The Geological Section of Nebraska

by G. E. Condra and E. C. Reed

Current Revisions

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NEBRASKA GEOLOGICAL SURVEY BULLETIN 14A

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Current Revisions to the Geologic Section of Nebraska

By E. C. Reed, *Director*

Nebraska Geological Survey

This bulletin is reprinted because of the growing demand for the availability of a summary of the geology of the state since the supply of the first two editions of this bulletin was exhausted several years ago. There has been considerable addition to our geological knowledge during the past fifteen years. The more significant revisions in respect to stratigraphy are included herewith in order to make this information available without further delay. These revisions are included in the order discussed in the bulletin.

Pleistocene System (pp. 4-10) The current classification involves the following significant changes: The name Peorian is restricted to the loess of early and middle Wisconsin age and Bignell is used for the late Wisconsin loess; Wisconsin till (possible Cary) is now recognized in the vicinity of Hartington in northeast Nebraska, occurring above an eroded remnant of Illinoian till; thicker till of Illinoian age is recognized extensively in eastern Knox and western Cedar Counties and probably occurs under the loess mantle southeastward across northeastern Pierce and western Wayne Counties to near the Elkhorn Valley; the formation name Sappa has been substituted for the Upland formation and the Pearlette volcanic ash is recognized as a member of the Sappa formation; the name Red Cloud has been added to apply to early Kansan sands and gravels in the non-glaciated area; and the name David City is used for the pro-Nebraskan sands and gravels.

Tertiary System (pp. 10-14) The Ogallala group is recognized as a formation with the Kimball, Ash Hollow and Valentine as members; the present conception of the stratigraphy of the Sheep Creek is that the Box Butte is an upland loessic phase of the formation and essentially equivalent to the coarser textured channel deposits and the interrelationship of the Sheep Creek formation members is open to question; the Brule formation is now subdivided into the Whitney (upper) and Orella (lower) members.

Cretaceous System (pp. 14-20) In the Dakota Group the Omadi formation of eastern Nebraska is now recognized as equivalent to the Mowry sandstones of western Nebraska including the oil productive Gurley ("D") and Cruise ("J") sandstones; the "Fuson" shale of eastern Nebraska is now correlated as equivalent to the Skull Creek, and the "Lakota" sandstone of eastern Nebraska is equivalent to the Fall River sandstone of western Nebraska and the Black Hills. The Fuson shale and Lakota sandstones seem to be represented only in western Nebraska, principally in the northern part of the Panhandle, but may have thin equivalents in the Denver-Julesburg Basin of the southern Panhandle.

Jurassic, Triassic and Permian Systems (pp. 20-40) There are no significant changes at this time in these sections.

Carboniferous Systems (pp. 40-61) The usage of Carboniferous has been abandoned by the Nebraska Geological Survey and the Pennsylvanian and Mississippian Subsystems have been elevated to System rank. The reader is referred to Nebraska Geological Survey Bulletin 16 for the current classification of Pennsylvanian rocks used by the Survey. The interval classified as the Hannibal Formation of the Kinderhook Group of the Mississippian is now called the Boice Shale.

Devonian System (pp. 61-64) The controversy as to the age of the rocks formerly classified as Sheffield-Lime Creek has not been settled among all geologists and paleontologists. The Nebraska Geological Survey now places this shale interval in the lower part of the Kinderhook Group of the Mississippian and recognizes it as an essential equivalent to the Chattanooga shale. Therefore the Devonian-Mississippian contact is placed at the base of this shale and not at its top.

Silurian, Ordovician and Cambrian Systems (pp. 64-73) No revisions are suggested in these sections of this bulletin at this time.

