,806	2,160,929

The total value assigned to this output is $646,784. Both in the number of tons used and the total value the figures for 1941 far exceed that of any previous year.

Granite.—Missouri red granite quarried at Graniteville in Iron County, has for many years been used as rough construction and monumental stock. In general there is very little annual fluctuation in production. The annual value since 1934 has varied from a maximum of $40,303 in 1935 to a minimum of $23,513 in 1939. In 1940 the value was $29,107.

The principal producer is the A. J. Sheahan Granite Company of Graniteville, Iron County. This firm produces a large part of the rough construction and rough monumental stone produced. The company does not finish any monumental stock.

There are five producers in St. Francois County and one in Wayne County. The total production of these six companies is less than one-fourth of the total production of the State.

The character of the granites of Missouri is described in Volume II, 2nd Series, of the Bureau of Geology and Mines reports, entitled "Quarrying Industry."

Marble.—The effect of the war on the type of construction using marble is indicated by the sharp reduction in the output in 1941. The production fell to a total of $287,781 which was more than $100,000 less than in 1940 when the output was valued at $392,762.

In 1939 the value of production was $556,014 which was the high figure for the past 10 years.

There has been no change in the number of plants furnishing Missouri marbles since the publication of the last Biennial Report.

The Carthage Marble Company of Carthage, Missouri, quarries the highly crystalline Boone limestone north of Carthage, on Spring River.

The Phenix Marble Company quarries a somewhat darker Boone limestone near Phenix, Greene County, Missouri.

The Ozora Marble Quarries Company operate a quarry near Ozora, Ste. Genevieve County, Missouri. The stone is obtained from the Little Saline and Grand Tower formations of Devonian age.

The Inkley Marble Quarries Company operates a quarry about three miles west of Ste. Genevieve, in Ste. Genevieve County, Missouri.

Sandstone.—The various sandstones occurring in the State are in general not suitable for building construction. The Warrensburg channel sandstone was formerly quarried extensively and used in St. Louis and Kansas City. It disintegrated rather easily and did not prove to be a durable building material, and the quarries were abandoned years ago.

Sandstone from this type of channel deposit has been quarried at Miami in Carroll County for use as riprap on the Missouri River. The stone cannot compete in the building trade.

Weathered beds of the Roubidoux formation in the Ozark region are extensively used in the construction of rather small dwellings in that area. The slabs are usually highly-colored in shades of brown, yellow and red, which forms a striking combination in rural construction. There are no figures available as to the amount of such sandstone that is used annually.

The St. Peter sandstone outcrops in a relatively narrow belt between the Missouri River and Cape Girardeau. It is extensively quarried at Crystal City, Pacific, and Klondike, for sand used in the manufacture of all types of glass, for grinding and for the manufacture of sand lime brick. This use is described under sand and gravel. It is too friable for use as a building material.

Rock Wool.—The rock wool plant at Easley, in Boone County, is the only plant in Missouri that is in operation. The Sedalia dolomitic argillaceous limestone has proved a very superior grade of rock for making rock wool.

This Department has consulted with citizens regarding the construction of plants near St. Joseph, Springfield, and St. Louis, but the formations at these places will not furnish anything except a high calcium stone that would require mixing various formations to get the proper composition for the manufacture of a good grade of wool.

Tripoli.—The leached, weathered residual material resulting from the weathering of a highly siliceous limestone or the weathering of chert is known in Missouri as tripoli. There are few areas where the decomposition has continued sufficiently uniform to result in a pure porous mass free from hard, unweathered portions. Weathered chert is widespread throughout the Ozark region, but the only area where this type of material is found in commercial quantities and of sufficient purity for high-grade use is near Seneca, in Newton County and in the adjacent territory across the state line in Oklahoma. In the eastern portion of the state, in northern Cape Girardeau County, an impure tripoli mixed with clay has been produced for use as railroad ballast.

The Seneca product after being milled is used for abrasives, scouring soaps, foundry fillings, filters and as an admix in Portland cement concrete.

As there are less than three producers in the State the value of production is concealed in the miscellaneous item in the tables of production at the beginning of this chapter.

Tungsten.—The need for tungsten in the war effort has again attracted attention to the Silver Mine area, located about 12 miles west of Fredericktown, in Madison County. In an area covering a few square miles in this part of the county, quartz veins occur cutting the pre-Cambrian porphyry. These veins carry varying amounts of Wolframite (tungsten ore), Argentiferous galena (silver-bearing lead ore), sphalerite (zinc sulphide), fluorite (fluor-spar), pyrite (iron sulphide) and a number of other minerals in lesser amounts.

Formerly this property was worked for the argentiferous galena, but was closed down for many years because of litigation. In 1918 it was worked for tungsten and because of the very high price of this metal during World War I the operations were successful. With the return of normal prices operations ceased.

Mr. Joseph Hahn and Mr. J. A. Smith worked the property intermittently during 1938 to 1941 and shipped approximately 14,000 pounds of tungsten concentrates to New York City.

The mineral rights to the property are owned by the Silver Dam Mining and Realty Company, of which Mr. A. H. Handlon of St. Louis is president. The surface rights are owned by the U. S. Forestry Department.

In May, 1942, the Silver Dam Mining and Realty Company gave a lease covering approximately 1100 acres to the Tungsten Company, a business trust organized by residents of St. Louis and Fredericktown. This lease did not cover the 160 acres upon which the original mines were located. The Tungsten Company rented a building in Fredericktown and installed a pilot plant for refining the tungsten concentrates to tungstic acid. Several thousand dollars was spent in equipping this plant and running a series of experiments on the ore.

Practically no prospecting was done by the Tungsten Company. On the original tract although some prospecting and a small production was made on a shallow test pit sunk on No. 1 vein, and some work was done at the new discovery shaft on the tract not under lease to the Tungsten Company. The Tungsten Company finally closed their laboratory and started to prospect No. 1 vein east of the river. No material production has been made.

Mr. Ralph Killian of Perryville in 1940 sunk a shaft on the Leo Rossieur property in the western portion of the district. Although the shaft was located on a quartz vein there was not sufficient encouragement to continue operations.

The Geological Survey has published a description of the district as Appendix I, entitled "Silver Mine Area," in the 57th Biennial Report. The department has also made a detailed survey of the surface and prepared a detailed map of surface workings. This report and map are available on request.

ZINC ORES.*

The tabulation on the adjoining page shows the production and value of zinc ores in Missouri for the years 1939, 1940 and 1941. The year 1941 shows an increase in value of 200% over 1940. The large percentage of the output is sphalerite with an almost negligible quantity of silicate and carbonate. As noted on the tabulation that the central district produces but a very small tonnage.

The acute need for every pound of zinc obtainable has caused every effort to be made during the past year to increase production in Missouri. Prospecting and development have been very active and the increased production from the Missouri area is due to new operations during the past two years. Some of the more notable activities are as follows:**

*Figures collected by the U. S. Bureau of Mines.

**Data collected by Edward L. Clark.

PRODUCTION OF ZINC IN MISSOURI, 1939-1941

District	*1939*				*1940*				*1941*			
	Sphalerite		*Silicate and Carbonate*		*Sphalerite*		*Silicate and Carbonate*		*Sphalerite*		*Silicate and Carbonate*	
	Short Tons	*Value*	*Short Tons*	*Value*	*Short Tons*	*Value*	*Short Tons*	*Value*	*Short Tons*	*Value*	*Short Tons*	*Value*
Alba and Neck City	144	$4,977	......	....	41	$1,636	......	....	135	$5,790	......	....
Aurora	......	....	50	$850	4	175	......	....	85	4,585	2	$40
Carl Junction	264	9,226	......	....	341	13,883	......	....	44	1,974	......	....
Carthage	......	....	......	....	......	....	......	....	84	4,501	......	....
Duenweg	98	3,500	......	....	169	6,561	......	....	135	6,237	39	557
Granby	47	1,001	651	10,947	221	4,625	59	$921	919	49,900	919	10,348
Joplin	2,470	86,082	......	....	2,039	88,678	......	....	1,962	88,946	......	....
Oronogo	13,209	457,712	......	....	12,954	552,050	......	....	15,630	794,128	......	....
Ozark, Christian, and Greene Counties	592	18,827	248	4,960	750	30,750	669	7,911	714	36,386	317	3,410
Spring City, Spurgeon	1,536	55,201	......	....	148	5,920	......	....	450	20,475	......	....
Stotts City	......	....	......	....	......	....	......	....	455	23,031	......	....
Stark City	5,939	199,047	......	....	2,836	119,550	......	....	2,945	146,897	......	....
Waco	1,914	62,384	......	....	2,278	90,903	......	....	5,459	278,197	......	....
Webb City, Carterville, and Prosperity	1,258	37,180	......	....	712	28,301	......	....	2,254	102,883	......	....
Wentworth, Diamond	270	9,450	......	....	424	16,324	79	2,133	7,242	359,542	......	....
Southwest Missouri Total	27,741	$944,587	949	$16,757	22,917	$959,356	807	$10,965	38,513	$1,923,472	1,277	$14,355
Central Missouri Total	......	....	......	....	315	12,600	500	7,400	472	16,042	......	....

Alba and Neck City.—The United Zinc Smelting Corporation dewatered a tract of land in the south edge of Neck City. Small operators are taking advantage of this dewatering and are mining in the upper ground. The Smith sludge mill and the Berkey tailing mill are in production. A small tailing mill constructed east of Alba has not been placed in operation.

Aurora.—The Harris Mining Company has mined an ore body in the Reeds Spring formation, and milled the ore over a 200-ton mill located on the property. Recently this company has opened a run of ore in the upper ground, but its extent is unknown. The Red Wasp Mining Company has dewatered the Red Wasp mine and is preparing to work headings left when the mine was abandoned; this company will also cross-cut to a new run of ore located a short distance east of the formerly known runs at the Red Wasp. The American Zinc Lead and Smelting Company has prospected a run of ore in the Reeds Spring formation south of the old Coleman mine. Mining will be on the 190-foot level and a 200-ton mill constructed early in 1943.

Carl Junction-Smithfield.—At Smithfield the Chief Mining Company is dewatering the former mines and is sinking a new shaft to a run of ore recently prospected.

Carthage.—The Iowa-Missouri Mining Company has opened the Rogers mine south and east of Carthage, and is mining on the 74-foot level. C. C. Playter has taken over the Pleasant Valley mines southwest of Carthage and is working in the upper ground; this ore is being concentrated at the Playter mill south of Waco.

Duenweg.—At Duenweg the Federal Mining and Smelting Company has under construction a 75 tons per hour mill which was moved from Kansas. Ore will be pulled from two field shafts and a mill shaft, with mining being in the sheet ground at the 200 foot level. A ramp has been constructed for handling the ore from the field shafts. The American Zinc Lead and Smelting Company is sinking three shafts to the sheet ground on the Henckel land southeast of Duenweg.

Granby.—The Federal Mining and Smelting Company has opened new field shafts at Granby and are now pulling ore from seven field shafts. The tailing mill of the Colonial Mining Company has been redesigned and now has a capacity of 400 tons per 24 hours. The Pilant and Ogle silicate mine has been reopened by the Goade Mining Company.

Joplin.—The Kansas Explorations Inc., has reopened the Jasper mine and constructed a 60 tons per hour mill. Fifteen headings will be worked when necessary equipment has been installed. The High Grade Mining Company has rebuilt the mill which burned in 1940. In 1941 the Northside Mining Company sunk a shaft to the 185-foot level. The Ethel Gray Mining Company has reopened a shaft and is now constructing a 30 tons per hour mill on the property. Several individual operators have leased shafts from the St. Louis Mining and Milling Corporation in the vicinity of Thoms Station. Five of these subleases have been placed in production and three additional shafts are now being opened. The H. & P. Mining Company have reopened a shaft and are sinking a new shaft southeast of Joplin.

Oronogo.—Fenix and Martin Mining Company secured mining rights and permission to close a street in the town of Oronogo. A new shaft was sunk and mining has proceeded on the 135-foot level. The Snapp mine of the Kansas Explorations, Inc., northwest of Oronogo, has reached full production, and the ore is being concentrated over a 600 tons mill completed in 1941. This company is sinking a shaft on the Buckingham lease north of Oronogo. The Uptown Mining Company is opening an old shaft on the south side of the valley flat of Spring River.

Ozark.—The Monark Mining Company has reopened a shaft on the Alma run southeast of Ozark. The ore makes up in a gumbo clay and mining will be on the 200-foot level. A small mill equipped with log washers has been completed.

Spurgeon.—The Midvale Mining Company is sinking a new shaft two miles west of Spurgeon, and will reopen two shafts to increase production. A mill will be constructed on this property.

Stotts City.—The Stotts City Mining Company opened the south end of the ore run being mined by the Capitol Mining Company, but after mining a short time, sold the shaft and property to the Capitol Mining Company.

Stark City.—The Southwest Mining Company is sinking a shaft to the 250-foot level southeast of Stark City. A 250 tons mill will be constructed to concentrate this ore.

Waco.—In 1942 the F. W. Evans Mining Company opened the Blue Rock shafts south of Waco. Mining is on the 225-foot level and the ore is concentrated at the Evans mill located across the state line in Kansas. C. C. Playter has opened a new shaft on the lease where his custom mill is located.

Prosperty-Porto Rico.—The Little Sallie mine at Porto Rico is to be dewatered. The major portion of the equipment for a mill is now on the ground and construction will begin early in 1943.

Wentworth-Diamond.—The Eagle Picher Mining and Smelting Company has opened the Owens mine northeast of Wentworth and the Priest mine southwest of Wentworth. For a short time ore was mined at the Johnson shaft southeast of Wentworth, but this is now abandoned. This ore is milled at the Navy Bean mill west of Wentworth. The Liberty Mining Company is operating the Shartel mine and mill west of Diamond. Rex Beyer has opened a shallow lead run near the Shartel mine.

There has never been a time in the past when prospecting activity in Missouri attained its present height. Every major field is spotted with churn drills.

FINANCIAL STATEMENT FOR 1941-42—GEOLOGY.

1941

Aid, Kenneth	$2,947.09
Al. J. Bader Co.	31.50
American Star Cork Co.	222.27
Ball, John R.	91.48
Baumgardner Studio	1.53
Brown, Solon	51.00
Buehler, H. A.	5,472.84
Bute, Harold	33.60
Bybee, Chas. J.	226.84
Capps, Jno. B.	144.25
Chase Bag Co.	414.37
Charles Bruning Company, Inc.	53.51
Clair, Jos. R.	442.54
Clark, Edward L.	588.49
Coffman Grocery Co.	8.70
Davis, W. E.	18.52
DeLaney, Willard	159.90
Dessieu, E. E.	24.00
Erker Bros. Optical Co.	11.95
Followill Drug Co.	7.70
Goodyear Tire & Tube Co.	184.74
Gott, Garland B.	663.32
Grawe, Oliver R.	723.37
Greene, Frank C.	3,337.71
Grim, Leonard J.	14.00
Grohskopf, John	2,767.24
Gwin's Service Station	205.17
Hassell, Burnie S.	177.20
Hawkins, E. E.	1,320.00
Heil Corporation	96.26
Herold, Paul G.	312.50
Hinchey, Norman	3,211.75
Houston, Mary	1,320.00
Hundhausen, Mary	1,160.00
Jno. W. Scott, Druggist	24.15
Kimble Glass Co.	547.74
Kinnin, Carl	51.00
Kline, Stephen S.	93.29
Klinefelter Motor Co.	89.08
Keuffel & Esser Co.	36.01
Liddell, J. W.	54.77
M. O. Martin, Hardware	113.35
Mayo Service Station	89.55
Maytag Co.	4.00
Melville B. Hall, Inc.	58.25
Mid-State Printing Co.	16.46
Monsanto Chemical Co.	130.70
Muilenburg, G. A.	705.00
McCaw, Jean I.	1,620.00

FINANCIAL STATEMENT FOR 1941-42—GEOLOGY—1941—Continued.

McCracken, Earl J.	$700.00
McKeever, Wm.	6.12
McManamy, Lyle	1,105.03
McQueen, H. S.	4,561.60
Office expenses and supplies	843.63
Planje, T. M. J.	151.60
Pollock, W. L.	37.09
Postmaster, Helen Baysinger	369.50
Powell Lumber Co.	89.95
Quinn, Patrick	65.97
Railway Express Agency	138.08
Reinoehl, C. O.	2,036.14
Robinson Lumber Co.	1.82
Rodewald, H. F.	431.64
Rodman services	30.75
Rolla Ice & Wood Co.	3.75
Rolla Printing Co.	8.75
Rolla Wholesale Grocery	10.88
Rolufs, R. T.	1,374.20
St. Louis-San Francisco Ry.	15.12
Shaughnessy-Kniep-Hawe Paper Co.	30.02
Shuey, Mrs. E. T.	19.69
Smith Service Station	12.61
Soper, David	86.65
Stewart, Dan R.	1,770.90
Stoddard County	25.00
Stoltz Stores	5.76
Student labor	880.33
Superior Chevrolet Co.	705.77
Thayer, W. H.	37.65
Tulsa Paper Co.	45.00
United Telephone Co.	86.75
Via, C. D.	4.80
Virgin, Charles	24.00
Welch, T. H.	81.55
Western Union Telegraph Co.	10.46
Wilhelm, Frederick	12.75
Winkle, Robert	111.30
Yope's Garage	106.45
Total	$46,117.75

1942

Association of American State Geologists	$7.00
Aid, Kenneth	3.032.86
Al J. Bader Co.	5.42
American Paulin System	12.25
Anderson, Geo. M.	4.55
Anderson, W. F.	4.90

FINANCIAL STATEMENT FOR 1941-42—GEOLOGY—1942—Continued.

Baker & Co., Inc.	$66.98
Barnes, James V.	349.88
Barrett Electrical Supply Co.	11.11
Birch, E. J.	27.30
Brackbill, R. M.	62.65
Breuer, Marvin	326.28
Bridge, L. F.	23.61
Buehler, H. A.	5,652.01
Bute, Harold	8.40
Bybee, Chas. J.	549.39
Capps, J. B.	69.25
Carney Hardware Co.	23.20
Central Scientific Co.	2.61
Charles Bruning Co., Inc.	102.20
Chase Bag Co.	469.10
Chernoff, Edward	50.22
Clair, Jos. R.	1,686.85
Cook, Keith A.	28.35
Curtis, Verna B.	14.70
Dace, B. L.	48.38
Davis, W. E.	1,068.37
Dougan, C. W.	349.99
E. E. Dessieux Tire Co.	28.00
Erker Bros. Optical Co.	2.86
Farnham, F. C.	631.49
Fisher Scientific Co.	12.55
Followill Drug Co.	10.25
Franklin Janitor Supply Co.	13.80
Frommer, Don	141.74
Gott, Garland B.	1,397.81
Goyer's Service Station	85.80
Graf Aspco Co.	3.78
Grawe, O. R.	685.58
Greene, Frank C.	3,170.32
Grim, Leonard J.	58.97
Grohskopf, John	2,924.48
G. W. Hendley Garage	60.85
Gwin's Cities Service Station	397.43
Harlan, E. L.	40.00
Harty, W. C.	5.00
Hawkins, E. E.	1,320.00
Heil Chemical Corporation	225.24
Heller, R. L.	427.11
Hendrix, E. P.	6.85
Herold, Paul G.	170.11
Higley, Jerry	391.67
Houston, Mary	1,375.00
Hundhausen, Mary	9.04
Hoen & Company	275.00
Jacoby, C. H.	109.72
Jaques & Lierman	2.10

FINANCIAL STATEMENT FOR 1941-42—GEOLOGY—1942—Continued.

Jefferson City Printing Co.	$.62
Joe G. Downs Co.	14.50
Joe Yope's Garage	11.75
John W. Ellis Chevrolet Co.	817.98
John W. Scott	22.25
John S. Swift Co.	1,980.00
Kallmeyer, M. F.	21.00
Kasten, R. O.	41.10
Keuffel & Esser Co.	17.28
Kimble Glass Co.	141.09
Kline, S. S.	20.47
Klinefelter Motor Co.	112.34
Lambelet, C. A.	10.24
Liddell, Walter	78.04
Line's Garage	6.90
McCaw, Jean I.	1,675.00
McDowell, Roy	72.27
McGraw-Hill Book Co.	7.62
McKeever, W. L.	6.12
McManamy, Lyle	1,260.27
McNeely Machine Shop	80.26
McQueen, H. S.	4,192.49
Main, Marion K.	3.00
Martin, M. O.	91.85
Meyer, K. E.	23.09
Midland Stationery & Supply Co.	16.87
Mid-State Printing Co.	845.09
Mid-West Printing Co.	2.36
Miller, Geo. J.	56.78
Miller Hardware Co.	8.76
Mitchell Transfer Co.	26.01
Missouri General Utilities Co.	9.12
Monsanto Chemical Co.	62.62
Muilenburg, G. A.	555.53
Ore Reclamation Co.	19.75
Pautler, R.	7.00
Pine Street Market	5.99
Pollock, W. L.	10.49
Postmaster (Helen Baysinger)	724.00
Powell Lumber Co.	61.30
Quinn, Patrick	150.79
Railway Express Agency	300.68
Reinoehl, C. O.	2,006.80
Rendlen Motor Co.	15.49
Rice-Stix Co.	16.38
Robinson Lumber Co.	11.26
Rolla Ice & Wood Co.	13.90
Rolla Printing Co.	22.50
Rolla Tire Co.	46.32
Rolla Truck Lines	26.38
Rolla Wholesale Grocery Co.	17.22

FINANCIAL STATEMENT FOR 1941-42—GEOLOGY—1942—Continued.

Rolufs, R. T.	$2,327.66
Ross, H. D.	3.32
Ruckert's Architects Supply Co.	1.25
St. L.-S. F. Railway Co.	52.67
S. G. Adams Co.	6.08
Schwob, L. B.	35.70
Schuman's Inc.	.80
Self, O. R.	29.50
Shuey, Mrs. E. T.	20.06
Shaughnessy-Kneip-Hawe Paper Co.	7.00
Singleton, Fred	940.00
Smith Hardware Co.	.30
Smith Service Station	110.95
Standard Oil Company	1.75
Standard Stores	1.54
Steckel, Edward	61.07
Steininger, D. H.	75.59
Stewart, Dan R.	2,729.33
Stobie Photo Copy Co.	49.53
Stockwell Office Supply Co.	100.50
Stoddard County	30.00
Stoltz Variety Store	4.50
Superior Chevrolet Company	350.26
Swinford, Thomas	10.00
Thayer, W. M.	35.79
Triangle Blue Print Co.	6.77
United Telephone Co.	281.15
Vance Motor Sales Co.	5.30
Van's Cabinet Shop	222.50
Virgin, Chas. F.	72.00
Walter Ruska Company	1,030.05
Weaver, H. J.	32.20
Welch, F. H.	201.95
West Disinfectant Co.	8.00
Western Union Telegraph Co.	30.01
Winkle, Robert	31.15
Wise, John	19.94
Woltz Studios	2,711.68
Woollard, George P.	160.00
Wyant, W. G.	284.00
Yellow Transit Company	56.96
Total	$55,926.09

FINANCIAL STATEMENT FOR 1941-42—WATER RESOURCES

1941

Beckman, H. C.	$26.83
Cahill-Moore Motor Co.	3.03
Charles Bruning Company, Inc.	59.83
Eyberg, Carl J.	420.17
Fuller, J. J.	18.50
Hardine, K. L.	31.70
Hely, A. G.	32.76
Janda, Benjamin	18.56
Jennings, C. H.	2,603.95
John W. Scott, Druggist	1.50
Kamelgarn, Stanley	16.28
Kirn Auto Company	1.43
Klinefelter Motor Co.	166.72
Leeson, E. R.	230.08
Line's Garage	1.75
M. O. Martin, Hardware	12.45
Mesnier, G. N.	207.54
Powell Lumber Co.	34.13
Roemer, E. A.	234.42
Schneider S. & S. Inc.	64.63
Schwob, H. H.	181.01
Short, J. A.	321.64
Singleton, F. L.	159.25
Spinner, L. G.	5.77
Stoltz Stores	4.20
Superior Chevrolet Co.	209.37
Trisch, D. L.	83.33
Vance Motor Sales	2.50
Western Auto Assoc. Stores	18.41
Total	$5,171.74

1942

Allied Construction Co.	$14.53
Baumgardner Studio	4.85
Burger-Bowman-Mathews	9.13
Beard, M. W.	57.40
Beckman, H. C.	32.28
Bobbit, Lewis E.	25.60
Boyd, Roy	186.55
Braezeal, D. F.	8.00
Breuer, Marvin	39.15
Brinkley, Wm.	4.80
Brinkley, L.	4.80
Brown, A. L.	16.20
Burberry, R. S.	166.50

FINANCIAL STATEMENT FOR 1941-42—WATER RESOURCES—1942—Continued.

Burrell Brothers	$2.20
Burroughs Adding Machine Co.	56.06
Central Battery & Electric Co.	11.50
Cities Service Co.	2.80
Charles Bruning Co., Inc.	119.85
Continental Oil Co.	7.92
Cyrus, G. R.	12.00
Cyrus, R. R.	3.20
Dake, Mrs. C. L.	48.00
Dixon Co.	17.60
Durst, S. H.	150.32
Eastman Kodak Co.	3.84
E. E. Dessieux Tire Shop	6.00
Esser, H. J.	80.37
Eyberg, Carl J.	42.21
F. Weber Company	3.88
Firestone Tire & Rubber Co.	56.47
Flocks, J. G.	17.00
F. B. Powell Lumber Co.	110.21
Fudge, Mrs. Etta B.	18.00
Gage Observers	280.65
General Electric Company	32.40
Gerhardt, Jos. F.	165.13
G. L. Christopher, Jeweler	4.50
Grant Motor Co.	16.95
Guilford, J. W.	20.25
Haley, Antonio W.	230.13
Hall, Loretta	60.00
Hardine, K. L.	31.78
Harris, Elmo G.	18.00
Hayden, W. E.	3.15
Hely, A. G.	10.90
Herman-Brownlow Co.	1.06
Herrman Lumber Co.	5.10
Homelite Corporation	10.28
Hotchkiss Sales Co.	7.50
Jacobs Auto Top & Body Works	83.55
Janda, B. H.	455.78
Jaques & Lierman	1.53
J. B. Gum Motor Co.	6.01
J. Emmett Mitchell Transfer Co.	7.20
Jennings, C. H.	2,956.28
J. Friez & Sons	1.28
J. J. Fuller, Jeweler	35.45
Joe G. Downs Co.	11.00
John S. Swift, Inc.	24.95
Johnson Motors Co.	104.93
Kamelgarn, Stanley	110.95
Katz, Howard M.	18.00
Kelly, W. M.	8.00

FINANCIAL STATEMENT FOR 1941-42—WATER RESOURCES—
1942—Continued.

Keuffel & Esser Co.	$5.57
Kirn Auto Supply Co.	3.10
Klinefelter Motor Co.	301.55
Krall, John	204.40
Leeson, E. R.	112.50
Leupold Stevens Co.	28.92
Leupold-Volpel Co.	17.23
Liddell, Walter	71.75
Littlefield, W. M.	43.09
Livingston, K. F.	430.56
Lofton, W. V.	10.80
Lofton, W. O.	11.70
Long Bell Lumber Co.	56.54
M. Jess Auto Shops	11.68
McMath, R. P.	104.13
Maxwell's	7.50
Means, Mrs. Z. P.	14.25
Mispagel, F. A.	4.80
Missouri General Utilities	9.12
Montgomery-Ward Co.	.62
Monroe Calculating Machine Co.	17.00
M. O. Martin Hardware	38.80
Morff, B. H.	3.20
Neumer, J. P.	13.20
Phillips Petroleum Co.	148.20
Piasecke, Richard	72.64
Preston, Court	8.00
Roberts, E. O.	4.80
Robert Judson Lumber Co.	64.87
Roemer, E. A.	568.52
Rolla Motor Parts Co.	1.31
Rolla Sheet Metal Co.	8.50
Rolla Truck Lines	6.67
Roofener, Frank	12.40
Rowe, R. L.	3.00
Rucker, J. C.	14.00
Rutter, K. L.	8.00
St. John's O. K. Rubber Welders	29.15
Schwob, H. H.	87.50
Seaman Lumber Co.	6.44
Service Blue Print Co.	11.63
Short, D. H.	473.96
Short, J. A.	377.33
Singleton, F. E.	525.19
Smith Service Station	134.57
Spinner, Leo	229.95
Standard Motor Co.	6.11
Standard Oil Co.	56.60
Star Boat & Motor Co.	13.65
Starks, Bob F., Jr.	9.60

FINANCIAL STATEMENT FOR 1941-42—WATER RESOURCES—
1942—Continued.

Starks R. M.	$12.80
Starks, V. L.	12.80
Stephens, Leo	154.06
Stephens, J. W.	113.79
Stockton, H. R.	232.41
Strain, Buel	15.20
Superior Chevrolet Co.	184.30
Thompson, E. W.	39.06
Todd, F.	6.82
Townley Metal & Hardware Co.	15.71
Trisch, D. L.	564.12
Trotter, C. R.	343.80
United Telephone Co.	35.50
VanAmsburg, L.	77.00
Walker, Richard	119.00
W. B. Young Supply Co.	22.94
Wegener, W. F.	148.61
Western Auto Supply Co.	12.67
Whitehead, Earl	25.00
Whitworth, D. S.	5.20
Wilkinson, M. A.	19.20
Winkels, A. L.	13.42
Wirt Company	6.25
Witte Hardward Co.	4.03
W. P. Cox Hardware Co.	27.57
Total	$12,677.77

FINANCIAL STATEMENT FOR 1941-42—TOPOGRAPHIC MAPPING

1941

Aldrich, E. H.	$125.00
Brewer, W. B.	287.54
Elmore, P. W.	24.50
Emory, A. E.	105.00
Fennell, E. J.	190.16
Galloway, C. T.	165.06
Hill, V. L.	114.85
Jella, E. D.	226.50
Johnson, L. L.	67.30
Kennedy, Daniel	249.42
Kolb, Opal R.	120.00
Leachman, J. B.	509.82
Mitchell, S. E.	937.40
Nelson, I. E.	171.56
O'Hara, S. B.	274.78
Pash, W. F.	250.00

FINANCIAL STATEMENT FOR 1941-42—TOPOGRAPHIC MAPPING—1941—Continued.

Pearcy, C.	$3.50
Roberts, R. G.	159.71
Rydeen, J. P.	103.09
Salley, C. L.	304.03
Shumate, J. A.	195.89
Smith, J. F. W.	220.58
Stites, C. L.	316.83
Stoddard, L. B.	125.00
Tuley, F. L.	652.89
Venable, L. W.	189.00
Wegener, W.	45.50
Williams, L. E.	608.14
Zumwalt, P. L.	328.74
Total	$7,071.79

1942

Adams, Harold	$133.00
Aldrich, E. H.	300.00
Barner, E. F.	488.32
Bethel, K. G.	14.00
Bounds, C. L.	14.00
Bourne, G. M.	31.50
Bradley, E. M.	249.50
Branson, J.	103.35
Brewer, W. B.	35.71
Broaddus, Richard	145.00
Broaddus, W. B.	33.46
Burch, D. C.	306.00
Burch, L. R.	121.50
Davis, Wayne W.	42.50
Durbin, J. C.	25.50
Fennell, E. J.	12.11
Gartman, G. C.	33.00
Gurley, A. N.	137.00
Hart, F. E.	1.00
Hilliard, J. C.	34.75
Holloway, K.	99.00
Hurd, R.	90.00
Jarvis, R. L.	7.50
Jella, E. D.	210.00
Juhre, C. C.	204.20
Kolb, Opal R.	420.00
Leachman, J. B.	557.96
Logan, Wm. F.	127.50
McCallon, J. N.	120.00
McCaw, Chas. W.	249.44

FINANCIAL STATEMENT FOR 1941-42—TOPOGRAPHIC MAPPING—1942—Continued.

Mann, L. S.	$366.64
Metcalfe, W. P.	1,598.08
Milsted, H. S.	164.88
Mitchell, S. E.	669.61
Montgomery, L. R.	31.50
Nelson, L. B.	345.00
O'Hara, S. B.	1,327.00
Pash, Wm. P.	75.00
Perham, G. M.	433.32
Peters, R. E.	540.00
Roberts, R. G.	216.66
Rogers, John	105.50
Rust, E. G.	178.46
Rust, Wm. R.	253.46
Salley, C. L.	18.26
Shelden, W. S.	234.00
Smith, J. F. W.	308.41
Soma, H. A.	166.50
Sooter, E. J.	144.00
Steffens, C. C.	78.78
Steinmetz, L.	135.00
Stites, C. L.	1,391.03
Stoddard, L. B.	585.00
Stone, A.	150.00
Tex, G. N.	674.80
Tuley, F. W.	687.29
Valencia, E.	58.06
Warner, H.	111.00
Weathers, H. C.	364.16
Weber, F. W.	216.66
Wehmeier, R. E.	76.62
Weishapple, C. E.	660.13
Whitaker, R. T.	295.08
Williams, L. E.	1,242.40
Total	$18,249.09

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The Polo Gas Field Caldwell County Missouri

By
FRANK C. GREENE AND HENRY S. MCQUEEN

Appendix I, 62nd Biennial Report

1943

MISSOURI
GEOLOGICAL SURVEY AND WATER RESOURCES

H. A. BUEHLER
DIRECTOR AND STATE GEOLOGIST
ROLLA, MISSOURI

CONTENTS

LIST OF ILLUSTRATIONS.

THE POLO GAS FIELD

Caldwell County, Missouri

By Frank C. Greene and Henry S. McQueen

ABSTRACT.

The Polo Gas Field, located in Caldwell County, was discovered in 1940. Twenty wells have been drilled which have an initial open flow capacity of 33,000,000 cubic feet. Rock pressure is 86 pounds. The field is not served by a pipe line, and the gas is not being used.

INTRODUCTION.

The Polo Gas Field was discovered July 9, 1940, by the Skelly Oil Company's Clarence Arnote No. 1, located in the center of the SW¼ NE¼ SW¼, Sec. 25, T. 55 N., R. 29 W., Caldwell County. The open flow, at first estimated to be about 3,000,000 cubic feet was gauged at 2,190,000 cubic feet when completed at a depth of 414 feet. The first completion was followed by active development in the summer and fall of 1940 and by less active development and some wildcatting in 1941 and 1942. To date 20 wells have been drilled with an initial open flow capacity of 33,000,000 cubic feet. The rock pressure is 86 pounds. No pipe line has been built in to the field and the only use of the gas at present is that by farm owners.

ACKNOWLEDGMENTS.

The writers wish to express their appreciation for the whole-hearted cooperation of the Skelly Oil Company, and especially to Messrs. J. E. Morero, O. M. Evans, E. A. Huffman, and P. E. Cosper, who were in charge of the development for that company; to Mr. H. L. Scott, independent operator; to Robert Wells and Sons, drilling contractors, and to the many residents of the Polo area and to Mr. Chas. C. Hoffman, of the Cities Service Gas Company for data on open flow capacity and rock pressure gauges of the wells taken in June, 1942, and

for chemical analyses of the gas. These gauges were made by a Cities Service Gas Company employee using the same methods usually followed, but the Cities Service Gas Company does not accept responsibility for the accuracy of the figures. In October, 1942, additional gauges were made on several of the wells by P. E. Cosper and F. C. Greene, and the results obtained are used in this report for the Clara Leamer No. 1, C. SW¼ NE¼ Sec. 31, T. 55 N., R. 28 W., and the Thompson No. 1, C SW¼ NW¼ Sec. 3, T. 55 N., R. 28 W.

LOCATION AND AREA.

The Polo Gas Field is situated on the upland area in the southwestern part of T. 55 N., R. 28 W., and the southeastern part of T. 55 N., R. 29 W., Caldwell County, Missouri (Plate V). It is about 50 miles northeast of Kansas City. The center of the field is two miles southwest of the town of Polo. Both the town and the field are on the main lines of the Chicago, Rock Island, and Pacific, and the Chicago, Milwaukee and St. Paul railways. The area is reached by Missouri State Highway 116. The topography is shown on the Polo quadrangle of the U. S. Geological Survey, published in cooperation with the Missouri Geological Survey.

The gently rolling upland has an elevation of around 1,000 feet above sea level and is mostly under cultivation. The rougher areas in the vicinity of the streams are given over to pasturage.

WATER SUPPLY.

Water for house and farm use is obtained from shallow wells in the glacial drift. This source of supply is described in detail under the heading "Pleistocene." As in other wells of this type, the water is sufficient for the use of the owner and the daily maximum capacity is unknown. However, in drilling for gas, it was estimated in one case, C. Arnote No. 1, SW¼ NE¼ SW¼ Sec. 25, T. 55 N., R. 29 W., that the well made 700 eight-inch bailers per day, or about 10,000 gallons. A sample of water from the same horizon; Leamer and Ivy well No. 2, C NE¼ SW¼ Sec. 31, T. 55 N., R. 28 W., collected by means of the bailer was analyzed in the laboratory of the Missouri Geological Survey and the results are presented in Table I.

Water from the Pennsylvanian is too mineralized to be of use for domestic or industrial purposes but may be obtained in larger quantities. A sample of water from the Jane Dixon well No. 1 SW¼ SW¼ Sec. 29, T. 55 N., R. 28 W., was collected by means of the bailer from the sand producing the gas and was analyzed in the laboratory of the Missouri Geological Survey. The results are also given in the following table.

TABLE I

Analyses of water, Polo gas field
Results expressed in parts per million

R. T. ROLUFS, *Analyst*

Constituents	*Sample No. 1*	*Sample No. 2*
Turbidity	Turbid	Turbid
Color	None	None
Odor	ND	ND
Total Suspended Solids	ND	ND
Total Dissolved Solids	489.0	4985.0
Loss on Ignition	124.0	88.0
Chloride Radicle (Cl)	15.1	2568.7
Nitrate Radicle (NO_3)	ND	ND
Sulphate (SO_4)	23.5	18.7
Bi-Carbonate Radicle (HCO_3)	507.3	542.7
Carbonate Radicle (CO_3)	00	18.0
Sodium (Na) Potassium (K) as Na	67.8	1899.3
Magnesium (Mg)	23.7	14.2
Iron (Fe)	ND	ND
Manganese (Mn)	....	....
Silica (SiO_2)	14.4	10.8
Calcium (Ca)	79.9	29.8
Total Hardness	296.9	132.7
Carbonate Hardness	296.9	132.7
Alkalinity	416.0	460.0
Precipitated Iron (Pp't. Fe.)	ND	ND
Temporary Hardness	ND	ND
Al_2O_3 / Fe_2O_3	.40	2.00

Sample No. 1: Water sample glacial drift, Leamer and Ivy well No. 2, C NE¼ SW¼ Sec. 31, T. 55 N., R. 28 W., Sample collected by bailer.

Sample No. 2: Water sample, Polo sand, Dixon well No. 1, SW¼ SW¼, Sec. 29, T. 55 N., R. 28 W., sample collected by bailer.

The nature of water from the Mississippian and older formations is unknown in the Polo area, but analyses from wells in surrounding counties indicate that it is too highly mineralized for industrial use, leaving impounded surface water as the only remaining source of a large supply of fresh water.

STRATIGRAPHY.

The rocks outcropping in the area belong to the Kansas City group of the Pennsylvanian System. They appear at the surface along the stream valleys but under the upland are buried by a few to over 100 feet of glacial clay, sand and gravel.

PLEISTOCENE SERIES.

The glacial material left by the melting of the ice sheet, is unique in that it has some semblance of stratification. At a depth of 50 to 60 feet under the higher uplands is a bed of sand and gravel three to eighteen feet thick. The material above the sand is a whitish clay relatively free from gravel. It weathers to a yellow color. The maximum thickness occurs of course only under the higher land and the thickness is less in the vicinity of the valleys.

The sand and gravel contains an abundant supply of fresh water, estimated in one well to be 700, eight-inch bailers per day (about 10,000 gallons).

Below the sand and gravel is 0 to more than 50 feet of yellow boulder clay, resting on the underlying Pennsylvanian shale and limestones. The base of the sand dips to the west, north and east from the southwest corner of T. 55 N., R. 28 W. If the sand and gravel and the overlying whitish clay are assumed to be lacustrine deposits, there is a possibility that the base of the sand was originally level. If this is the case, there is a probability of post-Pleistocene folding.

PENNSYLVANIAN SYSTEM.

The Pennsylvanian rocks encountered in drilling to the gas sand termed in this report the Polo, the nearby town of that name, are, in descending order, the Kansas City, Pleasanton, and Henrietta. A few dry holes have been drilled into the Cherokee in this general area.

Kansas City Formation.—The Kansas City formation is 190 to 200 feet thick. It consists of alternating shale and limestone. The shales are mainly gray, but include some red clay and black slaty shales. The latter carry a little water or small gas shows in some wells. The principal feature of the Kansas City is the assemblage of limestone in the lower 75 to 85 feet, namely the Winterset, Bethany Falls, Middle Creek, and Hertha limestones, which with the intervening black slaty shales mark the basal portion of the formation.

Pleasanton Formation.—The Pleasanton formation or "Big shale" is 90 to 110 feet thick in the Polo area. At a distance varying from five to fifteen feet below the top of the formation is the Knobtown sand, logged as five to twenty feet in thickness. The Knobtown consists of sandstone, sandy limestone or sandy shale. In many cases the Knobtown carries shows of oil or gas and in the Cowley well in Sec. 24, T. 55 N., R. 28 W., two miles east of the town of Polo, 125,000 cubic feet of gas was reported in this sand.

Near the base of the Pleasanton is the thin and non-persistent Wayside sand. It is not reported at all in some logs and in others it is logged as three to ten feet of lime, limey shale, sandy lime or sand. In some wells it had a small show of oil.

The main part of the Pleasanton between the Knobtown and Wayside is gray shale, locally sandy. A few miles north of the Polo area it contains much sandstone. Between the Wayside sand and the top of the Henrietta is an interval of gray shale and "red bed." The red material is a clay which slacks quickly in contact with water or air and causes trouble by caving. Locally a thin limestone is reported.

Henrietta Formation.—The extreme variability of this formation in the Polo area makes it difficult to draw a generalized picture. No two wells in the area show the same section. Typically the top of the Henrietta is marked by the Altamont member consisting of two relatively thin beds of limestone with an intervening shale. In the Polo area it is the practice to set casing on the top of the Altamont, thus shutting off the caving material mentioned above. In producing wells both limestones may be present or "sandy lime" or sand may be encountered a few feet below the top of the Altamont and continue for the next ten to thirty-five feet. In other wells both limestones may be thin or absent. In the dry holes the sand is usually absent, replaced by sandy shale or a variety of other material including thin limestones and red clay.

The lithology of the Polo sand is variable. It changes from an almost pure sand, to limey sand, shaley sand or shale. When the sand is pure it may be friable and porous although rarely is it very hard and almost a quartzite. In some instances the sand is tightly cemented by lime and may be slightly shaley, or it may be a shaley sand or sandy shale. The sand grains beneath the microscope would be classed as fine to medium and are subangular. To the naked eye the sand appears as very fine grained. The grain size is fairly uniform or well sorted. The average thickness of the sand body is fifteen feet. The color of the sand is gray to white when not stained by oil.

The shape of the Polo sand body is shown in Plate I. Due allowance should be made for the fact that it is based on present available information and that wells drilled in the future outside the edge of the sand body as shown by the map may change the present representation. Also the thickness of sand or the calcareous sand or the sandy shale or the shale into which it grades laterally may be subject to a different interpretation than that shown. It should also be noted that in several wells the base of the sand was not drilled, as indicated by the + sign and therefore the total thickness is not known Several structurally high holes were dry due to the shaley and limey condition of the sand and therefore the lack of porosity. They were as follows:

Name of Well	*No.*	*Location*
Jane Dixon	1	C SW SW 29-55-28
Zimmerman	1	C SW NE 30-55-28
Hickman Estate	1	C SW NW 30-55-28
Minger	1	NE cor. SW NW 32-55-28
Stonum	1	C NE NE 25-55-29
Van Olinda	1	C NE SE 26-55-29
Fowler	1	C SE SW 36-55-29

In addition, it is probable that other holes in the marginal zone would have shown some shale present in the sand if perfect conditions were available for observation.

The bottom of the Polo gas sand zone is marked by the limestones over the Lexington coal horizon. These are usually two limestones each about five feet thick and separated by five feet of shale. In some cases the shale is absent. These limestones are believed to represent both the upper and lower members of the Pawnee member.

The remainder of the Henrietta below the Lexington coal horizon is twenty-five to thirty-five feet thick. The Houx limestone and the underlying Summit coal horizon have been found in the few holes drilled entirely through the Henrietta in the Polo area. The Blackjack Creek limestone (lower Fort Scott) which marks the base of the Henrietta, has been found in the Virginia Baker No. 1, SW cor. NW¼ Sec. 30, T. 55 N., R. 27 W.

Cherokee Formation.—So few wells have been drilled into the Cherokee in the Polo area that little can be said of it. In the few wells drilled the Squirrel sand zone at the top of the Cherokee is represented by sandy shale and a few thin sandstones. However, it changes rapidly in other parts of the State and may reasonably contain more sandstone in nearby locations. The following holes in the Polo gas field have been drilled into the Cherokee: Leuhring et al, Linville No. 1, Cen. north line SE ¼ SE¼ Sec. 32, T. 55 N., R. 28 W., total depth 817 feet, or about 300 feet into the Cherokee; Skelly Oil Company's Petty No. 1, Cen. NE¼ NE¼ Sec. 35, T. 55 N., R. 29 W., total depth 695 feet, or about 200 feet into the Cherokee; and Hutchings and Lilley's Fowler No. 1, Cen. SE¼ SW¼ Sec. 36, T. 55 N., R. 29 W., total depth 455 feet, about 50 feet into the Cherokee.

The base of the Cherokee is estimated to be around 850 to 900 feet deep in the Polo area and it probably will be found to contain much sandstone in the lower 200 to 300 feet.

Plate IV shows a cross section, of the Polo gas field, showing the formation from the surface to the Polo gas sand.

TABLE II.

Showing Wells and Dry Holes in Polo Gas Field.

Operator	*Farm*	*No.*	*Location*	*Base of Hertha Elevation*	*Total Depth*	*Bottomed in*	*Remarks*
			T. 54 N., R. 28 W., RAY COUNTY				
Robt. Wells & Sons	Linville	1	NW Cor. 4	765	655	Cherokee	Dry
....	Jackson	1	SE SW SE 6	....	500+	....	Water well
R. Wells & Sons	Hoover	1	C SW NW 9	758	459	Henrietta	Dry
			T. 55 N., R. 27 W., CALDWELL COUNTY				
R. Wells & Sons	Baker	1	SW Cor. NW¼ 30	784	767	Cherokee	Dry
			T. 55 N., R. 28 W., CALDWELL COUNTY				
Zach Wheat	Fee	1	SW NW SW SW 10	786	315	Pleasanton	Water well
R. Wells & Sons	Stone Est.	1	SE NW SE SW 24	803	389	Henrietta	Dry
Gottschall	Cowley	1	NE SW SW 24	809 est.	240	Pleasanton	125,000 cu. ft. est.
R. Wells & Sons	Withers	1	C WL SW SE 28	781	420	Henrietta	Dry
Skelly Oil Co.	J. Dixon	1	C SW SW 29	766	405	Henrietta	Dry
H. L. Scott	Zimmerman	1	C SW NE 30	769	387	Henrietta	Dry
H. L. Scott	Hickman Est.	1	C SW NW 30	786	405	Henrietta	94,080 cu. ft.
H. L. Scott	O. Arnote	1	C SW SW 30	792	407	Henrietta	Dry
Skelly Oil Co.	J. Dixon	2	C SW SE 30	783	399	Henrietta	Dry
Skelly Oil Co.	J. Dixon "C"	1	C NW NE 31	786	416	Henrietta	162,000 cu. ft.
Skelly Oil Co.	Thompson	1	C SW NW 31	786	412	Henrietta	11,500,000 cu. ft.
Skelly Oil Co.	Leamer	1	C SW NE 31	799	384	Henrietta	9,000,000 cu. ft.
Skelly Oil Co.	Leamer	2	C NE NE SW 31	778	412	Henrietta	1,120,000 cu. ft
Skelly Oil Co.	Leamer	3	NW SW SE 31	768	440	Henrietta	Dry
Leuhring et al.	Linville	1	C NL SE SE 32	780+	817	Cherokee	Dry
Skelly Oil Co.	Minger	1	NE SW NW 32	765	370	Henrietta	Dry

Skelly Oil Co.	P. A. Fowler	1	C SE NE 32	784	406	Henrietta	439,000 cu. ft.
Skelly Oil Co.	Mayes	1	C NW SW 33	777	415½	Henrietta	162,000 cu. ft.
Skelly Oil Co.	McCollough	1	C SW NW 33	788	404	Henrietta	Now dead a/c oil
Skelly Oil Co.	J. L. Leamer	1	SE NW NW SE 33	783	387	Henrietta	Dry
Fred Jones	Fee	1	NW NW SW 34	794±	330	Henrietta	Water well
Mike Fowler	Fee	1	SE C SW SE 29	782	394	Henrietta	Small amount of gas and water

T. 55 N., R. 29 W., CALDWELL COUNTY

Newcomer & McQueen	Pollard	1	NE NE SW 13	768	264	Pleasanton	Dry
H. L. Scott	Gruendel	1	SE NE SW 24	772	350	Henrietta	Dry
H. L. Scott	Smith	1	C SE SE 24	792	400	Henrietta	Small gas well
H. L. Scott	Smith	2	C NE SE 24	766	375	Henrietta	Dry
Skelly Oil Co.	C. Arnote	1	SW NE SW 25	774	414	Henrietta	2,190,000 cu. ft.
H. L. Scott	Stonum	1	C NE NE 25	776	394	Henrietta	Small gas well
Skelly Oil Co.	Mount	1	C WL NE NW 25	786	375	Henrietta	517,000 cu. ft.
Skelly Oil Co.	J. Dixon "A"	1	C SW NE 25	791	391	Henrietta	584,000 cu. ft.
Skelly Oil Co.	J. Dixon "B"	1	SW NE SE 25	790	422½	Henrietta	139,000 cu. ft.
Skelly Oil Co.	Van Olinda	1	C EL SW SW 25	797	385	Henrietta	1,940,000 cu. ft.
Skelly Oil Co.	Van Olinda	1	C NE SE 26	808	465½	Cherokee	Small well sold to owner
Skelly Oil Co.	Petty	1	C NE NE 35	781	695	Cherokee	Dry
Skelly Oil Co.	C. Arnote	2	SW NE NW 36	779	413	Henrietta	2,190,000 cu. ft.
Skelly Oil Co.	Petty	2	C EL SW NW 36	790	404	Henrietta	486,000 cu. ft.
Skelly Oil Co.	F. G. Arnote	1	C NW NE 36	775	413	Henrietta	2,060,000 cu. ft.
Skelly Oil Co.	W. A. Arnote	1	C SE NE 36	751	425	Henrietta	584,000 cu. ft.
Skelly Oil Co.	W. A. Arnote	2	C E½ SE 36	741	430	Henrietta	Dry
Hutchings & Lilley	Fowler	1	C SE SW 36	802	455	Cherokee	Dry

WELL LOGS.

The following logs are considered to be representative for the Polo gas field:

Log of Skelly Oil Company's C. J. Arnote No. 1. Location: SW cor. NE¼ SW¼, Sec. 25, T. 55 N., R. 29 W., Caldwell County, Missouri. Completed July 10, 1940. Elevation 1021.6 feet. (Discovery well.)

	Thickness, feet	*Depth, feet*
Pleistocene Series:		
Soil	3	3
Yellow clay	17	20
Dry sand	3	23
Sandy clay	27	50
Water sand	15	65
700 bailers water in 24 hours		
Blue clay	13	78
Pennsylvanian System:		
Kansas City Group—		
Hard lime	7	85
Dark slate or shale	12	97
Hard lime	11	108
Red shale and white lime	10	118
Lime, hard	4	122
Grey shale	1	123
Dark shale	22	145
Hard lime	5	150
Grey shale	1	151
Lime	9	160
Dark shale	10	170
Lime and shale	3	173
Lime (Winterset)	35	208
Black shale	4	212
Lime, hard (Bethany Falls)	20	232
Black sandy shale (small amount of water, 40 feet overnight)	3	235
Lime (Hertha) (last 2 feet sandy and showing of heavy dark oil)	13	248
Pleasanton Group—		
Sticky grey shale	7	255
Sandy lime (gas 100,000 cu. ft.)	3	258
Sandy lime hard (black heavy oil in bottom)	12	270
Sandy shale grey	80	350
Sandy shale grey (show dark heavy oil)	5	355
Grey shale	5	360
Red and grey shale	15	365
Grey shale	10	375
Shale and lime	5	380
Red shale	5	385
Henrietta Group—		
Sandy lime (gas at 400)	15	400
Sand	13	413
Lime	1	414 T.D.

Casing record: 8″ — 70′; 6″ — 154′6″; 4-7/8″ — 379′

Log of Robert Wells & Sons', Virginia Baker No. 1. Location: SW Cor. NW¼ Sec. 30, T. 55 N., R. 27 W., Caldwell County, Mo. Completed: February 18, 1941. Elevation, 976.7 feet.

	Thickness, feet	*Depth, feet*
Pleistocene Series:		
Top soil	3	3
Clay, yellow	7	10
Sandy clay	10	20
Yellow sand (water)	10	30
Clay	15	45
Clay, blue	54	99
Pennsylvanian System:		
Kansas City Group—		
Lime	11	110
Shale, grey	13	123
Lime (Winterset)	30	153
Shale	4	157
Lime (Bethany Falls)	18	175
Slate and shale (water)	5	180
Lime (Hertha)	13	193
Pleasanton Group—		
Shale, grey	10	203
Lime	4	207
Shale, sandy	9	216
Shale, grey	66	282
Sand rock	4	286
Sandy shale white	7	293
Shale, dark	2	295
Shale, red and grey	5	300
Lime	5	305
Shale, sandy grey	18	323
Henrietta Group—		
Lime	3	326
Shale, grey	1	327
Shale, red	8	335
Shale, sandy grey and lime	15	350
Shale, red	4	354
Shale, grey	9	363
Lime	12	375
Shale and clay, dark	2	377
Coal (Lexington)	1	378
Shale	2	380
Lime	2	382
Shale, light	20	402
Lime, sandy	5	407
Shale, grey	2	409
Lime	2	411
Slate and shale	4	415
Lime and shale	5	420
Broken lime, brown	18	438
Lime	2	440

Log of Robert Wells & Sons' Virginia Baker No. 1—Continued.

	Thickness, feet	Depth, feet
Cherokee Group—		
Sandy shale, light—sand rock	30	470
Sandy shale, dark	6	476
Lime	2	478
Broken lime, dark	7	485
Shale, dark	15	500
Shale, white	16	516
Lime, dark	2	518
Slate, black	2	520
Sandy shale, grey	10	530
Sand rock (water)	10	540
Shale, grey	5	545
Shale, black	8	553
Shale, grey	10	563
Shale, black	15	578
Shale, light	22	600
Shale, dark	10	610
Shale, sandy, white	10	620
Shale, dark	10	630
Shale, black	15	645
Shale, sandy, white	10	655
Shale, black	50	705
Shale, sandy, grey	45	750
Sand rock, grey	5	755
Sand, white, salty water rose 200′ in short time	12	767 T.D.

Casing record: 8″ — 99′; 4-7/8″ — 416′

STRUCTURE.

Caldwell County, including the Polo area, lies on the southeastern margin of the Forest City basin and in an area where the prevailing northwest dip is low, averaging around three feet per mile. Locally, however, the beds may dip as much as 50 feet in one-half mile.

Two maps showing the structure of the Polo area are included in this report. Plate II is contoured on the base of the Kansas City (base of the Hertha limestone member) formation and Plate III is an approximation of the structure of the top of the Polo gas sand. An east-west cross section also shows the structure of the pool. (Plate IV). As will be explained later, the former is considered the more reliable picture of the structure of the Polo area.

The structural trend as developed by drilling is northwest-southeast. The effect of the regional dip is entirely absent in the area shown on Plate II. It will be noted that the base of the Hertha has an altitude of 784 feet in the SW cor. NW¼ Sec.

30, T. 55 N., R. 27 W., although it is 808 feet in a well 7 miles west in the Cen. NE¼ SE¼ Sec. 26, T. 55 N., R. 29 W.

The main structural highs indicated in Plates II and III are: (1) In the vicinity of the Cowley well in the SW¼ SW¼ Sec. 24, T. 55 N., R. 28 W.; (2) In Secs. 33 and 34, T. 55 N., R. 28 W.; (3) The northern part of Sec. 31, T. 55 N., R. 28 W., and extending northwest in Sec. 25, T. 55 N., R. 29 W.; (4) the southwest part of Sec. 19, T. 55 N., R. 28 W., and (5), in the western part of the Sec. 36, T. 55 N., R. 29 W., and extending northwest into the southwest of Sec. 25, T. 55 N., R. 29 W., and the southeast of Sec. 26, T. 55 N., R. 29 W.

The structure of the top of the Polo sand, shown on Plate III follows that indicated by the base of the Hertha limestone in a general way, but is considered much less reliable due to the difficulty of determining the top of the sand, even in cases where drill cuttings were saved and examined. There appears to be a lateral gradation of the sandstone into sandy shale, and the exact point to be used in computing the datum figure is uncertain in some wells.

ACCUMULATION OF GAS.

A glance at the structure maps, Plates II and III will reveal the wide discrepancy in the relation of the gas wells to their structural position. Some structurally high holes are dry and some producing wells are structurally low. The elevation of the top of the sand in producing wells ranges from 623 feet to 658 feet above sea level. All holes which have been drilled up to the time of preparing this report, which have topped the sand below an altitude of 623 feet have been dry and all dry holes to date which have topped the sand (or its horizon) between 623 and 658 feet above sea level have encountered broken or shaly sand or no sand at all. It thus appears that to obtain gas production a well must be drilled at a location where the sand top will be at least 623 feet above sea level and where a body of porous sand, free from shale exists.

As mentioned in the discussion of the stratigraphy, the Knobtown sand, lying a few feet below the base of the Hertha limestone has had shows of both oil and gas and in the Cowley well in the SW¼ SW¼ Sec. 24, T. 55 N., R. 28 W., is reported to have had about 125,000 cubic feet of gas.

The total reserve of gas in the Polo sand in the Polo field is estimated to be 1,028,310,000 cubic feet. In presenting this estimate it should be mentioned that four of the factors used in the computation are estimated and therefore subject to error. The estimated factors are:

Area of producing sand ....1,080 acres
Average thickness of producing sand .....15 feet
Average porosity of producing sand ......20 per cent
Gas recovery ....50 per cent

In the consideration of the porosity of the Polo sand, the results of analyses of cores from the Polo sand from several test core holes drilled by Skelly Oil Company in the Polo field will be of interest. These results were made available through the courtesy of Mr. Joseph Morero, Chief Geologist of the company.

In this connection it should be noted that in several test core holes oil saturated cores were recovered, and oil stains have been noted also in the cuttings of the Polo sand in several wells drilled with cable tools. No production of oil has been obtained, however, from any of the wells, due probably to the fact that the oil is 'heavy" and viscous. In the results of the core analyses, above mentioned, information of interest is given on the character of the oil. The results of the core analyses will be found in the following tables:

CORE ANALYSIS, POLO SAND.

Skelly Oil Company. Core Hole C-608.
Center north line NW ¼ Sec. 25, T. 55 N., R. 29 W.
Analyzed by Ginter Chemical Laboratory, 118 West Cameron Street, Tulsa, Oklahoma.

Sample No.	*Permeability millidarcys*	*Porosity per cent*	*Water Sat.* per cent*	*Oil Sat. per cent*	*Reserves** Bbl/Acre/Ft.*
3A—Can No. 1..	179	25.8	61.0	6.7	135
6A—Can No. 1..	82	24.9	61.0	9.8	190
10A—Can No. 1..	30	21.9	67.0	15.3	260
11A—Can No. 1..	38	23.7	63.0	12.2	225
13A—Can No. 1..	68	24.0	55.0	11.2	210
2B—Can No. 2..	329	22.4	50.5	31.0	540
4B—Can No. 2..	13	16.1	62.0	28.4	355
6B—Can No. 2..	8	15.0	64.0	36.0	415
8B—Can No. 2..	13	18.1	53.5	32.4	455
11B—Can No. 3..	82	24.7	47.0	34.0	650
14B—Can No. 3..	184	25.8	42.5	34.2	685
17B—Can No. 3..	94	23.5	45.5	31.2	570
19B—Can No. 3..	51	22.4	43.0	34.6	600
2C—Can No. 4..	37	20.6	52.5	30.2	485
6C—Can No. 4..	98	22.6	41.0	27.2	475
8C—Can No. 4..	162	25.8	41.0	34.2	685
11C—Can No. 4..	276	27.5	34.2	27.2	580

Average porosity = 22.6

Core, sand, with brown stain...................330-339 feet.
Core, sand, oil saturation.......................339-356 feet.

*30-50 per cent of this is drilling water.

**Of oil in place.

The following remarks by R. L. Ginter accompanied the above analysis:

"The crude isolated from this sand is 'heavy' and viscous and a commercial well is doubtful because of the lack of gas energy. On the basis of a viscosity of 10 centipoises and an average permeability of 100 millidarcys and a pressure in favor of flow of 15 pounds, a production per 10 feet of pay of 1 to 2 barrels could be expected per day."

Gravity of oil by pycnometer, 23° API
Viscosity tests using a small pipette:
Oil time at 85° F, 365 seconds
Water time at 85° F, 4 seconds
Soybolt time at 85° F (estimated) 2700 seconds
Absolute Viscosity (estimated) 540 centipoises

CORE ANALYSIS, POLO SAND.

Skelly Oil Company. Core Hole C-604.
NE¼ NW¼ SE¼ Sec. 18, T. 55 N., R. 28 W.

Analyzed by Core Laboratories, Inc., Dallas, Texas September, 19, 1939.

No.	*Depth*	*Permeability millidarcys*	*Porosity per cent*	*Residual saturation per cent pore space*	
				Oil	*Water*
A..................	..	2.5	14.1	17.0	21.3
B..................	..	1.7	18.6	21.5	25.3
C..................	..	.5	9.4	37.2	17.0
D..................	..	.4	10.2	45.1	0.0
E..................	..	1.3	14.6	22.6	21.9

Average porosity = 13.4

Core A 352′11″—353′3″
B 353′10″—354′2½″
C 355′11¼″—356′3½″
D 356′10″—357′1″
E 357′8″—358′0″

CORE ANALYSIS, POLO SAND.

Skelly Oil Company, Core Hole C-605.
SW¼ SE¼ SE¼ Sec. 30, T. 55 N., R. 28 W.

Analyzed by Core Laboratories, Inc., Dallas, Texas, September 22, 1939.

No.	*Depth*	*Permeability millidarcys*	*Porosity per cent*	*Residual saturation per cent pore space*		*Gravity*
				Oil	*Water*	
1a.......	..	170	23.8	8.8	24.4	....
4a.......	..	160	19.4	14.4	26.3	....
1b.......	..	90	21.5	27.9	32.1	....
4b.......	..	180	23.5	19.6	36.2	....
7b.......	..	54	24.1	21.9	35.2	27 API
2c.......	..	391	21.0	30.0	37.6	....
5c.......	..	91	18.1	49.2	35.3	26 API
8c.......	..	13	17.5	18.3	45.7	....

Average porosity = 20.1

Feet
Core A 380-83—6 sections
B 383-87—8 sections
C 387-91—9 sections

COMPOSITION OF THE GAS.

35144—State Geologist—227—10 on 13—8 on 10—Stivers......

The composition of the gas is shown by the following chemical analyses, made by The Cities Service Gas Company:

Analysis gas, Petty well No. 2
SW¼ SW¼ Sec. 36, T. 55 N., R. 29 W.

Constituent	*Percent*
Oxygen	0.0
Carbon Dioxide	0.25
Ethane	0.0
Methane	93.5
Residue	6.25
Total	100.00

Heating value, British Thermal Units, (B.T.U.) per cubic foot at 60° F—30 inches mercury, gross 940, net 845, at 8 oz.—60° F., gross 951, net 855

Analysis gas, W. A. Arnote well No. 1
SE¼ NE¼ Sec. 36, T. 55 N., R. 29 W.

Constituent	*Percent*
Oxygen	0.0
Carbon Dioxide	0.4
Ethane	0.0
Methane	93.4
Residue	6.2
Total	100.0

Heating value, British Thermal Units (B.T.U.), per cubic foot at 60°F—30 in. mercury, gross 939, net 844, at 8 oz.,—60° F., gross 950, net 854.

FUTURE OF THE AREA.

The discovery of gas near Polo indicates that other pools are likely to be found in the adjacent region, both in the Knobtown and Polo sands. The Cherokee formation also offers possibilities where the sand bodies in it are well developed. It will be necessary to detail the structure of surface outcrops and probably to supplement such geological work by shallow test holes in areas where surface outcrops indicate structural highs but fail to furnish complete information due to the glacial covering in interstream areas. After a structural high has been found, several holes should be drilled in the event the first one is dry.

As to the deeper possibilities in the Polo field or others subsequently discovered, the Squirrel, "Bartlesville", and McLouth sands have known production in nearby areas in Missouri or Kansas. Several oil and gas producing horizons also exist in the older formations below the Pennsylvanian.

Practically no information is available regarding the pre-Pennsylvanian formations due to the lack of deep drilling in the immediate area of the Polo gas field. Also the deep wells of record drilled in this general area, as mentioned in a previous section of this report, do not appear to have been favorably situated with respect to geologic structure. The nearest pre-Pennsylvanian production to the Polo field is in the McLouth pool, Ts. 9 and 10 S., R. 20 E., Jefferson and Leavenworth Counties, Kansas, where black heavy oil of low gravity is obtained from the upper portion of the Mississippian limestone section. This pool is approximately 60 miles southwest of the Polo pool.

Oil is found in dolomitic limestone and dolomite of Devonian age in pools in southeastern Nebraska, the nearest pool, being the one at Falls City, Richardson County (T. 1 N., R. 15 E.) some 90 miles northwest of the Polo gas field. Ordovician production has been found also in the Dawson pool (T. 1 N., R. 14 E.) southeastern Nebraska, some 100 miles northwest of the Polo fields. It should be remembered that the Devonian and Ordovician formations are comparatively thin in the Polo area, and the producing portions of each in southeastern Nebraska may be absent.

The following brief descriptions of the pre-Pennsylvanian formations may be of interest in connection with future deep drilling.

Mississippian System: The Mississippian formations consist chiefly of limestone, which varies from hard, dense and sandy, to crystalline and fossiliferous. Shale is locally present in the upper one-third of the section, and chert is abundant, particularly so in the middle portion. At the base of the Mississippian, the Kinderhook gray shale is found. This shale will probably be thin at Polo.

No information is available regarding the thickness of the Mississippian at Polo. If the full section is present, with the Ste. Genevieve formation at the top, the total thickness will be approximately 350 to 400 feet. It may be much less than that figure and will decrease on top of regional anticlinal features and on small structures superimposed upon them. Mississippian thickness in the closest wells to the Polo field are given in Table III. There is no production from the Mississippian in western Missouri. The nearest production is at McLouth, Kansas located some 60 miles southwest of Polo.

Devonian System: The Devonian rocks in this part of Missouri consist chiefly of limestone, with minor amounts of dolomite. Some shale is present, in fact the basal portion of the Kinderhook shale may in some localities be of Devonian age. The limestone varies from hard to medium hard, fine-grained to finely crystalline, or in some instances it may be very dense or lithographic. Production is obtained from dolomite of Devonian age in southeastern Nebraska but the horizon from which it is obtained may be absent in the Polo area. The thickness of the Devonian rocks in the Polo gas field is estimated to be 200 to 250 feet. The thickness drilled in deep wells in this general area is set forth in Table III.

Ordovician System: The Ordovician formations to be expected in the Polo area are, in descending order, the Kimmswick and Decorah limestones and St. Peter sandstone. The Maquoketa shale which is the uppermost formation of the Ordovician northwest of Polo is here absent. The total thickness of the Ordovician rocks lying above the St. Peter sandstone is believed to be 175 to 200 feet. The St. Peter sandstone will vary from 75 to 100 feet. In this area the Kimmswick formation will probably consist of three divisions. The uppermost one will be composed of white to gray, finely crystalline dolomite with small amounts of chert. The middle portion will consist almost wholly of blue to gray chert and the lower portion will consist of brown dolomite. The total thickness of the Kimmswick should be at least 150 feet.

The Decorah formation will have a thickness of about 25 feet. It will consist of dolomite or limestone with small amounts of shale.

The St. Peter sandstone underlies the Decorah. In the Polo area it will have a thickness of 75 to 100 feet and will consist of medium sized, rounded and frosted grains of sand. No shows of oil have been noted in this sand in wells drilled in this area to date.

Figures relating to the thickness of the St. Peter sand in wells in this area are given in Table III.

Beneath the St. Peter sandstone, a series of cherty dolomite with subordinate amounts of sandstone will occur. To this section the term "Arbuckle" is applied in the northern Mid-Continent Region. The total thickness is unknown for this area. However, the interval of the Arbuckle, including 120 feet of LaMotte sand was found to be 1125 feet in the Martin and Reiser No. 1 Perrin, Sec. 17, T. 50 N., R. 30 W., Jackson County. No oil and gas shows have been reported in the "Arbuckle" in western Missouri.

In any testing of the pre-Pennsylvanian formations in the Polo gas field it would be advisable to locate the well at the highest point on the structure. In some localities in northwest Missouri, the structure on the upper beds does not carry down into the pre-Pennsylvanian formations, however, and this should be kept in mind. The presence or absence of structure in the deeper beds may be reflected by the formation at the top of the "Mississippi" lime, except possibly in certain localities where the Mississippian surface has been greatly eroded into a series of hills and valleys. Samples of cuttings will be helpful in making the proper determination in either case, and should be carefully saved for examination by a geologist.

TABLE III

Showing thickness of pre-Pennsylvanian formations in nearest deep wells to Polo gas field.

Owner	*Farm*	*County*	*Location*	*Thickness Mississippian Limestone*	*Thickness Kinderhook Shale*	*Thickness Devonian*	*Thickness Ordovician Dolomite Interval*	*Thickness St. Peter Sand*
Baldwin Ranch	1 Fee	Ray	25–52–26	233?	0?	187	40	40*
City Excelsior Springs	1 Fee	Clay	1–52–30	390	5	195	121	30
Hopper	1 Black	Clay	36–52–32	382	16	122	75	85
Campbell, et al.	1 Rust	Ray	21–53–26	280	5	205	158	86
Eastern Drilling Company	1 Williams	Clay	28–53–32	346	25	220	105	109
Murray, et al.	1 Davis	Caldwell	4–55–26	213	30	?	?	73
King, et al.	1 Vandereau	Clinton	18–55–31	337	47	269	87	**
King, et al.	1 Willis	Clinton	13–55–31	343	71	246	117	74
Breckenridge Oil Co.	1 Glick	Caldwell	10–57–26	345	20	257	187	81
Moore, et al.	1 McQuate	DeKalb	26–57–31	289	31	120*	**	**

*Full thickness not drilled.
**Not reached by drill.

6

Occurrence of Dolomite

In the

Fredericktown Area

Madison County, Missouri

By

H. S. McQueen

Appendix II, 62nd Biennial Report

1943

MISSOURI

Geological Survey and Water Resources

H. A. BUEHLER

Director and State Geologist

ROLLA, MISSOURI

CONTENTS

ILLUSTRATIONS

OCCURRENCE OF DOLOMITE IN THE FREDERICKTOWN AREA, MADISON COUNTY, MISSOURI

By H. S. McQueen

ABSTRACT.

The Bonneterre dolomite in the Fredericktown area, Madison County, can be divided into four zones on lithologic character. Zone No. 3 up from the bottom of the formation consists of 150 feet of white to gray, very pure dolomite that is suitable for use in the manufacture of the metal, magnesium.

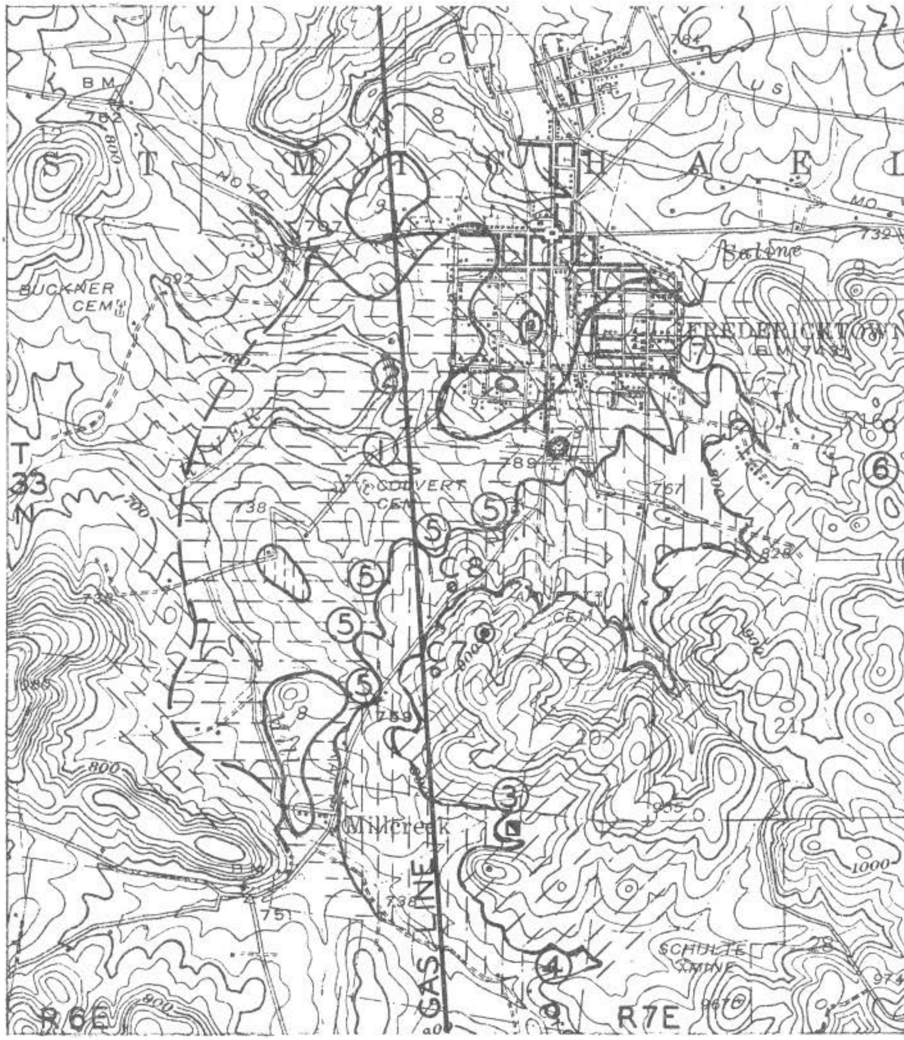
INTRODUCTION.

The Fredericktown area, Madison County, is situated in the extreme eastern portion of the St. Francois Mountains of southeastern Missouri. The area is underlain by igneous rocks of pre-Cambrian age and sedimentary rocks, sandstone and dolomite of Cambrian age.

In the Fredericktown area metalliferous ore bodies occur in the rocks mentioned, and as a result the area is one that has been and is being continually prospected. In this connection many diamond and churn drill holes have been completed, and a few shafts have been sunk. The Missouri Geological Survey makes it a practice to obtain cuttings and cores from all wells drilled in the state, and representative samples from the Fredericktown area were obtained through the courtesy of the operators and particularly the St. Louis Smelting and Refining Division of the National Lead Company.

A study of these samples indicated certain zones of dolomite in the Cambrian, Bonneterre formation, which upon digestion in dilute hydrochloric acid gave a comparatively small insoluble residue. In the spring of 1942 the Survey was requested to furnish information on occurrences of high-grade dolomite and with the information thus obtained, attention was directed toward the Fredericktown area. Field work was undertaken on March 20, 23, 26 and 27, 1942, and the results are the basis for the present report.

MISSOURI GEOLOGICAL SURVEY. BIENNIAL REPORT 1941-1942 APPENDIX II, PLATE I.



RECONNAISSANCE GEOLOGIC MAP OF FREDERICKTOWN AREA

LEGEND

- Recent Residuum
- Bonneterre Formation
  - Zones 1 and 2
  - Zone 3
  - Zone 4
- ⑨ Pre-Cambrian Igneous
- ①②⑤ Sample Localities
- Shaft
- o Drill Hole
- oC7-C8 City Water Wells
- ⊙ City Water Reservoir

Contour Interval 20 feet.

Scale

0 1 2 Miles

LOCATION AND FACILITIES OF THE AREA.

The dolomite to be described lies in the immediate area of Fredericktown, the county seat of Madison County (Plate I). The area is covered by the topographic map of the Fredericktown quadrangle. The city has a population of 3,414. It is located on Bismark-Charleston branch of the Missouri Pacific Lines, and on Federal Highways Numbers 61 and 67, and State Highway No. 70. The city is located also on the 22-inch main gas line of the Mississippi River Fuel Corporation which runs from Monroe, Louisiana to St. Louis, Missouri. Electric power is available from transmission lines of the Union Electric Company.

The city of Fredericktown obtains its water supply from wells drilled into the LaMotte sandstone of Upper Cambrian age. The wells recently completed lie south of the city a short distance and yield an average of 75 gallons per minute. Larger supplies of water would be available from the nearby Little St. Francois River, (Pl. I). Skilled labor is available in the area. At the present time the Fredericktown Lead Company is operating the Catherine and Fleming mines, the ore mined being galena. A shaft is also being sunk by the National Lead Company, southeast of the city in order to develop lead, copper, cobalt-nickle sulphide ore bodies found locally at or near the contact of the pre-Cambrian igneous rocks, the LaMotte sandstone or the lower beds of the Bonneterre formation. A shaft is also being sunk at the present time by the Park-City Consolidated Mining Company on the Ruth tract south of Fredericktown.

GEOLOGY.

A columnar section, showing the sequence of formations in the Fredericktown area is given on Plate II.

Pre-Cambrian Rocks.—These rocks range from red and gray granite to fine-grained felsite porphyry and to dark green basic dike rock. The pre-Cambrian rocks most often occur in the hills and ridges of higher elevation and bolder outline. In many instances these hills are barren or sparsely timbered. The location of some of the smaller masses of pre-Cambrian igneous rock in the dolomite area being considered is shown on Plate I.

Cambrian System.—The only rocks of Cambrian age known to this locality belong to the Upper Cambrian, and consist of the LaMotte sandstone at the base and the overlying Bonneterre dolomite.

LaMotte Sandstone.—The LaMotte consists of fine to medium to coarse grains of quartz sand. Occasionally the grains are very coarse particularly at or near the contact with pre-Cambrian rocks. The sandstone varies considerably in thickness. Near the pre-Cambrian masses it may be entirely absent and overlapped by the overlying Bonneterre dolomite, or it may attain a thickness of a few feet. An excellent example of the overlap of the LaMotte sandstone by the Bonneterre dolomite and the contact of the latter with pre-Cambrian rocks may be observed on Little St. Francois River, in the NW¼ SE¼ Sec. 6, T. 33 N., R. 7 E., slightly less than two miles northwest of the court house at Fredericktown.

The entire thickness of the LaMotte sandstone is seldom drilled in prospecting for ore. The Fredericktown city wells, however, are now completed through this sandstone. The thickness in well No. 6, C SE¼ SW¼ Sec. 8, T. 33 N., R. 7 E., was 155 feet; in well No. 7, SE¼ SW¼ NW¼ Sec. 20, T. 33 N.,. R. 7 E., the thickness was 140 feet, and in well No. 8, NE¼ SW¼ NW¼ Sec. 20, T. 33 N., R. 7 E., the thickness was 151 feet.

Bonneterre Formation.—This formation consists almost wholly of dolomite, one zone of which (Number 3) is the subject of this report. Locally green and brown shale occur and sand is common to the basal portion. The formation has a maximum thickness of 400 feet and consists of four lithologic units in the vicinity of Fredericktown. In ascending order they may be described as follows:

Zone 1.—This zone lies at the base of the formation and is a dark gray, fine-grained, silty or argillaceous dolomite. In thickness it varies from 0 to 35 feet. Sand is very common, particularly in the lower beds. This member appears to weather to a red, sandy, "mealy" soil. It is known to the drillers of the area as the "lower gray." Most of the metalliferous deposits occur in this zone.

Zone 2: The succeeding member is also a fine-grained, slightly argillaceous dolomite. It is compact and fairly hard. This member is best characterized by a very dark brown or black color. Among the drillers it is known as the "lower brown."

Zone 3: This zone, with a maximum thickness of 150 feet, is the subject of this report. It is a light colored, white or gray, dolomite, finely crystalline, compact, and hard. In surface outcrop it appears to be massive bedded. The weathered surface is dark, dirty gray and small vugs and pits, formed by the dissolving action of ground water are common.

Green clay occurs in small amounts as irregular masses filling vugs, or openings in the dolomite. It appears to be common to the top of the formation, but may occur in other portions also. There is a suggestion that the green clay is secondary in origin. An analysis of the green clay is as follows:

GREEN SHALE FROM RUTH SHAFT NEAR FREDERICKTOWN
MADISON COUNTY, MISSOURI

Silica (SiO_2)	48.66%
Alumina (Al_2O_3)	22.37
Ferric Oxide (Fe_2O_3)	4.74
Titania (TiO_2)	.79
Lime (CaO)	2.17
Magnesia (MgO)	3.13
Alkalies (as Na_2O)	7.05
Sulphur Trioxide (SO_3)	2.38
Moisture	1.86
Ignition Loss	5.61
Total	98.76

The gray dolomite, "Big gray" of the drillers, is remarkably pure and approaches closely the theoretical composition of dolomite. Insoluble material is comparatively low. Iron is present in small but varying amounts, and some of it is probably in the ferrous state. Table No. I gives the analyses of a number of samples of dolomite from this zone. These samples are believed to be representative of the zone as a whole.

TABLE I

Analyses of Dolomite, Zone 3

Plate I, Locality No.	1	1	1	1	1
Laboratory Sample No.	2721-8	2722-1	2721-6	2722-3	2722-2
Insoluble	0.32%	0.38%	0.88%	0.44%	1.06%
Calcium Carbonate ($CaCO_3$)	55.25	54.99	55.25	55.08	55.34
Magnesium Carbonate ($MgCO_3$)	43.17	43.55	42.59	42.86	42.59
Ferris Oxide (Fe_2O_3)	0.79	0.86	1.00	1.19	0.77
Alumina (Al_2O_3)	0.05	0.18	0.64	0.05	0.37
Sulphur (S)	0.003		0.007		
TOTALS	99.583	99.96	100.367	99.62	100.13

Description of Samples

Lab. No. 2721-8: Collected southwest of Fredericktown, north of Calvert Cemetery, and east of point where road crosses small creek tributary to Little St. Francois River. Sample is from the top of the section exposed, which is in the lower portion of the gray dolomite, Zone 3 of the Bonneterre formation.

Lab. No. 2722-1: Collected as described above (2721-8). Represents sample taken from weathered face. Weathered material was not removed.

Lab. No. 2721-6: Collected from above locality (2721-8), and four feet below 2722-1 and from top of low bluff on west side of road.

Lab. No. 2722-3: Same locality as above. Sample from west side of road, five feet below 2721-6; and five feet above base of exposure.

Lab. No. 2722-2: Same locality as above. Sample from west side of road at base of exposure and five feet below sample 2722-3.

TABLE I (Continued)

Plate I, Locality No.	2	2	2
Laboratory Sample No.	2721-7	2722-4	2723-7
Insoluble	0.48%	1.34%	1.36%
Calcium Carbonate ($CaCO_3$)	55.25	54.04	54.54
Magnesium Carbonate ($MgCO_3$)	42.99	42.48	41.83
Ferric Oxide (Fe_2O_3)	0.90	1.36	1.84
Alumina Al_2O_3)	0.00	0.22	0.24
Sulphur (S)	0.005		
TOTALS	99.625	99.46	99.81

Description of Samples

Lab. No. 2721-7: Collected on the southwest edge of Fredericktown (see attached map) from a bluff approximately 30 feet high located on the east bank of Little St. Francois River. Sample from top of section. From lower part of gray dolomite, or zone 3 of Bonneterre formation.

Lab. No. 2722-4: Collected from the base of the section (1½′ above river level) above described and 31 feet below 2721-7.

Lab. No. 2723-7: Represents a large piece of dolomite from the gray or No. 3 zone of the Bonneterre of above described section. Sample contains much green shale and was analyzed for that reason.

TABLE I (Continued)

Plate I, Locality No.	3	4	4	4
Laboratory Sample No.	2721-9	2721-3	2721-4	2721-5
Insoluble	1.20%	0.36%	0.46%	0.30%
Calcium Carbonate ($CaCO_3$)	53.47	55.25	55.43	55.34
Magnesium Carbonate ($MgCO_3$)	43.45	39.41	42.30	41.62
Ferric Oxide (Fe_2O_3)	0.98	4.30	1.17	1.89
Alumina (Al_2O_3)	0.40	0.00	0.15	0.00
Sulphur (S)	0.08	0.01	0.01	0.006
TOTALS	99.58	99.43	99.52	99.156

Description of Samples

Lab. No. 2721-9: Composite sample picked from dump at shaft on Ruth Tract. Shaft is 225 feet deep. Sample from gray dolomite or zone 3 of Bonneterre formation. Estimate zone was penetrated 75-100 feet but base was not reached. Dolomite is very vuggy and appears to have undergone some alteration. Shaft, 7x9 feet is now full of water.

Lab. No. 2721-3: Specimen of diamond drill core from light gray-dolomite, zone 3 of the Bonneterre formation, drilled on the Hahn Tract. No information pertaining to depth of top of gray or other zones or total depth of hole is available. Cores from pieces scattered around drill site. Specimen has visible green clay.

Lab. No. 2721-4: This is a specimen also of core, without green shale as described above, 2721-3. Depth not known. Gray or zone 3 of Bonneterre formation.

Lab. No. 2721-5: Same as 2721-4.

TABLE I (Continued)

Plate I, Locality No.	5	6	6
Laboratory Sample No.	2723-5	2721-1	2721-2
Insoluble	0.70%	4.14%	3.52%
Calcium Carbonate ($CaCO_3$	54.52	51.58	52.31
Magnesium Carbonate ($MgCO_3$)	44.01	38.56	38.18
Ferric Oxide (Fe_2O_3)	0.64	3.92	4.72
Alumina (Al_2O_3)	0.10	1.04	0.00
Sulphur (S)		0.29	0.92
TOTALS	99.97	99.53	99.65

Description of Samples

Lab. No. 2723-5: Composite sample prepared from several samples collected from the uppermost portion of the gray dolomite or zone 3 of the Bonneterre formation in the area on the west side of U. S. Highway 67, extending from a point just west of the barn west of the Melbourne Ward residence southwest to a point near the center, south line of the Spickerman Tract, located just north of Mill Creek village.

Lab. No. 2721-1: Sample from churn drill hole, National Lead Co., No. 3 Smith, Missouri Geological Survey No. 7699, located approximately 1200 feet east of Cobalt Company shaft. From gray dolomite or zone 3 of the Bonneterre formation, depth 230-235 feet.

Lab. No. 2721-2: Sample from above well, depth 240-245.

In the consideration of the dolomite from zone 3 for the production of magnesium the low bluff on the Little St. Francois River, southwest edge of Fredericktown, Plate I, Map No. 2 was drilled and shot off. A composite three ton sample was taken by Dr. F. J. Williams, Research Laboratories, National Lead Company, Brooklyn, New York, who reported the following analysis:[1]

Analysis of Dolomite, Zone 3

Magnesium Oxide (MgO)	20.43%
Calcium Oxide (CaO)	29.89
Silica (SiO_2)	0.83
Acid Insoluble	1.61
Alumina (Al_2O_3)	0.85
Iron (Fe_2O_3)	1.35
Carbon Dioxide (CO_2)	46.06
Combined Water (H_2O)	0.69

The distribution of Zone No. 3 is shown on the accompanying map. Exposures of the dolomite of Zone 3 are available for examination and sampling in the following localities, the numbers of which correspond to the locality numbers given on Plate I.

1. Southwest of Fredericktown, north of Calvert Cemetery and east of point where road crosses small creek tributary to Little St. Francois.
2. On Little St. Francois River, on southwest edge of Fredericktown, in sharp bend of river and on east bank.
3. Shaft on Ruth Tract.
4. Diamond drill hole on Hahn Tract.
5. West of road from a point west of barn, west of Melbourne Ward farm house, southwest to a point near the center south line of Spickerman Tract located just north of Mill Creek village.

[1]Written communication, April 16, 1942.

6. National Lead Company prospect hole No. 3 Smith.
7. North American Cobalt Company property.

In addition to the area of outcrop, this zone also will be found under a cover of overlying dolomite, zone 4, and cherty residual clay. The two combined vary from a few to possibly as much as 300 feet in thickness.