Pre-Cambrian System (pp. 73-74) The old concept that the pre-Cambrian rocks of large areas of the state were similar lithologically has been refuted generally as more wells have been drilled to and into the Pre-Cambrian in Nebraska. These rocks may be igneous such as granites and related rocks, they may be quartzites in part similar to the Sioux quartzite or they may be metamorphic rocks such as schists or related rocks which in part were originally of sedimentary origin. There is some evidence that the Sioux quartzite was not necessarily metamorphosed by heat and pressure but may be quartzose because of groundwater action. In some areas the pre-Cambrian rocks which appear to correlate with the Sioux quartzite are only moderately indurated and consist of red, fine-grained sandstones with some coarser and finer textured zones. It appears that the Sioux quartzite and its less consolidated equivalents represent the youngest pre-Cambrian in Nebraska and that these rocks are underlain unconformably in some areas by metamorphosed sedimentaries which have been altered by the intrusion of igneous rocks such as granite.

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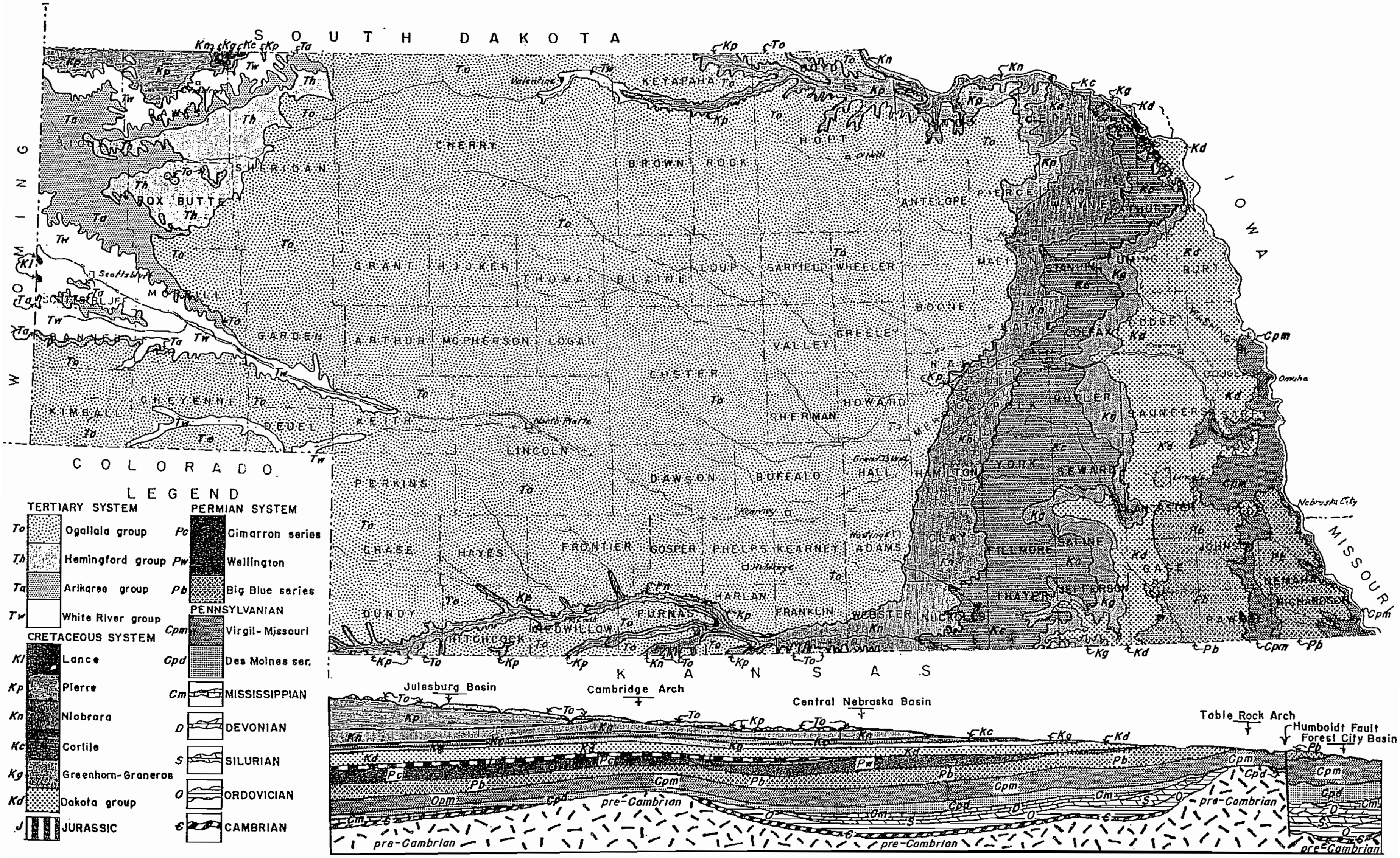