Zone 4: This zone forms the top of the Bonneterre formation. It is characterized by massive dolomite, very dark brown in color, finely crystalline, hard and compact. Good exposures of the zone occur in the vicinity of city well No. 8 and the Arnett cemetery south of Fredericktown; also at the bridge on U. S. 61 over Mill Creek, southwest of the village of that name.

In connection with this investigation chemical analyses were made of samples from this zone and the results given in Table II. This zone, as shown by analysis 2723-6 is composed of relatively pure dolomite also. The dark color of the rock is due to organic matter.

TABLE II

Analyses of Brown Dolomite, Zone 4

Plate I, Locality No.	6	3
Laboratory Sample No.	2723-6	2723-4
Insoluble	0.52%	1.76%
Calcium Carbonate ($CaCO_3$)	55.02	53.82
Magnesium Carbonate ($MgCO_3$)	43.42	43.22
Ferric Oxide (Fe_2O_3)	0.90	0.80
Alumina (Al_2O_3)	0.10	0.00
Sulphur (S)		
TOTALS	99.96	99.60

Description of Samples

Lab. No. 2723-6: Composite sample of several samples collected from near the base of the upper brown dolomite, Zone 4 of the Bonneterre formation from a point just north of the Melbourne Ward farm house thence southwest to a point just west of the bridge over Mill Creek on U. S. Highway 67.

Lab. No. 2723-4: Composite sample representing upper brown dolomite, Zone 4 of Bonneterre formation, collected on dump at the Ruth Shaft, the location being described under Lab. No. 2721-9. This zone is estimated to have been penetrated from the surface to a depth of 125 to 150 feet.

Residum: Zone 4 of the Bonneterre formation is overlain by cherty red residual clay. The chert and red clay appear to have been derived from the thorough weathering of the Potosi, Eminence and possibly Gasconade formations. Between the Potosi and the Bonneterre, there normally intervenes a sequence of dolomite, shale, and sandstone which comprise the Davis and Derby-Doe Run formations. These appear to be absent, however, in the locality being described.

Structure: The area immediately adjacent to Fredericktown is not complex structurally and there appear to be no major features that would preclude economical mining or quarrying of the dolomite. The area is that of a structural and sedimentary basin and one rimmed on the west and southwest, at least, by high hills and ridges of igneous rocks. The area is further marked by knobs of igneous rock which stood above the floor of the basin during the deposition of a portion, and in some instances all of the Bonneterre formation. Adjacent to these knobs dips similar to those described by Dake and Bridge[2] may be observed in the Bonneterre, and in such cases the upper zones of the formation may overlap the lower ones. The exposure on Little St. Francois River, NW¼ SE¼ Sec. 6, T. 33 N., R. 7 E., less than 2 miles northwest of the Fredericktown courthouse is an example. In the first valley north of the village of Mill Creek, and on the west side of the Fredericktown road, Plate I, Locality No. 5, the white dolomite of Zone 3 is in contact with pre-Cambrian porphyry. The character of the dolomite does not appear to have been affected and the dolomite appears to be flat lying. There are, no doubt local folds and faults present in the area but such features have not been noted in the present survey and as mentioned there are no large structural anomalies that will prevent economical quarrying or mining of the rock.

Summary: This report briefly describes the occurrence of zones of dolomite in the Bonneterre formation of Upper Cambrian age in the Fredericktown area of Madison County, of which zone 3 and possibly zone 4 are sufficiently pure to warrant further consideration. A map showing the area of outcrop, and the area where these zones are comparatively close

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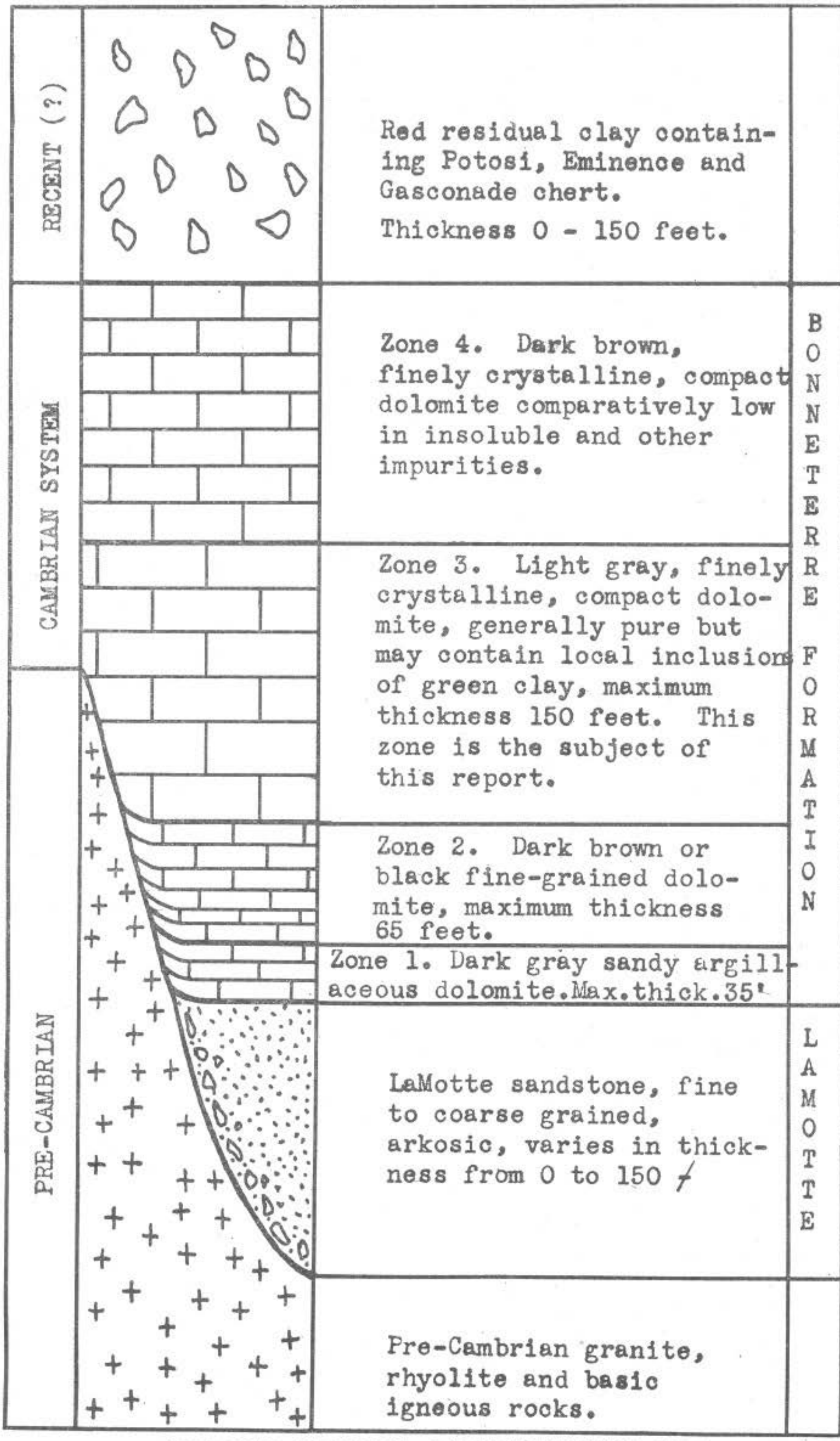
[2]Bridge, Josiah and Dake, C. L., Initial dips peripheral to resurrected hills, 55th Bien. Rept., State Geologist, App. I, pp. 93-99, 1929.



COLUMNAR SECTION, FREDERICKTOWN AREA

to the surface is given (Pl. I). The location of the samples analyzed is given on that map also.

The dolomite is relatively low in insoluble material and fairly low in iron. No attempt, however, has been made to utilize the dolomite on a commercial scale. Tests have shown it can be converted, however, into the light weight metal magnesium by a new ferrosilicon process developed by L. M. Pidgeon of the Canadian National Research Council. The process has recently been described by Killefer.[1]

There is also a possibility of utilizing the dolomite in the manufacture of burned "dolomitic lime." The iron content of the samples analyzed appears to be too high to use the dolomite in the plate glass industry. However, by careful selection to exclude the green shale, a useable grade of stone might be obtained. Other uses of the dolomite may be possible and the present report is to present for consideration of possible users the occurrence of high grade rock in the Fredericktown area.

[1]Killefer, D. M., Magnesium from dolomite by ferrosilicon reduction, Chemical and Engineering News, New Edition, March 25, 1942, p. 369. Ibid, Rock Products, Vol. 45, No. 5, May, 1942, pp. 65 and 68.

V

Occurrence *of* Bauxitic Clay

In

Stoddard County, Missouri

By

DAN R. STEWART, LYLE MCMANAMY
AND HENRY S. MCQUEEN

Appendix III, 62nd Biennial Report

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MISSOURI
GEOLOGICAL SURVEY AND WATER RESOURCES

H. A. BUEHLER
DIRECTOR AND STATE GEOLOGIST
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LIST OF ILLUSTRATIONS.

AN OCCURRENCE OF BAUXITIC CLAY IN STODDARD COUNTY, MISSOURI

By

Dan R. Stewart, Lyle McManamy, and Henry S. McQueen

INTRODUCTION.

In 1934, the Missouri Geological Survey began an intensive study of the Cretaceous and Tertiary formations of southeastern Missouri in order to evaluate properly the mineral resources of the area.

As the investigation was continued and as the details of the geology were worked out it became apparent that among the resources present, clay was an important one. Consideration has been given to some of the clays in other reports[1]. Field studies of the clays and the containing formations were continued and in the summer of 1940, Dan R. Stewart, while engaged in the detailed mapping of the geology of Crowley's Ridge discovered, near Ardeola, Stoddard County, an outcrop of pisolitic or "bauxitic" clay. Upon subsequent investigation, the outcrop proved to be a fairly large boulder.

This discovery represents the first known occurrence of this type of clay in Missouri. The highly aluminous diaspore clay and the associated burley clay have been mined commercially in the North Central Ozark region for a number of years, but differ materially in physical properties and chemical composition from the clay described in this report. Insofar as is known the only other occurrence in the State has been reported by Robertson[2], who has described a boulder of bauxite occurring in a gravel deposit near St. Louis.

Geologically, the Missouri bauxitic clay is found in sediments of early Tertiary age and at the contact of the Paleocene

[1]Farrar, Willard, Grenfell, Donald S., and Allen, V. T., The geology and bleaching clays of southwest Missouri, 58th Bien. Rept., State Geologist, App. I, 1935.

[1]Farrar, Willard, and McManamy, Lyle, The geology of Stoddard County, 59th Bien. Rept., State Geologist, App. VI, 1937.

[1]Davis, W. E., Herold, P. G., and McManamy, Lyle, Further investigations of southeastern Missouri clays, 61st Bien. Rept., State Geologist, App. I, 1941.

[2]Robertson, Percival, Implications of a cobble of bauxite found in the LaFayette gravel of St. Louis County. Missouri Acad., Science, Proceedings, Vol. 6, pp. 80-81, 1941.

and Eocene series. It is of interest to note that the occurrence is at the same specific geologic contact, Midway-Wilcox, where most of the bauxite occurs in the Coastal Plain areas of Arkansas, Mississippi, Alabama, and Georgia.

Since the discovery of the original outcrop it has been possible to explore a considerable area through the cooperation of the Federal Works Agency-Work Projects Administration, Statewide Project, sponsored by the Missouri Geological Survey. The area surrounding the discovery location has been thoroughly prospected by both drill holes and trenches. In addition numerous samples have been collected and chemical analyses made in order to determine the composition of the clay, the possible origin and the relationships between the bauxitic clay and the other clays of the district. Although the results of both the prospecting and chemical analyses have shown the bauxitic clay in this locality to consist of boulders of inferior grade, its geologic position together with the widespread distribution of early Tertiary sediments in southeastern Missouri justify further prospecting of the Midway-Wilcox contact, at the surface and in the subsurface of the area.

LOCATION OF THE OCCURRENCE.

The southeastern Missouri bauxitic clay occurrence is located on the eastern face of that upland area of Stoddard County, known as Crowleys Ridge. (Fig. I). This locality is about nine miles northeast of Bloomfield, the county seat, and

Fig. 1. Map showing location of area.

approximately three-eights of a mile southwest from the school house at the village of Ardeola. The occurrence is exposed in an outcrop on the wooded hillside in the NE¼ NE¼ SE¼ Sec. 9, T. 27 N., R. 11 E., on the A. H. Bohler property. The outcrop can best be reached by following the dim wagon road which runs southwestward along the top of the bluff from the Ardeola School House to the exposure. (See Map, Pl. I).

The topographic maps of the Advance and Bloomfield quadrangles cover the locality and these maps may be purchased from either the Missouri Geological Survey and Water Resources at Rolla, Mo., or from the United States Geological Survey, Washington, D. C. A detailed topographic and geological map, showing the outcrop area of the bauxitic clay locality near Ardeola on a scale of 1:1,200 has been prepared to accompany this report. (Pl. I).

GENERAL GEOLOGY

The bauxitic clay occurrence near Ardeola lies within the Mississippi Embayment area of southeastern Missouri, and is associated with Gulf Coastal Plain deposits of early Teritary age. Stratigraphically the bauxitic clay occurs at the contact of the Midway Group of the Paleocene Series and the overlying Wilcox Group of the Eocene Series. The time interval represented by this contact has been shown to have been one of pronounced bauxitization throughout most of southeastern United States.

The embayment area of southeastern Missouri is largely a lowland area. It is bounded on the northwest by a line of steep bluffs of Paleozoic rocks which extend from Cape Girardeau southwestward through Poplar Bluff to the Arkansas line. Rising above this lowland level and extending from Commerce southwestward to Campbell is a broken chain of hills known as Crowleys Ridge.

Structurally the embayment area is a regional syncline developed in comparatively recent geologic time. It is filled to its present level with Cretaceous and Tertiary sediments which lie upon a truncated surface of faulted and folded Paleozoic rocks. The Cretaceous and Tertiary sediments dip in a southeast direction, and in the vicinity of Caruthersville attain a thickness of more than 2700 feet. Throughout the lowland area alluvial deposits completely cover the Coastal Plain sediments, except in the Crowleys Ridge area, in portions of Scott, Stoddard, and Dunklin counties, they can outcrop and can be traced and studied. These beds consist largely of unconsolidated or poorly consolidated sands, marls, clays, and gravels. Although the succession at the Ardeola locality is graphically portrayed by Plates I and II, the general succession may be again presented as follows:

Section exposed by landslide on southeastern face of Crowleys Ridge, three-eighths of a mile southwest of Ardeola School in the NE¼, NE¼, SE¼, Sec. 9, T. 27 N., R. 11 E., Stoddard County.

	Thickness, in feet
Quaternary System:	
Pleistocene Series:	
Loess:	
No. 7 Silty clay, yellow, brown	10
Tertiary System:	
Pliocene (?) Series:	
No. 6 Gravel, brown, well rounded with some red sand	18
Enocene Series:	
Wilcox Group:	
No. 5 Clay, silty, light gray to brown, somewhat lignitic	18
No. 4 Sand, light yellow to brown, medium grained with boulders of bauxitic clay erratically distributed	19
Paleocene Series:	
Midway Group:	
Porters Creek Formation:	
No. 3 Clay, dark gray to black, weathering to light gray with characteristic conchoidal fracturing	85
Clayton Formation:	
No. 2 Clay, sandy, greenish brown, very glauconitic and fossiliferous	5
Cretaceous System:	
Gulf Series:	
Owl Creek Formation:	
No. 1 Clay, sandy, yellowish brown to dark gray, sparingly glauconitic and very fossiliferous	10
Total	165

Base not exposed.

CRETACEOUS SYSTEM

GULF SERIES.

In the Crowleys Ridge area of Stoddard County between 200 and 300 feet of rock assigned to the Gulf Series of the Cretaceous System occupy the interval between the Paleozoic rocks and the overlying Tertiary strata. These sediments consist of an alternating series of sand, sandy clay, calcareous clay, and clay, all with varying amounts of disseminated mica and glauconite; lignite, and Limonite. Of this section only the uppermost formation, the Owl Creek, is exposed at the Ardeola bauxitic clay locality. However, a short distance north, and on the road into the village of Ardeola the McNairy sand member of the Ripley formation underlying the Owl Creek is well exposed.

Ripley Formation: This formation is represented by the NcNairy member which consists of clay, sand, quartzite and lignite. The make-up of this member is well shown by the section exposed along the road into the village of Ardeola which is as follows:

Section of McNairy Member, Ardeola Hill.

		Thickness	
Number	*Lithology*	*Feet*	*Inches*
1.	Clay, brown, with fossil leaves, very micaceous, with sand lenses	11	0
2.	Sand, white, angular, interbedded with clay	11	0
3.	Clay, light, gray to dark brown, sandy	28	8
4.	Lignite	1	0
5.	Sand, fine, white, angular	10	3

Owl Creek Formation:[1] The Owl Creek formation is separated from the underlying McNairy member by one of the important unconformities of the Coastal Plain region. This formation is a dark gray, sandy, micaceous clay containing small amounts of disseminated brownish glauconite. Scattered rather erratically through the clay are rounded, pebble like, nodules averaging from ½ inch to one inch in diameter. Chemical analyses of these nodules show them to be calcium phosphate bearing clay, the mineralogy of which has not been studied. Upon weathering the formation alters to a yellowish brown

[1]Stephenson, L. W., and Monroe, W. H., (1937), "Prairie Bluff Chalk and Owl Creek formation of the eastern Gulf region," Amer. Assoc. Petr. Geologists, Bull., Vol. 21, No. 6.

color. The Owl Creek is characterized by the presence of a vast assemblage of molds and casts of marine invertebrate fossils. The thickness ranges from a feather edge to a maximum of eleven feet.

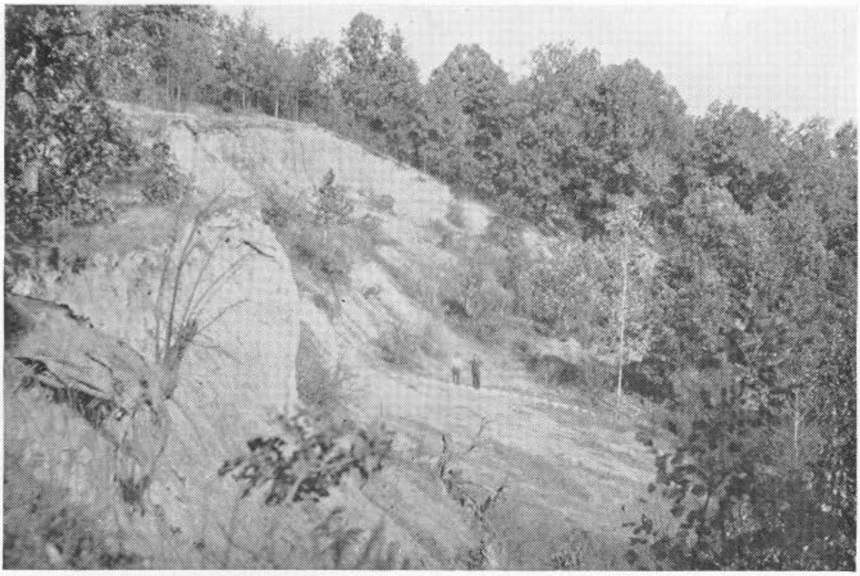
TERTIARY SYSTEM

PALEOCENE SERIES, MIDWAY GROUP.

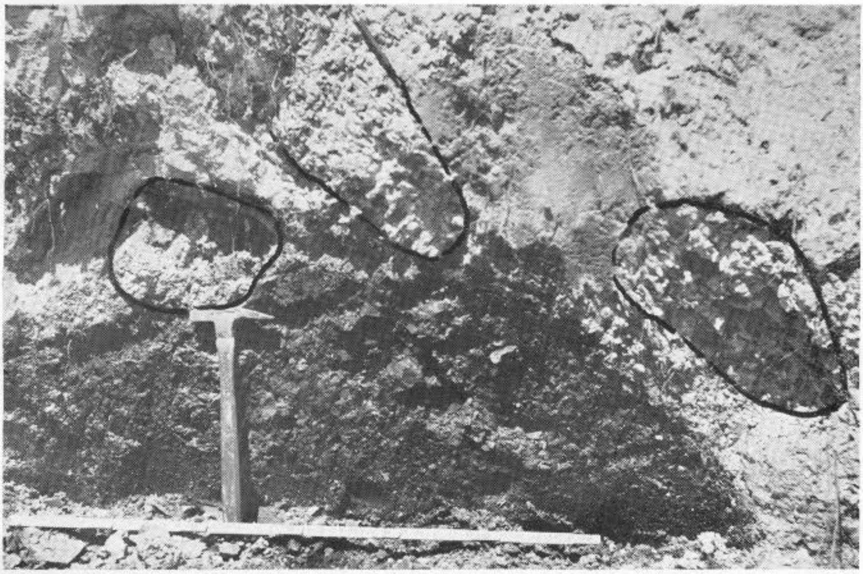
Clayton Formation: The Clayton formation is separated from the underlying Owl Creek formation by an unconformity that marks the break between the Cretaceous and Tertiary systems. This formation is composed essentially of glauconite with sand and limey clay making up the remainder of its bulk. The distinctive greenish color imparted by the mineral glauconite makes it the easiest formation to recognize in the Coastal Plain section of this locality. Calcium phosphate nodules are also scattered throughout the Clayton beds. In addition the Clayton is very fossiliferous and contains many molds and casts of poorly preserved marine invertebrates. This formation has a thickness ranging from a few inches to about ten feet.

Porters Creek Formation: Overlying the Clayton and resting conformably upon it is the clay of the Porters Creek formation. This formation consists entirely of a dark gray, almost black, massive, non-plastic clay which weathers almost white and with a characteristic shelly fracture. This formation is remarkably uniform in lithology, maintaining its diagnostic features throughout both its vertical and lateral extent. Nodules of spathic iron ore, or iron carbonate, occur erratically distributed throughout. The Porters Creek clay is almost totally unfossiliferous in its outcrop area, but down dip in the direction of increased thickness, drill hole samples have shown the lower few feet of this formation to become increasingly more fossiliferous, and many foraminfera and small pelecypods have been noted.

In parts of the Crowleys Ridge area of Stoddard County the upper few feet of the Porters Creek clay has been found to be more or less altered. In these scattered areas the upper part of the formation has been altered to an almost white, semi-plastic clay which grades downward into typical black Porters Creek material. This residual clay in all probability formed during the period of weathering and leaching which followed



A. View looking north across the landslide area at the bauxitic clay locality near Ardeola, Stoddard County.



B. Areas outlined are boulders of bauxitic clay, embedded in Wilcox sand. The dark mass behind hammer is Porters Creek clay.

the deposition of the Porters Creek clay. The resemblance, both chemically and physically, between this kaolinitic clay and some of the slightly bauxitized material at Ardeola is strikingly similar. It is believed that the bauxitic clay near Ardeola is the result of prolonged leaching of this type of weathered material. Analyses showing this possible gradation are given in Table II.

In Stoddard County the thickness of the Porters Creek ranges from a few inches along its outcrop to more than two hundred feet in the vicinity of Idalia, and in extreme southeast Missouri, the thickness approaches 650 feet.

EOCENE SERIES, WILCOX GROUP

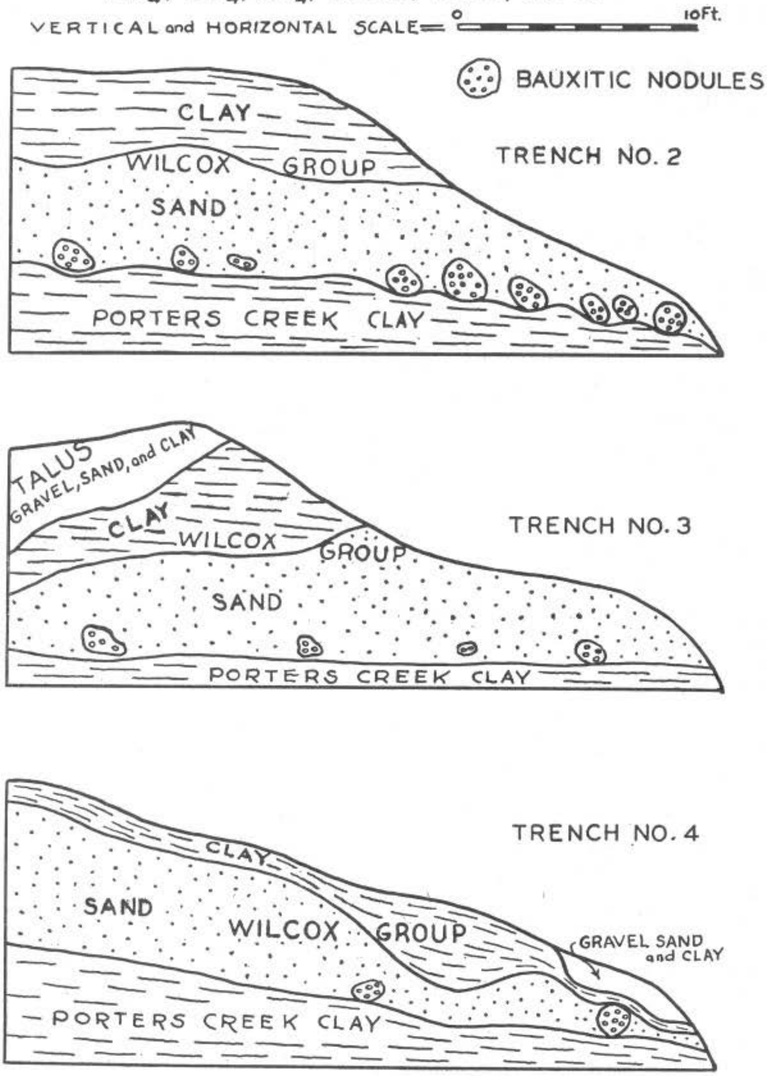
The sediments of the Wilcox group in southeastern Missouri are variable. In general this section consists of sand, sandy clay, and clay with minor amounts of gravel, all more or less crossbedded and lenticular in nature. Over most of southeastern Missouri the lower member of the Wilcox consists of a massive, light gray to brown, sandy, lignitic, clay, which averages about one hundred feet in thickness. However in some localities, sand is present beneath the silty clay, the bauxitic locality being an example. This lower sand is medium grained, yellow to orange in color, and contains fine clay particles disseminated throughout its mass. Where present it commonly reaches a thickness of fifty feet or more. It is believed to represent a channel deposit. The boulders of bauxitic clay are found in the exposure near Ardeola in the basal portion of this sand and the contact with the underlying Porters Creek clay. The remainder of the Wilcox section lying above this lower member consists largely of a comparatively thick section of coarse and medium grained sand which weathers to a deep red color. Numerous clay lenses of varying sizes and grades occur in the sand. In thickness the Wilcox group, as developed in Stoddard County, ranges from almost nothing to more than three hundred feet in the southeastern part.

PLIOCENE (?) SERIES

Immediately overlying the Wilcox group in the Crowleys Ridge area of southeastern Missouri are deposits of gravel of Pliocene or possibly Pleistocene age. In general these beds are composed of water-worn, brown, chert pebbles ranging in size

CROSS SECTION OF PROSPECT TRENCHES
AT BAUXITIC CLAY OCCURRENCE

NE¼, NE¼, SE¼, SEC. 9, T27N, R11E.



from one-half to three inches in diameter. Interbedded and intermixed with the gravel are many lenticular bodies of brightly colored sand and clay. The entire formation is highly crossbedded and very irregular in its make up. It varies considerably in thickness and ranges from a few inches to more than sixty feet in relatively short distances. Many of the gravel deposits now occur as erosional remnants capping the higher hills.

QUATERNARY SYSTEM

PLEISTOCENE SERIES

The Crowleys Ridge area of southeastern Missouri is capped particularly in the upland area by loess, which in many localities entirely conceals the underlying sediments. It consists of light yellowish-brown silty clay and occasionally contains limestone concretions and fossil shells of terrestrial mollusks. In thickness the loess varies from almost nothing to more than one hundred feet.

STRUCTURE

As the result of prospecting by means of hand powdered earth augers, and from field observations, some knowledge of the structure of the area has been obtained. The Ardoela locality lies well up on the northeast flank of an anticline, which trends northeast-southwest. This feature is bounded on the southeast by a fairly deep syncline, the structural relief from the deepest known low point to the clay locality being about 100 feet in 2½ miles. There is a suggestion that the clay was weathered in the area of the anticline and subsequently was redeposited down the flanks of the structural feature described.

DESCRIPTION OF THE DEPOSIT.

The deposit was exposed, in what was once a wooded hillside, as the result of a landslide, which occurred during a sharp earthquake on May 7, 1927, (Pl. III). The earthquake was felt over a fairly large area in southeastern Missouri and northeastern Arkansas. The landslide area is about 500 feet in extent, and the vertical movement involved was considerable. Some interesting features regarding the mechanics of the movement may be observed and it is apparent that the main movement occurred along the Porters Creek-Wilcox contact as is evidenced by the "billowing" of the basal sand of the Wilcox, and highly developed slickensides at the top of the Porters Creek clay.

The boulders of bauxitic clay occur in the basal portion of the Wilcox sand. In some instances they rest directly upon the Porters Creek clay, while in others the sand completely surrounds them. In all cases the boulders are in sharp contact with the adjacent sediments, and in no instance does the immediately underlying Porters Creek clay show evidences of any alteration or bauxitization.

The bauxitic clay is found as smooth, ovoid-shaped boulders ranging in size from less than one inch to more than four feet in diameter. (Plates IV, V). They are erratically spaced, although in one prospect trench, No. 2, they have a somewhat imbricate arrangement. (Plates IV and V). Here the egg-shaped boulders are tilted in a general easterly direction. (Pl. VI). Hillside erosion has loosened several of these boulders, allowing them to roll down the slope where they may be found associated with the talus accumulations. (Pl. VII).

It is very evident that the bauxitic clay represents a detrital deposit, and boulders, that were transported to their present position during the initial deposition of the Wilcox sediments. This fact is shown by (1), the rounded condition of the boulders, (2), their erratic distribution, (3), some of the boulders being entirely surrounded by the basal Wilcox sand, and (4), the associated clays show no alteration and exhibit a sharp contact with the boulders. It is, however, evident that these boulders could not have been moved very far because of their soft, friable condition, and it is believed they were obtained from a nearby source, but one which has not been located to date.

CHARACTER OF THE CLAY.

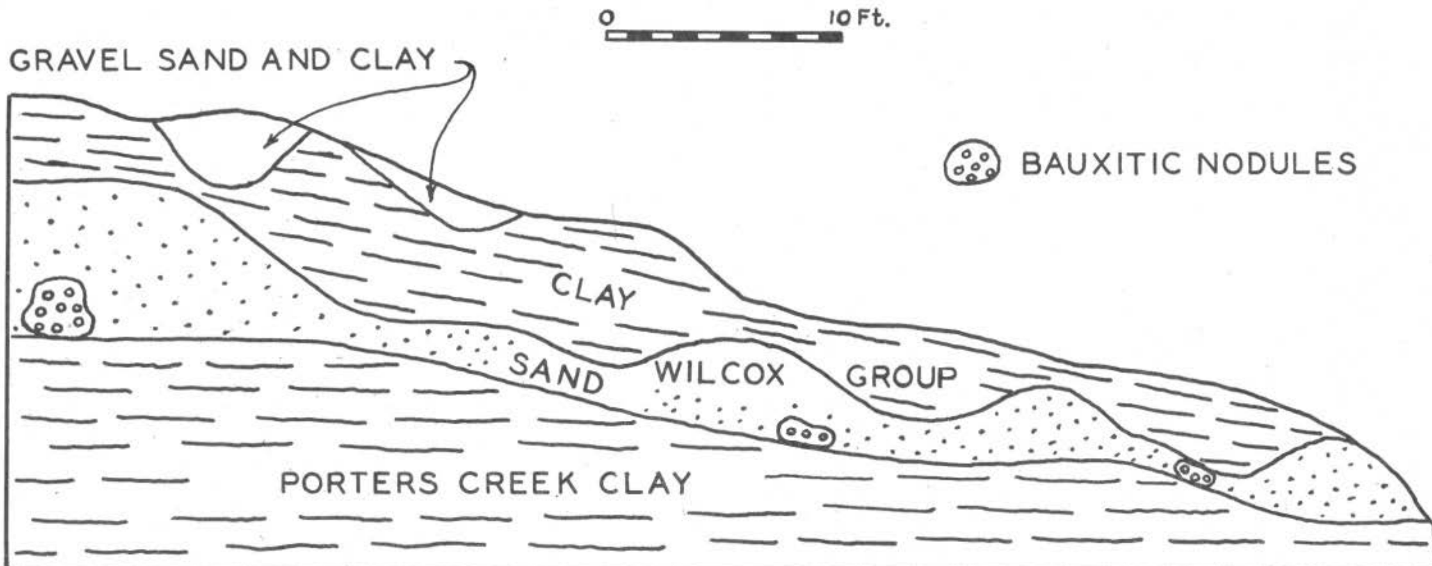
The clay is soft, friable, non-plastic and mealy. It is characterized by the presence of pisolites or rounded particles, or angular fragments of white clay.

The pisolites range in diameter from a fraction to possibly an inch or more in diameter, with the average being about one-quarter of an inch. The color of the pisolites ranges from red, to reddish-brown and yellow, and a few of them are black or have black centers. They also exhibit a banded or concretionary

CROSS SECTION OF PROSPET TRENCH NO. 5 AT BAUXITIC CLAY OCCURRENCE

NE 1/4, NE 1/4, SE 1/4, SEC. 9, T 27 N, R 11 E.

VERTICAL AND HORIZONTAL SCALE



structure and the centers of the larger ones often have a lace-like or honey combed structure.

The angular fragments consist of white clay with a satinly luster, on the average the fragments are not larger than one inch in the longest direction. The angular fragments often compose the boulders alone, or may occur with the pisolites.

CHEMICAL COMPOSITION.

At the time the original boulder of clay was discovered it was thought to be bauxite, because of the pisolitic structure. Chemical analyses, however, show the clay to be an aluminum silicate, rather than an hydrated oxide. It has undergone some alteration, however, and appears to be in the early stages of the process of conversion from the silicate to the oxide state. That such a conversion actually takes place has been noted in recent studies of the flint fire clays and the high alumina, diaspore clay of the north central Ozark region. Physical and chemical evidence that such alteration has taken place here is present also.

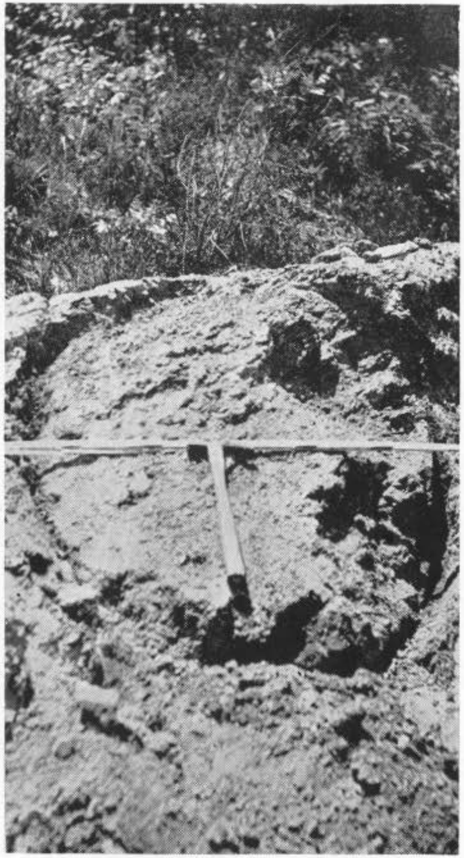
A number of analyses have been made of the bauxitic clay and the various fractions thereof. Some of the results are given in Table I. An examination of this table will show but little difference, however, between samples of the clay as a whole, and the angular "conglomeratic" fragments or the pisolitic portions of the clay.

The analyses of the clay show it to be an aluminum silicate and closely related to kaolinite, the theoretical composition of which is given in Table I for the purpose of comparison. The clay, according to the present bauxite classification would be considered as grade D material.[1]

ORIGIN OF THE CLAY

It is now almost universally accepted that bauxites are the result of the alteration of aluminous bearing rocks under favorable climatic, topographic and geologic conditions. When these conditions exist the exposed aluminous rocks are leached of their more soluble constitutents, such as the alkalies, lime, magnesia, and slica, with the iron, titania, and alumina remaining in the parent material. The solvents most generally regarded

[1]Thoenen, J. R., and Burchard, E. F., Bauxite Resources of the United States, U. S. Bur. Mines, Rept. Investigation No. 3598, p. 38, Nov. 1941.



A. View showing the discovery site of the bauxitic clay near Ardeola, Stoddard County.

B. One of the larger boulders of bauxitic clay.

as the leaching agents are alkaline and carbonate waters, while organic acids from rotting vegetation and bacterial activity are sometimes included. The resulting product from such weathering whether it be an iron ore or bauxite, depends upon the dominant insoluble constituent of the original rock.

The types of rocks which lend themselves most favorably to lateritic weathering are the clays. Some of the bauxite deposits of the world are thought to have been leached, however, from igneous rocks, such as granites, syenites, diabases, or basalts. Regardless of the parent rock the leaching processes are the same, in that the rocks are first altered to kaolin and then to bauxite of various grades.

This hypothesis, being one of pronounced chemical weathering or decomposition, must necessarily presuppose a tropical or sub-tropical climate, since in temperate or cold regions mechanical weathering or disintegration becomes increasingly more important. The abundant occurrences of bauxite and laterite in the tropical regions of the world today coincides with these facts. That such a climate existed over southeastern United States during the Midway-Wilcox interval has been shown by E. W. Berry[2] from an examination of lower Wilcox plant remains, and by the wide spread occurrence of lignite associated with the Wilcox sediments.

The bauxitic clay appears to have resulted from the alteration of the Porters Creek clay. The latter was deposited over the southeastern portion of the State with a thickness up to 650 feet. After deposition of the material, the area became land and the Porters Creek clay was subjected to the processes of weathering and broken down and altered. That alteration of the clay actually takes place is indicated by the chemical analyses of various samples from the Porters Creek formation which are presented in Table II. These analyses show desilification, of the clay and aluminous enrichment. This is particularly true of sample No. 5 which represents a clay collected from between two oxidized lime-bearing siderite (iron carbonate) concretions which are located nor far from the plane of a fault in the Dunn Shaft, SW¼ NE¼ SE¼, Sec. 21, T. 26 N., R. 10 E. The aleration of the clay by meteoric water charged with carbon dioxide is at once suggested. In the discussion of

[2]Berry, E. W., (1916), "The Lower Eocene Floras of Southeastern North America," U. S. Geological Survey, Prof. Paper, No. 91, p. 135.

the origin of aluminous clays the action of ground water, charged with carbon dioxide, upon clays has been commented upon by many authors. The present case appears to be a specific example. Some of the iron and lime liberated in the break down of the concretion subsequently invaded the clay mass and resulted in the comparatively high content of each in sample No. 5, Table II. The weathering of similar concretions, common to the Porters Creek may well have entered into the alteration of the clay in other localities. The erratic areal distribution of altered Porters Creek clay suggests possibly the presence of faulting or fracturing which would permit the circulation of ground waters, hence it might be well to keep in mind the presence of any structural features in prospecting.

Throughout the bauxitic clay are irregular to rounded opalescent areas. Similar areas have been noted in the flint fire clays of the North Central Ozark region, and they are believed to represent the first stage in the aluminous enrichment of a clay. They are also believed to be the forerunner in many instances of more highly aluminous oolites or pisolites. Allen[3] has shown that oolites are formed in Missouri flint fire clay and may range from kaolinite to diaspore depending upon the completeness of alteration.

At the end of the period of weathering, the Porters Creek surface in this area was covered by a mantle of altered clay. The surface was tilted to the southeast and the clay mantle was stripped off with the possible exception of a few localities, such as locally downwarped areas. In the process, the clay now altered to the present bauxitic type was eroded and portions of it were transported short distances. It seems unlikely, the comparative softness of the clay being considered, that these boulders could have been moved any great distance. The material that was broken down into finer sizes probably was transported much longer distances. This fact, together with the fact that some 600 feet or less of Porters Creek is now believed to be missing, to a large extent as the result of erosion, in the Ardeola locality has caused the writers to speculate on the possibility that the weathered and transported material derived from the Porters Creek clay might well be the source of some

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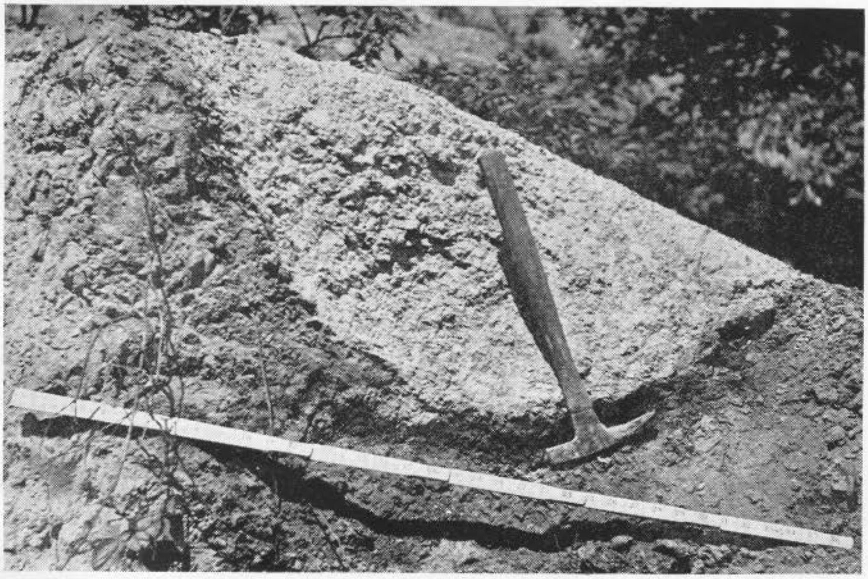
[3]Allen, V. T., Mineral composition and origin of Missouri flint and disaspore clay, 58th Bien. Rept., State Geologist, App. IV, p. 17, 1935.

A. Boulders of bauxite associated with talus material.



B. Close up view of one of the slumped bauxitic clay boulders, associated with talus material.

of the large scale kaolin deposits found in the lower part of the Wilcox group throughout Arkansas, Mississippi, Alabama, and Georgia. The idea is one that deserves some consideration.

The question arises, however, as to the absence of extensive, widespread, thick deposits of kaolin in this portion of southeast Missouri. It is believed that the surface was tilted as mentioned, at least once, if not several times, in early Wilcox time, and being at or near the shore line of the advancing Wilcox sea it was almost entirely denuded of the soft weathered clay. Exceptions may be cited as occurring in the area of the Dunn Shaft, SW¼ NE¼ SE¼ Sec. 21, T. 26 N., R. 10 E., 2½ miles west and south of Bloomfield, Stoddard County and in the vicinity of the Sim Jones farmhouse, SE¼ SW¼ Sec. 16, T. 27 N., R. 11 E., Stoddard County.

FUTURE POSSIBILITIES.

The occurrence of the clay has resulted in considerable prospecting. This work has necessarily been confined to a rather narrow belt as hand powered, earth auger, drill holes become impractical at depths exceeding 100 feet. Also, in the upland areas of Crowleys Ridge the thick mantle of gravel precludes such drilling. As a result the drilling to date has been virtually confined to the flanks of Crowleys Ridge. The boulders suggest, however, that the mass of clay from which they were derived occurs not far from their present point of occurrence.

In connection with future prospecting the writers suggest that several power driven holes be drilled on a line running northwestward and southeastward from the present locality, through the ridge area of the E½ of Sec. 9, and the upland areas in Secs. 16, 17, 20 and 21, T. 27 N., R. 11 E., in order to determine whether or not there exists a deposit of clay of sufficient size and quality as to warrant development operations.

It is true the present clay is low grade, but in the present war effort the discovery of a large body of such material would be an important addition to the known reserves of aluminous clays.

TABLE I

Analyses of Bauxitic Clay, Ardeola Locality

Sample No.	*1*	*2*	*3*	*4*	*5*	*6*
Silica (SiO_2)	42.86	41.96	44.86	44.86	45.16	46.36
Alumina (Al_2O_3)	35.37	35.30	36.45	34.07	32.32	39.73
Ferric Oxide (Fe_2O_3)	3.27	1.86	1.61	1.25	2.14	
Titania (TiO_2)	1.68	1.48	0.10	1.38	1.78	
Lime (CaO)	0.59	0.98	0.43	0.75	0.68	
Magnesia (MgO)	0.38	0.09	0.30	0.13	0.16	
Alkalies (as soda Na_2O)	0.30	ND	ND	ND	ND	
Moisture	2.93	5.25	2.31	6.24	5.88	
Ignition Loss	12.65	12.22	13.24	11.33	11.55	13.91
Total	99.88	99.14	99.30	100.01	99.67	100.00

Sample No. 1. Bauxitic clay boulder.

Sample No. 2. Pisolites from bauxitic clay boulder.

Sample No. 3. Angular fragments of white soft clay occurring with pisolites in bauxitic clay.

Sample No. 4. Clay matrix cementing pisolites.

Sample No. 5. Bauxitic clay boulder, very pisolitic structure, located immediately west of Trench No. 1.

Sample No. 6. Theoretical composition of kaolinite.

TABLE II

Analyses of Porters Creek Clays

Sample No.	*1*	*2*	*3*	*4*	*5*
Silica (SiO_2)	61.52	59.96	57.22	55.76	35.72
Alumina (Al_2O_3)	14.64	19.71	15.43	18.19	28.29
Ferric Oxide (Fe_2O_3)	3.93	2.32	6.08	6.97	8.05
Titania (TiO_2)	0.59	0.59	0.59	0.58	0.40
Lime (CaO)	0.83	0.54	1.16	0.83	5.81
Magnesia (MgO)	0.74	1.62	1.19	2.27	1.51
Moisture	7.51	6.85	9.15	6.67	6.62
Ignition Loss	6.28	6.41	6.51	6.67	9.98
Total	96.04	97.94	97.33	97.94	96.38

Sample No. 1. From shaft on Merle Dunn farm, SW¼ NE¼ SE¼ Sec. 21, T. 26 N., R. 10 E., 2 miles west, and ½ mile south of Bloomfield. Shaft sunk May, 1942. Total depth 25 feet. Unweathered Porters Creek clay from bottom of shaft.

Sample No. 2. Weathered Porters Creek clay, Dunn Shaft, total thickness of weathered material is 19 feet.

Sample No. 3. Fractured and weathered clay adjacent to plane of fault and on upthrown side thereof. Dunn Shaft.

Sample No. 4. Weathered or residual clay from top of Porters Creek formation, south side of county highway No. J about 2¼ miles west of Bloomfield, NE¼ NE¼ Sec. 21, T. 26 N., R. 10 E.

Sample No. 5. From area of weathered clay lying between limonite (altered iron carbonate) nodules, and on downthrown side of fault. Clay is white, but grades into gray colored clay a short distance away. Clay is fractured and iron stained.

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The Fortune, A New Devonian Formation

In

Southwestern Missouri

By

J. G. Grohskopf, E. L. Clark
and S. Ellison

Appendix IV, 62nd Biennial Report

1943

MISSOURI
Geological Survey and Water Resources
H. A. BUEHLER
Director and State Geologist
ROLLA, MISSOURI

LIST OF ILLUSTRATIONS

THE FORTUNE, A NEW DEVONIAN FORMATION IN SOUTHWESTERN MISSOURI

by

J. G. Grohskopf,* E. L. Clark,** and S. Ellison ***

INTRODUCTION

This report discusses the location, name, lithology, thickness, stratigraphy and paleontology of the Fortune, a new Devonian formation in southwestern Missouri. The following formations are found in association with the Fortune in the area of this report.

Mississippian System:
- Kinderhook Group:
  - Compton limestone
  - Chattanooga shale
  - Sylamore sandstone

Devonian System:
- Fortune, chert, limestone, and sandstone

Ordovician System (Canadian of E. O. Ulrich)
- Cotter dolomite

The above section is common to the area except for the restricted distribution of the Fortune. At places the Compton may lie upon Chattanooga, Sylamore, Fortune, or Cotter. Also the Chattanooga may rest upon Fortune and Cotter with the Sylamore absent. In the routine examination of well samples at the Missouri Geological Survey laboratories Grohskopf noted, in two wells from eastern Barry County, an occurrence of chert which appeared to intervene between the Cotter and Chattanooga. The character of the chert and its stratigraphic position were suggestive of Devonian age; it was tentatively correlated with the Penters, a chert of Devonian age which is described by Miser[1] from northwestern Arkansas.

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[1]Miser, H. D., 1920 (U. S. G. S. Bull. 715 G.). p. 98.

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Clark, in his mapping of the Cassville quadrangle was successful in finding the chert on the outcrop and noted that it was associated with black dense limestone, an argillaceous dolomitic limestone and a basal ferruginous sandstone. The thickness of the interval ranges from 6 feet to the vanishing point. The upper 2½ feet are composed of the limestone mentioned above which is absent at most localities, the underlying 3 feet is brecciated chert; and the lower 6 to 9 inches is sandstone. Clark also found that these rocks rested on the Cotter dolomite and at various places in the area was overlain by the Sylamore sandstone, the Chattanooga shale, or the Compton limestone. A conodont fauna obtained from the limestone and basal sandstone was identified by Ellison as Devonian. The rocks described above are a new element in southwestern Missouri stratigraphy; their lithologic character, stratigraphic position and faunal content represent a new formation, for which the name Fortune is proposed.

LOCATION OF THE AREA

The area in which the Fortune has been found is located in Barry County, southwestern Missouri, as shown by the outline map (Fig. I.) This area occupies the eastern one-fourth of the Cassville quadrangle and the western one-fourth of the Shell Knob quadrangle. The topography of these two quadrangles was mapped by the U. S. Geological Survey and the printed maps are available for distribution.

FIG. 1. Location of area.

STRATIGRAPHY OF THE FORTUNE AND ASSOCIATED FORMATIONS

COTTER FORMATION.

Outcrops of dolomite near the town of Cotter, Baxter County, Arkansas, were called Jefferson City by E. O. Ulrich.[2] However, in 1912[3] he determined that these beds were younger than Jefferson City and he then named them Cotter. These beds are described by Purdue and Miser.[4]

McQueen[5], has shown that the Cotter is present in southwestern Missouri, and examination of insoluble residues of cuttings from wells has shown that the Cotter is present in the area under discussion. It has a thickness of 175 feet in the city of Cassville well in sec. 29, T. 23 N., R. 27 W. It may be overlain by the Fortune, Sylamore, Chattanooga or the Compton. The top of the Cotter is an unconformable surface in each case.

SYLAMORE FORMATION

The name Sylamore was first proposed by J. C. Branner in an unpublished report[6] with the type locality designated on South Sylamore Creek in Stone County, Arkansas. Ulrich extended the name into northwestern Arkansas, and his usage was followed by Purdue and Miser in the Eureka Springs and Harrison Quadrangles. Moore[7] extended the name into southwestern Missouri, assigning to the formation an early Mississippian age, but implying that the Compton was disconformable on the Sylamore without so stating. The name Sylamore as used in this report is applied to the sandstone that underlies the Chattanooga shale or the Compton limestone and rests upon Cotter dolomite or Fortune chert and limestone. It is the same sandstone described by Moore.[8]

[2]Ulrich, E. O., Revision of the Paleozoic Systems: Bull. Geol. Soc., of America, Vol. 22, pp. 281-680, 1911.

[3]Willmarth, M. Grace, Lexicon of geologic names of the United States; U. S. Geol. Survey Bull., 896, page 529, 1938.

[4]Purdue, A. H., and Miser, H. D., U. S. Geol. Survey, Geol. Atlas, Eureka Springs, Harrisonville folio (No. 202) p. 4, 1916.

[5]McQueen, H. S., Insoluble residues as a guide to stratigraphic studies: Mo. Bur. Geol. and Mines, 56th Bien. Rept., App. I, p. XIII, 1931.

[6]Willmarth, M. Grace, Lexicon of geologic names of the United States: U. S. Geol. Survey Bull. 896, page 2103, 1938.

[7]Moore, Raymond C., Early Mississippian in Missouri: Mo. Bur. Geol. and Mines, Vol. XXI, 2nd ser. p. 108 and 110, 1928.

[8]Op. cit.

The Sylamore is composed of medium to coarse quartz grains which are translucent, well rounded, and sometimes are frosted. The color varies from white to light brown to olive green; the latter is common and distinctive. It frequently contains grains of phosphate rock, fragments of fish teeth and conodonts. Usually the sand is calcareous but may be secondarily silicified. The lower surface of some of the basal beds shows a pronounced development of a tangled mass of elevated ridges which may represent the filling of sun cracks. The thickness of the Sylamore in the area varies in short distances from zero to three feet, but is usually less than 12 inches. At many localities it is represented by a persistent one to two inch bed of sandstone, The Sylamore lies unconformably on the Cotter or the Fortune, but appears to be conformable with the overlying Chattanooga of which it may be a basal member. Fragments of oolitic Cotter chert and chert of the Fortune formation have been observed in the lower portion of the Sylamore.

CHATTANOOGA FORMATION

The name Noel was proposed by Adams and Ulrich[9] for the black carbonaceous fissile shales that outcrop in the vicinity of Noel, McDonald County, Missouri. In 1905[10] they correlated this shale as it occurs in the Fayetteville quadrangle, Arkansas, with the Chattanooga shale of Tennessee, and adopted the name Chattanooga. Moore[11] continued this usage and mentions[12] the shale as occurring in the area of this report. He classed the shale as lower Mississippian, Kinderhook. The age of the Chattanooga has been the subject of much controversy some placing it in the Devonian and others in the Mississippian. This report does not attempt to place an age on the Chattanooga other than it is younger than the Fortune.

In the area of this report the shale is black and carbonaceous and may possess a bituminous odor, with weathering it breaks into thin sheets and plates and the color lightens to shades of green and brown. It becomes somewhat argillaceous

[9]Adams, G. I., and Ulrich, E. O., The zone deposits of northern Arkansas: U. S. Geol. Survey Prof. Paper 24, pages 24-25, 1904.

[10]Adams, G. I., and Ulrich, E. O., U. S. Geol. Survey, Geol. Atlas, Fayetteville folio (No. 119), page 1, 1905.

[11]Moore, Raymond, C., Early Mississippian in Missouri: Mo. Bur. Geol. and Mines, Vol. XXI, 2nd ser. p. 114, 1928.

[12]Op. cit., p. 115.

at places but contains very little sandy material. Pyrite is common and tan disc like organic specks, sporangites, have been noted. In the area of the report the shale ranges in thickness from zero to four feet in short distances. It appears to rest comformably on the Sylamore but is unformably overlain by the Compton.

COMPTON FORMATION

The name Compton was applied by Moore[13] to a limestone which is somewhat widespread in southwestern Missouri. He considered it to be of Kinderhook age and probably a representative of the Chouteau formation of central Missouri. In the area of this report it consists of a gray, fine grained slightly crinoidal limestone which becomes shaley near the base. Portions of it are dense and lithographic in texture. The insoluble residue remaining after digestion of the rock in hydrochloric acid is less than 5 per cent by volume, and consists of bright "lattice like" crystalline pyrite, green shale and silicified worm casts or tubes which are common to the formation. The Compton has been traced from the type area in the subsurface by samples from deep wells and on the surface into the area of the report. The average thickness in this area is 15 feet. It may rest upon the Chattanooga, Sylamore, Fortune, or Cotter. It is the oldest limestone of Mississippian age known in southwestern Missouri, and represents the lower 10 to 15 feet of the beds called St. Joe in northern Arkansas.

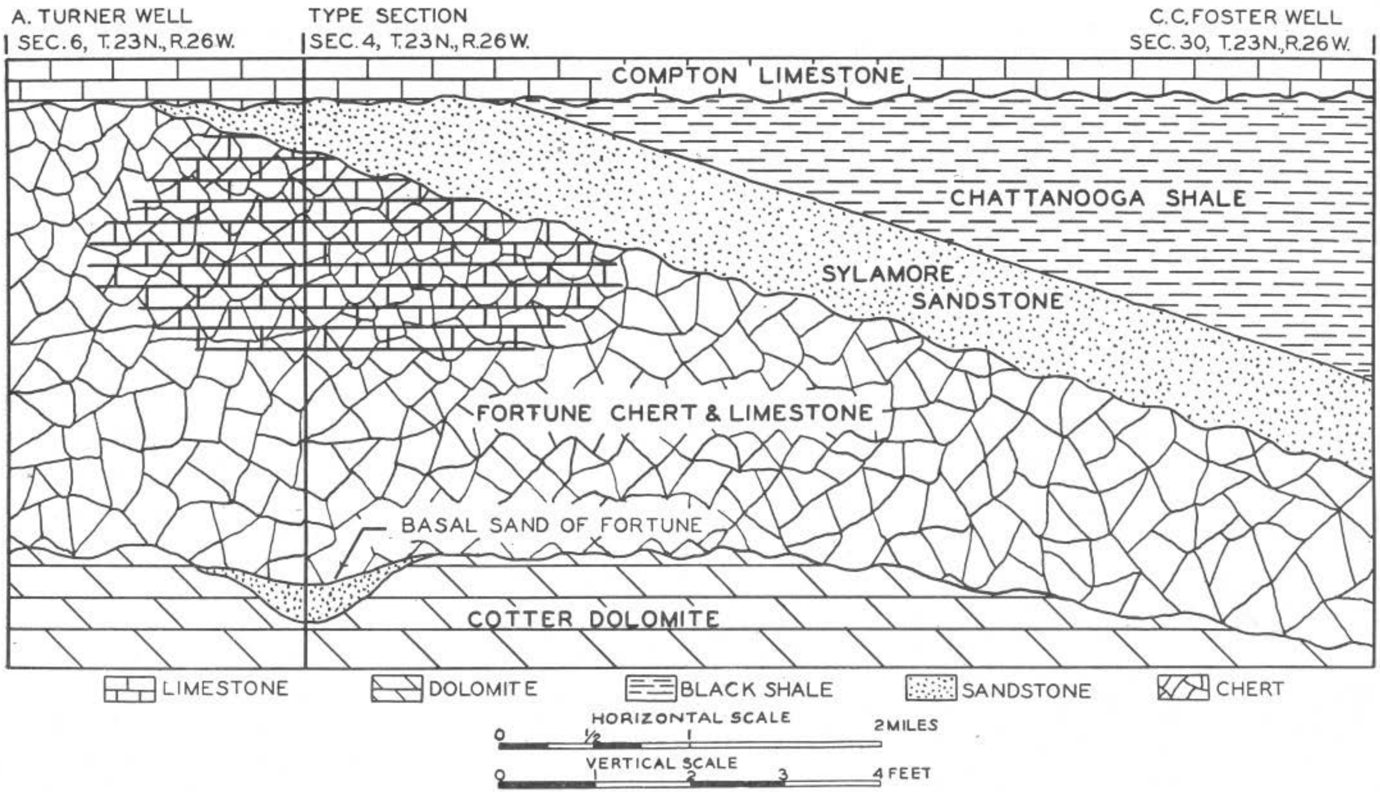
FORTUNE FORMATION

Name: The name Fortune is given to the rocks which intervene between the Cotter dolomite below and the Sylamore sandstone above. The name is taken from Fortune Branch located in the SW¼ sec. 4, T. 23 N., R. 26 W., Barry County, Missouri. The location of the branch is shown in the extreme northeastern portion of the topographic map of the Cassville quadrangle. The type section can be reached by following a private road or trail, which leaves Missouri State Highway No. 44 about 9 miles northeast of Cassville at a point in the SW¼ sec. 33, T. 24 N., R. 26 W., and proceeding one mile to within approximately 150 feet of Fortune Branch in the NE¼

[13] Op. cit., p. 118.

CROSS SECTION SHOWING STRATIGRAPHIC RELATIONS OF FORTUNE FORMATION

DATUM BASE OF COMPTON



SW¼ SW¼ sec. 4, T. 23 N., R. 26 W. The type section forms a small bench in the private road or trail about 20 feet above the bottom of Fortune Branch.

Type Section: At the type section the following sequence of rocks may be observed.

	Thickness	
	Feet	*Inches*
Compton, Limestone, gray dense to finely crystalline, somewhat shaley at base	15	
Sylamore, sandstone, gray green, friable, argillaceous, and contains phosphatic pebbles. (Exposed north of trail at base of tree alongside a mineral prospect, the sand occupies a light depression in the underlying limestone)		9
Fortune, limestone, black dense with secondary calcite brecciated and mineralized with pyrite and sphalerite	2	6
Fortune, chert, dense, light cream to olive buff interrupted by small areas of chert that is citrine drab to grayish olive gray in color. These areas produce a distinctive mottled or speckled appearance which is characteristic and makes it so easily recognized. The chert has embedded in it what appear to be small white spicules	2	9
Fortune, sandstone, poorly sorted fine and coarse grains of quartz stained brown by iron oxide, and cemented in part by calcium carbonate. Fragments of fish teeth are common		9
Cotter, dolomite fine grained, slightly cherty and argillaceous, observed thickness	10	

A sketch of the succession at the type section is shown on Plate I.

Distribution: The Fortune formation is restricted in its outcrops to the eastern one-fourth of the Cassville quadrangle, and the western one-fourth of the Shell Knob quadrangle, covering an area of approximately 100 square miles. The most southern outcrop is on the north side of the rounded hill in the SW¼ sec. 9, T. 21 N., R. 26 W. The western limits are along Off-Davis Hollow, T. 22 N., R. 27 W.; gravels of the Fortune chert are present in the Sylamore sandstone in Roaring River Hollow, but the chert itself was eroded away prior to the deposition of the Sylamore. To the north it has been recognized along Missouri State Highway 44 in the NE¼ SE¼ sec. 27, T. 24 N., R. 26 W. The easternmost extension of the formation is in the vicinity of Shell Knob where only the chert is present.

Description of succession in wells: As mentioned in the Introduction the Fortune was first noted by Grohskopf in samples from two wells in the area.

The first well in which it was noted was the C. C. Foster well, Mo. Geological Survey No. 4281, SW cor. SE¼ SE¼ sec. 30, T. 23 N., R. 25 W., in which the following formations were logged:

	Depth in Feet *From*	*To*
Mississippian System:		
No Samples	0	195
Fern Glen Formation:		
Limestone, dark green, dense to fine grained, a few pieces dark red to maroon	195	200
Limestone, cream and red, dense to finely crystalline	200	203
Limestone, as above	203	207
Limestone, dark green, finely granular, some green shale	207	212
Compton Formation:		
Limestone, pale green and white, finely crystalline, some pyrite	212	215
Limestone, light gray, dense, some finely crystalline; a little green limestone, pyrite	215	220
Compton and Chattanooga Formations:		
Limestone as above; shale black, hard and fissile, containing spores	220	228
Devonian System:		
Fortune Formation:		
Chert, gray-tan, dense, waxy lustre, alternate light and dark banding; contains embedded white spicules; the sample also contains some dolomite, rounded white sand grains (Sylamore?) and black shale (Chattanooga ravelled from above)	228	231
Ordovician System (Canadian of E. O. Ulrich)		
Cotter Formation:		
Dolomite, gray and tan, finely crystalline; some sand and green shale; a little dolocastic chert	231	265 Total Depth

It will be noted that in this well the Chattanooga shale is present, but the upper black limestone and the basal sand of the type section are absent. Furthermore the thickness of the Fortune is only 3 feet. This is shown by the sketch Plate I.

A different relationship is noted from the samples of the Alvin Turner well, Mo. Geological Survey No. 5469, located at the NE cor. sec. 6, T. 23 N., R. 26 W., where the following was logged:

	Depth in Feet From	Depth in Feet To
Mississippian System:		
No samples	0	205
Fern Glen formation	205	250
Compton formation	250	260
Devonian System:		
Fortune formation	260	265
Ordovician System (Canadian of E. O. Ulrich):		
Cotter formation	265	280 Total Depth

The lithology of the Mississippian and Cotter formations in this well is essentially similar to that in the C. C. Foster well. However, the Fortune is here composed entirely of chert which has a thickness of five feet. The Sylamore and Chattanooga are absent in this well by regional overlap as shown by Plate I.

Description of Localities: The unconformity of the Sylamore on the Fortune can be best observed in two mine tunnels on the east wall of a small tributary of Fortune Branch in the NE¼ NE¼ SW¼ sec. 4, T. 23 N., R. 26 W. This locality is on the topographic map of the Shell Knob quadrangle. The two tunnels were driven into the hillside about 30 feet above the valley floor in search of zinc ore. The tunnels, which are about 150 feet long, 7 feet high, and 6 feet wide, have been driven along the Fortune formation. In the tunnels the Compton, which forms the roof or back, is seen resting on the Sylamore sand. The Sylamore averages about 3 inches in thickness for the tunnel length but at places it cuts into the underlying Fortune and at these points the sand is up to 12 inches thick. It will be noted that the Chattanooga is here absent. The Fortune in the tunnels is six feet thick and is composed in the main of chert. A little of the black limestone of the type locality, which is about ½ mile southwest, is present at isolated spots. The basal sand of the Fortune is also absent and the floor of the tunnels is on the Cotter dolomite.

The occurrence of Chattanooga on Fortune can be seen opposite the east entrance to Natural Bridge in the SW¼ SE¼

NE¼ sec. 18, T. 22 N., R. 26 W. and along the west side of Barry County Highway P in the NE¼ SW¼ NW¼ sec. 33, T. 22 N., R. 26 W., at Wolfpen Gap. Other areas where the character of the formation and its relations above and below may be seen are as follows: in Sugar Camp Hollow, in the SW¼ NW¼ NE¼ sec. 17, T. 23 N., R. 26 W.; in the SW¼ SE¼ SW¼ sec. 21, T. 23 N., R. 26 W.; in Galena Hollow, in the NW¼ SE¼ SE¼ sec. 17, T. 23 N., R. 26 W.; and in Garner Hollow, in the NW¼ SW¼ SW¼ sec. 28, T. 22 N., R. 26 W.

Thickness: The Fortune formation in its type locality has a maximum thickness of six feet. From this locality it thins and varies from two to four feet, the average thickness of the preserved portion being two feet.

Lithologic Character: In the type locality, as has been described, the formation consists of an upper limestone, a middle chert, and a basal sandstone. Over most of the area the chert is the only portion of the formation which has been preserved because of its resistance to weathering.

Topographic expression: The Fortune formation does not exert a great influence on the topography. A bench is often noted just below the Chattanooga shale which frequently marks the occurrence. However, the underlying Cotter forms similar benches which cannot be distinguished except by very close inspection of the character of the cherts.

Structure: The area in which the Fortune occurs is a syncline which has a trend of northeast by southwest. The thickest sections of the Fortune occur near the bottom of this syncline, where it was protected from erosion.

Stratigraphic relations: The Fortune formation has nowhere been seen resting on beds older than the Cotter. It has not been possible to show by work to date whether different portions of the Cotter underlie the Fortune at various places but considering the unconformity at the top of the Cotter it is believed that this is the case. The Fortune may be overlain by either Sylamore, Chattanooga, or Compton. This is shown by the sketch Plate I. The section is drawn along a northwest-southeast line between the two wells heretofore described. The type section is about one-half mile northeast of this line and has been placed in the section at its proper position. This section shows the overlap of the Compton on the Sylamore or Fortune. Were the section continued farther northwest it could be shown from wells that the Compton finally overlaps onto the Cotter. The unconformity of the Sylamore on the Fortune is also evident in the mine tunnels in sec. 4, T. 23 N., R. 26 W. This evidence of unconformity together with the fact that conglomerate of Fortune chert has been found in the Sylamore indicates that there was erosion of the Fortune prior to the deposition of the Sylamore. During this period most of the Fortune, except that in the synclinal area was removed.

Paleontology: Conodonts were obtained from the limestone and basal sandstone of the Fortune collected at the type locality. Some fish remains were also obtained but no specific identification of these have been made. All of the conodont species described were common in the black limestone but the basal sandstone contained only the conodont *Polygnathus pennata,* Branson and Mehl. The conodont identifications were all made by Ellison and specimens are deposited in the School of Mines and Metallurgy microfossil collections.

CONODONTS

Genus *Icriodus* Branson and Mehl, 1934
Icriodus alternatus Branson and Mehl
Plate II, Figures 3, 6

Icriodus alternatus Branson and Mehl, 1934, Univ. Missouri Studies, vol. 8, p. 225, pl. 13, figs. 4-6. Branson and Mehl, 1938, Jour. Paleontology, vol. 12, p. 161, pl. 26, figs. 4-6.

This species is easily distinguished by the alternate position of the median row denticles and the lack of a wide flaring apron at the posterior end. Many of the smaller specimens from the Fortune limestone fall into this species. It is known elsewhere in Missouri from the Snyder Creek shale and the Grassy Creek shale both of Devonian age.

Icriodus expansus Branson and Mehl
Plate II, Figures 1, 2, 5, 8, 11, 13

Icriodus expansus Branson and Mehl, 1938, Jour. Paleontology, vol. 12, p. 160, pl. 28, figs. 18-21.

The thin widely flaring sides and the coalescence of the denticles transversely to form three node ridges are the characteristic features of this species. Most of the Icriodids found in the Fortune limestone belong to this species.

It was designated the genotype for Icriodus in 1934 but the specific description was not published until 1938. The forms are found elsewhere in the Mineola limestone, Snyder Creek shale, Genundewa limestone, Silica shale, New Albany shale, Alpena limestone, and Sylamore sandstone.

Icriodus latericrescens Branson and Mehl
Plate II, Figures 4, 7

Icriodus latericrescens Branson and Mehl, 1938, Jour. Paleontology, vol. 12, p. 164, pl. 26, figs. 30-37.

Several small specimens of this unique species were found in the Fortune limestone. The distinguishing feature is the presence of a postero-lateral spur. The Fortune limestone specimens are small and do not exhibit long spurs neither do they show the suppression of the median row of denticles, a feature so characteristic of the larger specimens described by Branson and Mehl. The species is known elsewhere from the Mineola limestone, Jeffersonville limestone, Ferron shale, and Silica shale. One rare occurrence in the Genundewa limestone is explained by Branson and Mehl as a stratigraphic admixture.

Genus *Polygnathus* Hinde, 1879
Polygnathus pennata Hinde
Plate II, Figures 9, 10, 12

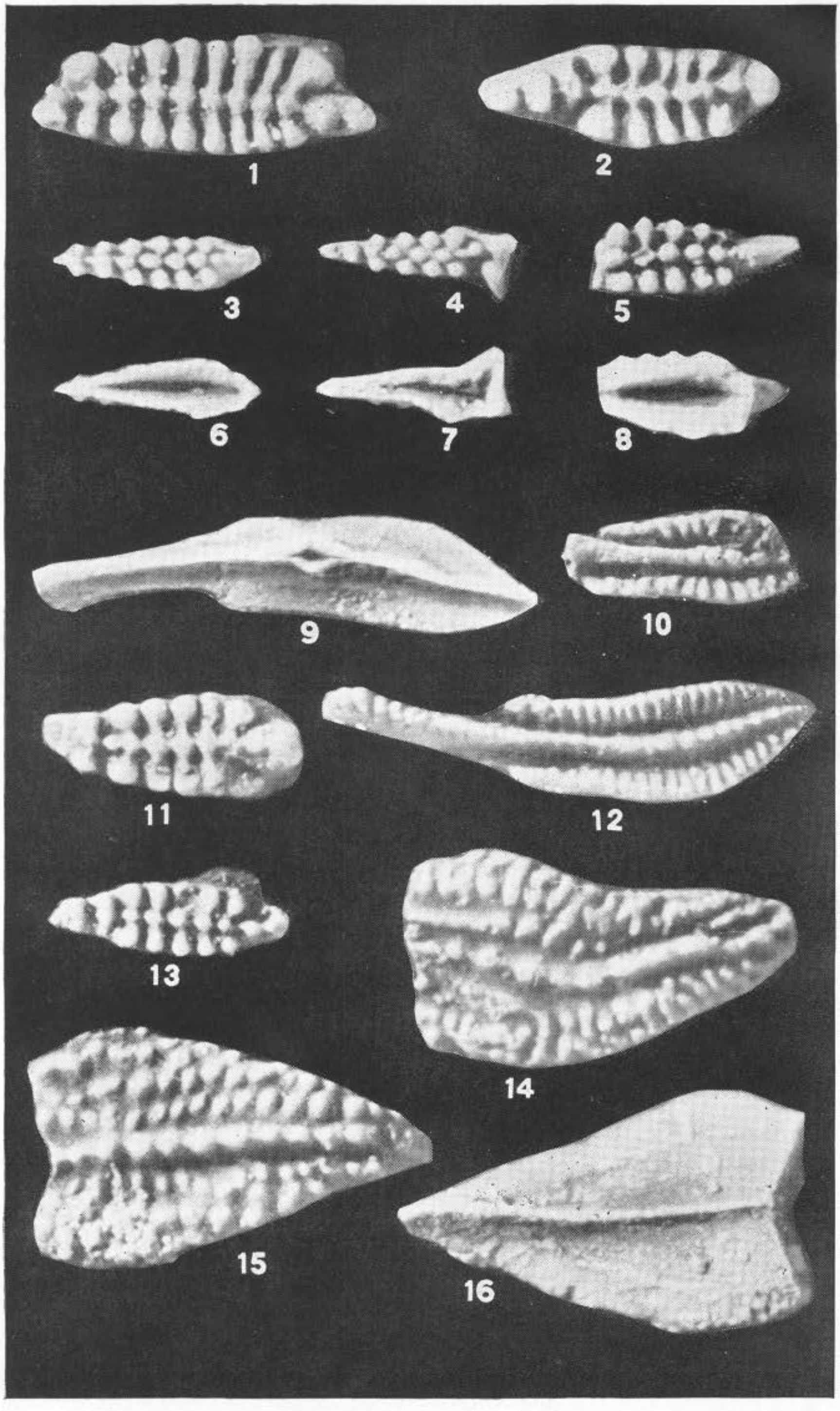
Polygnathus pennata Hinde, Branson and Mehl, 1934, Univ. Missouri Studies, vol. 8, p. 144, pl. 11, fig. 3. (Complete synonomy given here.)

The low median carina flanked by low tuberculate transverse ridges on the oral surface are the distinguishing features of this species. It is common in the shales and limestone of middle and upper Devonian rocks in New York, Tennessee, and Missouri.

Polygnathus nodocostata Branson and Mehl
Plate II, Figures 14, 16

Polygnathus nodocostata Branson and Mehl, 1934, Univ. Missouri Studies, vol. 8, p. 246, pl. 20, figs. 9-13; pl. 21, fig. 15.

Polygnathus signata Huddle, 1934, Bull. American Paleontology vol. 21, no. 72, p. 98, pl. 8, fig. 11.



Conodonts of Fortune Formation.

This highly variable form is distinguished by the low median carina and the arrangement of the oral tubercles in rows longitudinally. The species is the largest of the conodonts in the Fortune limestone and is known elsewhere from the Grassy Creek shale and New Albany shale.

Huddle's species is placed in synonomy here without examination of the types. However, the forms are distinctive enough to warrant this conclusion.

EXPLANATION OF PLATE II

(All figures X40)

Figures

1, 2, 5, 8, 11, 13. *Icriodus expansus* Branson and Mehl (all oral views except figure 8 which is an aboral view). Fortune limestone, Fortune Branch creek, Barry County, Missouri. M. S. M. No. 7166.

3, 6. *Icriodus alternatus* Branson and Mehl (oral and aboral views). Fortune limestone, Fortune Branch creek, Barry County, Missouri. M. S. M. No. 7165.

4, 7. *Icriodus latericrescens* Branson and Mehl (oral and aboral views). Fortune limestone, Fortune Branch creek, Barry County, Missouri. M. S. M. No. 7167.

9, 10, 12. *Polygnathus pennata* Hinde (aboral and two oral views). Fortune limestone, Fortune Branch creek, Barry County, Missouri. M. S. M. No. 7168.

14, 16. *Polygnathus nodocostata* Branson and Mehl (two oral and one aboral views). Fortune limestone, Fortune Branch creek, Barry County, Missouri. M. S. M. No. 7169.

MACRO FOSSILS

Very few macro fossils have been found in the Fortune. At the type locality two genera of silicified brachiopods were found, they are poorly preserved but suggest an *Atrypa* and a *Spirifer* type. Dr. G. A. Cooper, of the U. S. National Museum, has confirmed these identifications.

Age and correlation: The lithology and stratigraphic position of the Fortune suggest a Devonian age. The conodont assemblage is somewhat more restrictive in that it indicates a middle or upper Devonian age. No regional formational correlation is here attempted, but it is interesting to note that chert similar to that of the Fortune occurs in the Callaway limestone in northeast Missouri, at what is known as the Bobs Creek section, located in the SE¼ sec. 34, T. 50 N., R. 1 E., and described in detail in the Guidebook of the 15th Annual Field Conference of the Kansas Geological Society, 1941.

V

The

LEXINGTON COAL

In

Northwestern Missouri

By

FRANK C. GREENE

Appendix V, 62nd Biennial Report

1943

MISSOURI

GEOLOGICAL SURVEY AND WATER RESOURCES

H. A. BUEHLER

DIRECTOR AND STATE GEOLOGIST

ROLLA, MISSOURI

THE LEXINGTON COAL IN NORTHWESTERN MISSOURI

By Frank C. Greene

When the Missouri Geological Survey published its report on the coal resources of Missouri[1] in 1913, attention was called to the persistence of the Lexington coal seam, but at that time active mining was confined to the Lexington-Richmond district in Lafayette, Ray and southeastern Clay counties and the Mendota district in Putnam, Schuyler, Adair and Sullivan counties. Between the two districts some mining had been attempted, but in general the bed was not found to be satisfactory. This does not preclude the possibility that the intervening area contains areas of workable coal at the Lexington horizon. Prospecting may show good reserves of coal in this intervening area.

Since the above-mentioned report was published, the Lexington coal has been opened to production in a large area to the west of the earlier development. New shafts have been sunk in the vicinity of Excelsior Springs, Mosby and Kearney in Clay County, Elmira in Ray County, near Cameron, in Caldwell County and near Winston in Daviess County. An advantage enjoyed by the district is that the region to the west has few coal mines of importance and presents a good market.

EXCELSIOR SPRINGS-MOSBY AREA, CLAY COUNTY.

In the Excelsior Springs-Mosby area the Lexington coal averages about 24 inches thick, but ranges from 18 inches to 32 inches. The black slatey shale above the coal is about 6 inches thick. In all mines the longwall method is used.

The depths of the shafts vary according to the surface topography, but many of the mines are situated in valleys, thus reducing the depth. The following log of a test hole is typical of the formations which will be encountered in sinking a shaft.

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[1]Hinds, Henry, The Coal Deposits of Missouri, Mo. Bur. Geol. & Mines, Vol. XI, 2d ser., 1913.

Log of test hole drilled by Mr. Geo. Rice in the SW. 1/4, NW. 1/4 sec. 15, T. 52 N., R. 30 W., Clay County, Missouri.

	Thickness, Ft.	Thickness, In.	Depth, Ft.	Depth, In.
Pleistocene series:				
Clay	18		18	
Pennsylvanian system:				
Kansas City group:				
Lime (Bethany Falls)	18		36	
Blue shale	4		40	
Lime (Hertha)	7		47	
Pleasanton group:				
Blue shale	11		58	
Red shale	4		62	
Light shale	14		76	
Lime (water)	3		79	
Gray shale	71		150	
Sandy lime	5		155	
Sand (Wayside)	9		164	
Blue shale	2		166	
Red shale	4		170	
Gray shale	2		172	
Light blue shale	30		202	
Blue shale	8		210	
Henrietta group:				
Lime	4		214	
Gray shale	3		217	
Lime	1		218	
Shale gray green	12		230	
Lime	2		232	
Gray shale	2		234	
Brown lime	9		243	
Gray shale	2		245	
Black shale	1		246	
Lime	2		248	
Black shale	3		251	
Lime	4	6	255	6
Slate		6	256	
Coal (Lexington)	2		258	
Clay		6	258	6
Lime	..		T. D.	

It will be noted that the top of the coal is 209 feet below the Hertha limestone. The Hertha limestone is easy to recognize in drilling and the approximate depth to the coal can be computed.

An analysis of the Lexington coal from the Excelsior Springs area by the U. S. Bureau of Mines follows:

Analysis of coal from mine of Excelsior Springs Coal Company, SE. 1/4 NE. 1/4 sec. 15, T. 52 N., R. 30 W., Clay County, Missouri.

	As Received.
Moisture	12.6 %
Volatile Matter	41.4 %
Fixed Carbon	47.7 %
Ash	10.9 %
Sulphur	4.2 %
British thermal units	12,690

KEARNEY AREA, CLAY COUNTY.

In the Kearney area a shaft was sunk by Mr. John Desideric (Kearney Coal Company). The log of the prospect hole 200 feet north of the shaft is as follows:

Log of prospect hole on Louis Tapp farm, NW. 1/4 NW 1/4 sec. 14, T. 52 N., R. 31 W., Clay County, Missouri.

Formation	*Thickness,* *Ft.*	*In.*	*Depth,* *Ft.*	*In.*
Pleistocene series:				
Clay, yellow	12		12	
Pennsylvanian system:				
Kansas City group:				
Shale	4		16	
Lime, white, hard	2		18	
Shale, blue	2		20	
Lime, hard	2		22	
Shale, gray	10		32	
Lime, hard	10		42	
Shale, gray	2		44	
Lime, white, hard	16		60	
Lime and shale layers	3		63	
Shale, dark	3		66	
Lime, hard (Bethany Falls)	22		88	
Shale and slate	2		90	
Lime (Hertha)	13		103	
Pleasanton group:				
Shale	1		104	
Lime, hard	1		105	
Shale	22		127	
Lime	6		133	
Shale	61		194	
Sandrock, not solid (Wayside)	9		203	
Dark shale	2		205	
Red shale	7		212	
Gray shale	4		216	
Sandrock	20		236	
Gray shale	13		249	
Henrietta group:				
Limerock	2		251	
Shale, gray	7		258	
Lime, gray	3		261	
Shale, dark	4		265	
Sandrock (water)	15		280	
Shale	5		285	
Limerock	7		292	
Lime, gray	3		295	
Shale, dark	6		301	
Lime, blue	6		307	
Slate		8	307	8
Coal (Lexington)	2	2	309 T. D.	10

Coal production in the Excelsior Springs-Mosby-Kearney district in 1941 according to the Fifty-fourth annual Report of the Department of Mines and mining for the Fiscal Year 1941 was as follows:

Company	*Tons produced.*
Boothe Coal Co.	43,759
Excelsior Springs Coal Co.	15,141
Kearney Coal Co.	9,103
Mosby Coal and Development Co.	28,416
Producers Coal Co.	5,502
Rice Coal Co.	39,550
Perry Rice Coal Co.	......

ELMIRA AREA, RAY COUNTY.

The Lexington coal has been mined in Ray County for many years in the vicinity of Richmond, Camden, Knoxville and other places in the central and southern part of the county, where it has achieved an excellent reputation under the trade name of Richmond coal. In 1922 a prospect hole was drilled in the northwest part of the county near Elmira, as follows:

Log of Prairie Block Coal Co., T. G. Fowler farm. Location: SW. 1/4 NE. 1/4 sec. 16, T. 54 N., R. 29 W., Ray County, Mo. Elevation: 883 feet. Completed May 15, 1919 Well No. 19 on map, Pl. I.

	Thickness, Ft.	*Thickness, In.*	*Depth, Ft.*	*Depth, In.*
Recent series:				
Clay	5		5	
Pennsylvanian system:				
Kansas City group:				
Shale, dark	5		10	
Lime, broken	3		13	
Limestone	5		18	
Soapstone	13		31	
Limestone	1		32	
Soapstone, rotten	5		37	
Limestone and shale	4		41	
Shale	2		43	
Lime shale	16		59	
Limestone	4		63	
Shale	3		66	
Limestone	2		68	
Shale	16		84	
Limestone	5		89	
Shale	2		91	
Limestone (Bethany Falls)	25		116	
Shale	6		122	
Limestone	2		124	
Shale	2		126	
Flinty limestone, very hard	13		139	
Pleasanton and Henrietta groups:				
Shale	5		144	
Flinty limestone	4		148	
Shale	2		150	
Limestone	10		160	
Shale	10		170	
Limestone, shale	15		185	
Shale	2		187	
Limestone	2		189	
Shale	4		193	
Sandstone, shaly, dense, hard	3		196	
Shale, blue	38		234	
Shale, dark	23		257	

Log of Prairie Block Coal Co.—Continued.

	Thickness, Ft.	Thickness, In.	Depth, Ft.	Depth, In.
Shale, blue	4		261	
Shale, light	14		275	
Shale, sandy	4	6	279	6
Limestone		1	279	7
Shale, black	4	9	284	4
Coal, good, fairly hard, no pyrite in core		8	285	
Fire clay	3		288	
Lime, shale	8		296	
Red shale	2		298	
Limestone	6		304	
Shale	3		307	
Limestone	7		314	
Soapstone	11		325	
Limestone, good cap rock not jointed appreciably	10		335	
Shale, dark	3	2	338	2
Coal } Lexington		8	338	10
Clay band } Lexington		2	339	
Coal, very good, is somewhat pyritic } Lexington	2		341	
Fire clay	2		343	
Limestone	4		347	
Limestone shale	13		360	
Soapstone	9		369	
Shale, dark	3		372	
Coal, dirty		6	372	6
Fire clay	2	6	375	
Lime, shale	5		380	
Shale	3		383	
Limestone	3		386	
Shale	8		394	
Lime, shale	19		415	
Limestone	2	6	417	6
Cherokee group:				
Dark shale		2	417	8
Coal		4	418	
Sandstone	5		423	
Shale	2		425	
Sandstone	5		430	
Shale	19		449	
Sandstone	5		454	
Sandy shale	4		458	
Shale, blue	11		469	
Coal		7	469	7
Fire clay		5	470	
Lime shale	10		480	
Shale, light	2		482	
Shale, blue	2		484	
Shale	3		487	
Carbonaceous shale	6	6	493	6
Coal (Bedford ?)	1	6	495	
Shale	13		508	
Shale, dark	3		511	
Coal (Bevier ?)	2		513	
Sandy shale	5		518	
Lime, shale	7		525	
Coal	1		526	
Shale	9		535	
Shale, blue	3		538	
Shale, dark	3		541	
Coal	1		542	
Shale, light	3		545	
Lime, shale	5		550	
Shale, light	3		553	
Shale, dark, lime partings	7		560	
Sandy shale	40		600 Total depth*	

*Base of Cherokee not reached.

In the shaft of the Elmira Coal Company, near the above prospect hole, but at a higher elevation, the coal averages 30 inches thick and the shaft is 360 feet deep. According to the Fifty-fourth Annual Report of the Department of Mines and Mining for the Fiscal Year 1941, the production for that year was 41,931 tons.

CAMERON AREA, CALDWELL COUNTY.

The shaft of the Cameron Mining Company is three miles east of Cameron in Caldwell County, although Cameron is in Clinton County. A core drill hole was put down in 1937 with the following log:

Core Drill Hole of the Cameron Mining Company in the NE. 1/4 NE. 1/4 sec. 20, T. 57 N., R. 29 W., Caldwell County, Missouri.

	Thickness,		*Depth,*	
	Ft.	*In.*	*Ft.*	*In.*
Pleistocene series:				
No core—surface clay and sand	0		33	6
Pennsylvanian system:				
Kansas City group:				
Lime	8	6	42	
Shale, dark	2		44	
Lime, dark gray	1		45	
Shale, dark gray	2		47	
Lime, gray	3		50	
Shale, dark	1		51	
Lime	2		53	
Shale, gray, firm	2		55	
Shale, gray, soft	5		60	
Shale, gray, soft	10		70	
Lime, gray, dark bands	23		93	
Shale, black, slaty	4		97	
Clay, gray	3		100	
Lime, gray	17		117	
Lime, dark, hard (Bethany Falls)	3		120	
Shale, black, slaty	2		122	
Lime, gray (Hertha)	14		136	
Pleasanton group:				
Shale, gray	2		138	
Shale, greenish, sandy	6		144	
Sandstone, gray, limy	5		149	
Sandstone, gray, some dark bands. (Long cores indicate sandstone is massive to a large extent)	95		244	
Limestone (nodular)	2		246	
Sandstone	11		257	
Shale, gray	11		268	
Shale, dark	2		270	
Henrietta group:				
Lime, gray		6	270	6
Shale, black	2	6	273	
Shale, gray	4		277	
Clay, gray	3		280	
Lime, greenish dense	2		282	

Core Drill Hole of the Cameron Mining Company—Continued.

		Thickness,		*Depth,*	
		Ft.	*In.*	*Ft.*	*In.*
Clay, calcareous		2		284	
Shale, gray		7		291	
Clay, greenish		1		292	
Clay, gray and maroon		7		299	
Clay, green and maroon		1		300	
Clay, greenish		2		302	
Lime, gray, dense argilliceous		6		308	
Lime, gray		4		312	
Shale, gray		1		313	
Lime, gray		1		314	
Sandstone, gray, banded		3		317	
Shale, dark, slightly sandy		3		320	
Lime, hard, gray to dark gray		4	8	324	8
Shale, black		1		325	8
Coal			10	326	6
Bat			1.5	326	7.5
Coal	Lexington	1	8.5	328	4
Bone coal			3	328	7
Clay			5	329	

The shaft, at a higher level than the prospect hole, is 350 feet deep and was completed in 1938. An analysis of the coal made by the U. S. Bureau of Mines is as follows:

Analysis of the Lexington Coal from the shaft of Cameron Mining Company, three miles east of Cameron, Missouri.

Proximate analysis:	*Air dried.*	*As Rec'd.*
Moisture	2.1 %	9.9 %
Volatile matter	39.6 %	35.4 %
Fixed carbon	44.5 %	41.0 %
Ash	13.8 %	12.7 %
	100.0 %	100.0 %
Ultimate analysis:		
Hydrogen	4.9 %	5.4 %
Carbon	69.0 %	63.5 %
Nitrogen	1.1 %	1.0 %
Oxygen	7.8 %	14.3 %
Sulphur	3.4 %	3.1 %
Ash	13.8 %	12.7 %
	100.0 %	100.0 %
British thermal units	12,290	11,310

The mine is inactive at present.

WINSTON AREA, DAVIESS COUNTY.

The shaft of the Winston Coal Company is about one mile south of Winston. It is the deepest in the state and the most northwestern point at which the Lexington coal has been mined. The log of the second shaft is as follows:

Log of second shaft of Winston Coal Company. Location: About center SE. 1/4 NW. 1/4 SE. 1/4 sec. 4, T. 58 N., R. 29 W., Daviess County, Mo. Elevation: 1,012 feet. Completed March 27, 1937.

		Thickness, Ft.	Thickness, In.	Depth, Ft.	Depth, In.
Pleistocene series:					
Clay, yellow, slightly sand, few boulders		75		75	
Pennsylvanian system:					
Lansing group:					
Shale, hard, gray, sandy		8		83	
Sandstone, fine-grained, gray, micaceous, ripple-marked, and gray sandy shale; coaly streak at 85.		18		101	
Kansas City group:					
Described as "4 layers of bastard limestone 3″-9″ thick, soapstone between" (2 beds hard gray, mic. calc. sandstone and 2 beds coarsely x-line limestone)		4		105	
Gray "soapstone"		4		109	
Gray mic. shale, foss, slightly limy.					
Blue "soapstone"		6		115	
Dark thinly lam. shale mic. and sandy, and carb. material.					
Limestone, fine-grained to coarse, crystalline (Raytown)		9		124	
Black slaty shale, reported as immediately under limestone (probably some gray shale intervening)		1	2	125	2
Gray shale		10 ±		135 ±	
Dark clay		7 ±		142 ±	
Lime rock, gray and green (Cement City)		8		150	
Shale		2		152	
Soapstone		4		156	
Limerock (Westerville)		4		160	
Soapstone		14		174	
Gray rock and soapstone		1		175	
Gray limestone		4		179	
Soapstone		8		187	
Limerock		1	6	188	6
Soapstone		4		192	6
Limerock		3		195	6
Dark shale		1		196	6
Limerock		2		198	6
Dark shale		8	6	207	
Limestone, dense, fine-grained, brecciated appearance, with clay veins, alt. with calc. shale		7		214	
Limestone, dense, cherty, dark shale, partings		17		231	
Limestone, dense, cherty, dark shale partings	Winterset	6		237	
Dark gray shale					
Black foss. shale		3		240	
Dense black shale					
Limestone, gray		8		248	
Gray shale					
Black slaty slate		5		253	
Limestone, mottled light and dark gray (Bethany Falls)		14		267	
Gray "soapstone"		1	4	268	4
Black slaty shale		1	4	269	8
Gray limestone			8	270	4
Dark "soapstone"		4	8	275	
Limestone, top uneven and nodular		7		282	

Log of second shaft of Winston Coal Company—Continued.

	Thickness,		*Depth,*	
	Ft.	*In.*	*Ft.*	*In.*
Pleasanton group:				
Shale, gray, some purple shale	23		305	
Sandstone, gray	15		320	
Shale, little pockets of sand	10		330	
"Soapstone" (gray shale)	31		361	
Limestone, gray, nodular, dense		2	361	2
Shale, gray	8	7	369	9
Limestone, gray, nodular, dense		3	370	
Shale, gray	3		373	
Red bed, some green shale	4		377	
Sandstone, uneven streaked	4		381	
Red bed	1		382	
Sandy "soapstone"	4	6	386	6
Soapstone	8		400	
Henrietta group:				
Limestone, hard pinkish ("granite")	1	3	401	3
"Jointed slaty soapstone" (shale) dark gray and purple	5	9	407	
"Turtle backs," limestone lenses and nodules, dense lithographic, in shale, and banded gray and yellow shale	4		411	
Shale, gray, green, and maroon	3		414	
Shale, gray, massive	16		430	
"Dirt" grayish-black (shale)	3		433	
"Turtle backs" (Nod. Ls.)	3		436	
Gray shale	5		441	
Limestone	1		442	
Dark shale	2		444	
Limestone		6	444	6
Shale		6	445	
Limestone 8″ or 10″		6	445	6
Gray-banded shale, sandy, sharp contact	4		449	6
Black bat (black calc. foss. shale)		8	450	2
Limestone, shaly at top, grades into above		4	450	6
Limestone, brownish-gray, Chaetetes at top, has calcite lined cavities	4		454	6
Black bat (black calc. foss. shale)		6	455	
Hard black slaty shale, small rounded concretions at base		6	455	6
Black bat (black calc. foss. shale, local pocket on south side of shaft	..		...	
Coal (Lexington)	3		458	6
Fire clay with local "sulphur balls"	1		459	6
Green shale with many calc. concretions	1	6	461* Total depth	

*Base of Henrietta not reached.

A detailed measurement of the coal is as follows:

	Inches.
Limestone	....
Black "slate"	12
Coal	9½
Clay seam	2
Coal	20
Sulphur seam	½
Coal	3
Clay	....

An analysis made by the U. S. Bureau of Mines follows:

Analysis of coal from mine of Winston Coal Company, Winston, Daviess County, Mo.

Proximate	*Air dried.*	*As rec'd.*
Moisture	6.1 %	11.5 %
Volatile matter	37.7 %	35.5 %
Fixed carbon	42.9 %	40.4 %
Ash	13.3 %	12.6 %
	100.0 %	100.0 %
Ultimate		
Hydrogen	5.2 %	5.6 %
Carbon	64.6 %	60.8 %
Nitrogen	1.2 %	1.1 %
Oxygen	11.7 %	16.1 %
Sulphur	4.0 %	3.8 %
Ash	13.3 %	12.6 %
	100.0 %	100.0 %
British thermal units	11,740	11,060

The production in 1941 was 20,000 tons according to the Fifty-fourth Annual Report of the Department of Mines and Mining for the Fiscal Year 1941.

CONCLUSIONS.

A large area of the Lexington coal is available in northwestern Missouri at a depth of 200 feet to 600 feet with excellent conditions for longwall mining and a good trade territory in northwestern Missouri and adjoining areas in Kansas, Nebraska and Iowa.

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Manganese Deposits

of

MISSOURI

by

Oliver R. Grawe

Appendix VI, 62nd. Biennial Report

1943

MISSOURI
Geological Survey and Water Resources

H. A. BUEHLER, *State Geologist*
ROLLA, MISSOURI

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MANGANESE DEPOSITS OF MISSOURI

By

Oliver R. Grawe

CHAPTER I.

INTRODUCTION

STRATEGIC IMPORTANCE OF MANGANESE

High grade manganese ore is the most important of all the ores designated as strategic by the Commodities Division of the Army and Navy Munitions Board. Although a considerable quantity of low grade manganese ore is known to exist within the borders of the United States, very little high grade ore suitable for direct use by the chief consumer, the steel industry, has been discovered. Manganese is absolutely essential in the manufacture of all kinds of steel, an average of 12.5 pounds of manganese being required for each ton of steel produced. In 1940, according to the U. S. Bureau of Mines[1], this country produced only 3 percent of its domestic requirements, the other 97 percent being supplied chiefly by Russia, The Gold Coast, British India, Union of South Africa, Brazil, and Cuba.

Although as early as 1924 a competent committee[2] advised the government to establish stock piles of high grade manganese ore for use in an emergency, no action was taken upon this sound advice until June 7, 1939, when Congress passed the Strategic Minerals Act[3]. This act provided funds for the purchase of strategic and critical materials by the Procurement Divi-

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[1]Ridgway, R. H., Davis, H. W., and Mathews, A. F., Manganese and manganiferous ores: U. S. Bur. Mines Minerals Yearbook, Review of 1940, p. 547, 1941.

[2]Report of the Subcommittee on Manganese of the Committee of the Mining and Metallurgical Society of America on Foreign and Domestic Mining Policy and the Committee of the American Institute of Mining and Metallurgical Engineers on Industrial Preparedness; *International Control of Minerals*, p. 85, 1925.

[3]Public No. 117, 76th Congress, 1st session, ch. 190.

sion of the U. S. Treasury Department and appropriated funds to the U. S. Bureau of Mines and to the U. S. Geological Survey for the investigation, development, mining and utilization of domestic ores which are essential to the common defense and to the industrial needs of the United States. In 1942 these appropriations were greatly enlarged to permit the speeding up of the work of these governmental agencies.

PURPOSE OF THIS INVESTIGATION

In order to lend all possible assistance to increasing the nation's production of strategic minerals, the Missouri Geological Survey formulated a program for the investigation of such of these minerals as are known to exist within the State. As a part of this program the Director of the Survey, Dr. H. A. Buehler, assigned the writer to examine the manganese deposits, to ascertain their size, character of the ore, mode of occurrence and such other features as might lead to the development of known deposits and to the discovery of new ones. This report is the result of field studies conducted principally during the summer of 1941.

ACKNOWLEDGMENTS

The writer is indebted to Dr. H. A. Buehler for the opportunity of conducting this investigation and for his general supervision of the project and to a host of land owners and lessees for permission to examine their properties. In locating the properties much time was saved by the assistance rendered by Mr. Ernest Pearce, who showed the writer his prospects in Iron and Madison counties, by Senator Carter Buford, who spent a week with the writer in Reynolds county and to Mr. Clifford J. Benson, who served as an invaluable guide in Carter and Shannon counties. Mr. W. M. Nash permitted the Survey to make a detailed examination of his prospect in Reynolds county and furnished the Survey with certain data not otherwise obtainable. All analyses not otherwise credited were made by the Survey chemist, R. T. Rolufs.

PREVIOUS WORK

Manganese minerals, particularly pyrolusite, have been known since ancient times. Called by many names, they can be traced back in history through their universal use in decolorizing glass. The metal itself was first recognized as a distinct element by C. W. Scheele in 1774 and was isolated by J. G. Gahn[4] later in the same year.

Who first found manganese in Missouri may never be known, but credit for the first recorded discovery probably goes to that extensive traveler and keen observer, Schoolcraft[5], who 124 years ago, 44 years after the discovery of the element, found it in at least three places in the State and listed it as one of the substances of probable future commercial value in Missouri. Manganese has been intimately tied up with the iron ores of the State from mode of ocurrence to ultimate use. Schoolcraft noted this association with iron ores on the Fourche a Courtois and "near the head of Merrimack River." He also found "a body of manganese on the dividing ridge between Eleven-points and Fourche a Thomas."

Manganese is mentioned in the first publication of the Missouri Geological Survey. Litton[6] found considerable manganese in specimens of iron ore from the Madison Iron and Mining Company's Bogy or Buford Bank in Iron County and Swallow[7] noted the presence of minor amounts of manganese oxide in Cooper, Marion, and Ste. Genevieve counties. Several other minor and unverified occurrences in Warren, Crawford, and Perry counties are recorded in the series of county reports published by the Survey in 1873[8], but in all of these early reports manganese is considered only trivially. The possible

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[4]Mellor, J. W., A Comprehensive Treatise on Inorganic and Theoretical Chemistry, pp. 139-141, 1932. (Longmans, Green and Co.)

[5]Schoolcraft, H. R., A View of the Lead Mines of Missouri including some Observations on the Mineralogy, Geology, Geography, Antiquities, Soil, Climate, Population and Productions of Missouri and Arkansas, and other sections of the Western Country, pp. 44, 168, 199, 270, 1819. (Charles Wiley and Co., New York.)

[6]Litton, A., A preliminary report on some of the principle mines in Franklin, Jefferson, Washington, St. Francois and Madison Counties, Missouri: First and Second Annual reports, Geol. Sur. Mo. p. 83, 1855.

[7]Swallow, G. C., First and Second Annual Reports Geol. Sur. Mo. pp. 164-165 and p. 200, 1855.

[8]Broadhead, G. C., Reports on the Geological Survey of the State of Missouri, 1855-1871, pp. 63, 255 and 288, 1873.

economic importance of Missouri manganese minerals was first noted in 1872 when Pumpelly[9] studied and described the deposits near Arcadia, Iron county. The close proximity of these manganese deposits to those of iron ore at Pilot Knob and Iron Mountain created special interest. The deposits were mined for a short time without success, and interest in managnese in Missouri waned. In succeeding reports of the Survey very little is recorded concerning the occurrence of this element in the State. Nason[10] devoted only about one-half of a page to the subject and Keyes[11] slightly more than a page.

Interest in Missouri manganese was not revived until 1917 when World War I, created a manganese deficiency in the United States similar to that which exists at the present time. Lack of ships nearly eliminated importation for a while and then, as now, it became necessary to investigate every known deposit and to increase domestic production many fold. The Missouri Geological Survey cooperated in this work, one of its members, V. H. Hughes, spending several months of 1918 in locating and examining reported occurrences of ore. The results of this work were not published in full but a summary appears in one of the biennial reports of the State Geologist[12]. After the war, domestic manganese production fell almost to its pre-war level. There was no need to investigate the Missouri ores any further. In June, 1934, D. F. Hewett[13] made a brief study of the Missouri manganese deposits for the United States Geological Survey but he did not complete his investigations and his findings have not been published. It has taken a second World War to create a new interest in the local deposits. The consumption of high grade manganese ore is greater now than ever before and since the passage of the Strategic Minerals Act prospecting for manganese has been revived in Missouri. Almost as soon as the conflict started in

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[9]Pumpelly, Raphael, Notes on the Geology of Pilot Knob and its vicinity: Geol. Surv. Mo. Preliminary Report on the Iron Ores and Coal Fields from the Field Work of 1872, pp. 20-28, 1873.

[10]Nason, F. L., A report on the iron ores of Missouri: Mo. Geol. Surv. Vol. II, pp. 94-95, 1892.

[11]Keyes, C. R., A report on the Mine LaMotte sheet: Mo. Geol. Surv. Vol. IX, pp. 80-82, 1895.

[12]Buehler, H. A., Bienniel Report of the State Geologist to the Fiftieth General Assembly, pp. 15-17, 1919.

[13]Hewett, D. F., Letter dated August 25, 1942.

Europe prospectors began reopening some of the old deposits in this State. This was called to the attention of the public by Hinchey[14] and, in an endeavor to aid in this prospecting, the Director of the Missouri Geological Survey sent the writer into the field to gather the information which forms the basis for the present report.

PRODUCTION

Up to the present time the total quantity of manganese ore produced in Missouri probably does not exceed 2500 long tons. Accurate production figures are not available and just when manganese was first produced in this State is unknown. According to Weeks[15], a small amount of manganiferous iron ore containing 15% manganese was shipped to the Vulcan Steel Works in St. Louis from the Bogy or Buford Bank, Iron County, sometime prior to 1885. This mine was opened by the Madison Iron and Mining Company about 1850 and the presence of considerable manganese in the ore was detected by Litton in 1852. The property was being reworked when visited by Pumpelly[16] in 1872, and it is likely that the ore mentioned by Weeks may have been produced about this time. At the same time the adjoining Cuthbertson property also was being developed solely for manganese and the Cuthbertson Mine may be considered to be the oldest manganese mine in the State. According to Weeks, in 1881, the Arcadia Mining Company shipped 2000 tons of manganese ore from this mine to the Missouri Furnace Company in St. Louis, where it was used to produce manganiferous pig iron. Apparently the mining of manganese in Missouri began a little more than sixty years ago.

About 1890 some prospecting for manganese was conducted in Shannon County. It is reported that a shaft was sunk on what is now known as the Turley property and that a car of manganiferous chert breccia was shipped. About this same time some manganiferous iron ore was mined near Cornwall

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[14]Hinchey, Norman, Mineral production of Missouri: Biennial Report of the State Geologist to the Sixty-First General Assembly, pp. 54-55, 1941.

[15]Weeks, J. D., Manganese: U. S. Geol. Survey Mineral Resources of the United States, pp. 346-348 1885.

[16]Pumpelly Raphael, op. cit. pp. 20-28.

in Madison County, but, so far as is known, all of this ore was used as flux in the lead smelters at Mine LaMotte. Probably no manganese was mined in Missouri between 1890 and the beginning of World War I.

Even before this country entered World War I, the shortage of ships made necessary the production of as much domestic manganese as possible. Under the stimulus of high prices, prospecting for manganese was revived and old, long abandoned properties were reopened. In 1915 the Bogy or Buford deposit was reprospected by the Big Muddy Coal and Iron Company and in 1916 John Baird reopened the Cuthbertson Mine, but both properties soon were abandoned because the ore was considered to be too siliceous and to lack depth. In the same year Luther Norris searched for manganese and iron ore for the Mid-Continent Iron Company and in this year discovered the manganese veins on Thorny Mountain which now are being worked by the Shannon County Mining and Ore Company. In the same year several other properties were prospected by John F. Church and by Frank Ross and it is said that a carload of ore gathered from several Shannon County prospects was shipped from Winona. Another car of ore was reported to have been produced at the Lindsay Mine at Johnson's Shut-In near Lesterville, Reynolds County. In 1918 G. L. Barnes worked what is now the Clover Mine. About 80 tons of mixed manganese and iron ore were taken out and one car of hand sorted manganese ore shipped. Apparently even under the stimulus of high prices prevailing during World War I only 3 cars of manganese ore were produced. The signing of the Armistice eliminated the need for the local manganese and the Missouri deposits were abandoned until a second World War created a new demand more urgent than the first.

The passage of the Strategic Minerals Act in 1939 created the incentive to prospect for manganese. Even as early as 1938 D. F. Govro of Perryville prospected the Buxton, Clover and Cook properties near Cornwall in Madison County and in 1940 Ernest Pearce of Cadet reprospected the Clover Mine and reopened the Cuthbertson mine in Iron County, producing one short carload of ore. About this same time W. M. Nash leased the property on Thorny Mountain in Shannon County, where Luther Norris had discovered manganese veins in 1916, and opened a shallow pit in the porphyry. While engaged in prospecting this property, Nash became interested in a more easily worked and apparently larger deposit on the Oliver Tucker farm near Ellington in Reynolds county. In July, 1940 Nash obtained a lease on the Tucker farm, abandoned his work on Thorny Mountain and with the aid of Mrs. Blanche McCaw began prospecting the new lease. Up to the present time no ore has been produced from the Tucker property, but late in 1941 Luther Norris succeeded in creating new interest in the Thorny Mountain prospect. The Shannon County Mining and Ore Company was organized and began mining early in 1942. Nash's old pit was deepened to 40 feet and a second shaft was sunk on the same set of veins about 140 feet southwest of the first shaft. The first car of manganese ore was shipped in March, 1942 and up to the present time six cars have been sold. The fact that some ore has been shipped has encouraged the reprospecting of several other vein deposits in the porphyry of Shannon County. Production at Thorny Mountain is not expected to be large but whatever ore is produced will contribute just that much toward the war effort.

CHAPTER II.

MINERALS OF THE MANGANESE DEPOSITS OF MISSOURI

INTRODUCTION.

Manganese is the twelfth most abundant element of the earth and one of the most widely distributed. It occurs both in the igneous and in the sedimentary rocks of Missouri and although it is not determined in the ordinary analysis, special analyses have shown it to be present usually in amounts of less than one per cent. Traces of manganese have been detected both in the surface and in the subsurface waters of the State, a few containing several parts per million. The association of manganese with the iron ores of the Ozark region is well known. In the secondary limonite deposits and hematite of the filled sink deposits the manganese content seldom exceeds 0.2 per cent but in the primary limonite deposits it is higher, averaging 1.12 per cent.

MANGANESE MINERALS.

As early as 1874 Chauvenet[1] wrote, "No pure binoxide of manganese has been found in Missouri. Many of the ores containing manganese show in places a crystallization resembling that of pyrolusite, but none of them gives as high an oxygen ratio as is required for a commercial article." Leonard[2] included hausmannite, psilomelane, wad and wolframite in his list of Missouri minerals and the wolframite bearing quartz veins at Silver Mine, Madison County were described by Haworth[3]. According to Wheeler[4], W. B. Potter found rhodochrosite "in massive form filling thin seams in specular hematite" and mangano-calcite "as crystalline masses of a reddish-brown color associated with calcite in specular hematite" at Iron Moun-

[1]Chauvenet, Regis, Chemical analyses: Report of the Geological Survey of the State of Missouri, including the Field Work of 1873-74, p. 719, 1894.

[2]Leonard, A. V., Notes on the mineralogy of Missouri: Trans. St. Louis Acad. Science Vol. 4, pp. 445 and 447, 1886.

[3]Haworth, Erasmus, Crystalline rocks of Missouri: Mo. Geol. Survey Vol. VIII, pp. 160-161, 1895.

[4]Wheeler, H. A., Recent additions to the mineralogy of Missouri: Trans. Acad. Science St. Louis, Vol. 7, p. 128, 1898.

tain, St. Francois County. Of these minerals only psilomelane, pyrolusite and wolframite, or, as the writer prefers to call it, huebnerite, were noted during the present investigation and, in addition, the manganese mineral braunite was identified. Manganite may be present but it has not been identified with certainty. A separate investigation dealing with the identification and paragenesis of the minerals in the Missouri manganese deposits is being carried on at the present time with the aid of X-rays and polished sections.

The identification of manganese minerals is fraught with certain difficulties. Unlike the ore minerals of many other metals those of manganese cannot be identified so simply. They frequently lack crystallinity, often are pseudomorphous and usually occur together. Most of them are black and quite similar in physical properties and in chemical activity. Pure samples of any one mineral often are difficult, if not impossible, to obtain and consequently mineralogical tests frequently are made on mixtures rather than on a single mineral. Several ores described as containing new minerals have been found on closer examination to be mixtures of well-known minerals. The identifications made here in this report are based upon simple chemical tests and upon quantitative analyses by the Survey chemist, R. T. Rolufs, of the purest material that the writer could obtain by crushing the ore and by hand-picking it beneath a binocular microscope. The identifications are not considered to be complete, other minerals also may be present. The detection of such additional minerals is the purpose of studies now being made.

BRAUNITE

($3MnMnO_3 \cdot MnSiO_3$)

Braunite is the chief ore mineral in the manganese veins which cut the rhyolite porphyries. It occurs as a dense, black or, more rarely, as a steel gray, granular mineral filling fractures, cementing and replacing angular fragments of the wall rock and, to a slight extent, replacing the wall rock itself. Most of the braunite is massive, but occasionally crystalline grains with pseudo-octahedral outline may be observed. Braunite is about as hard as a knife, it has a metallic luster, a brownish black streak and exhibits tetragonal dipyramidal (pseudo-octahedral) cleavage. The specific gravity of pure braunite varies from 4.7 to 4.8 but the ore, being impure, has a specific gravity somewhat less than this. Chunks of the solid, black ore tested by the writer had specific gravities between 4.1 and 4.3, or about 65 per cent higher than that of the associated rock. Braunite is slightly magnetic and is very similar to another manganese mineral, hausmannite ($MnMn_2O_4$), from which it differs chiefly by its reaction in hot hydrochloric acid. Powdered braunite yields gelatinous and powdery silica when boiled in this acid whereas hausmannite does not. Braunite is known to occur in acid igneous rocks so its presence in the rhyolite porphyry of this State is not unusual. It is believed to be hydrothermal in origin.

The composition of braunite is indicated by the chemical formula, $3MnMnO_3 \cdot MnSiO_3$, but such a formula does not take into account the common replacement of manganese by other elements such as calcium, barium, cobalt, iron, magnesium and zinc; and it does not take into account the variable manganese—silicon (Mn:Si) ratio. Chemical analyses of braunite specimens deviate somewhat from the theoretical composition calculated on the basis of this formula but all of them reveal the presence of three essential elements: manganese, oxygen and silicon. It is apparent that in concentrating braunite ores, as distinct from treating manganese oxide ores, the silica content cannot be reduced below a certain minimum value determined by the amount present in the pure ore mineral. Analyses indicate that the silica content of braunite is about 10%.

Detailed analyses of two hand-picked specimens of braunite, one from the Swearingim prospect in Iron County, the other from the Elliot Mine in Shannon County, are given in Table I. In the analysis all of the manganese was converted into a permanganate and the total manganese so determined was calculated as MnO and $Mn0_2$, in accordance with the chemical formula for braunite. According to the theortical formula, braunite should contain 63.3% manganese. The specimens analyzed contained 56.8% and 51.7% manganese respectively. It is likely that some of this was present as psilomelane, pyrolusite or some manganese mineral other than braunite. Both samples undoubtedly contained a little quartz and feldspar and its alteration products. Sample No. 2 is known to have contained free quartz.

TABLE I.

ANALYSES OF MISSOURI MANGANESE ORE MINERALS

(Analyst: R. T. Rolufs)

Mineral	BRAUNITE		PSILOMELANE		PYROLUSITE	
Sample No.	1	2	3	4	5	6
Property	Swearingim	Elliot	Culpepper	Tucker	Senter	Phillips
County	Iron	Shannon	Shannon	Reynolds	Madison	Madison
Silica (SiO_2)	10.22	17.64	5.32	8.64	0.40	0.40
Alumina (Al_2O_3)	0.48	0.46	10.33	11.34	0.01	0.01
Iron oxide (Fe_2O_3)	0.70	0.96	1.24	0.55	0.48	0.82
Lime (CaO)	1.86	1.86	0.48	0.41	0.46	0.48
Magnesia (MgO)	0.30	0.17	2.31	2.37	0.12	1.09
Soda (Na_2O)	0.41	0.21	0.53	0.11	0.23	0.20
Potash (K_2O)	0.27	0.14	0.16	0.19	0.10	0.17
Manganous oxide (MnO)	41.96	38.32	52.32	52.37		
Manganese dioxide (MnO_2)	38.68	35.32			94.72	92.66
Barium oxide (BaO)	0.13	0.15	6.62	7.35	0.13	2.89
Cobaltous oxide (CoO)	0.23	0.33	2.53	1.03	0.25	0.33
Zinc oxide (ZnO)	0.05					
Phosphorus pentoxide (P_2O_5)	0.015	0.016	0.194	0.265	0.070	0.072
Moisture (H_2O below 110°C.)	0.17	0.22	1.00	1.47	0.15	0.12
Ignition loss (Chiefly water and oxygen)	2.84	1.48	14.10	14.67		
	98.315	97.276	97.134	100.765	97.12	99.242

PSILOMELANE.

$(R^{1}_{4}\ R''_{2}\ Mn_{8}\ O_{20})$

$(R^{1}=H, Li, K, Na)$

$(R''= Ba, Ca, Co, Cu, Fe, Mg, Mn, Ni, Zn)$

Psilomelane, as the term is used in many reports dealing with manganese minerals, is not a well defined mineral species. It frequently is used for any dense, botryoidal, hard gray or black manganese mineral without regard to composition. In a more restricted sense psilomelane is a manganite of hydrogen and certain divalent elements, chiefly barium and manganese, but the vicarious replacement of hydrogen by the alkali elements and of barium and manganese by other divalent elements causes psilomelane to be quite variable in composition. Its manganese content normally varies from 55 to 60 per cent. A psilomelane-type mineral rich in potassium recently has been designated cryptomelane by Richmond and Fleischer[5].

The material referred to in this report as psilomelane is an opaque, bluish—or grayish-black to iron black mineral with a dull to submetallic luster, a dense, botryoidal structure, a con-

[5]Richmond, W. E. and Fleischer, Michael, Cryptomelane: Am. Mineralogist, Vol. 27, pp. 607-610, 1942.

choidal fracture and a very dark brown streak. It is as hard as a knife blade, brittle, and has a specific gravity of 3.8 to 4. Much of the mineral is cellular and clinkery in appearance. In polished sections it exhibits very fine concentric banding. It lacks visible crystallinity and hence does not exhibit cleavage. It is the most common mineral in the sedimentary manganese deposits in Missouri. It coats sand grains and cements angular fragments of chert into a breccia.

Missouri psilomelane contains considerable aluminum, barium, cobalt and magnesium. Detailed analyses of two samples are given as No. 3 and No. 4 in Table I. Sample No. 3 came from the Culpepper prospect in Shannon County, sample No. 4 from the Tucker farm in Reynolds County. Neither sample was entirely free of quartz in the form of sand grains, chert and minute druses and a very small amount of an earthy brownish material invariably was present as a thin coat on the psilomelane and as a cavity filling. Not enough of this material was present, however, to account for the high alumina content of the selected material.

The chemical analyses bring out several important facts. First, the manganese content of the pure mineral is low, sample No. 3 contained only 40.52% manganese and sample No. 4 only 40.56%. It is evident that a high grade concentrate cannot be made by mechanical ore-dressing methods. These at best would not produce a concentrate as rich in manganese as the samples which were analyzed. Second, the phosphorus content is higher than that of either the braunite or the pyrolusite ores and the phosphorus apparently is intimately bound with the manganese mineral, for the phosphorus content of the purest material is greater than that of the raw ore. Third, the cobalt content of the psilomelane ores is unusually high. In testing these ores chemically it was found that they yield a green solution when dissolved in hydrochloric acid, whereas ores containing little or no cobalt yield an amber-colored solution, the green color apparently being the result of a mixture of the blue cobalt compound and the amber manganese salt. This high cobalt content suggests the use of this ore as a source of cobalt. These facts suggest that this type of ore is more suitable for the production of electrolytic manganese than for ferro-manganese. In the electrolytic process the relatively low manganese and high phosphorus content are not detrimental and the cobalt can be recovered as a valuable by-product.

PYROLUSITE.

(MnO_2)

Pyrolusite probably is the third most important manganese mineral in Missouri manganese deposits. It usually is recognized as a sooty, black powder although it also occurs in the crystalline state. It apparently is quite soft, but actually is harder than glass. It has a specific gravity of 4.7 to 5, but usually is so porous that the effective specific gravity is much less than that. In attempts to concentrate the ore by tabling earthy pyrolusite is carried over the table while the gangue remains on the table. Pyrolusite is distinguished from other manganese minerals by its high content of available oxygen and this property gives rise to its extensive use in the battery, paint and chemical industries. When heated in a test tube pyrolusite emits enough oxygen to cause a glowing splint introduced into the test tube to burst into flame. In this way pyrolusite may be distinguished from other manganese minerals. When heated it yields little or no water and in this it differs from manganite and from psilomelane.

Chemically pyrolusite is manganese dioxide. Theoretically it should contain 63.2 per cent metallic manganese. Analyses of two selected samples of crystalline pyrolusite are given in Table I. These samples were not entirely free of visible quartz but were selected from crushed material. Sample No. 5 came from the Senter prospect and sample No. 6 came from the Phillips prospect, both in Madison County. The samples were identical physically and the analyses show that they are almost alike chemically.

Pyrolusite is a common alteration product of other manganese minerals, frequently it is pseudomorphous after the original minerals and usually is associated with them. It is quite common in sedimentary deposits associated with limestones and frequently occurs with a dendritic or moss-like structure on joint and fracture surfaces and on bedding planes. It is deposited directly from ground water. In Missouri, pyrolusite is a constitutent of both the hard and of the soft ore of the Cuthbertson Mine in Iron County and it is present in the manganese deposits of Madison County. It is a constituent of the residual ore at the Clover Mine and is the chief component of the black, earthy seams in the residual clay, such as at the Cook property. The best material was that used for the analyses. These specimens were residual boulders consisting of granular, crystalline, grayish black, pseudo-orthorhombic and fibrous pyrolusite which was mistaken in the field for manganite. Pyrolusite is a constitutent of the so-called wad ores.

WAD.

Wad is soft dark brown to black low grade manganese ore. It is not a mineral and it does not have a characteristic composition. Most commonly it is a mixture of iron and manganese oxides. The iron is present as limonite or goethite and the manganese as manganite, psilomelane or pyrolusite. It is found in Missouri as a replacement material in the tuff beds on Cuthbertson Mountain in Iron County and as a fracture filling in residual clays in a number of counties. The cobalt bearing wad, asbolite, has been reported by King[6] to occur at Rives' Copper Mine (Hobo Mine) in Crawford County, but neither Shumard nor the present writer have been able to confirm the occurrence. Asbolite has been known to occur at Mine La Motte and Old Copper Mines in Madison County. According to Leonhard[7] this material contained 5% nickel as well as cobalt and copper. Dana[8] gives the nickel content as 10 or 11% NiO.

HUEBNERITE (Wolframite)

$(Mn,Fe)\ WO_4$

Huebnerite is a manganese mineral mined in Missouri at the Einstein Silver Mine west of Fredericktown in Madison County. It is mined, however, for its tungsten content rather than for its manganese. Its occurrence has been described in another Survey publication by Tolman[9], where it is listed as wolframite.

[6]King, Henry, private report. Quoted by B. F. Shumard, in his report on Crawford County. Reports of the Geological Survey of the State of Missouri, 1855-1871, p. 255, 1873.

[7]Leonhard, A. V., op. cit., p. 445, 1886.

[8]Dana, J. D., The System of Mineralogy, p. 258, 1909. (John Wiley and Sons, New York.)

[9]Tolman, Carl, The geology of the Silver Mine area, Madison county, Missouri: Biennial Rept. State Geologist, Appendix I, 1933.

The mineral occurs in bladed crystals and grains in quartz veins. It is brown and has an adamantine to resinous luster. It is quite brittle and cleavable and is almost as hard as glass. It has a brownish streak and it is translucent in thin sections in transmitted light. It is easily confused with sphalerite with which it is associated in the quartz veins at the Silver Mine. It differs from sphalerite in its much higher specific gravity. Sphalerite has a specific gravity of 4 while that of huebnerite is about 7. The mineral occurs in imperfect crystals as much as 4 inches long, in grains and in bouldery masses which have weighed as much as 100 pounds. An analysis by the St. Louis Sampling and Testing Works showed it to contain over three times as much manganese as iron. The pure mineral contained:

FeO	5.12%
MnO	18.33
WO_3	76.50
Total	99.95

It has not been found outside of the Silver Mine area in Missouri. Present production amounts to several thousand pounds annually.

GANGUE MINERALS.

The ore minerals are accompanied by a very few gangue minerals. Mineralogically the Missouri manganese deposits are rather simple. The ores in the igneous rocks are accompanied by alunite, barite, calcite, feldspar, fluorite, hematite, kaolinite, mangansericite, quartz, sericite, and tremolite; those in sedimentary rocks by clay, limonite and quartz in various forms.

Alunite ($K\,Al_3\,(OH)_6\,(SO_4)_2$): This pinkish mineral was identified optically in ore from the Daniells prospect in Shannon County. It consists of soft, microcrystalline aggregates formed by the hydrothermal alteration of feldspar contained in the rhyolite porphyry cut by braunite veins.

Barite ($BaSO_4$): Small amounts of this mineral probably are present in a number of the manganese deposits of this state, since it commonly is associated with manganese ores. Up to the present time it has been noted only at the Reeves prospect in Shannon county. There somewhat radial platy masses of glassy, colorless and gray, cleavable barite occur in cavities in the ore. The manganese mineral is deposited between the individual barite crystals in the radial aggregate and occasionally may be observed invading or cutting across the barite. In some of the ore observed on the dump, the barite crystals are gone but the cavities left in the ore form partial moulds of the original crystals. Some of the barite is stained by limonite.

Calcite ($CaCO_3$): This a common constituent of sedimentary rocks and a common product of weathering of calcium bearing minerals. It was encountered chiefly as a product of weathering of volcanic tuff and as the component mineral of a limestone interbedded with the tuff and cut by rhyolite lava flows at the Cuthbertson Mine. Here it was earlier than the manganese oxide, which forms dendrites upon it.

Fluorite (CaF_2): Purple fluorite is fairly abundant as a late mineral in some of the rhyolite porphyry flows cut by manganiferous veins, as at the Miller property on Lee Mountain in northeastern Reynolds county. It also has been found as constituent of these veins, particularly at the Elliot shaft in Shannon county. It accompanies quartz in microscpopic veins cutting limestone at the Cuthbertson Mine.

Hematite (Fe_2O_3): Manganese oxide, probably pyrolusite, is deposited on dense specular hematite at the Big Muddy Coal and Iron Company Mine and at the Pilot

Knob Ore Company Mine in Sec. 18, T. 33 N., R. 4 E., Iron county. Some of the tuff deposits adjacent to the manganese beds in Iron county, are colored red by earthy hematite.

Kaolinite or Halloysite ($Al_4(OH)_8Si_4O_{10}$): This mineral is a product of the weathering of feldspar in the rhyolite porphyry associated with braunite veins and it, or a similar clay mineral, is a constituent of the residual clay in the deposits of manganite, psilomelane and pyrolusite in the sedimentary residual cherty clays.

Limonite or Goethite (FeOOH): This brown basic oxide of iron is a common constituent of the wad ore. In Butler, Wayne and other southeastern Missouri counties it is the chief iron ore. In a few deposits it is quite manganiferous, being coated by a black manganes oxide, probably pyrolusite.

Mangansericite: A specimen of manganese ore from Thorny Mountain was given to the writer by Luther Norris. It was obtained in opening the second shaft. This specimen contains two minerals not seen in any other deposits, although they are likely to be present elsewhere. One mineral is a copper-red, highly micaceous mineral which occurs as tiny books and scales lining cavities in the manganese ore, the other is a white to bluish fibrous mineral which is deposited on the micaceous mineral. The first mineral, because of its lack of elasticity, is referred to here as a type of sericite. It is very soft, flexible, has a pearly luster and a specific gravity below that of methyelene iodide. It gives a strong test for manganese with a soda-niter bead. It is biaxial, negative and has an apparent optic angle of about 50°. The optic plane is inclined to the cleavage, which is taken to the basal. The indices of refraction, as determined from a cleavage flake are 1.628 and 1.653. The mineral is markedly pleochroic being rose red when the slow ray is parallel to the vibration plane of the lower nicol and yellowish when the faster ray is in the same position. The mineral seems to be inert toward hot acids but becomes dark when heated before the blowpipe. In many respects it is like manganophyllite, but has too wide an optic angle and is not elastic. It resembles manganchlorite described by Fermor[10], but its birefringence is rather high for chlorites. A mass of fibers which show strong absorption when the fibers are parallel to the vibration plane of the lower nicol were taken from the same specimen and may be the same mineral. The pleochroism varied from dark brown in the position just described to yellowish in the perpendicular position. In this respect the mineral resembles biotite and the minimum refractive index was found to be 1.615. This copper-colored micaceous mineral contains inclusions of braunite and is deposited on braunite. It probably is a late hydrothermal mineral.

Quartz (SiO_2): Several forms of quartz are found in the manganese ores. Glassy anhedral quartz is a constituent of both the groundmass and the phenocrysts in the rhyolite porphyries and it often is the only visible residual mineral where these rocks are replaced by manganese minerals. It is a constituent of the veins themselves and probably was deposited contemporaneously with the braunite. Glassy quartz crystals with equally developed positive and negative rhombohedral faces and of dipyramidal habit were observed lining cavities in the ore along with others less perfectly developed exhibiting hexagonal prism faces. Quartz is a constituent of the volcanic tuff at Cuthbertson mountain and is less replaced by manganese minerals than is the feldspar.

In the sedimentary deposits quartz is present chiefly as chert but also as sandstone, sand grains, and in druses. Chert forms a large part of the residual mantle resulting from the decomposition of the dolomites and its characteristics are governed largely by the formation from which it was derived. It is the chief constituent of the manganiferous breccia which was formed by the cementation of the angular chert particles principally by psilomelane. In some places the breccia contains angular fragments of sandstone instead of part or all of the chert, and loose sand grains are quite common in this type of ore. Cavities in the ore may be lined by banded quartz and by small quartz crystals. Sandstone indurated with psilomelane is quite common, the manganese mineral forming a thin coat about each sand grain, firmly cementing it to its neighbors. This type of rock may appear very dark or black, yet contain only a small amount of manganese.

Sericite ($KAl_2(OH)_2AlSi_3O_{10}$): This mineral is a product of the hydrothermal alteration of the orthoclase feldspar in the rhyolite porphyry. Its best development was seen at the Miller prospect on Lee Mountain in Reynolds county, where it occurs as soft pearly white scales on the surfaces of joints.

Tremolite ($(Ca_2MgMn)_5(OH)_2Si_80_{22}$): This mineral appears in silky, white, radial, fibrous tufts on the coppery red mangansericite in the specimen from Thorny Moun-

[10]Fermont, L. L., The manganese-ore deposits of India: Memoirs Geol. Survey, India. Vol. 37, pp. 195-196, 1909.

tain given to the writer by Luther Norris. The interiors of some of the tufts are light azure blue and it is likely that the mineral is identical with winchite described by Fermor[11] from the Indian manganese deposits. The fibers are flexible, tough and very fine so that they are difficult to work with beneath a petrographic microscope. They seem to be bixial, negative, and are length slow. They have an extinction angle of about 17° to 20°. The indices of refraction as determined in the fibers are close to 1.63 and 1.65.

The fibers give a manganese reaction with a soda-niter bead. The presence of this amphibole of probable hydrothermal origin in the manganese ores emphasizes the similarity between these ores and the iron ores at Iron Mountain, where tremolite also is present along with the garnet, andradite.

[11]Fermor, L. L., op. cit. pp. 149-158, 1909.

CHAPTER III.

MANGANESE ORES IN MISSOURI.

GEOGRAPHIC DISTRIBUTION.

Figure 1 gives the location of the principal manganese deposits in the State. It will be noted that these are irregularly distributed over an elliptical area, having a major axis of approximately 80 miles and a minor axis of approximately 60 miles, which includes the geologic core of the Ozarks, the St. Francois Mountains. The center of the area is about 90 miles S. 15 W. of St. Louis and 50 miles N. 25 W. of Poplar Bluff. The area has a general northeast-southwest trend extending from Ironton in Iron County to Eminence in Shannon County and from Fredericktown in Madison County to Van Buren in Carter County. The deposits occur principally in Iron, Madison, Reynolds, and Shannon Counties, but others are located in the adjacent counties.

Transportation facilities in the district are good. It is served by the Missouri Pacific Railroad on the east and by the St. Louis and San Francisco Railroad on the south, but the Missouri Southern line through Reynolds County, from Leeper to Bunker, was taken out in 1941. A number of federal and state highways traverse the area: Missouri State Highway No. 32 on the north, U. S. Highway No. 60 on the south, U. S. Highways No. 61 and 67 on the east, and Missouri State Highway No. 19 on the west. The central part is served by Missouri State Highways No. 21, No. 34, No. 49, No. 70, No. 72, and No. 106.

PHYSIOGRAPHIC DISTRIBUTION.

The manganese deposits occur in some of the roughest part of Missouri, on the southeastern slope of the Ozark plateau. Some of them are on the porphyry peaks of the St. Francois Mountains and some are on similar peaks in Shannon county. The remainder are associated with the sedimentary rocks between and on the flanks of the porphyry knobs. The region is drained by the headwaters of the Castor, St. Francois, Black and Current Rivers and their tributaries, which flow southeastward to the Mississippi. Much of the water of these rivers comes from large springs such as Big, Greer, Welch, Blue, and Alley.

All of the manganese deposits in Missouri are closely related to the present erosional surface. All begin at the present surface and extend downward or laterally from it. Through erosion the sedimentary cover has been stripped from the porphyry knobs exposing the manganese veins cutting through them. Through erosion a great thickness of dolomite beds has been dissolved away leaving a residual mantle of insoluble matter chiefly chert, sand, and clay in which the sedimentary manganese minerals have been concentrated. No concentration of manganese minerals, other than stains and dendrites, ever has been observed in the solid strata beneath the residuum. It is believed that the sedimentary manganese deposits in the State are genetically related to the present land surface and that they do not extend any deeper than does the zone of oxidation. The igneous deposits, however, have only been exposed by erosion and genetically are unrelated to the present surface. The vein deposits in the porphyry may have considerable depth.

STRATIGRAPHIC DISTRIBUTION.

It already has been stated that traces of manganese occur in practically all rocks in Missouri and minor concentrations may be found at several stratigraphic horizons, but the deposits of actual or potential value are restricted to just two horizons, at opposite ends of the geologic column: the pre-Cambrian or oldest and the Recent or youngest. Some manganiferous limonite has been observed in Pennsylvania sandstone associated with residual Mississippian chert in southern Shannon County and manganiferous umber is mined at or near the contact of the Devonian and Silurian formations in Perry County, but the real manganese deposits occur in veins in the pre-Cambrian rhyolite of Iron, Reynolds, and Shannon Counties or in the cherty, clay residum of these and adjacent Ozark counties. Because the residuum is the product of weathering of older formations, a genetic relationship exists between the residuum and the rock from which it has been derived and, consequently, there is a relationship between the manganese deposits in this residuum and the adjacent strata. It is in this sense that the stratigraphic position of each manganese deposit is noted in the following portion of this bulletin. Unless otherwise noted, it is to be understood that the deposit actually occurs in Recent residual clay which has been derived from the older formation indicated. Some minor concentrations of manganese oxide occur in the Jefferson City and Roubidoux formations of Bollinger, Howell, Oregon, and Ripley Counties, but the major deposits of sedimentary manganese are in residuum derived from the Gasconade, Eminence, and Potosi formations of Carter, Madison, Reynolds, and Shannon Counties. The manganiferous chert breccia is particularly common in residuum at or near the contact of the Gasconade and Eminence formations and it can be found at this horizon in many places, particularly in Reynolds County. Seams of wad in clay and pebble and boulder ore are especially characteristic of the reddish cherty clay residum of the Eminence and Potosi formations in Madison County and it seems that there is a direct relationship between the type of ore and the rock with which it is associated. It certainly can be said that the hydrothermal type ores occur in the pre-Cambrian igneous rocks while the sedimentary type ores occur in the Recent sedimentary residuum. The two types of ore are separated as much genetically as they are stratigraphically.

Since all of the manganese ore except that of the pre-Cambrian is in residuum; there is no need for an elaborate discussion of stratigraphy in this report. For this the reader is referred to the previous publications of the Missouri Geological Survey, particularly to the reports of Dake[1] and of Bridge[2], where the formations associated with the manganese deposits are described in great detail. For a complete picture of the stratigraphic sequence the above mentioned reports and the 1939 edition of the Geological Map of Missouri should be consulted.

STRUCTURAL DISTRIBUTION.

Very little definite information can be given concerning the distribution of manganese with respect to structure. Only certain general relationships have been observed. Whatever detailed relationships might exist will have to await detailed geologic mapping of the entire manganese district.

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[1]Dake, C. L., The geology of the Potosi and Edgehill quadrangles: Mo. Bur. Geol. and Mines, Vol. XXIII, Second Series, 1930.

[2]Bridge, Josiah, Geology of the Eminence and Cardareva quadrangles: Mo. Bur. Geol. and Mines, Vol. XXIV, Second Series, 1930.

It is quite evident that the manganese veins in the porphyry have a general NE-SW strike which is roughly parallel to the apparent structural axis of the region. Whatever regional forces were at work in this area in pre-Cambrian time they permitted NE-SW tension cracks to form and become filled with mineral matter deposited from solutions.

The most obvious structural relationship of the sedimentary deposits is that to unconformity. They definitely are related to the present erosional surface and in part seem to be related to past erosional surfaces. The occurrence of the manganiferous chert breccia in residuum close to the Gasconade-Eminence unconformity is too common to be accidental and the occurrence of the manganiferous umber at the Devonian-Silurian unconformity is another example.

The occurrence of igneous vein types of manganese in association with igneous rocks would be expected but the sedimentary deposits, associated with the sedimentary rocks of the same general area, occur on the flanks of the porphyry knobs and ridges and in the synclinal basin between the igneous rocks of the St. Francois Mountains in Iron County and the porphyry knobs of Shannon County. The whole area structurally is the highest portion of the State and it may be that here not only are the older more manganiferous rocks exposed but also groundwater circulation is better. It is even possible that a portion of the manganese in the sedimentary rocks was derived locally from the weathering of the manganese bearing porphyries.

Just why the manganese deposits occur where they do cannot be answered at the present time. As already pointed out the formations associated with the sedimentary manganese ores are noted for the large springs, caves, and sink structures which they contain. The association of pyrites and iron ore deposits with such structures is very common in the Ozarks. It is highly probable that as these formations were being weathered, chiefly by solution of their dolomite, unequal settling took place which led to the development of local solution structures which served to guide the flow of groundwater and bring about the deposition of its contained manganese in local areas. No definite proof of this idea has been obtained because the deposits are in residuum where bed rock is not exposed, but it is worthy of consideration.

GEOLOGIC CLASSIFICATION AND DESCRIPTION OF THE ORES.

Manganese ores occur both in the igneous and in the sedimentary rocks of Missouri and both types of ore have been mined. At the present time it is the ore in the igneous rhyolite porphyry that is being mined, but in times past deposits in volcanic tuff and sedimentary residuum have been worked.

MANGANIFEROUS VEINS IN PORPHYRY.

The deposit which is being worked at present is on Thorny Mountain in Shannon County. It is representative of several deposits in which the manganese mineral braunite, occurs in vertical veins and in brecciated zones which cut rhyolite porphyry. The black color of the veins causes them to stand out sharply against the reddish brown color of the porphyry, but their narrowness makes it easy for one to overlook them. On the outcrop they are not over two inches wide, usually narrower, but they seem to widen out with depth. The writer obtained a specimen of solid ore four inches wide from a depth of forty feet at the Thorny Mountain property and the miners claimed that much wider masses have been taken out. The veins occur singly or in closely spaced groups, the mineralized zone, commonly brecciated, varying in width from that of a single vein to several feet across. At Thorny Mountain it is about 4 feet wide and on Taum Sauk it is even wider. The ore is hard, dense, black, massive or compactly granular. Only occasionally are cleavage faces of individual grains observable. The ore fills fractures, cements the broken fragments of wall rock into a breccia and replaces these fragments as well as the wall rock itself. In places it grades into the rock, in others the contact is quite sharp. Some of the ore breaks free of the gangue, some of it can be freed by hand cobbing, but much of it adheres tenaceously to the wall rock or actually grades into it.

In general, the mineralized zone, whether a single fracture or a series of fractures, is well defined. On Thorny Mountain it strikes N. 15 E.-S. 15 W. and it can be traced for several hundred feet. Other outcrops in the direct line of strike are known. Perpendicular to the principal zone is a complimentany set of cross fractures which are only slightly mineralized.

The contact of the ore with the wall rock at first sight appears quite sharp but closer examination often reveals a marginal zone in which the wall rock has been converted to sericite and to a clay mineral, probably kaolinite or halloysite. The porosity of the rock has been increased and the color has been leached out. In place of the hard, dense, porcelaneous reddish brown porphyry there is a marginal zone of softer, earthy, dull, ash-gray "burnt" rock, as the miners call it. Through replacement the porphyry has been converted into a hard, dense, black mass in which only the original phenocrysts may be left from the parent rock. A study of thin sections shows that the groundmass was replaced first, then the phenocrysts. In some of the ore both feldspar and quartz phenocrysts are clearly visible, in some the feldspars are completely kaolinized, and in much of it only the quartz phenocrysts remain. A complete gradation from solid ore to solid poryhyry may be observed. This leads to some difficulty in distinguishing and separating the ore from the rock and accounts for the high alumina content of this ore. However, since the ore is localized in veins it is possible by proper selection to produce a high grade concentrate. Unlike some of the sedimentary ores, the cobalt content of this type of ore is uniformly low. Partial analyses of this type of ore are summarized in the following table:

TABLE II

ANALYSES OF MANGANESE ORES FROM PORPHYRY DEPOSITS

County	*Name of Deposit*	*Location*			*Partial Composition (percent)*		
		Sec.	*T.*	*R.*	*Insol.*	*Mn.*	*Co.*
Iron	Swearingim	19	33N.	3E.	43.26	31.75	0.05
Reynolds	Lindsay	16	33N.	2E.	31.10	36.66	0.18
	Miller	33	33N.	2E.	55.59	21.69	tr.
Shannon	Daniells	14	28N.	3W.		50.75	
	Elliot	35	28N.	3W.	25.09	36.90	0.07
	Reeves	11	28N.	3W.	19.40	40.32	0.18
	Thorny Mt.	8	28N.	2W.	21.34	38.99	tr.
			AVERAGE		32.63	36.72	0.12

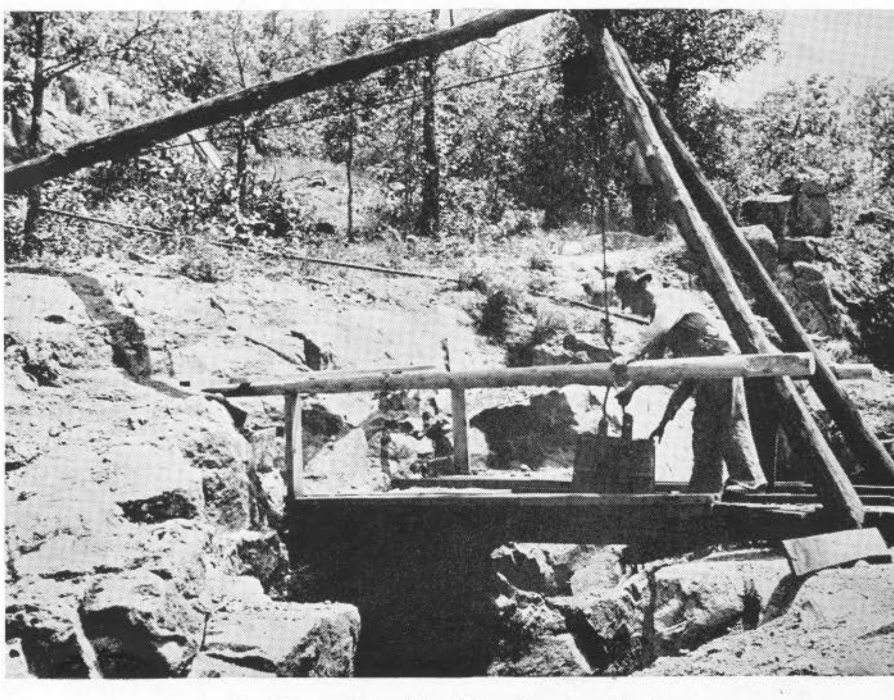
From these analyses it is apparent that it is possible to produce at least low grade "B" ore from the veins in the porphyry, and if careful selection is exercised to bring the manganese up as high as possible and to keep the insoluble silica and alumina as low as possible, high grade ore can be produced. At the Thorny Mountain property the ore after being hoisted to the surface is separated into three grades, shipping ore, waste and a middling. The latter is hand cobbed and the middling from this process is being placed on a stock pile for further concentration, should the property be developed to a size that would warrant the installation of a concentrating plant.

Their apparent small size and the quantity of rock which must be moved are serious drawbacks to working deposits of this type. Moreover, they are located in the roughest part of the State so that transportation is expensive. The chief hope for their future lies in the possibility that they may become bigger with depth. Encouragement is given by the mineralogy of the deposits. The association of alunite, fluorite and sericite with the ore suggests that it is of hydrothermal origin. This means that the ore was deposited from ascending hot solutions which came up along fractures in the porphyry. It is possible, then that there might be more ore at depth than at the surface although this is not necessarily true. Further encouragement, however, is given by the fact that at Thorny Mountain the ore seems to be getting better and more abundant with depth.

MANGANIFEROUS TUFF DEPOSITS.

On Cuthbertson Mountain in Iron County a second type of manganese deposit is associated with igneous rocks. Here beds of volcanic tuff are interlayered with rhyolite porphyry lava flows. The rocks have been altered but a study of thin sections shows that the tuff originally was made up of angular fragments of rhyolite and shattered grains of quartz and of feldspar. The tuff now is altered to sericite and clay and impregnated with calcite, hematite, limonite, pyrolusite and psilomelane. Several attempts have been made to mine this ore and some has been shipped. The ore consists chiefly of hard, dense, black, nodular, pebbly and bouldery masses of an intimate mixture of pyrolusite and psilomelane irregularly distributed through beds of low-grade, soft earthy, dark-brown wad, which impregnates and replaces the volcanic tuff. These masses are high grade and have been shipped, but they do not seem to be sufficiently abundant to make mining worth while. The wad ore is too lean to be used directly. This ore differs from most other ores in that it contains little or no cobalt. Hard lump ore collected by the writer contained only 1.84% insoluble and 50% manganese, while the soft lump contained 37.16% insoluble and only 18.31% manganese.

A. Specimen of manganiferous chert breccia, Carter Buford prospect, Reynolds County.



B. Thorny Mountain Mine, Shannon County.

MANGANIFEROUS CHERT BRECCIA.

The most widespread and the most promising of the manganese ores in the sedimentary rocks of Missouri is a manganiferous chert breccia. Some of it is reported to have been shipped from the Turley Mine in Carter County but it is developed best in Reynolds County, where it has been found at many places and where it has been opened up through prospecting by McCaw and Nash on the Tucker Farm.

The ore consists of irregular bouldery and ledge like masses of manganiferous chert breccia embedded in cherty reddish clay residuum formed by the weathering of the underlying cherty dolomite formations. It is especially abundant in the Gunter zone near the contact of the Gasconade and the Eminence formations and is believed to be the result of the cementation of the residual chert by a manganese mineral deposited from the groundwater which seeped through the residuum, after traveling along the unconformable contact between the two formations.

The ore is largely made up of angular fragments of chert although in places it may consist wholly of sandstone fragments and it usually contains some individual grains of sand. The chert is white or grayish white; dull, porous and weathered or hard, dense and porcelaneous. Some of the fragments contain grains of sand, some are oolitic. They are the result of the breaking up of chert nodules, concretions and lenses in the outcropping formations. Locally and sporadically these fragments are cemented by a hard, dense, black to bluish black manganese mineral of the psilomelane group. Where deposited in open spaces between the fragments, this mineral exhibits a well developed concentric and botryoidal structure. Where massive, it contains numerous cavities which give the ore a decided clinkery appearance. The concentric, botryoidal structure suggests that the ore may have been formed from a colloidal gel and the cavities in the massive ore may be the result of the contraction of this gel on solidification.

This type of ore has been found at many places particularly, in Carter, Reynolds, and Shannon Counties, and the best of it seems to occur at about the same stratigraphic horizon, the Eminence-Gasconade contact or the so-called Gunter zone. At the present time there is no production from this type of ore in

Missouri, but if it is developed commercially it is likely to be found at many places along the above mentioned contact. That will be the zone to prospect.

A number of analyses of this type of ore have been made in the Survey laboratory. Naturally it contains a great amount of insoluble matter, chiefly chert, other forms of quartz and a little clay. The manganese content is quite variable but the better ore averages 17% manganese. The ore is unusual in its high cobalt content. This too, is quite variable, varying from a trace to 2.30% and averaging 0.74%. If the manganese is extracted from the ore chemically, which seems to be the only way it can be done efficiently, the cobalt could be recovered as a by-product. The partial analyses of this ore made by R. T. Rolufs for this report are summarized below:

TABLE III

ANALYSES OF MANGANIFEROUS CHERT BRECCIAS FROM MISSOURI

County	*Name of Deposit*	*Location*			*Partial Composition (percent)*		
		Sec.	*T.*	*R.*	*Insol.*	*Mn.*	*Co.*
Carter	Brown	4	27N.	2W.		15	
	Foster	3	27N.	2E.	38.26	21.56	1.30
	Turley	31	28N.	2W.	43.73	22.36	0.46
	Turley	31	28N.	2W.	53.78	19.02	0.38
Iron	Martin	9	31N.	4E.	86.13	1.31	0.16
Reynolds	Anderson	28	31N.	2W.	55.66	15.19	0.39
	Buford	26	29N.	1W.	40.39	22.24	1.04
	McIntosh	8	30N.	2E.	68.78	11.94	0.41
	Skaggs	34	28N.	1E.	61.85	13.22	0.43
	Tucker	11	29N.	1W.	31.41	27.61	0.47
	Williams	35	29N.	1W.	43.01	21.42	0.81
Shannon	Culpepper	2	28N.	4W.	17.43	29.33	2.30
	Egyptian Tie	29	29N.	1W.	79.71	3.93	tr.
			AVERAGE		51.68	17.24	0.74

MANGANIFEROUS NODULES IN RESIDUUM.

Some manganese ore has been obtained from the residuum of the Potosi formation in Madison County. During the last World War about 80 tons of manganese and iron ore were dug at the Clover Mine, north of Cornwall, and at least one carload was shipped. This ore consisted of particles of manganese ore and of manganiferous iron ore varying in size from that of small pebbles to that of boulders weighing several hundred pounds. These are haphazardly distributed through the reddish residual clay along with fragments of chert, quartz druse, and pebbles and bouldery masses of limonite. Some of the masses are quite pure and consist almost entirely of pyrolusite, others are mixtures of limonite, pyrolusite, psilomelane and probably manganite. The ore occurs at and close to the surface. Like the chert, clay, limonite and druse it seems to be part of the residuum from the weathering of dolomite formations which formerly outcropped where the deposits are located. The residuum at the Clover Mine contains the typical druse of the Potosi formation and the oolite of the Eminence formation. At the Phillips prospect, similar mixed residum rests upon beds of the Upper Davis formation. Apparently both the manganese ore and the iron ore have been concentrated by the weathering of a thick section of dolomite beds, in which all of the soluble carbonates and much of the finer clay have been removed, while the insoluble oxides of iron, manganese and silicon have remained behind and have accumulated. Analyses of some of the best types of this ore are given in Table IV. The silica content of some of this ore might be high even after concentration due to the fact that in some places, as at the Buxton prospect, the residual ore contains considerable sand. Pilot plant tests should be run before any large scale operation is undertaken. The ore is low in sulphur, phosphorus and cobalt.

TABLE IV

ANALYSES OF RESIDUAL MANGANESE ORE IN MADISON COUNTY

Name of Deposit	*Location*			*Partial Composition (percent)*		
	Sec.	*T.*	*R.*	*Insol.*	*Mn.*	*Co.*
Buxton	2	32N.	7E.	30.20	33.15	0.14
Clover	30	33N.	8E.	19.72	36.55	0.12
Phillips	10	31N.	5E.	4.63	41.79	0.17
		AVERAGE		18.18	37.16	0.14

MANGANIFEROUS FISSURE FILLINGS IN CLAY.

A type of manganese ore which has attracted a number of prospectors is that which occurs in fissures in residual clay. These fissures, horizontal or vertical, are filled with a sooty, black, earthy pyrolusite or wad of high manganese content. It is the richness of the ore which is so attractive but the quantity of ore available is very disappointing. The fissures are not numerous and not more than an inch or two wide. Larger pockets do occur along them but the amount of ore is small. An attempt was made to develop one of these properties, the Cook prospect in Madison County, but the venture was unsuccessful. The loose, powdery texture of this ore makes it unfit for direct use in the manufacture of steel, unless it is sintered, but a high grade concentrate of the pyrolusite ore would be suitable for use in the manufacture of dry batteries. The following table is a summary of partial analyses of this type of ore:

TABLE V

ANALYSES OF EARTHY MANGANESE ORES FILLING SEAMS IN RESIDUAL CLAY

County	*Name of Deposit*	*Location*			*Partial Composition (percent)*		
		Sec.	*T.*	*R.*	*Insol.*	*Mn.*	*Co.*
Iron	Campbell	4	32N.	3E.	25.16	31.09	0.12
Madison	Cook	12	32N.	7E.	28.81	35.76	0.15
	White	32	34N.	8E.	0.94	48.30	0.15
Reynolds	Hackworth	9	28N.	1E.	7.83	34.21	0.07
	McIntosh	8	30N.	2E.	40.97	14.56	None
			AVERAGE		20.74	32.78	0.10

MANGANIFEROUS SANDSTONE.

Manganiferous sandstone also is found in Missouri. Wherever manganiferous solutions traveling through sandstone come in contact with the air, manganese minerals are apt to be precipitated on and between the sand grains. The deposit frequently is only a black film around each sand grain, but in some places, the sandstone may be well indurated. The Gunter sand in Reynolds and Shannon Counties frequently is manganiferous and other sands have been observed to be elsewhere. In Bollinger County, for example, a sandstone member of the Jefferson City formation was found to contain 20.44% Mn. Usually the manganese content of such sandstones is considerably less and it is unlikely that they will become commercial sources of this element. The following table summarizes the analyses of this type of ore made for this report:

TABLE VI

ANALYSES OF MANGANIFEROUS SANDSTONES

County	*Name of Deposit*	*Location*			*Partial Composition (percent)*		
		Sec.	*T.*	*R.*	*Insol.*	*Mn.*	*Co.*
Bollinger		34	32N.	9E.		20.44	
Reynolds	Chitwood	25	29N.	1W.	39.43	21.06	0.73
Shannon	Fears	12	29N.	2W.	66.84	8.52	0.57
			AVERAGE		53.14	16.67	0.65

From the foregoing discussion of the manganese ores in Missouri it is evident that they fall naturally into two large classes which may be further subdivided as follows:

I Manganese ores associated with igneous rocks.

1. Vein deposits in porphyry.
2. Replacement deposits in volcanic tuff.

II Manganese ores associated with sedimentary rocks.

1. Manganiferous chert breccias.
2. Nodular concentrations in residuum.
3. Fracture fillings in residual clay.
4. Manganiferous sandstones.

CHAPTER IV.

MANGANESE DEPOSITS OF MISSOURI

INTRODUCTION.

Manganese is such a widespread element that it is likely to be found in any county in the State. This especially is true in the Ozark region where small hydrothermal manganiferous veins fill fractures and joints in the pre-Cambrian porphyry and where cherty and sandy residuum, formed by the weathering of the sedimentary formations, has formed locations suitable for the precipitation of manganese from ground water seeping through it. In most places the deposition of manganese is confined to areas too small for commercial development; in a few deposition has been more persistent and widespread creating deposits of possible commercial importance.

The more important known occurrences of manganese in Missouri are located in five counties: Carter, Iron, Madison, Reynolds, and Shannon. Only one property, Thorny Mountain in Shannon County, is productive at the present time. In the following pages the individual deposits in these counties, where some work has been done, are described. The list is not complete. It does not include many of the minor showings visited by the writer in Bollinger, Butler, Howell, Oregon, Perry, Ripley, St. Francois and Wayne counties. These usually show only a few boulders of cemented chert and similar occurrences could be found in practically every county in the Ozark region. Small amounts of manganese are associated with the iron deposits of the Ozark region. At the Deal No. 2 Mine (SE¼ SE¼ Sec. 9, T. 25 N., R. 6 E.) in Butler County a sample of brown iron ore containing 20.86% manganese was collected by the writer. At the Hoehne Mine (E½ SW¼ SW¼ Sec. 26, T. 34 N., R. 13 E.) in Perry County, the umber which is produced commercially contains 3.62% manganese. Such occurrences as these are not described in the following pages.

The descriptions are written in a uniform manner. The number preceding the title is the same as that used to locate the property on the map of Figure 1. On this map the vein-type deposits in porphyry are indicated by a triangle, the sedimentary deposits by a dot. No attempt has been made to indicate the relative importance of the deposits since only a few have been prospected beyond the sinking of a test pit or two. Unless otherwise indicated, the analyses of the ores were made by the Survey chemist, R. T. Rolufs.

CARTER COUNTY

All of the manganese deposits known to occur in Carter County are of the chert breccia type consisting of angular fragments of residual chert cemented by psilomelane. The ore occurs at or close to the contact of the Eminence and Gasconade formations and is believed to be the result of the deposition of manganese from ground water seeping out at the surface at this horizon. Only one attempt has been made to mine this manganiferous breccia within the county.

1. J. A. FOSTER PROSPECT.

Land owner: Unknown

Lessee: None

Location: NW¼ sec. 3, T. 27 N., R. 2E., about 3 miles southeast of Garwood, in Carter County, Missouri. Near J. Atwood Foster's house on Big Bushy Creek.

Description: Black, dense and botryoidal psilomelane cements chert and sandstone fragments into a breccia which appears as bouldery masses and ledges in the residual soil. Mr. Foster stated that this material can be traced at precisely the same horizon into section 2 and northward into Reynolds County. No development work has been done.

Stratigraphic position: Gunter horizon, Gasconade formation.

Ore: A sample of ore was obtained from the outcrop and analyzed by R. T. Rolufs. It contained:

Insoluble	38.26%
Manganese (Mn)	21.56
Cobalt (Co)	1.30

2. C. P. TURLEY SHAFT.

Land owner: C. P. Turley

Lessee: C. J. Benson and F. B. Greene

Location: NW¼ NW¼ sec. 31, T. 28 N., R. 2 W., in the saddle of a ridge, about 200 feet above Mill Creek, just east of the Shannon County line and 7 miles N. 60 E. of Winona.

Altitude: 1000-1020 feet

History: The presence of a chert breccia cemented by manganese oxide on the land of the Missouri Lumber and Mining Company was noted by Lonsdale and recorded by Nason[1] in 1892. At that time a shaft already had been sunk and several shallow test pits had been dug by J. B. White or the Stegall and Southern Missouri Mining Company. When visited by Hughes[2] in 1917, it was still owned by J. White but apparently no further work had been done since the original shaft was sunk.

Description: The shaft is located in the saddle of a porphyry ridge which here is covered by a mantle of angular chert and red clay residuum. Porphyry is exposed at the base of the hill, where the Ross prospect in Shannon County is located, but about half way up the slope chert residuum covers the porphyry. A ledge of chert residuum cemented by psilomelane is exposed in the wall of the shaft within 3 feet of the surface. According to Lonsdale the shaft cut about 3 feet of this manganiferous breccia and then cut a red gritty clay containing occasional small nodules of manganese ore. The lower 20 feet of the shaft is in chert residuum. The shaft is 5x6 feet and is reported to be 30 feet deep. A drift was cut at the base of the shaft, but no manganese was found. Some additional prospecting has been carried on at the base of the hill, apparently without success.

Stratigraphy: The chert residuum has been derived chiefly from the Gasconade formation Large cryptozoan structures in chert were observed on the surface about 10 feet below the collar of the shaft. Solid rock does not outcrop but it is believed that the ore occurs approximately at the Gunter horizon.

Ore: The mineral probably is psilomelane. The ore itself is very siliceous and of low grade. An analysis given by Nason records 25% Mn and 50% SiO_2. Two samples collected by the writer were analyzed by R. T. Rolufs. The results are as follows:

	Sample No. 1	*Sample No. 2*
Silica (SiO_2)	40.50	52.48
Alumina and Iron Oxide (Al_2O_3 & Fe_2O_3)	3.23	1.30
Manganese (Mn)	22.36	19.02
Cobalt (Co)	0.46	0.38

Production: One car of ore is reported to have been shipped. It is said that it contained 32% manganese, which just about paid for the freight.

Future: If an economically successful method is developed to treat this type of ore, the deposit should be re-examined.

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[1]Lonsdale, E. H. Missouri Geol. Survey notebook 161, p. 85. Nason, F. L. A report on the Iron ores of Missouri; Geol. Survey of Missouri Vol. II, pp. 20 and 95, 1892.

[2]Hughes, V. H. Unpublished manuscript in Survey files.

3. HENRY PECK PROPERTY.

Land owner: Henry Peck heirs

Lessee: C. J. Benson and F. B. Greene

Location: NE¼ NW¼ sec. 19, T. 28 N., R. 2 W., in Carter County, about ¼ mile south of the Shannon County line.

Altitude: 1050 feet

Description: Sandstone and chert boulders in which psilomelane acts as a cement for the sand grains and angular chert fragments are exposed in a small ravine. Because of the extensive amount of residuum the parent ledge of these boulders could not be found. No prospecting has been done.

Stratigraphic position: Possibly the Gunter horizon of the Lower Gasconade formation.

ADDITIONAL OCCURRENCES IN CARTER COUNTY

4. S½ NW¼ sec. 16, T. 26 N., R. 2 E. The property was prospected by M. J. Hardwick of Glen Alen, Bollinger County in 1940. Mr. Hardwick reported that thin seams of wad occur at several places in residual clay, and that chert and sandstone fragments are cemented by harder manganese oxide. Shallow prospecting failed to uncover a commercial quantity of ore.
5. NW¼ sec. 18, T. 26 N., R. 2 E. Lonsdale[3] reported the occurrence of black manganese oxide encrusting fragments of chert and sandstone. In a pit 4 feet deep considerable cherty ore in a sandy red clay was uncovered on one side, but none could be seen in the other walls. Some limonite pseudomorphous after pyrite was found near the top of the hill.
6. NW¼ NW¼ sec. 22, T. 26 N., R. 2 E., on land belonging to J. W. Pointer. A man named Hammond is reported to have prospected for manganese about 1916.
7. NW¼ NE¼ sec. 4, T. 27 N., R. 2 W., on the southwest side of a ravine tributary to Mill Creek, about 6 miles north of Fremont. The property was reported to have been prospected by Carl Schoop in 1925. A residual chert breccia cemented to psilomelane and reported to contain 15% manganese outcrops for about 50 feet along a ravine. The formation was considered to be Gasconade by Bridge.
8. SW¼ NE¼ NW¼ sec. 6, T. 27 N., R. 2 W., on the spur of a hill about 50 feet above a ravine tributary to Mill Creek and 6½ miles N. 27 W., of Fremont, Carter County. Manganese was reported to have been found here in 1917 by a brother of Luther Norris. A single pit about 6 feet in diameter and 8 feet deep was dug into the cherty manganiferous residuum of the Gasconade formation. The pit was only about 2½ feet deep when visited and the manganese content of the chert appears to be too low to warrant further prospecting.

IRON COUNTY

Iron County has the distinction of being the first county in Missouri to produce manganese. As early as 1852, Litton[4] detected the occurrence of this element in considerable quantity

[3]Lonsdale, E. H. Survey notebook No. 161, p. 79, 1892.

[4]Litton, A., A preliminary report on some of the principal mines in Franklin, Jefferson, Washington, St. Francois and Madison counties, Missouri: First and Second Annual Repts., Geol. Survey of Missouri, p. 83, 1855.

in the iron ores of this county and in 1872 Pumpelly[5] gave a description of the deposits and recognized their possible economic importance. The first ore, according to Weeks[6], was shipped in 1881.

Although the production has been small, critical conditions in our country have revived an interest in the manganese ore of this county. During World War I, the old deposits were examined again and during the present emergency interest in them has been renewed. None of the deposits is considered large, but under present circumstances a small quantity of ore might be produced from two or three properties.

The manganese ore occurs in the form of oxides which:

1. Fill fractures in porphyry.
2. Partially replace porphyry adjacent to the fractures.
3. Partially replace volcanic tuff beds interlayered with porphyry.
4. Form nodular segregations within the tuff.
5. Cement chert fragments and sand grains resulting from the weathering of the sedimentary rocks which lie on top of the porphyry.
6. Fill fractures in residual clays.

The first three types of deposit are believed to be the result of the deposition of manganese oxides from hydrothermal solutions. The last three types are the result of the deposition of manganese oxides from circulating ground water.

Only the deposits associated with the igneous rock, the porphyry and the tuff, are considered to be good prospects in the county at the present time. The others are believed to be of too low a grade for economic exploitation.

9. BIG MUDDY COAL AND IRON COMPANY MINE.

Land owner: Big Muddy Coal and Iron Co., St. Louis, Missouri

Lessee: None

Location: SW¼ SW¼ sec. 18, T. 33 N., R. 4 E., on south slope of a ridge 3½ miles southwest of Arcadia.

Altitude: 1250 feet, approximately.

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[5]Pumpelly, Raphael, Notes on the geology of Pilot Knob and its vicinity: Geol. Survey of Missouri: Preliminary Report on the Iron Ores and Coal Fields from the Field Work of 1872 pp. 20-28, 1873

[6]Weeks, J. D., Manganese: U. S. Geol. Survey Mineral Resources of the United States, pp. 346-348, 1885.—U. S. Geol. Survey Sixteenth Annual Rept. (1894-1895) Pt. III pp. 416-417, 1895.

History: This property was opened by the Madison Iron and Mining Company about 1850. In 1852 specimens analyzed by Litton[7] were found to contain considerable manganese. The property was visited by Pumpelly[8] in 1872 and described by Schmidt[9]. It was known as the Ackhurst, Bogy or Buford Bank but it is not to be confused with Buford Mountain, which is in T. 35 N., R. 3 E. This error was made by Nason[10] and by Crane[11]. The Big Muddy Coal and Iron Company reopened the property in 1915. According to Hughes[12], a trench not over 10 feet deep was cut westward into the hillside. The ore body dipped sharply southward and was followed 40 feet by a drift near the bottom of the west end of the open cut. The property has not been worked since 1915.

Description: The location of the trench with its caved walls is all that can be seen of the old workings today.

Stratigraphy: According to Hughes, the ore body is underlain by porphyry which in some places is decomposed to a reddish clay and in others is altered only slightly. The ore is overlain by partly decomposed porphyry. All the rocks are pre-Cambrian.

Ore: The manganese ore associated with considerable dense, blackish gray hematite, fills fractures in a reddish brown rhyolite porphyry and replaces the porphyry adjacent to the veins. Most of the ore is specularite which appears to be earlier than the manganese oxide. The following analyses made in 1915 by the Big Muddy Coal and Iron Company show the variable character of the ore:

Silica (SiO_2)	12.21 to 43.40%
Manganese (Mn)	2.40 to 22.00%
Iron (Fe)	22.89 to 49.04%
Phosphorus (P)	0.028 to 0.089%
Sulphur (S)	0.00 to 0.15%

Production: According to Weeks[13] a small amount of manganiferous iron ore, containing about 15% Mn, was shipped to the Vulcan Steel Works in St. Louis sometime prior to 1885. None is known to have been shipped since.

Future: Apparently the deposit was rather thoroughly prospected in 1915 without success. The ore apparently is too siliceous, too high in iron and not extensive enough for profitable mining as a high grade manganese ore.

7Litton, A., op. cit. p. 83, 1855.

8Pumpelly, R., op. cit. pp. 22 and 26, 1873.

9Schmidt, Adolf, The iron ores of Missouri: Geol. Survey of Missouri, Preliminary Report on the Iron Ores and Coal Field, from the Field Work of 1872, p. 65, 1873.

10Nason, F. L., Op. cit., pp. 49, 338.

11Crane, G. W., The iron ores of Missouri: Mo. Bur. Geol. and Mines, Vol. X, p. 262, 1912.

12Hughes, V. H., Unpublished manuscript in Survey files.

13Weeks, J. D., Manganese: U. S. Geol. Survey Mineral Resources of the United States, pp. 346-348, 1885.

10. CAMPBELL PROSPECT.

Land owners: John R. Campbell and his wife, Letha Campbell.

Lessee: The Western Mining Corporation of Missouri (G. Earl Doane, Poplar Bluff, Missouri, Secretary-Treasurer).

Location: E½, Lots 1 and 2, NW¼ Sec. 4, T. 32 N., R. 3 E., on north side of State Highway No. 21, just east of Carver Creek.

Altitude: 1100 feet, approximately.

Description: Soft, black, sooty, manganese oxide, associated with earthy brown limonite, is exposed in vertical and horizontal seams in a cut along the old highway. The seams are not over 2 or 3 inches wide and are not numerous.

Stratigraphy: According to a reconnaissance map by Dake, the residuum has been derived from the Gasconade formation.

Ore: It is possible to dig rather high grade, soft ferruginous manganese oxide out of the fracture fillings and small pockets but there is no indication that a commercial manganese deposit exists here. The manganese mineral probably is manganite. It yields water when heated in a closed tube but it does not yield oxygen as pyrolusite would. Cavities in the porous ore are coated with minute black crystals which appear to be orthorhombic. An analysis of the sooty ore by R. T. Rolufs shows it to contain:

Silica (SiO_2)	23.51
Alumina and iron oxides ($Al_2O_3+Fe_2O_3$)	1.65
Manganese (Mn)	31.09
Cobalt (Co)	0.12

11. CUTHBERTSON OR MARBLE CREEK MINE.

Land owners: The mine is located on two 40 acre tracts which are owned by two parties. The northern 40 belongs to the Pilot Knob Ore Company (Union Trust Company, St. Louis, Trustee), the southern 40 to Mrs. Anna D. Schmidt, St. Louis.

Lessee: Dr. J. H. Martin, et al.

Mining Company: The Western Mining Corporation of Missouri (G. Earl Doane, Poplar Bluff, Missouri, Secretary-Treasurer)

Location: S.½ NE¼ NW¼ and N.½ SE¼ NW¼ Sec. 19, T. 33 N., R. 4 E. About 3½ miles S. 20 W. of Arcadia, and ½ mile west of White School on Marble Creek. The mine is on the south slope of Cuthbertson Mountain.

Altitude: 1200 to 1300 feet.

History: This is the oldest manganese mine in Missouri. It was visited by Pumpelly[14] in 1872. At that time the land belonged to a Mr. Cuthbertson, after whom the hill is named. The surface was strewn

[14]Pumpelly, R., Op. cit. pp. 20-21.

"with large and small fragments of manganese ore, and, in places, of specular iron ore." A trench, probably the eastern most one, observable at present, had been cut into the hillside. In it "a bedded deposit consisting of exceedingly ragged tabular masses of manganese ore, separated by a red ochreous clay," was exposed. In a sketch of the wall, Pumpelly shows that the deposit dips southward with the slope of the hill, the head of the deposit abutting against decomposed rhyolite porphyry. Analyses of the manganese ore and of the iron ore, made by Chauvenet, yielded the following results:

	Manganese ore	*Iron ore*
Insoluble	0.44	2.45
Iron oxide (Fe_2O_3)	3.30	97.85
Manganese oxide (MnO)	68.02	trace

According to Weeks[15], in 1881 the Arcadia Mining Company of Arcadia, Missouri, shipped about 2000 tons of manganese ore to the Missouri Furnace Company in St. Louis, where it was used to produce pig iron containing 0.75% manganese.

Analyses of this ore, given by Weeks are as follows:

	Sample No. 1	*Sample No. 2*
Manganese (Mn)	64.98	58.02
Iron (Fe)	2.82	3.35
Phosphorus (P)	0.04	0.03

How long the property was operated has not been recorded but it was idle for over 30 years, or until World War I created a demand for domestic manganese. The property was reopened in 1916 but was closed again in 1917 because the ore was considered to be too siliceous and to lack depth.

In 1939 Dr. J. H. Martin of Arcadia and his associates leased the property, did some prospecting, and piled up several tons of good ore. However, a lot of dirt had to be moved to get it and in the spring of 1941, the mining was turned over to Ernest Pearce of Cadet, Missouri, who carried on enough surface work to produce about 30 tons of ore, which were shipped. At the present time the Western Mining Corporation of Missouri has a contract to mine, but has taken out only enough ore for ore-dressing tests by the Mississippi Valley Experiment Station of the U. S. Bureau of Mines at Rolla.

Description: The workings lie on the steep south slope of Cuthbertson Mountain and cover an area approximately 500 feet square. The old cut, a trench about 100 feet long, 25 feet wide and not over 15 feet deep is still to be seen east of the more recent diggings. The banks of this cut are covered by surface debris but at its head is a dark gray, apparently bedded, decomposed rhyolite porphyry which contains considerable calcium carbonate. According to Pumpelly, the manganese ore in this trench occurred as irregular masses in a reddish clay in sharp contact with the porphyry.

[15]Weeks, J. D., Manganese: U. S. Geol. Surv. Mineral Resources of the United States, pp. 346-348, 1885; and U. S. Geol. Surv. Sixteenth Ann. Report, 1894-1895, Pt. III, pp. 416-417, 1895.

The other workings are probably all of more recent origin, most of them having been dug initially in 1916 and 1917. On the south edge of the mined area a narrow, exploratory trench recently was reopened by the Western Mining Corporation of Missouri. In the northwest portion of the trench a brownish to blackish manganiferous clay, probably similar to that encountered in the earlier work is exposed for a distance of 50 feet. At the heading it is 6 feet thick. This clay is quite plastic when wet and probably is an altered rhyolitic tuff or ash. The manganese and iron oxides are disseminated throughout the clay and occur as segregations or irregular lumps of soft, porous, black manganese ore and as smaller amounts of dense grayish hard ore in the clay. The ore horizon is overlain by approximately 4 feet of decomposed porphyry and is underlain by a reddish brown porphyry. It seems to dip southeast.

This same type of manganiferous clay is exposed in the north and west walls of a cut on the west side of the property, just northwest of the trench. It is reported to have been dug by a steam shovel in 1917. It is a shallow excavation in the hill side, open on the east and south sides, not over 8 feet deep and about 100 feet long by 45 feet wide. Apparently the ore was chiefly wad which seems to occur in a bed which dips as much as 15° S. 84 E. with the hillside. In more recent prospecting, three small pockets were dug into the west wall to ascertain the character of the deposit, and the Western Mining Corporation of Missouri opened a shaft in the floor. This shaft is 20 feet from the west wall and 37 feet from the north wall. It is 6 feet square and about 12 feet deep. The shaft cut 3 feet of surface dirt and 4 feet of soft brownish manganiferous clay and then went into a manganiferous limestone cut by rhyolite porphyry. This is of special interest since it is the only place in Missouri where limestone is known to occur in the pre-Cambrian. Since the limestone is exposed only in this shaft, nothing is known about its extent or distribution but the fact that it has been cut by the rhyolite porphyry is well shown by material taken from the shaft and by thin sections of this rock.

North of the workings just described is another group of trenches, shafts and short adits, the latter not over 10 feet long, where an attempt was made to mine the ore underground. Here again irregular, nodular masses of soft, porous manganese oxide associated with minor amounts of hard, steely ore occur in a soft, manganiferous clay, probably decomposed tuff, which is about 3 feet thick and dips about 10° to the north. This ore horizon is overlain by dark felsitic flows which extend from here to the crest of the hill. Apparently the tuff beds afforded an avenue of circulation for water. Beneath the ore bed is a dull, fine-grained, porous, light, reddish tuff.

Above these workings are several shallow pits, probably the sites of old, shallow shafts. According to one report, a drift was cut underground here. Some additional shallow prospecting has been carried on more nearly in the center of the mined area but the results were less favorable here than elsewhere.

Stratigraphic position: The foregoing description is sufficient to show that the manganese is concentrated chiefly in beds of altered volcanic tuff, 3 to 6 feet thick, which occur between acidic lava flows regarded as pre-Cambrian.

Ore: The manganese occurs principally in two forms:

1. In a brownish to blackish soft, clayey wad ore in which the dull, earthy manganese oxide, associated with limonite, is disseminated through the clayey, altered tuff.

2. In irregular, nodular, masses or segregations of pyrolusite and psilomelane in the soft wad ore. Most of these lumps are dull, black, soft, earthy and porous, but a few are submetallic, grayish, hard and dense. The writer collected samples of each type of lump ore which were analyzed by R. T. Rolufs. Admittedly both analyses are of the highest grade of ore observed. Sample No. 1 was taken as representative of the best hard ore, sample No. 2 as representative of the soft lump ore.

	Sample No. 1	*Sample No. 2*
Silica (SiO_2)	1.47	24.79
Alumina and iron oxides ($Al_2O_3+Fe_2O_3$)	0.37	12.37
Manganese (Mn)	50.00	18.31

These analyses are not representative of the ore body as a whole. Other samples of the ore submitted to the Survey for analyses ran 53.21 and 54.82% manganese respectively. These, like the writer's samples, were hand picked. Since its phosphorus content is quite low, qualitatively the hard ore is highly desirable, but unfortunately it is not abundant.

Most of the manganese occurs as wad disseminated in the decomposed tuff. This ore is very clayey, high in silica and alumina, contains some limonite and calcite, and considerable absorbed and combined water. All of the ore contains a small amount of barium but no cobalt. This type of ore is not very amenable to economic concentration. The low specific gravity of the manganese mineral, due to its high porosity, would prohibit satisfactory gravity concentration while the clay content would give trouble with sliming in flotation. Chemical leaching would require the handling of a large volume of material and the expenditure of more money for equipment than the size of the deposit would justify.

Production: Apparently all the ore which has been shipped from the property has been lump, sorted at the working face. There is no evidence of any type of concentrating plant having been used on the property and the production has been very small. Weeks[16] reported that 2000 tons were shipped to St. Louis in 1881. A small amount of ore may have been removed in 1916-1917 but there is no known production between 1881 and May, 1941, when 30 tons of lump ore were reported to have been sold to the Sheffield Steel Corporation at Sheffield Station in Kansas City, Missouri.

Future production: Additional work on this property probably would yield an additional small quantity of lump ore but the grade of the ore will not be high, unless very close sorting is employed, and the production costs will be high.

[16] Weeks, J. D. Op. cit. pp. 346-348, 1885.

12. PILOT KNOB ORE COMPANY MINE.

Land owners: Vimont heirs

Mineral rights: Pilot Knob Ore Co. (Union Trust Co., St. Louis, Trustee)

Lessee: None

Location: NW¼ SE¼ Sec. 18, T. 33 N., R. 4 E., on west slope of a porphyry knob, 3 miles south of Arcadia.

Altitude: 1250 feet, approximately

History: Iron ore was mined here by the Pilot Knob Ore Company many years ago

Description: A number of cuts have been made into the hillside. One is approximately 100 feet long and 40 feet wide, another is about 50 feet long. None is very deep. Near the top of the hill, above the other workings, a shaft, now filled, is reported to have been sunk 50 feet in solid porphyry.

Stratigraphy: The hill is underlain by pre-Cambrian felsite porphyry flows, and interlayed tuff beds. One of these was observed to be thinly laminated, decomposed and about 5 feet thick.

Ore: Specular hematite fills fractures in the felsite porphyry and in part replaces it. The manganese oxide apparently occurs in irregular masses in the tuff and seems to be later than the hematite. The quantity of manganese ore appears to be very small. The hematite in the fractures is of good grade but to produce it would require the quarrying of a considerable amount of porphyry and careful selection of the ore.

Production: One car of iron ore is reported to have been shipped, but no manganese ore is known to have been produced.

13. RUSSELL PROPERTY.

Land owner: Arch S. Russell, Box 24, R .F. D. 3, Sikeston, Missouri.

Lessee: None

Location: NW¼ NW¼ Sec. 19, T. 33 N., R. 4 E., in Clark National Forest, on west slope of Cuthbertson Mountain, 3½ miles southwest of Arcadia, Missouri.

Altitude: 1200 feet, approximately.

History: As early as 1872 Pumpelly[17] noted the association of manganese oxides with specular iron ore at the surface on a porphyry hill owned by a Mr. Cuthbertson. Some prospecting and mining were carried on, probably between 1872 and 1892, by the Pilot Knob Iron Company. Several trenches and pits were dug and some iron is said to have been shipped.

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[17]Pumpelly, R. Op. cit. pp. 20-28, 1873.

Description: The property now is overgrown with so much brush that the sites of the old workings are not seen readily. These occur on the slope of the hill and are not over 10 feet deep. One trench is about 50 feet long and 12 feet wide, others are smaller. Higher on the hillside, above the trenches and pits, are two shallow shafts which, judging from the debris about them, cut soft manganiferous earth, probably a decomposed volcanic tuff. No work has been done here for more than thirty years.

Stratigraphic positions: The hill is underlain by trachyte and quartz porphyry flows interbedded with volcanic tuff of pre-Cambrian age. These were described by Pumpelly.

Ore: The hematite and some of the manganese oxide appear to fill fractures in the volcanic flows and to partially replace these rocks, while some of the manganese oxide seems to have replaced intercalated tuff, forming a soft, brown wad ore. The deposit is low in manganese and highly siliceous. Some iron ore is reported to have been shipped from this property but the quantity of manganese oxide appears to be too small to warrant its development as a manganese mine.

14. FRED SWEARINGIM PROSPECT.

Land owner: Pilot Knob Ore Company (St. Louis Union Trust Co., St. Louis, trustee)

Lessee: The Western Mining Corporation of Missouri (G. Earl Doane, Poplar Bluff, Missouri, secretary-treasurer)

Location: W½ SE¼ SW¼ Sec. 19, T. 33 N., R. 3 E., on the steep east valley wall of a ravine tributary to Little Tom Sauk Creek; about 4 miles, N. 75° W. of Hogan.

Altitude: 1100 feet, approximately

History: Manganese ore was discovered here by Fred Swearingim about 1929. His first prospecting was done somewhat below the present site. The property never has been worked but was leased for prospecting to the present lessees.

Description: Only two surfaces of the hillside have been cleaned off to expose the ore. One exposure is 20 feet long and six feet high; the other, about 125 feet N. 10 W. of the first, is 50 feet long and about 10 feet high. These exposures are little more than ledges cut into the steep porphyry hillside. The ore occurs along a N.W.-S.E. set of nearly vertical joints which are cut by a later set which strike N.E.-S.W. and dip with the hillside but at steeper angles.

Stratigraphy: The ore is in a reddish to brownish gray rhyolite porphyry.

Ore: The ore mineral is chiefly a hard, dense, brittle braunite. It has a blackish to brownish streak, a conchoidal fracture and occasionally contains grains which exhibit cleavage. It yields very little water or oxygen when heated in a closed tube but it is decomposed by boiling hydrochloric acid with the formation of a silica gel. In thin section the ore appears dull, earthy and dark chocolate brown in reflected light but black in transmitted light because it is opaque. An analysis by R. T. Rolufs of the carefully selected mineral already has been given in Table I. Most of the ore is far from being as pure as that selected for this analysis. In the field it is very apparent that the ore has not only filled joints or fractures but it has replaced the porphyry itself, particularly the ground mass, and a perfect gradation may be observed from nearly pure ore to solid porphyry. Most of the material which had been quarried as ore and placed in piles was very siliceous; glassy quartz and kaolinized feldspar phenocrysts being quite apparent in the dense, black, manganiferous groundmass. A study of a thin section of the ore beneath a petrographic microscope showed that the manganese oxide has replaced chiefly the feldspathic portion of the groundmass, leaving the quartz untouched, although it does fill fractures in the quartz. The ore here definitely has replaced the porphyry and this has occurred in a rather spotty, irregular fashion along the mineralized joints. At various places along these joints mineralization has spread out over areas 2 to 3 feet long and as much as 2 feet wide.

The tenor of the ore as a whole is considerably less than that of the carefully selected material. An analysis of the best grade of material which had been segregated during prospecting resulted as follows:

Silica (SiO_2)	31.77
Alumina and iron oxides ($Al_2O_3+Fe_2O_3$)	11.49
Manganese (Mn)	31.75
Cobalt (Co)	0.05

Future: At the time the property was visited only the surface had been scratched. In the southernmost quarry manganese oxide veins were distributed over a distance of 5 feet, in the other excavation they were distributed over about 7 feet. Most of the face was porphyry, much of the ore was highly siliceous and of low grade. It is possible that these mineralized joints might widen with depth. The property should be further prospected by sinking a shaft on the veins.

ADDITIONAL OCCURRENCES IN IRON COUNTY.

15. W½ SE¼ SE¼ sec. 9, T. 31 N., R. 4 E., one mile west of Minimum. A layer of sandy chert residuum of the Lower Gasconade formation cemented by iron and manganese oxides outcrop along County Highway C at the home of Mrs. Vina Martin. The ledge is 12 to 18 inches thick and was found on analysis to contain 1.31% manganese and 0.16% cobalt.

16. NW¼ NE¼ NW¼ sec. 33, T. 33 N., R. 3 E., on the L. P. Marr property along Carver Creek. This property was under lease to the Western Mining Corporation of Missouri. Thin bands of soft black manganese oxide occur in the cherty hillside residuum derived from the Lower Gasconade formation. Very little prospecting has been done and surface showings are not indicative of a commercial manganese deposit.

MADISON COUNTY

The occurrence of manganese in Madison County was recorded by Broadhead[18] in 1874. A sample taken 4 miles northwest of Fredericktown was analyzed by Chauvenet who reported it to contain:

Siliceous matter	56.82%
Manganese (Mn)	9.86
Iron (Fe)	13.07
Water (H_2O)	3.19
Lime (CaO)	present
Magnesia (MgO)	present

A number of other occurrences were recorded by Keyes[19]. These were chiefly of wad in residuum and none was important.

It was not until World War I that an attempt was made to produce manganese commercially in the county. In 1917 G. L. Barnes leased the Harrison White property, now known as the Clover Mine and succeeded in shipping at least one car of ore. Since that time interest in the deposits waned until recently. Several properties have been leased and prospected and one attempt was made by D. F. Govro to concentrate the ore. Up to the present time, however, no additional ore has been shipped.

All of the manganese of interest in Madison County occurs in residual clays of the Potosi and Eminence formations. Some of it occurs as vertical and horizontal seams of black, earthy oxide cutting through the clay, some of its impregnates sandstone and cements angular fragments of chert, forming a breccia, but that which has been shipped consisted of pebbles and boulders associated with limonite scattered through the surface residuum. One of the manganese minerals is known to be pyrolusite, another may be manganite and the third is psilomelane or some mineral closely related to psilomelane. None of the deposits appears to be extensive.

At Silver Mine, SW¼ Sec. 12, T. 33N., R. E., about 8 miles west of Fredericktown, the manganese bearing tungstate, huebnerite, is being produced from quartz veins. It is mined, how-

[18]Broadhead, G. C., Madison County: Report of the Geological Survey of the State of Missouri. Including Field Work of 1873-1874, p. 347, 1874.

[19]Keyes, C. R., A report on Mine LaMotte Sheet: Mo. Geol. Survey Vol. IX, pp. 80-92, 1895.

ever, as a source of tungsten rather than of manganese. An analysis by the St. Louis Sampling and Testing Works showed it to contain:

Manganese oxide (MnO)	18.33
Iron oxide (FeO)	5.12
Tungstic oxide (WO_3)	76.50
Total	99.95

This deposit has been discussed by a number of writers to whom reference is made in the Survey publication on the area by Tolman[20].

17. BUXTON PROSPECT.

Land owner: Buxton

Lessee: None (Formerly leased by D. F. Govro, Perryville, Missouri)

Location: SW¼ NE¼ Sec. 2, T. 32 N., R. 7 E., on a hillside near the head of White Spring Branch, 0.15 miles west of White Spring and 2½ miles, S. 65° W. of Cornwall.

Altitude: 900 feet, approximately

History: This may have been one of the deposits referred to by Keyes[21] in 1895. It was opened by D. F. Govro of Perryville, Missouri, during the last part of 1938 and the first part of 1940. A prospecting permit was held by Ernest Pearce of Cadet, Missouri, subsequent to Govro's work, but no additional work was done.

Description: A single trench about 100 feet long, 6 to 8 feet wide and 6 to 10 feet deep has been dug northeastward into the hillside residuum. Irregular pellets and masses of black manganese oxide occur principally in the upper 4 to 5 feet of the residuum, the bottom of the trench is in reddish clay.

Stratigraphic position: The residuum, at least in part, is Potosi. Ledges of limestone, probably Bonneterre, are exposed beneath the workings along White Spring.

Ore: Much of the ore is a manganiferous sandstone associated with limonite, chert and reddish clay. Some of the lumps consists of hard, dense, black, clinkery, botryoidal, and stalactitic psilomelane. It contains some cobalt and considerable barium. Roluf's analysis of a hand-picked sample of the ore collected by the writer shows it to contain:

Insoluble	30.20%
Manganese (Mn)	33.15
Cobalt (Co)	0.14

[20]Tolman, Carl, The geology of the Silver Mine Area Madison County, Missouri: Biennial Report of the State Geologist, Appendix I, 1933.

[21]Keyes, C. R., Op. cit. p. 81, 1895.

Production: Only about two tons of ore have been obtained in digging the trench. Some of this has been used for ore-dressing tests. No ore has been produced commercially.

Future: Further prospecting ought to be devoted to determine the areal extent and depth of the manganiferous boulders. A sufficient amount of ore would have to be blocked out to warrant the installation of a small mechanical shovel, washing plant and jigs.

18. CLOVER MINE.

Land owner: Harry Clover

Lessee: None (Formerly leased to D. F. Govro of Perryville, Missouri, and later to Ernest Pearce of Cadet, Missouri)

Location: SW¼ NW¼ NW¼ Sec. 30, T. 33 N., R. 8 E., on the southwest slope of a ridge just east of Henderson Creek on the Belmont Branch of the Missouri Pacific Railroad, about one mile N. 15 W. of Cornwall.

Altitude: 760 to 800 feet.

History: The property was opened about 1890 to produce brown iron ore for use as a flux at Mine LaMotte. Many shallow pits were dug on the west slope of the tract in a belt 600 feet wide and 1000 feet long and both sides of the small gully south of the present house were quite thoroughly dug up for a distance of several hundred feet. In 1917, 58 acres were leased from Harrison White by G. L. Barnes, who is reported by Smith[22] to have dug seven pits from which 80 tons of manganese ore and manganiferous iron ore were produced. After careful screening and hand sorting, 40 tons were shipped. The property remained idle for over 20 years until D. F. Govro of Perryville, Missouri, dug four test pits, but abandoned the property because he was not able to obtain a satisfactory lease, the mineral rights being held by many heirs of the Basham estate. In 1940 about twelve pits were dug by Ernest Pearce of Cadet, Missouri, but the results were not encouraging. No work has been done on the property recently.

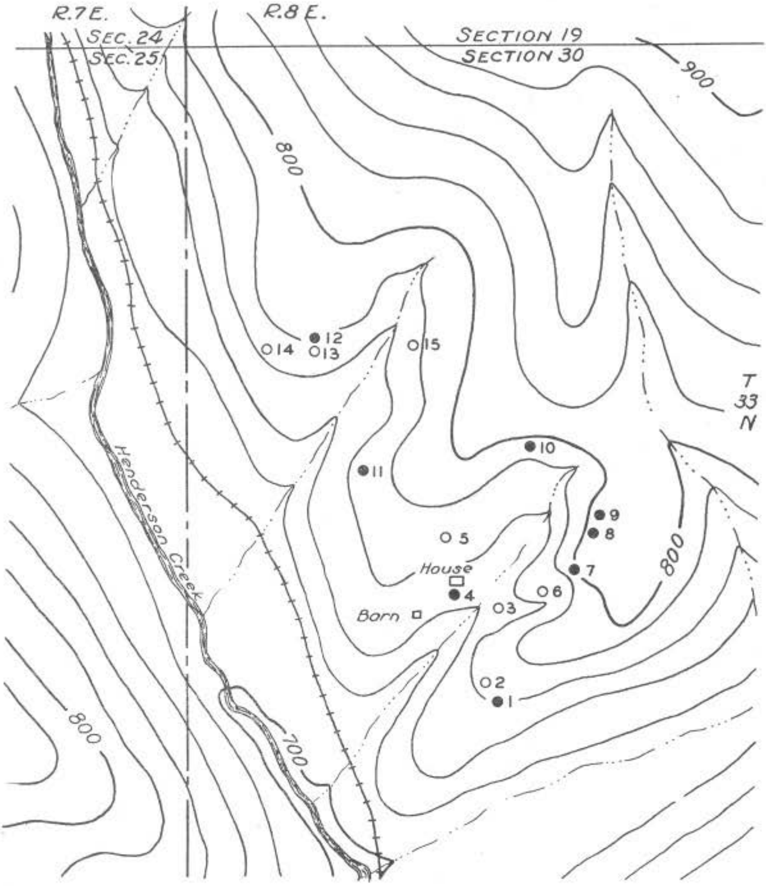
Description: Test pits of at least four different ages are scattered over an area of about 40 acres. As shown in Figure 2, these have been dug around the head of two gullies which drain southwestward to Henderson Creek. The pits vary from 3 to 25 feet across and from 3 to 16 feet deep. Some of them were barren while others yielded several tons of boulders and pebbles or brown iron ore and manganese oxide. The locations of some of the more recent pits and some of the older ones are shown on the accompanying map.

Pit No. 1. This pit was dug by Barnes in 1917. Although it now is filled in, according to Smith, originally it was 20 feet long, 3 feet wide and 9 feet deep, and exposed the following section:

Depth feet	*Rock*
0-2	Reddish clay containing pebbles of chert, limonite, and manganese oxide.
2-3½	Light colored residuum containing boulders of chert.
3½-9	Reddish clay similar to that at the top of the pit. A streak of black clay occurred in the center.

[22]Smith, A. F., Survey notebook No. 549.

MISSOURI GEOLOGICAL SURVEY. BIENNIAL REPORT, 1941-1942, APPENDIX VI, FIG. 2.



CLOVER MINE" MANGANESE PROSPECT
MADISON COUNTY, MISSOURI
Contour interval 20 feet
Scale
0 200 400 800 feet

● Pit, ore in pit and dump
○ Pit, filled, no ore showing on dump

Very little ore was obtained and all of it was of pebble size. Pearce sank a pit 6 feet deep on the south edge of the old pit, encountered the blackish clay and obtained only a little pebble ore.

Pit No. 2. This is another pit dug by Barnes. It is 15 feet northwest of No. 1 and orginally was a right-angled trench, the north arm of which was 10 feet long, 2 feet wide and 5 feet deep, except at the end where it was 7 feet deep. The west arm was 6 feet long, 4 feet wide and 3 feet deep. Several hundred pounds of pebbles and boulder ore were obtained from pockets in the clay. Most of this was obtained within 2 feet of the bottom. The north end of the pit was barren.

Fifteen feet north of Pit No. 2 Barnes dug a third pit 15 feet long, 6 feet wide and 8 feet deep. The western half of this pit was nearly barren, but about 2 tons of brown iron ore carrying manganese and a smaller amount of manganese ore were obtained from the eastern half. The ore is reported to have occurred in runs which died out to the north.

A pit dug by Barnes 10 feet west of the above pit was 6 feet long, 4 feet wide and 6 feet deep. It was entirely in cherty red clay and did not yield any ore.

Pit No. 3. This is in the valley bottom, at the site of an old pit that was probably dug for iron ore. The pit was only 4 feet deep when visited. It is in red cherty clay but did not encounter any ore.

Pit No. 4. This pit, about 5 feet deep encountered chiefly red cherty clay and some chunk ore.

Pit No. 5. This pit is in red clay and 16 feet deep. A few chunks of manganese oxide were obtained. This pit is at the site of an old pit.

Below pit No. 5, near the bottom of the gully, is a small cut dug by Pearce. It is about 3 feet deep, in reddish clay. A few chunks of manganese ore were obtained.

Near the crest of the ridge and southwest of pit No. 5 is another small pit in red clay from which a few chunks of manganese ore were obtained.

Pit No. 6. This pit was dug by Pearce to a depth of 6 feet in yellowish cherty clay. Very little ore was obtained. Northeast of this pit is a shallow cut near the bottom of the gully. This probably also proved to be a poor location.

Pit No. 7. This pit, about 8 feet in diameter was dug by Govro in 1939. It was 12 feet deep. Very few masses of manganese ore were obtained and a blackish clay was noted. The bottom of the hole was in thinly laminated sandstone.

Pit No. 8. Several old pits occur here as well as the more recent one dug by Pearce. Barnes dug one of the pits 15 feet long, 6 feet wide and 3 feet deep. Soft manganese oxide and small chunks of harder ore were obtained. Barnes also dug three other shallow test pits near here. More recently Govro dug several pits without finding much ore and Pearce sank one pit until it encountered a disintegrated dolomite.

Pit No. 9. Much of the manganese ore obtained by Barnes is reported to have been obtained from this and nearby pits. One of these was 25 feet long, 8 feet wide, and 4 to 6 feet deep. At its southeast end a round pit 7 feet in diameter and 15 feet deep was sunk. Boulders of manganiferous limonite and of manganese oxide weighing as much as 100 pounds were taken out. About 20 tons of ore were piled around the pit where it was visited by Smith in 1917 and some ore had been hauled away. Most of this ore occurred on the southeast side of the pit.

The pit was reopened by Govro who verified the fact that most of the good manganese ore occurs on the southeast side. Pearce sank a hole in the bottom of the west side of the old pit so that its total depth was about 16 feet below the rim of the pit. Red clay containing some chunk ore was taken out. The hole was bottomed in a thinly laminated, glauconitic sandstone.

Pit No. 10. Most of the ore shipped by Barnes came from the vicinity of this pit, according to Smith. Barnes' pit was 20 feet long, 10 feet wide and 8 feet deep. The ore obtained from it was chiefly chunks of manganiferous iron ore which varied in size from pebbles to large boulders. A streak of black clay was exposed on the east wall of this pit, where there was considerable iron ore rather uniformly distributed in the face. The manganese ore occurred chiefly in the western end of the pit and was separated from the iron ore by a barren zone.

This was the first place tested by Pearce. He sank a pit to a depth of 12 feet and reported considerable chunk ore and fine ore in clay between depths of 6 and 10 feet.

S. 80 W. of Pit No. 10 is a small, old pit. No manganese is evident in the residuum.

Pit No. 11. This is the best test pit opened in recent prospecting by Pearce. A trench 25 feet long and 4 feet wide has been dug in cherty red clay to a depth of 3 feet, except at the north end, where a round hole was sunk to a depth of 16 feet. A considerable amount of chunk ore and pebble ore was taken from the trench. Lumps of limonite and manganese oxide occur together, some being a foot in diameter. According to Pearce most of the ore was obtained near the surface. A cubic yard of this dirt yielded about 300 pounds of ore. Very little additional ore was obtained in sinking the hole at the north end of the trench to a greater depth.

Pit No. 12. This is a right-angled trench, each arm of which is about 10 feet long, 3 feet wide and 3 feet deep. It was dug by Pearce, who reported that some masses of manganese oxide were as much as 4 inches in diameter but that most of the ore was in pellets less than one inch in size. All of the manganese was obtained within 2½ feet of the surface.

Pit No. 13. A small pit, 3 feet deep, about 25 feet south of No. 12 encountered chert boulders in red clay and very little ore.

Pit No. 14. This pit is about 50 feet southwest of No. 12. It is a trench 6 feet long, 3 feet wide, and 4 feet deep. It also cuts cherty red clay which contains very few pieces of manganese oxide.

Pit No. 15. This is a small pit east of No. 13. It is about 3 feet deep and cut reddish cherty clay containing very little manganese oxide.

Stratigraphic position: The surface of the ground is covered by a mantle of cherty clayey residuum which contains a siliceous oolite typical of the Eminence formation and druse characteristic of the Potosi. The thinly bedded, glauconitic sandstone encountered in the bottoms of some of the prospect pits may belong to the Davis formation.

Ore: The ore consists of particles of manganese oxide and manganiferous limonite which vary in size from less than an inch to boulders weighing several hundred pounds. These are embedded in a cherty reddish clay which forms the soil of the hillside. Most of the ore seems to be residual and to occur within a few feet of the present surface. It may be the result of natural concentration of the larger and heavier particles by washing away of the finer soil material. The ore apparently is irregularly distributed, occurring in pockets within the residuum.

The ore seems to be a mixture of pyrolusite and psilomelane. Some of it is coarsly crystalline, fibrous and may be hard, and quite similar to the psilomelane in the chert breccia in Reynolds and Shannon counties.

An analysis of a sample of the ore by R. T. Rolufs showed it to contain:

Insoluble	19.72%
Manganese (Mn)	36.55
Cobalt (Co)	0.12

The ore is known to contain some iron and barium. Analyses of samples collected by Smith and analyzed by the Survey in 1917 while Barnes was prospecting the property, ran as follows:

	Sample Number							
	1.	*2.*	*3.*	*4.*	*5.*	*6.*	*7.*	*8.*
Manganese (Mn)	34.3	13.85	19.10	27.80	27.70	22.55	15.70	36.20
Iron (Fe)	5.5	16.92	10.10	1.81	2.22	11.38	18.63	0.75
Silica (SiO_2)	18.7	36.90	35.10	33.50	34.20	33.80	29.40	23.60
Phosphorus (P)	0.112	0.07	0.112	0.10	0.061	0.05	0.205	0.042

(1) Average specimen from Pit No. 2 sunk by Barnes.
(2) Average specimen from a pit 15 feet north of No. 2, sunk by Barnes.
(3) Average specimen from a pit sunk by Barnes near Pit No. 10.
(4) Average sample of 11 tons of ore freed of clay.
(5) Average sample of small pebbles in soil.
(6) Average sample of 2 tons of material produced by Barnes near Pit No. 8.
(7) Analysis of manganiferous iron ore from pit sunk by Barnes.
(8) Best grade of manganese ore produced by Barnes.

Additional analyses made by the Survey in 1917 of samples submitted by R. G. Alexander and by C. L. Barnes gave the following results:

Silica (SiO_2)	20.10	26.30	39.4			5.1	23.7	14.2
Manganese (Mn)	32.45	34.27	25.9	50.55	36.10	35.79	11.83	5.05
Iron (Fe)			2.6			12.69	23.97	41.69
Phosphorus (P)	0.059	0.029	trace	0.064		0.164	0.269	0.098

Production: Originally the property was opened to produce iron ore for smelter flux at Mine LaMotte. The quantity of brown ore shipped is not known but it probably did not exceed a few hundred tons. In 1917 G. L. Barnes took out between 80 and 100 tons of manganese ore and manganiferous iron ore. He reported to Hewett[23] that the ore contained 40% manganese, 5% iron, and 15% silica. No ore is known to have been shipped since.

Future: There has been some talk concerning the installation of a log washer, crushing unit and jig to handle the ore, but more prospecting should be done especially in the vicinity of pits No. 9, 10, and 11 to determine if the amount and quality of the ore will warrant the cost of such an installation.

19. S. B. COOK PROSPECT

Land owner: S. B. Cook

Lessee: None (Formerly leased to D. F. Govro, of Perryville, Missouri, and to Dr. J. H. Martin of Arcadia, Missouri)

Location: NE¼ NW¼ SW¼ Sec. 12, T. 32 N., R. 7 E., at the head of Snowden Branch, 3 miles S. 20 W. of Cornwall, and northwest of Cottoner Mountain

Altitude: 950 feet, approximately

History: This may be the property referred to by Keyes[24] as occurring seven to eight miles south of Fredericktown, where a decidedly black earthy variety of manganese ore is present. How long ago the property was prospected is unknown but at least two shafts were sunk. In 1938 D. F. Govro, of Perryville, Missouri, put down one shaft 20 feet deep and another 10 feet deep. Some attempt was made to cut into the hillside. Several tons of ore were taken out and an attempt was made to concentrate it by means of a table.

[23]Hewett, D. F., Manganese and manganiferous ore. U. S. Geol. Survey Mineral Resources of the United States, 1917, Pt. 1, p. 684.

[24]Keyes, C. R., A report on the Mine LaMotte Sheet: Mo. Geol. Survey Vol. IX, p. 81, 1895.

This met with failure. In 1939 Gruner and Driebelbiss of Farmington took out a ninety-day lease but gave it up without doing any work. In 1940 Dr. J. H. Martin of Arcadia acquired a short-term lease and likewise did no work.

Description: The shafts sunk during the former prospecting period are now caved and filled in. They are marked only by shallow pits and mounds of waste. The newer shafts sunk by Govro are southwest of the older shafts and are set in an excavated pit. The first or southernmost shaft was 20 feet deep and the second was 10 feet deep. At the time of the visit the pit contained water so that little could be seen. The shafts were sunk to cut a nearly vertical seam of soft manganese dioxide which is said to trend N. 55 W.—S. 55 E. across the pit. This seam is reported to have a thickness of 2 to 3 feet. Another seam of less width cuts across the first and is said to trend N. 67 E.—S. 67 W.

Stratigraphic position: The surface residuum consists of a reddish cherty clay which contains the quartz druse typical of the Potosi formation.

Ore: The ore occurs as stringers and seams in the clayey residuum. It consists chiefly of soft, black, earthy pyrolusite together with smaller amounts of harder, dense psilomelane, earthy limonite, quartz and clay. A sample of the ore which had been taken out by Govro in 1939 and piled up on a wooden platform was taken by the writer and analyzed by R. T. Rolufs. It ran as follows:

Insoluble	28.81
Manganese (Mn)	35.76
Cobalt (Co)	0.15

Other samples sent to the Survey from time to time by various interested individuals varied in manganese content from 32 to 46%. The ore is known to contain from 4 to 5% iron; about 2% barium; 0.013% copper; and equal amount of nickel; lesser amounts of phosphorus and sulphur; and traces of arsenic, lead and molybdenum. An analysis by the U. S. Bureau of Mines[25] gave the following result:

Silica (SiO_2)	27. %
Manganese (Mn)	35.
Iron (Fe)	4.
Barium (Ba)	2.
Cobalt (Co)	0.1
Nickel (Ni)	0.015
Phosphorus (P)	0.077
Sulphur (S)	0.01
Ignition Loss	7.

Govro attempted to concentrate several tons of the ore by crushing and tabling. He found that the soft, friable ore washed over the table while the table product contained the gangue. A sample of the material which had flowed over his table and which

[25]Engel, A. L., and Shelton, S. M.; Progress reports, Metallurgical Division, Ore-testing studies of the ore-dressing section: R. I. No. 3484, pp. 6-7, Jan., 1940.

had been caught in a sluice box was taken by the writer and analyzed by Rolufs. It contained:

Insoluble	12.35
Manganese (Mn)	43.15
Cobalt (Co)	0.15

It is considerably lower in gangue, higher in manganese, and definitely of commercial grade. As it is produced it would be suitable for battery ore. By sintering it could be converted into nodules suitable for use in the steel industry. Tests made by the United States Bureau of Mines indicated that the soft ore might be concentrated by crushing to 10-mesh, grinding differentially and classifying properly. They recommended separating the minus 200-mesh product in a drag classifier and the minus 400-mesh material in a bowl classifier. The minus 200-mesh product was found to contain 45% manganese and 17% silica while the minus 400-mesh fraction contained 47.75% manganese, 13% silica and gave a 73.5% recovery.

Production: No ore has been sold

Future: Apparently a marketable product could be produced rather cheaply from this deposit. It is doubtful, however, that a sufficient quantity of ore is present to warrant the installation of even a small amount of milling equipment. The aim of any future work should be to establish a stock pile of ore sufficient to feed a small concentrator for a period of time sufficient to pay the cost of installation.

20. E. L. PHILLIPS PROSPECT.

Land owner: E. L. Phillips

Lessee: None

Location: W½ NE¼ NE¼ Sec. 10, T. 31 N., R. 5 E., about two miles east of Jewett, on the east side of a ravine tributary to St. Francois River.

Altitude: 550 feet, approximately

History: According to Mr. Phillips, the property was prospected a number of years ago by a Mr. Green. In 1933 Phillips reopened the prospect but has not done any new development work.

Description: Seven pits and shafts dug during the early prospecting cover an area about 100 feet long, east-west, and 50 feet wide, north-south, on the slope of a hill. One of the shafts is reported to have been 60 feet deep. At present none of the pits is more than 10 feet long, nor more than 6 feet deep. The sides are covered with debris and several are overgrown with brush.

Stratigraphic position: The surface of the hillside is covered by a cherty clay residuum in which cherts of the Lower Eminence and Potosi formations have been identified. This residuum rests on dolomite of the Elvins or Upper Davis formation, which is well exposed along the St. Francois River not far from the property.

Ore: Only a few lumps of manganese ore could be seen. These varied in size from pebbles to one boulder about 9 inches in diameter. This boulder contained well crystallized pyrolusite. It has a granular, somewhat loose porous structure. Cavities were lined with compact fibrous crystals of manganese dioxide of orthorhombic character and by botryoidal ore. The mineral yielded very little water and a large quantity of oxygen when heated in a closed tube, indicating pyrolusite. It contains a little barium and cobalt. A sample of the ore collected by the writer and analyzed by R. T. Rolufs contained:

Insoluble	4.63%
Manganese (Mn)	41.79
Cobalt (Co)	0.17

A sample sent to the Survey for analysis by Phillips in 1933 contained 47.26% manganese. As part of the mineralogical investigation of the ores, a detailed analysis was made by Rolufs of rather pure mineral carefully selected beneath a binocular microscope. This analysis already has been given in Table I.

Production: None

Future: If the quantity of manganese oxide now visible at the surface can be taken as a criterion of the quantity present in the deposit, it is unlikely that this prospect can be developed into a mine. The sinking of at least one new prospect pit might be feasible since what oxide is present is of good grade.

21. OTTO SENTER PROSPECT.

Land owner: Otto Senter

Lessee: None

Location: SE¼ SE¼ SW¼ Sec. 29, and NE¼ NE¼ NW¼ Sec. 32, T. 31 N., R. 7 E., about ¾ mile southwest of Buckhorn.

Altitude: 650 feet, approximately

History: This land was prospected about 1906. More recent work has not been done.

Description: Four shafts or pits were sunk at intervals up a hillside. The deepest was reported to have been 17 feet deep. It is the third one up the hillside. These workings now are filled with dirt and only the site of each hole is visible.

Stratigraphic position: The manganese ore is present as pebbles and boulders in the residuum of the Eminence and Potosi formations which here rests upon rhyolite porphyry flows, some of which contain angular fragments of similar material. The three lower pits apparently were entirely in residuum but the uppermost pit is in porphyry.

Ore: Small pebbles of manganese oxide were picked out of the debris at the sites of the three lower pits and a single large boulder of nearly pure manganese oxide was seen at Mr. Senter's house. The ore mineral is pyrolusite. It yields much oxygen and only a little water when heated in a closed tube. It is black, fibrous and quite similar to the ore at the Phillips property. An analysis of a hand-picked sample of the mineral is given in Table I.

Future: Apparently very little manganese ore was found here. Further propsecting is necessary to determine the distribution and abundance of the ore.

22. ELZA WHITE PROSPECT.

Land owner: Elza White

Lessee: None

Location: NW¼ NW¼ SW¼ Sec. 32, T. 34 N., R. 8 E., on hillside above White's house one mile northwest of Higdon

Altitude: 840 feet, approximately

Description: Two shafts have been dug in reddish, cherty clay residuum. The lower shaft is 6x8 feet and attained a depth of 14 feet. It cut streaks of soft black manganese oxide. The upper shaft, 8x8 feet, is 28 feet deep and is about 25 feet S. 25 E. of the lower shaft. Chert stained by manganese oxide was encountered.

Stratigraphic position: Potosi residuum

Ore: The soft, earthy manganese mineral dug from the lower of the two shafts may be the same mineral that cements the chert. It yields water but no oxygen when heated in a closed tube. It contains considerable barium, some iron and cobalt. A partial analysis of the soft ore by R. T. Rolufs shows that it contains:

Insoluble	0.94%
Manganese (Mn)	48.30
Cobalt (Co)	0.15

Future: The deposit is quite similar to the Cook prospect. It is doubtful that very much manganese oxide could be produced here.

ADDITIONAL OCCURRENCES IN MADISON COUNTY.

Keyes[26] mentioned several showings of manganese minerals in Madison County and Hughes[27] reported an occurrence in NE¼ SW¼ Sec. 11, T. 33 N., R. 6. E. The writer observed boulders of manganiferous chert breccia on top of pre-Cambrian porphyry along a ravine near the center of SW¼ Sec. 14, T. 31, N., R. 7 E. The deposit did not appear to be of commercial importance.

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[26]Keyes, C. R., op. cit. p. 81, 1895.
[27]Hughes, V. H., Survey notebook No. 567, pp. 15-16, 1918.

REYNOLDS COUNTY

Manganese has been known in Reynolds County for at least 70 years. In 1872 P. N. Moore[28] examined the deposit at Johnson's Shut-In on the East Fork of Black River and correctly interpreted it as a fracture filling and replacement deposit in porphyry. During the last World War interest in the porphyry deposits was revived but no great amount of work was done. It is reported that a little ore was shipped from the property on Black River. During the present emergency the old deposits have been examined again and a number of new ones have been studied. The most important of these is the Tucker property prospected first by William M. Nash and Mrs. Blanche S. McCaw and later by the Mining Division of the U. S. Bureau of Mines. Approximately 80 test pits varying in depth up to 64 feet have been dug. This property is important not only because of the ore which it contains but also because the development of many similar prospects depends upon what can be done with the ore here. The ore consists of residual chert and minor amounts of sandstone cemented by psilomelane. It occurs at the contact of the Gasconade and Eminence formations. This type of material is rather widespread at this contact in Reynolds County. Its utilization depends on the development of a suitable method of treating the low grade ore.

There are at least four modes of occurrence of manganese in Reynolds County:

1. In veins and replacement deposits in rhyolite porphyry.
2. In the cementing material of breccias derived from the residuum of weathered sedimentary formations.
3. In thin seams in residual clay.
4. In brown iron ores as a thin film on limonite.

23. CARTER BUFORD PROSPECT.

Land owner: Carter Buford, Ellington, Missouri

Lessee: None

Location: Center of N½ Sec. 26, T. 29 N., R. 1 W., just below the crest of a ridge near the head of Dark Hollow, 6 miles S. 33 W. of Ellington

[28]Pumpelly, Raphael, Notes on the geology of Pilot Knob and its vicinity: Geological Survey of Missouri Preliminary Report on the Iron Ores and Coal Fields from the Field Work of 1872, pp. 24-28, 1873.

Altitude: 980 feet

History: A prospect shaft and several pits had been sunk here many years ago. When this shaft was reopened in April, 1941, the old timbers were found.

Description: A single untimbered shaft, 8x8 feet and 20 feet deep has been sunk in the residuum. Boulders of manganiferous chert breccia were encountered in the upper 17½ feet of the shaft and a ledge of breccia was reported to have been struck in the bottom of the shaft.

Stratigraphic position: The ore occurs in the Gunter zone close to the Eminence-Gasconade contact. Chert residuum above the shaft has been identified as Lower Gasconade by the subsurface laboratory of the Survey, while an oolite obtained below the shaft, at about the same horizon as the base of the shaft, has been identified as Eminence.

Ore: The manganiferous chert breccia is similar to that found elsewhere at the same horizon. Fragments of white, angular, porcelaneous and somewhat sandy chert together with some fragments of sandstone are cemented by black, botryoidal, concentrically banded psilomelane. The chert breccia occurs in a cherty red clay. An analysis by Rolufs of some of the best material from the shaft follows:

Insoluble	40.39%
Manganese (Mn)	22.24
Cobalt (Co)	1.04

Future: The ore here is of the same type as that at the Tucker prospect. If an economic method of recovery can be developed for this type of ore then further prospecting would be justified here. Some manganiferous chert has been encountered in a rectangular pit about 150 feet southeast of the shaft, and it is likely that similar material can be found at the same horizon, elsewhere on the hill.

24. LINDSAY MINE.

Land owner: Joseph Desloge, St. Louis, Missouri

Lessee: None

Location: NE¼ SW¼ SW¼ Section 16, T. 33 N., R. 2 E., on the west side of the East Fork of Black River, along an old road which parallels the river above Johnson's Shut-In, about 5 miles north of Lesterville.

Altitude: 940 feet, approximately

History: According to Pumpelly[29], the property was examined by P. N. Moore in 1872 and was then known as "Lindsay's ore bed." About 1917 James T. Dobbins and J. C. McHenry reopened the property and are reported to have shipped one car of ore. No work has been done recently.

[29]Pumpelly, Raphael, op. cit. pp. 24-28, 1873.

Description: A trench 50 feet long, 10 feet wide and not over 6 feet deep has been quarried into the porphyry hillside, apparently to follow the N.E.-S.W. trending mineralized fractures. Most of the rock removed has been piled up adjacent to the trench.

Stratigraphic position: The ore definitely is in the pre-Cambrian rhyolite porphyry which here, as elsewhere, is interlayered with beds of tuff.

Ore: Pumpelly described the occurrence of the black manganese ore very well when he wrote, "It is in narrow, comby strings, which are in places isolated, in others united to form a reticulated network throughout the mass; in this form the rock resembles a conglomerate, the manganese mineral representing the cement. In other places the manganese has wholly replaced the matrix, the crystals of feldspar and grains of quartz alone remaining intact. Finally, in portions of the rock the replacement has been complete, here no traces of the porphyry, either crystals or matrix remain, while a more or less porous, semi-crystalline mass of the manganese ore takes their place."

The ore mineral is braunite. A study of the ore in thin sections shows that the braunite has replaced the fine-grained, sericitized groundmass of the porphyry leaving the quartz and feldspar phenocrysts only slightly corroded. The alteration has produced some calcite and has resulted in an acid porphyry with a very black color. Incidentally the orthoclase phenocrysts were observed to contain abundant losenge-shaped and rod-like inclusions of apatite, a source of the phosphorus in the ore.

Chemical analyses of specimens of the ore were made by Chauvenet[30]. Specimen No. 1 was described as a jet black, hard dense ore with metallic luster having the texture of the porphyry and containing phenocrysts of quartz and orthoclase. Specimen No. 2 was not so impure.

	Specimen No. 1	*Specimen No. 2*
Insoluble	45.55	28.81
Iron oxide (Fe_2O_3)	5.48	4.81
Manganese oxide (MnO)	37.04	50.84
Lime (CaO)	2.73	6.24
Magnesia (MgO)	0.81	....

A sample of the best grade of ore that could be obtained from the dump was collected by the writer and analyzed by R. T. Rolufs. It contained:

Insoluble	31.10
Manganese (Mn)	36.66
Cobalt (Co)	0.18
Zinc (Zn)	0.12

Production: Unknown

Future: The occurrence of manganese here appears to be quite limited and the average tenor of the ore is quite low. The economic re-

[30]See Pumpelly, R. op. cit., p. 25, 1873. Chauvenet, Regis, Chemical analyses: Report of the Geological Survey of the State of Missouri including Field Work of 1873-1874, p. 719, 1874.

covery of manganese under ordinary conditions would not be justified and it is doubtful even under present conditions. However, the sinking of one test shaft to a depth of 40 or 50 feet might be justified.

25. J. C. MILLER PROSPECT.

Land owner: J. C. Miller, W. Z. Miller and Adam Troupe, of Lesterville, Missouri

Lessee: None

Location: NW¼ NW¼ Sec. 33, T. 33 N., R. 2 E., on the southeast slope of Lee Mountain, 3 miles north of Lesterville

Altitude: 1180 feet, approximately

History: This property was prospected for manganese in June, 1941, by J. C. Miller

Description: An opening 10 feet square and 3 to 6 feet deep has been quarried out of the hillside revealing several sets of manganese bearing joints. One set is parallel to the hillside and dips with the slope of the hill but at a steeper angle of about 45°. Another set, complimentary to the first, dips into the hill, while a third set strikes N. 70 E.—S. 70 W. and dips 70° S. 20 E. Some of the joints are nearly horizontal. They are closely spaced, one to six inches apart and their surfaces are coated by manganese oxide. The thickest filling is about one-half inch.

Stratigraphic position: The manganese occurs in pre-Cambrian porphyry.

Ore: The deposit consists wholly of joint and fracture fillings. A sample of some of the best material contained:

Insoluble	55.39%
Manganese (Mn)	21.69
Cobalt (Co)	trace

Future: The deposit appears to be quite lean, but the sinking of a single shaft to determine the persistence of the manganese with depth is suggested.

26. McCAW-NASH PROSPECT.

Land owners: Oliver P. Tucker (SW¼ SE¼ Sec. 11), William M. Nash and Mrs. Blanche McCaw remainder of SE¼ Sec. 11 and Amos Stogsdill (NE¼ SW¼ Sec. 11)

Lessees: William M. Nash and Mrs. Blanche S. McCaw, Rolla, Mo.

Location: Chiefly in W½ SE¼ Sec. 11, T. 29 N., R. 1 W., but prospect holes also have been dug in E½ NE¼ SW¼ Sec. 11, and W½ NE¼ SE¼ and W½ SE¼ SE¼ Sec. 11. The property is at the head of a ravine tributary to Christian Hollow, about 4 miles southwest of Ellington.

Altitude: 900 to 1000 feet

History: Manganese was discovered about 1931 by Oliver Tucker while searching for iron ore on his farm. The identity of the mineral was unknown to the local people. Sometime later Tucker read a newspaper description of the pitch blende of Canada and noted a certain similarity to the mineral on his property. He sent a sample to Rolla where it was identified as a manganese mineral. Nothing more was done until July, 1940, when Hale J. Neely, learning that W. M. Nash was prospecting for manganese on Thorny Mountain in adjacent Shannon County, acquired a half interest in the property and induced Nash to visit the Tucker farm. On July 10, Nash and his associate, Mrs. Blanche McCaw, leased the property and began prospecting. Two shafts and a large number of shallow test pits were dug over an area of more than 80 acres. Some manganese mineral was found in most of these but the ore was low grade. In November and early December, 1941, the United States Bureau of Mines prospected the property.

Description: Nearly 80 test pits varying from a few feet to 64 feet in depth have been dug over an area of approximately 80 acres. These are shown on the accompanying map (Figure 3). The letter *P* designates the pits dug by McCaw-Nash, the letter *G* designates the pits dug by the U. S. Bureau of Mines. All of the pits are in a buff to reddish cherty clay residuum in which psilomelane has cemented angular fragments of chert, and in some places of sandstone, to form bouldery masses of breccia. When the McCaw-Nash pits were dug, the manganiferous boulders were segregated from the dirt and piled near the pit, hence the character of the ore was readily visible. When the government prospected the property, channel samples were taken for analyses.

In the following descriptions the dimensions of the pits in feet are given in the order: length x width x depth. The long dimension of the pit is usually parallel to the hillside.

Tucker Pit:

T. 1. Pit originally dug by Tucker in search of iron ore and in which he first found the manganese.

McCaw-Nash Pits:

P. 1. Pit 5 x 7 x 6. Some manganiferous chert breccia of less than average grade in buff cherty soil.

P. 2. Shaft 6 x 3 x 64. The entire shaft was not accessible to the writer. It was boarded over at a depth of about 22 feet and much of the shaft above 22 feet was cribbed. The log furnished the Survey by S. H. Lloyd is as follows:

Depth (feet)	*Material cut*
0-7	Cherty surface soil.
7-10	Rounded chert breccia containing some manganese oxide.
10-15	Angular chert breccia containing some manganese oxide.
15-21	Solid chert breccia cemented by manganese oxide.
21-42	Leaner chert breccia with some manganese oxide.
42-55	Siliceous chert breccia with some manganese oxide.
55-64	Chert with some manganese oxide in a clay matrix.

In the section of the shaft visible to the writer the ore consisted of streaks of white chert breccia cemented by psilomelane. These cherty masses were separated by a reddish brown highly plastic clay. The mineralized streak seemed to pitch north with the hillslope. A drift was started in the southwest corner of the shaft at the 22 foot level but was abandoned 5 feet from the shaft. About 2 tons of manganiferous chert breccia were piled about the shaft. The shaft was dry at the time of the visit, July 11, 1941.

P. 3. Pit 8 x 7 x 6. This pit is S. 17 W. of P. 2. Only loose, cherty, reddish soil was taken out and only a small amount of manganese mineral was observed to be associated with the chert.

P. 4. Pit 10 x 5 x 8. A considerable quantity of loose manganiferous chert was taken out and about one-half ton of manganiferous chert breccia boulders were piled at the edge of the pit.

P. 5. Pit 9 x 4 x 12. This pit is just below the crest of the ridge on the southern edge of the prospect. The manganiferous chert breccia seemed to be pitching S. 30 W. into the ridge and appeared to be of low grade. The breccia occurs in a highly cherty reddish clay which contained very little loose manganiferous chert.

P. 6. Pit 7 x 4 x 6. This pit seems to have penetrated only the soil zone. More clay is present here than in the previously described pits and it is buff instead of red in color. The chert is dense, dull, white and only slightly stained by manganese oxide.

P. 7. Pit 8 x 3 x 6. This pit is near the head of a ravine on the south edge of the property. About one half ton of manganiferous chert breccia was taken out of the reddish cherty clay.

P. 8. Shaft, 6 x 3 x 20. Manganiferous chert breccia is reported to have been encountered from the grass roots down. Several tons of the breccia were piled adjacent to the shaft. This shaft is perhaps the second best showing of ore on the property.

P. 9. Pit 6 x 4 x 10. This pit is on the same ridge as No. 6. The soil is buff and cherty and contains breccia boulders stained by iron and manganese oxides. About 100 pounds of manganiferous chert of low grade were piled near the pit.

P. 10. Pit 5 x 2½ x 5. The hillside here is covered with dense, white, sandy and banded chert, some of which exhibits cryptozoan structure. Only six boulders of manganiferous chert breccia were dug from the buff, cherty soil.

P. 11. Inclined pit, 7 x 4 x 18, N. 34 E. of P. 10. This pit was sunk at an angle to follow a lead of manganiferous chert breccia which seems to pitch S. 50 E. into the hill. About 4 or 5 tons of manganiferous breccia were piled adjacent to the opening. The hillslope in the vicinity is covered by numerous fragments of manganiferous chert breccia.

P. 12. Pit N. 49 E. of P. 11, not over 4 feet deep. About one-half ton of manganiferous chert breccia was piled adjacent to this pit.

P. 13. Pit 7 x 5 x 6. This pit is north of the main ravine and is the westernmost pit. Boulders of manganiferous chert breccia occur on the hillside but the manganese content is below the average for the property. Limonite is more abundant here than elsewhere.

P. 14. Pit 5 x 3 x 10. Psilomelane cements angular fragments of sandstone and chert. Boulders of manganiferous breccia may be seen in the wall of the pit to a depth of five feet below the surface. About a ton of ore of average grade was piled adjacent to the pit.

P. 15. Pit 6 x 3 x 12. Considerable manganiferous chert of average grade occurs in the reddish cherty clay.

P. 16. Pit 6 x 3½ x 8. The manganiferous chert breccia boulders which were taken out of the reddish cherty clay appear to be below average grade.

P. 17. Pit 7 x 3 x 6. The manganese content of the chert breccia removed from this pit is better than average and very little dirt was associated with the ore.

P. 18. Pit very irregular and about 4 feet deep. The manganiferous chert piled at the edge of the pit was of average grade. The chert was noted to be quite cellular and may have been derived from a silicified cryptozoan reef.

P. 19. Pit 6 x 3 x 9. The manganiferous chert which occurs here in a limonitic clay is sandy and of low grade.

P. 20. Pit about 4 feet deep. The chert breccia is like that in P. 19. It is limonitic, sandy and low in manganese. Sandstone blocks occur on the hillside adjacent to the pit.

P. 21. Pit irregularly shaped, not over 8 feet deep. The manganiferous chert breccia is of low grade. Some sandstone boulders are present.

P. 22. Shaft 6 x 6 x 22. Some of the best ore on the property was uncovered here. The chert is oolitic and is believed to be residuum of the Eminence formation, just below the Gunter sandstone.

P. 23. Pit 6 x 3 x 7. The manganiferous chert breccia obtained in the reddish cherty clay is of less than average grade.

P. 24. Pit 6 x 3 x 6. Some manganiferous chert breccia was dug from reddish clay.

P. 25. Pit 5 x 2½ x 10 on the southeast edge of the prospected area. Manganiferous chert was encountered two feet beneath the surface and extended to the bottom of the pit. The ore seems to dip westward. About one-half ton of manganiferous breccia was piled at the edge of the pit.

P. 26. Pit 5 x 2½ x 6. This hole was nearly full of water. It was dug in a cherty red clay which contained some manganese bearing boulders perhaps of less than average grade.

P. 27. Pit 5 x 2½ x 6, 25 feet N. 25 E. of P. 4. Considerable manganiferous chert was encountered here.

P. 28. Pit 6 x 6 x 10, 90 feet N. 40 W. of P. 3. A little manganese mineral occurs in the cherty reddish soil.

P. 29. Pit 5 x 2½ x 10, about 50 feet N. 45 E. of P. 1. Sandstone boulders and slabs occur on the surface but manganiferous chert breccia occurs in the red clay beneath. The pit probably is in the top of the Eminence residuum.

P. 30. Pit 9 x 4 x 6. This pit is cut into the hillside near the head of a shallow ravine. The ore seemed to pitch into the hillside. About a ton of manganiferous chert breccia of average grade had been dug from the cherty, reddish clay. Some sandstone slabs were noted near this pit.

P. 31. Pit 7 x 3 x 10. This pit is entirely in barren clay containing sandstone boulders.

P. 32. 6 x 3 x 12. Sandstone slabs and boulders are abundant on the hillside. The manganese content of the dirt taken from the pit is low.

P. 33. Pit 6 x 6 x 6. Very little manganese was found here.

P. 34. Pit 5 x 5½ x 4, 200 feet S. 64 E. P. 18. Only 3 or 4 manganiferous breccia boulders were taken out of this pit which is above the sandstone horizon.

P. 35. Pit 5 x 4 x 4, 180 feet S. 63 E. of P. 34. Boulders and slabs of sandstone are abundant on the surface. The angular particles of the breccia are composed of sandstone and the manganese content is low. Some limonite is present.

P. 36. Pit 6 x 3 x 10. Some manganiferous chert breccia was obtained here.

P. 37. Pit 6 x 4 x 5, 25 feet N. 30 W. of P. 36 and 190 feet N. 43 W. of P. 24. The manganiferous chert breccia dug from the red clay was among the best obtained on the property.

P. 38. Pit, very shallow, 15 feet S. 40 W. of P. 21. No ore.

P. 39. Pit 6 x 3 x 10. This pit is 45 feet S. 45 E. of P. 22. Although close to a good showing of ore, it encountered sandstone stained by manganese oxide but no manganiferous chert breccia.

P. 40. Pit 6 x 3 x 6, about 35 feet S. 20 E. of P. 23. Very little manganese oxide was found in the reddish cherty soil.

P. 41. Pit. The writer failed to record the data.

P. 42. Pit 5 x 3 x 4. A sandstone breccia is cemented by a small amount of manganese mineral.

P. 43. Pit 5 x 2 x 8, 75 feet N. 85 W. of P. 15. About one-third of the material removed from this pit was a manganiferous chert breccia of average grade.

P. 44. Pit 5 x 3 x 4. Considerable manganiferous chert breccia was dug out between 1½ and 4 feet below the surface.

P. 45. Pit 6 x 3½ x 6, 15 feet N. 5 W. of P. 44. About one-third of the material removed from this pit was a manganiferous chert breccia of average grade.

P. 46. Pit about 18 feet deep. Some manganiferous chert was taken out close to the surface.

P. 47. Pit 6 x 2½ x 6, 80 feet S. 53 W. of P. 44 and 18 feet S. 12½ E. of P. 46. Approximately three-fourths of a ton of manganiferous chert breccia of average grade or less was piled at the edge of the pit.

P. 48. Pit 6 x 6 x 7, 60 feet N. 47 E. of P. 16. The manganiferous chert and sandstone breccia obtained in the reddish clay is of average grade. Two shallow trenches were cut for a distance of 15 feet, one north and the other east of this pit.

P. 49. Pit 6 x 2½ x 8, 80 feet S. 50 W. of P. 16. Some sandstone boulders occur at the surface. The manganiferous chert is of less than average grade.

P. 50. Pit 6 x 3 x 6. A small amount of manganiferous chert was taken from the cherty limonitic clay, across the ravine north of the house.

P. 51. Pit, west of house and southwest of P. 51, very shallow. Manganese stains occur on the surface chert.

P. 52. Trench, shallow, L shaped, 75 feet S. 55 E. of P. 11. Manganiferous chert is present on the dump.

P. 53. Shaft 6 x 3 x 20, 35 feet N. 38 E. of P. 8. This shaft offsets one which had a good showing of ore, but very little manganese oxide was uncovered. Sandstone boulders were encountered to within 5 feet of the bottom.

P. 54. Pit, very shallow, 45 feet S. 19 E. of P. 32 and 70 feet N. 65 W. of P. 31, in sandstone breccia cemented by psilomelane.

P. 55. Pit, shallow, L-shaped, not over 2½ feet deep, 23 feet N. 52 W. of P. 1. No ore.

P. 56. Pit, shallow, 30 feet S. 5 W. of P. 2. This pit cut cherty clay but no ore.

P. 57. No ore visible.

P. 58. Pit, 6 x 3 x 4, blocks of sandstone on dump but no manganese.

P. 59. Pit, 5 x 5 x 2 in cherty soil, no manganese.

P. 60. Pit, 4 x 2½ x 2, N. 26½ E. of P. 48, sandstone and chert, no ore.

P. 61. Pit, 4 x 2½ x 2½, northwest of P. 17, cherty soil, very poor showing of manganese.

P. 62. Pit, 7 x 4 x 8 in cherty soil, no manganese.

P. 63. Pit, 6 x 3 x 6, in reddish cherty soil, no manganese.

P. 64. Pit, 6 x 3½ x 2, 88 feet N. 16 E. of P. 33. No manganese.

Bureau of Mines Pits:

G. 1. Pit 5 x 4 x 3, north of P. 15, in chert and sandstone residuum, no ore.

G. 2. Pit, 8 x 4 x 6, 25 feet N. 68 W. of P. 8, in reddish cherty soil stained by manganese mineral.

G. 3. Pit, 8 x 8 x 10, a small amount of manganiferous chert was obtained.

G. 4. Pit, 8 x 3 x 8 in cherty soil, no manganese.

G. 5. Pit, 7 x 3 x 9, 30 feet S. 80 W. of P. 2 in buff cherty soil, no manganese.

G. 6. Pit, 6 x 6 x 6, 30 feet S. 75 E. of P. 2 in cherty red clay, no manganese.

G. 7. Pit, 8 x 3 x 8, 75 feet S. 95 E. of P. 2, cherty, buff clay but no manganese.

G. 8. Pit, 7 x 3 x 10, only a little showing of manganese on the dump.

G. 9. Pit, 7 x 3 x 8, in buff cherty soil, a little manganese oxide was visible on the dump.

G. 10. Pit, 7 x 4 x 5. Sandstone blocks occur about this pit but no ore apparently was encountered.

G. 11. Pit, 5 x 5 x 5, in cherty red soil, no manganese visible.

G. 12. Pit, 5 x 5 x 3, in cherty soil, no ore visible.

G. 13. Pit, 5 x 5 x 3, in sandstone. No ore.

G. 14. Pit, 5 x 5 x 5, in reddish cherty clay, no ore.

G. 15. Pit not seen by the writer but mapped as barren by Kenneth Aid.

G. 16. Pit not seen by the writer but mapped as barren by Kenneth Aid.

G. 17. Pit, 7 x 3 x 15, in reddish cherty soil, no manganese visible on dump.

G. 18. Pit not over 3 feet deep, no manganese.

G. 19. Pit, 5 x 5 x 5, 25 feet S. 80 E. of P. 8, in cherty red clay, no ore.

G. 20. Pit, 7½ x 3 x 9, in cherty soil, very little manganiferous chert on the dump.

G. 21. Two shallow trenches were cut N. 78 E. and S. 20 E. from P. 48. No ore was encountered.

G. 22. Pit, 6 x 5 x 5, some manganiferous chert boulders were seen at edge of the pit.

G. 23. Pit, 5 x 5 x 2½, in sandstone, no ore.

Stratigraphic position: There are no outcrops within the prospected area and even the deepest shaft did not cut bedrock. The hillsides are covered chiefly by a cherty clay residuum. Near the crests of the ridges boulders and slabs of sandstone occur. In mapping the

Cardareva quadrangle, Bridge[31] took this sandstone to be Roubidoux. This would place the manganiferous breccia in the Gasconade formation. According to McQueen, however, the chert is typical of the Eminence formation and this identification is substantiated by the presence of Eminence fossils in a cellular chert zone just beneath the sandstone. The fossils were obtained by the writer from a bouldery mass of chert near P. 32 and from residual chert at P. 17 and P. 59, at an elevation of approximately 990 to 1000 feet. The chert is white, porous, stained by limonite and contains numerous vugs lined by drusy quartz. The following fossils were identified by J. S. Cullison:

Euptychaspus typicalis	Ulrich
Triarthropsis nitida	Ulrich
Plethometopus modestus	Ulrich
Finklenburgia	sp. und.

The sandstone slabs, taken by Bridge to be Roubidoux, apparently represent the Gunter horizon at the base of the Gasconade and the manganese occurs close to this horizon, particularly below it.

Ore: The manganese bearing material consists of angular chert and some sandstone fragments cemented into a breccia by psilomelane. The psilomelane itself is hard, black, dense, cellular and botryoidal. Some of it exhibits a very fine banded structure. An analysis of the purest mineral already has been given in Table I. A sample of some of the best ore collected by the writer from the dump of the shaft P. 2 was found by Rolufs to contain:

Insoluble	31.41%
Manganese (Mn)	27.61
Cobalt (Co)	0.47

The manganiferous breccia is of low grade and appears to be quite patchy in its distribution. It probably has been formed by the deposition of the manganese from groundwater which, after having travelled along the Eminence-Gasconade unconformity, seeped through the surface residuum and came in contact with enough oxygen to precipitate the maganese as colloidal psilomelane. This was deposited on the surfaces of the chert and sandstone fragments, ultimately cementing them into irregular masses. It is believed that wherever the seeps occurred manganese was deposited, elsewhere it was not. There is very little probability of the ore extending below the residuum, nor is there a probability of a large high grade ore body in this type of deposition.

Future: Although a large number of pits have been dug over an area of approximately 80 acres, the prospecting cannot be considered to have been satisfactory. Most of the pits were too shallow to adequately test the deposit, none reached bedrock. A few deep shafts would have yielded more information, particularly if drifts had been run into the ore bearing horizon. Since it is likely that

[31]Bridge, Josiah, Geology of the Eminence and Cardareva quadrangles: Mo. Bur. Geol. and Mines, vol. XXIV, 2nd ser., 1930.

the most economical way of mining this residuum is by a mechanical shovel, the writer suggests that additional prospecting be carried on by this means.

The ore cannot be utilized without some type of treatment. The average manganese content of the richest portion probably does not exceed 15%. The manganese mineral coats the rock fragments and occurs in seams cutting through them. The ore appears to be more amenable to chemical than to mechanical concentration. Such chemical treatment not only would recover most of the manganese but would permit the recovery of the cobalt as well.

ADDITIONAL OCCURRENCES IN REYNOLDS COUNTY.

27. NE¼ NW¼ sec. 9, T. 28 N., R. 1 E., about ¼ mile east of Missouri State Highway No. 21 and 7½ miles south of Ellington. According to L. M. Hackworth of Ruble the property was prospected by his father J. I. Hackworth in 1932. Soft grayish black wad containing some yellow ocher was reported to occur in a seam or tube-like body in clay. Mr. Hackworth considered the occurrence to be too small to work. A sample furnished by him contained 34.21% manganese and 0.07% cobalt.
28. SE¼ NE¼ sec. 33, T. 28 N., R. 1 E., 4 miles west of Garwood. A manganiferous chert breccia occurs in boulders and thin ledges in the hillside residuum close to the Eminence-Gasconade contact.
29. SE¼ NW¼ sec. 34, T. 28 N., R. 1 E., on the Dry Prong of Carter Creek, about ½ mile south of Missouri State Highway No. 21 and about 3½ miles west of Garwood on land owned by Isaac Skaggs. No prospecting has been done here but manganiferous chert boulders occur in the soil. A sample collected by the writer contained 13.22% manganese and 0.43% cobalt.
30. NE¼ and SW¼ sec. 8, T. 30 N., R. 2 E., about 2½ miles southeast of Redford, on land owned by J. R. McIntosh. In the NE¼ of the section a very little manganiferous chert was observed on top of a mottled rhyolite porphyry known locally as "blue granite". In the SW¼ of the section near Barbara Hampton cave on Sinkin Creek a thin horizontal seam of wad occurs at the contact of the cherty reddish clay residuum with the underlying Eminence dolomite. This wad ore contained 14.56% manganese and 40.97% insoluble matter. Neither occurrence is believed to be of commercial value.
31. SE¼ SE¼ NE¼ sec. 30, T. 30 N., R. 2 E., near the head of a small revine, 5 miles N. 78 E. of Ellington on land owned by W. M. Sutterfield of Ellington. A little manganiferous chert breccia was discovered by Jennings Smith in 1936. In 1940 one small pocket was dug into the hillside residuum but no attempt was made to prospect seriously.
32. SE¼ sec. 9, T. 33 N., R. 2 E., about 6 miles west of Ironton, on land owned by Mr. D. Lindsay Carter of St. Louis. Mr. G. Earl Doane of the Western Mining Corporation of Missouri reported that the property was under lease to this corporation and that only one vein of manganese ore, a few inches wide, could be observed in the pre-Cambrian porphyry.
33. NE¼ sec. 25, T. 29 N., R. 1 W., on a hillside just south of Deer Run State Park, about 5 miles S. 25 W. of Ellington on land owned by William J. Chitwood. In 1941 a single pit, 5 feet long x 2½ feet wide x 4 feet deep, was dug by W. M. Nash. A small amount of manganiferous sandstone breccia was taken out of the Gunter zone close to the Eminence-Gasconade contact. An analysis of the best material collected by the writer yielded 39.43% insoluble, 21.06% manganese and 0.73% cobalt.
34. NW¼ NW¼ sec. 35, T. 29 N., R. 1 W., near the crest of a ridge about 7 miles S. 30 W. of Ellington, on land owned by John Williams. Botryoidal and dense psilomelane cementing a sandy, chalcedonic chert breccia is exposed at two places along the hillside. A sample of the best matérial contained 43.01% insoluble, 21.42% manganese and 0.81% cobalt. No prospecting had been done here at the time of the visit.

35. NE¼ sec. 28, T. 31 N., R. 2 W., about ¼ mile north of Sweetwater School and 13½ miles N. 53 W. of Ellington on land owned by Mrs Tenna Anderson. A manganiferous chert breccia containing 15.19% manganese and 0.39% cobalt is exposed in cherty Gasconade residuum.

RIPLEY COUNTY

WILSON MAGANESE PROSPECT

Examination by J. G. Grohskopf.

This property is now owned by the U. S. Forest Service and is under lease to G. A. Wilson of Fairdealing for mineral development. It is located at the C SW NE Sec. 18, T. 24 N., R. 2 E., Ripley County, about 12 miles north of Doniphan which is the nearest shipping point. The U. S. Forest Service road to Pleasant Grove School is within two miles of the property. The last two miles of road is an unimproved woodland trail. The prospect lies near the head of a small draw which is tributary to Capps Creek to the northeast and is on the southwest slope of a ridge about 60 feet below the crest.

The area is underlain by the Roubidoux formation, residual chert and sandstone of which cover the hillside. An outcrop of lower Roubidoux sandstone was noted in the draw about 750 feet southeast of the prospect. The manganese ore is of two types: psilomelane or hard ore and pyrolusite which is soft ore. It occurs embedded in the residual clay along with chert and sandstone. Some of the chert and sand is heavily impregnated with manganese oxide.

Prospecting has been confined to trenching along the draw for a distance of approximately 75 feet. On the uphill side of the draw a face about 4 feet high is exposed. In this face can be seen nodules of hard ore and soft ore disseminated in the clay. The bottom of the trench is in very cherty clay which also carries some ore. The ore piled out does not exceed 200 pounds and much of it is siliceous. Samples of what appeared to be the best grade of ore were picked and chemical analysis shows the following:

	Hard Ore	*Soft Ore*
Manganese	13.17%	7.18%
Silica	50.70	21.70

SHANNON COUNTY

As this is written, Shannon County is the only county in the State producing manganese ore. Although the occurrence of manganese in the county was reported by Nason[32] as early as 1892, very little has been done to produce ore. Some of the earliest prospecting on the manganiferous veins was done in search of other metals such as gold or silver and some of the properties were prospected during the period of greatest activity in iron-mining in the State. During the last World War a number of properties were located, particularly by Luther Norris and some were prospected in a small way but no mining was actually carried on. One car of ore is said to have been shipped, but this was made up of ore obtained in prospecting several deposits. In 1936 or 1937 another car of ore obtained by working over the dump at the Elliot Mine was shipped but no actual mining of manganese ore was attempted until 1942, when the Shannon County Mining and Ore Company began working on Thorny Mountain. To date six cars of ore have been shipped from this property, as much as had been shipped from the county in all previous time.

There are two types of manganese ores in Shannon County: hard, dense braunite filling fractures and brecciated zones in a reddish brown rhyolite porphyry and softer, botryoidal psilomelane which occurs as a cement in residual chert and sandstone breccia. At the present time the harder ore in porphyry is more likely to be profitable. The worst feature of this ore is its high silica content. It is difficult to mine, occurring as it does in a hard porphyry, and none of the deposits is expected to be large.

Concentrations of manganese oxides are known to occur in 22 localities in Shannon County, about half of these are worth prospecting.

36. CULPEPPER PROSPECT

Land owner: Everett Beasley, Springfield, Missouri

Lessee: None

Location: SW¼ SW¼ SE¼ Sec. 2, T. 28 N., R. 4 W., at the base of the north end of a ridge just west of Missouri State Highway No. 19 and 2 miles S. 8 E. of Eminence.

[32]Nason, F. L., A Report on the Iron Ores of Missouri. Geol. Survey of Missouri vol. II, pp. 20 and 95, 1892.

Altitude: 950 feet, approximately, and about 40 feet above the ravine.

History: In 1892 Lonsdale[33] noted the occurrence of several boulders of sandy chert breccia cemented by manganese oxide on the west slope of the hill on land owned by L. W. Munsell. The property was again visited by Hughes[34] in 1918. It was then held by John F. Church of Winona and had not been prospected. Boulders and fragments of manganese ore intermingled with residual chert and sandstone were strewn over the ground. Some of the powdered ore is said to have been used in Eminence by Jack Culpepper, to aid him in hardening steel used in cold chisels. Very little prospecting has been done. In 1939 N. Franks cleaned out the old pit but the property never has been gone over thoroughly.

Description: A single small prospect pit uncovered a face of ore 1½ feet wide and 3 feet high. The pit now is caved. The strike of the ore was reported as S. 35 W.—N. 35 E. but this cannot be seen now.

Stratigraphic position: The deposit occurs at the Gunter horizon close to the Eminence-Gasconade contact.

Ore: The ore consists of angular fragments of weathered chert and sandstone cemented by black, clinkery and botryoidal psilomelane. An analysis of the selected mineral is given in Table I. An analysis of a sample of the ore taken from the dump showed it to contain:

Insoluble	17.43%
Manganese (Mn)	29.33
Cobalt (Co)	2.30

In 1917, before any prospecting had been done, Hughes collected a surface sample that contained 21.52% manganese. A sample collected by T. J. Humphrey was analyzed by the Survey and found to contain 13.58% manganese.

Future: The deposit appears to be very limited in extent. It cannot be traced beyond the initial pit because of the surface residuum. Additional pits should be dug.

37. DANIELLS PROSPECT

Land owner: Daniells, Winona, Missouri

Mineral rights: Leland and Wilbur Adair

Lessee: None

Location: SW¼ NW¼ Sec. 14, T. 28 N., R. 3 W., on crest of Horner Mountain, about one mile north of Horner School and 7 miles S. 57 E. of Eminence.

Altitude: 1100 feet

History: According to V. H. Hughes[35], this property was prospected by John F. Church about 1917. A pit originally 10 feet long, 8 feet wide and 10 feet deep was blasted out of porphyry along a mineral-

[33]Lonsdale, E. H., Survey notebook No. 161, p. 94.

[34]Hughes, V. H., Unpublished manuscript in Survey files.

[35]Hughes, V. H., Unpublished manuscript in Survey files.

ized zone 3½ to 4 feet wide at the crest of the mountain. Lower on the western slope, about 300 yards N. 85 W. is a second pit now about 5 feet in diameter and 3 feet deep. This likewise was dug on a mineralized zone about 2½ feet wide, but traceable for only a few feet. The property was idle from 1917 to 1939, when N. Franks cleaned out the old pits. It is reported that Franks found three vertical mineralized fissures, one inch, three inches and four inches wide respectively in the wall of the upper pit. About a ton of manganese bearing rock has been piled up.

Descripton: The property is little different now from that described in the historical account above. The upper pit is not over 8 feet deep, while the lower one is 2½ feet deep.

Stratigraphic position: The reddish rhyolite porphyry is pre-Cambrian.

Ore: Fractures and joints in porphyry are filled with the hard, blackish gray, manganese mineral, braunite. These strike N. 25 E.—S. 25 W. Where the joints are close together the porphyry is largely replaced by ore and all gradations from solid ore to country rock may be observed. Small amounts of the typical hydrothermal mineral, alunite, occur as soft, pinkish microscopically crystalline aggregates, dispersed through the ore. This is an alteration product of the feldspar and is strong evidence in favor of the hydrothermal origin of the ore. A picked sample contained 50.75% manganese.

Production: None

Future: The ore seems to be very limited but the sinking of one prospect shaft might be justified under present conditions.

38. ELLIOT PROSPECT

Land owner: Missouri Lumber and Mining Company

Lessee: Clifford J. Benson and F. Bosser Greene

Location: SE¼ NW¼ NW¼ Sec. 35, T. 28 N., R. 3 W., at the head of a valley which drains S. 20 W., about 9 miles southeast of Eminence

Altitude: 1150 feet, approximately

History: It is reported that a Mr. Elliot in search for gold sank a shaft here about 45 years ago. The rock and manganese ore were piled about the shaft. This furnished a small amount of saleable ore.

Description: A single shaft, approximately 6x6 feet has been sunk in rhyolite porphyry to a reported depth of 60 feet. At the time of the visit the shaft was filled with water to within six feet of the surface. Some ore occurred in small dumps adjacent to the shaft. Very recently the shaft has been cleaned out and a good showing of manganese ore in the bottom is reported.

Stratigraphic position: The ore occurs in a reddish-brown rhyolite porphyry of pre-Cambrian age. The outcrop is very small, most of the area being covered by chert residuum. Several shallow pits indicate that an unsuccessful attempt was made to locate ore at the contact of the residuum and the porphyry.

Ore: The ore consists of hard, dense grayish black braunite with minor amounts of pyrolusite. An analysis of the clean, hand-picked mineral is given in Table I.

The ore mineral apparently followed fractures or joints. One set is vertical and strikes N. 55 E.—S. 55 W., while the other dips 60° N. 60° E. and strikes N. 30 W.—S. 30 E., being complimentary to the first set. The shaft is said to have been sunk on a vein which was only two inches wide at the surface but which widened out across the whole shaft in the bottom.

The porphyry along these fractures is highly brecciated and somewhat altered and replaced. The feldspars have been converted to kaolinite and sericite and have been replaced by braunite, especially near the contact. In many places the walls of the vein and the margins of the angular porphyry fragments embedded in the ore are altered for short distances from the contact. Here the porphyry is kaolinized, dull and bleached to an ash-gray color.

The solutions which brought in the ore are believed to have been hydrothermal. Since the property originally was opened as a gold prospect, the writer had a sample of the ore assayed in the Metallurgy Department of the School of Mines at Rolla with negative results. The solutions apparently did not carry gold or silver but they did carry manganese and fluorine. This ore contains many patches of blue and of purple fluorite, and in some instances rather well formed tetragonal dipyramidal crystals of braunite have been observed in a fluorite matrix. The solutions were able to alter and replace the porphyry, particularly the feldspars, and in so doing have formed a strong bond between the massive ore and the wall rock so that the ore does not break free of the rock very readily, if at all. It is not very adaptable to hand-cobbing. A rather high grade sample selected by the writer from the material on the dump about the shaft was analyzed by R. T. Rolufs, who reported:

Insoluble	25.09
Manganese (Mn)	36.90
Cobalt (Co)	0.07

Production: It is said that one short car of ore, about 20 to 25 tons, was shipped about 1936 or 1937. This is reported to have been mixed with some iron ore and shipped from Winona.

Future: Although the deposit will not yield a large quantity of ore, it might be profitable to work this deposit in a small way under present conditions. At least further prospecting would be desirable.

39. LIBERTY SCHOOL PROSPECT

Land owner: Mrs. Mavis Seaman Akers

Lessee: F. B. Greene and C. J. Benson

Location: NE¼ NE¼ NW¼ Sec. 8, T. 28 N., R. 2 W., on the northwest side of Thorny Mountain, about ¼ mile southeast of Liberty School, 9½ miles S. 76 E. of Eminence.

Altitude: 1000 feet, approximately

Description: One shallow test pit, not over 5 feet deep, has been quarried in the reddish rhyolite porphyry. The manganese oxides are confined to narrow joint spaces, which strike E.-W. and dip N. with the slope of the hill.

Stratigraphic position: Pre-Cambrian

Ore: The ore is braunite in a brecciated zone in rhyolite. It is similar to the ore at Thorny Mountain.

Future: Further prospecting would be feasible at this time.

40. REEVES PROSPECT

(Reed School House Prospect)

Land owner: W. M. Reeves

Lessee: C. J. Benson and F. B. Greene

Location: SW¼ NW¼ NE¼ Sec. 11, T. 28 N., R. 3 W., about 0.35 mile southeast of Reed School, on the northwest slope of a porphyry knob about 7 miles S. 68 E. of Eminence, Shannon County.

Altitude: 900 feet, approximately

History: According to C. J. Benson this property was prospected by Jim Kile many years ago. Hughes[36] referred to it as the James Jones prospect. When he visited the property in 1917 a pit 10 feet long, 9 feet wide and 4 feet deep had uncovered a mineralized zone in porphyry from a few inches to two feet in width, but no ore was shipped. The property has been idle for many years but in August, 1942, a sublease was taken and prospecting started under the supervision of Henry Miner of Picher, Oklahoma. Very recently the South Central Mining Company has been installing machinery preparatory to sinking a new shaft at the summit of the hill.

Description: The prospect consists of two shafts and a trench. The southern or uppermost shaft is said to have been about 10 feet deep, the lower shaft, about 75 feet north, was reported to have been 30 feet deep. The trench is about 75 feet long and apparently a shaft was started in the bottom of it. About 6 or 8 tons of ore are piled near the workings. This ore is reported to have been taken out of a pocket near the surface in the deeper shaft but none was shipped.

Stratigraphic position: The ore occurs in joints and fractures in a reddish rhyolite porphyry of pre-Cambrian age.

Ore: The ore is hard, black, dense braunite associated with a minor quantity of sooty pyrolusite and some barite. It is similar to the other ores in the porphyry and seems to follow fractures which strike N. 50 W.—S. 50 E. and N. 50 E.—S. 50 W. An analysis by R. T. Rolufs of the best material picked from the dump by the writer gave the following composition:

Insoluble	19.40
Manganese (Mn)	40.32
Cobalt (Co)	0.18

[36]Hughes, V. H., Unpublished manuscript in Survey files.

A sample of this ore submitted to the Survey on September 7, 1938, contained 33.56% Mn., while another submitted by T. J. Humphrey of Birch Tree contained 52.77% Mn. and 0.022 phosphorus. The dump contains boulders of very high grade ore.

Production: Some ore has been shipped for test purposes, and one truck load of ore containing 40.2% manganese was reported to have been sold by Mr. Miner.

Future: Under present conditions this property merits further prospecting. At least one shaft should be sunk along the manganese bearing fractures to determine the persistence of the ore with depth. The quantity of ore is not expected to be large but whatever amount could be produced would aid in the present emergency.

41. ROSS PROSPECT

Land Owner: James Ross

Lessee: C. J. Benson and F. B. Greene

Sublessee: Freeman Williams

Location: NE¼ SE¼ NE¼ sec. 36, T. 28 N., R. 3 W., at the base of a porphyry hill just west of the Carter County line and 6.75 miles N. 60 E. of Winona.

Altitude: 920 feet.

History: Nason[37] reported the occurrence of veins of manganese of remarkable purity from 3 inches in thickness down to minute seams, cutting the porphyry. About 1917 these were prospected for the Mid-Continent Iron Company by Frank Ross, father of the present owner. In August, 1942, prospecting was renewed by Freeman Williams of Eminence, but little had been done up to the time of the writer's last visit.

Description: A single trench about 12 feet long, 2 to 4 feet wide and not greater than 10 feet deep has been quarried into the hillside, following a vertical vein which strikes N. 15 E.—S. 15 W.

Stratigraphic horizon: The reddish brown rhyolite porphyry is pre-Cambrian.

Ore: The ore filling fractures or joints in the porphyry is dense, grayish black, hard braunite. Unfortunately it cannot be traced very far.

Future: It is likely that only a small amount of manganese is present here.

42. THORNY MOUNTAIN MINE

(Rocky Creek, Norris or Seaman No. 1 Mine)

Land owner: Mrs. Mavis Seaman Akers

Lessee: C. J. Benson and F. B. Greene

Sublessee: Shannon County Mining and Ore Company.

[37] Nason, F. L. A report on the Iron Ores of Missouri, Geol. Surv. Missouri, Vol. II, pp. 20 and 95, 1892.

Location: SW¼ NE¼ SE¼ sec. 8, T. 28 N., R. 2 W., on the west slope of Thorny Mountain, about 10 miles S. 72 E. of Eminence.

Altitude: 900 feet, approximately

History: Manganese veins, exposed over an area 11 feet long and 3 feet wide, were discovered by Luther Norris in 1916, while employed by the Mid-Continent Iron Company, but no work was done. In 1937 Benson and Greene blasted out a little rock and in 1940 W. M. Nash opened a pit about 20 feet long, 6 feet wide and 8 to 10 feet deep. Several fractures filled with manganese ore were uncovered, but the grade of material removed was not marketable at that time. In November, 1941, the property was leased by the Shannon County Mining and Ore Company and in January, 1942, mining began with the deepening of Nash's pit. The first car of ore was shipped in March. In June a new shaft was sunk and since that date the production has come from both shafts.

Description: At present this is the only manganese mine operating in Missouri. It consists of two vertical shafts or, more accurately, over-deepened pits. Shaft No. 1 simply is Nash's original pit enlarged and deepened. It is about 30 feet long, 7½ feet wide and 45 feet deep, sunk vertically along the vein. Shaft No. 2 is located 138 feet along the strike of the vein, S. 25 W. from No. 1, and is similar to it. It was 30 feet long, 8 feet wide and 40 feet deep at the time of the writer's last visit, but since that time it has been deepened to 60 feet. The walls of the shafts are very irregular, and in porphyry. The vein can be traced for several hundred feet along the strike and several other narrow fractures filled with manganese ore are known to approximately parallel the vein being mined. Cross fractures, nearly at right angles to the main vein are slightly mineralized. Although the new vein being mined is in general vertical, it does show some tendency to pitch. The vein consists of a series of interlacing fractures filled with manganese ore, chiefly braunite, which replaces the porphyry and encloses fragments of the wall rock.

Stratigraphic position: The ore occurs in rhyolite porphyry of pre-Cambrian age.

Structure: This deposit definitely is of the vein type. The strike is from N. 15 E.—S. 15 W. to N. 25 E.—S. 25 W.

Ore: The ore consists chiefly of braunite with minor amounts of pyrolusite and perhaps psilomelane. Most of it is hard, dense, black and tough. Near the surface some of it exhibits occasional botryoidal and finely banded structures suggestive of psilomelane but with depth the ore seems to become granular. A sample of the ore collected by the writer in 1941 and analyzed by R. T. Rolufs contained:

Insoluble	21.34%
Manganese (Mn)	38.99
Cobalt (Co)	Trace

As the shafts have been deepened the width of the fracture has become larger and the grade of the ore better. One car of ore was shipped which contained over 48% Mn. At the surface no fracture was over 2 inches wide but at a depth of 40 feet the writer obtained a solid mass of ore 4 inches wide and the miners reported greater widths than this. The vein consists of a number of ore filled fractures which cut the porphyry giving rise to a typical vein breccia. With depth the proportion of ore to rock is increasing. At the surface less than one-fifth of the width of the vein was ore, at the present level one-third to one-half of the face is ore. Adjacent to the ore the rhyolite is partially decomposed and bleached to an ash-gray color. The miners refer to this as "burnt rock". Much of the wall rock is replaced by manganese ore to a variable degree. It is this type of material which must be sorted very carefully if the grade of the ore is to be maintained.

Mining: Up to the present time the ore produced has come from the sinking of exploratory shafts. These have been sunk on the vein in a very irregular fashion. Systematic mining has not yet started. A few holes are drilled and shot. The ore is hauled to the surface in buckets suspended from a cable over a pulley which is mounted on a wooden tripod over the shaft. The ore is hauled to the surface by a drum hoist, then dumped and sorted. The shipping grade is placed in a loading bin, the waste is eliminated and the intermediate grade is hand cobbed. Nine men were employed when the mine was last visited. The ore is hauled in trucks, chiefly over poor roads, to the shipping point, Winona, about 14 miles southwest of the mine. The trucks have been hauling 4 to 5 tons per load, and making 3 trips per day.

Production: The first car of ore was shipped to the Sheffield Steel Corporation in Kansas City in March, 1942. The ore now is being sent to the stock pile of the Metals Reserve Corporation in St. Louis. Six cars were reported to have been produced. The most recent car was shipped in September, 1942, and at the date of this writing another car is reported to be ready to ship. The manganese content has averaged about 40%.

Future: The property is not expected to produce a large quantity of ore. The chief problem will be to keep what ore is produced up to grade. Much of the ore consists of partially replaced porphyry which, although black in appearance, is highly siliceous and lacks the density of good ore.

If systematic mining continue and is profitable, new shafts should be sunk. Adequate hoisting and other equipment installed.

ADDITIONAL OCCURRENCES IN SHANNON COUNTY

43. SE.¼ SE.¼ sec. 29, T. 29 N., R. 1 W., on the southeast end of a ridge spur near the head of Wolf Pen Hollow, about 16 miles east of Eminence, on land owned by the Egyptian Tie and Lumber Company. A chert breccia of the lower part of the Gasconade formation is cemented by psilomelane. No prospecting has been done and very little manganese-bearing rock is exposed. An analysis of the surface material showed it to contain 3.93% manganese and only a trace of cobalt. The insoluble portion constituted 79.71%.

44. SE.¼ NE.¼ NE.¼ sec. 8, T. 28 N., R. 2 W. Crafton prospect. This prospect is at the high rock on Thorny Mountain and in the line of strike of the ore at the Thorny Mountain Mine. A series of narrow manganese bearing veins cut rhyolite porphyry.

45. SW.¼ SW.¼ sec. 9, T. 28 N., R. 2 W. Manganese bearing veins reported to occur in porphyry.

46. NE.¼ NE.¼ NE.¼ sec. 17, T. 28 N., R. 2 W. Manganese bearing veins reported to occur in porphyry.

47. SE.¼ sec. 12, T. 29 N., R. 2 W., on land owned by Leroy Fears. A sample of sandstone cemented by psilomelane was submitted by Carter Buford for analysis It contained 8.52% manganese and 0.57% cobalt.

48. NW.¼ NW.¼ sec. 34, T. 27 N., R. 3 W., on the south side of U. S. Highway No. 60, about 4 miles southeast of Winona on land owned by James Hulbert. Chert and sandy residuum of the Roubidoux formation are coated and stained by manganese oxide. Two shallow prospect pits were reported to have been dug into the residuum by N. Franks in 1939. No important concentration of manganese is indicated here.

49. NE.¼ NE.¼ sec. 18, T. 28 N., R. 3 W. This property was visited by Hughes in the fall of 1918. A shaft had been dug 30 feet in cherty residuum on the crest of a small knoll. The chert was stained by manganese oxide and in the bottom 3 feet of the shaft narrow seams of wad were found in residual clay.

50. S.½ NW.¼ sec. 25, T. 28 N., R. 3 W. Hughes reported that a manganiferous chert breccia was exposed over an acre of land at the head of a ravine.

51. Sec. 36, T. 28 N., R 3 W. Lonsdale[38] reported that a Mr. Lucas had dug some manganese ore from a reddish-yellow, sandy, cherty residual clay at the base of the same mountain as that on which the Turley prospect is located in Carter County. The writer visited this prospect in August, 1942. No new work had been done.

52. SE.¼ SE.¼ SE.¼ sec. 2, T. 29 N., R. 3 W. This prospect is south of Simpson School. It is reported to have been opened by Irby Henry and John McClellan, who sank a shaft 10 feet on a vein of manganese ore two inches wide.

53. W.½ SE.¼ sec. 8, T. 27 N., R. 4 W. Chert float of the Roubidoux formation cemented by psilomelane.

54. SW.¼ NE.¼ SW.¼ sec. 17, T. 27 N., R. 4 W., about 100 yards east of Bartlett School. This property was described by Bridge[39] who reported that some of the black clay of this area contains a little manganese. A pit dug by Jess Webb, just east of the schoolhouse, exposed a manganiferous sandstone and chert breccia, similar to that found elsewhere in the county.

55. SW.¼ sec. 8, T. 28 N., R. 4 W., on a hillside about one-fourth mile northwest of Delaware School and 4 miles southwest of Eminence, on land owned by Julius Lahmeyer. Black pellets of manganese oxide occur in the residuum of the upper part of the Gasconade formation but the quantity is too small to warrant prospecting.

56. SW.¼ SW.¼ NW.¼ sec. 17, T. 28 N., R. 4 W. Lonsdale[40] reported the occurrence of boulders of sandy, cherty residuum cemented by manganese oxide for a distance of 30 yards, in a narrow strip along the hillside.

57. NE.¼ SE.¼ sec. 24, T. 28 N., R. 4 W. Lonsdale[41] noted manganese oxide cementing sandstone and coating angular fragments of sandstone taken out of shallow pits near the crest of a hill. "Pipe ore" was taken out nearby.

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[38]Lonsdale, E. H. Survey notebook No. 161, p. 88, 1892.

[39]Bridge, Josiah, Geology of the Eminence and Cardareva quadrangles: Mo. Bur. Geol. and Mines, vol. XXIV, 2nd ser., pp. 129-132, 1930.

[40]Lonsdale, E. H. op. cit.

[41]Lonsdale, E. H. op. cit.