Figure 1.—Areal Geologic Bedrock Map of Nebraska. The profile section at the base of the map is measured in an east-west direction near the Nebraska-Kansas line and is based on subsurface studies.

The Geological Section of Nebraska

By G. E. Condra and E. C. Reed

THIS bulletin is a review of the age relations and general lithologic character of the rock formations of Nebraska. It is intended to serve as an introduction to the study of the stratigraphic paleontology, economic geology, groundwater and soils of the state and probably will be of considerable value to oil-company geologists in their studies of deep wells drilled in the state as tests for oil and gas.

COMPOSITION OF THE LAND

The geological formations of Nebraska occur as (1) unconsolidated sediments called mantlerock, shaped by wind, streams and glaciers, (2) widespread sedimentary bedrock known as shale, mudstone, sand, sandstone, and limestone, and (3) deep-seated granite and granite-like rocks. Much of the state is mantled with rock debris beneath which the bedrock outcrops in places.

The sequence, nature and thickness of the rocks which occur at depth in most of the state is now fairly well known through studies of outcropping formations and examination of samples from deep wells. A number of deep well records have been published (Nebraska Geological Survey Bulletin 4, Papers 13, 14, 15) and both published and unpublished information of this nature are available through the Nebraska Geological Survey.

In general, the bedrock formations of Nebraska lie nearly flat, with a low westward dip. The oldest sedimentary rocks are deeply buried in the state. However, some quite old formations are exposed in the southeastern counties and are overlain in regular succession westward by younger formations, as shown by Figure 1. Their attitude is modified regionally by well-defined arches (anticlines), faults, and basins.

STRUCTURE

The locations of the major structures of the state are shown by Figure 2. These structures are the Cambridge, Table Rock, Redfield and Richfield arches or anticlines, and the Julesburg, Central Nebraska and Forest City basins. Also, there are a number of small anticlines, domes, and synclines in the state, also several faults with little displacement. Three anticlines nose out in Nebraska from other states. One of these enters Sioux County from South Dakota west of Ardmore; another reaches into Dundy County from Colorado, and the third extends into southeastern Gage County from Kansas. The Humboldt fault located along the east side of the Table Rock Arch in Richardson County, extending into Kansas, has a displacement of about 1000 feet.

DEEP-SEATED ROCKS

At a considerable depth under all of Nebraska and extending to great depths are primary granite and granite-like rocks. The oldest sedimentary rocks rest on this basement complex. Granite is shallow in the Table Rock Arch west of the Humboldt fault where it forms a buried granite ridge known as the Nemaha Mountains.

Granite and other ancient rocks are exposed in the Rocky Mountains, Laramie Range, in the Hartville and Black Hills uplifts west and northwest of Nebraska, in the Siouxan Highlands of eastern South Dakota and southwestern Minnesota, and in the Ozark Uplift of Missouri, Arkansas and Eastern Oklahoma. They extend from these areas to and under Nebraska and have important relation to the structural conditions of the state.

SEDIMENTARY ROCKS

The various systems, series and groups of rocks in Nebraska were not formed by continuous deposition. Much of the rock section was deposited in ocean or sea waters and is said to be of marine origin. Some of the formations were laid down on land above or near sea level and are classed as of continental origin. Then, too, at times in geologic history, the marine-made formations were elevated above sea level and eroded, resulting in the removal of rock

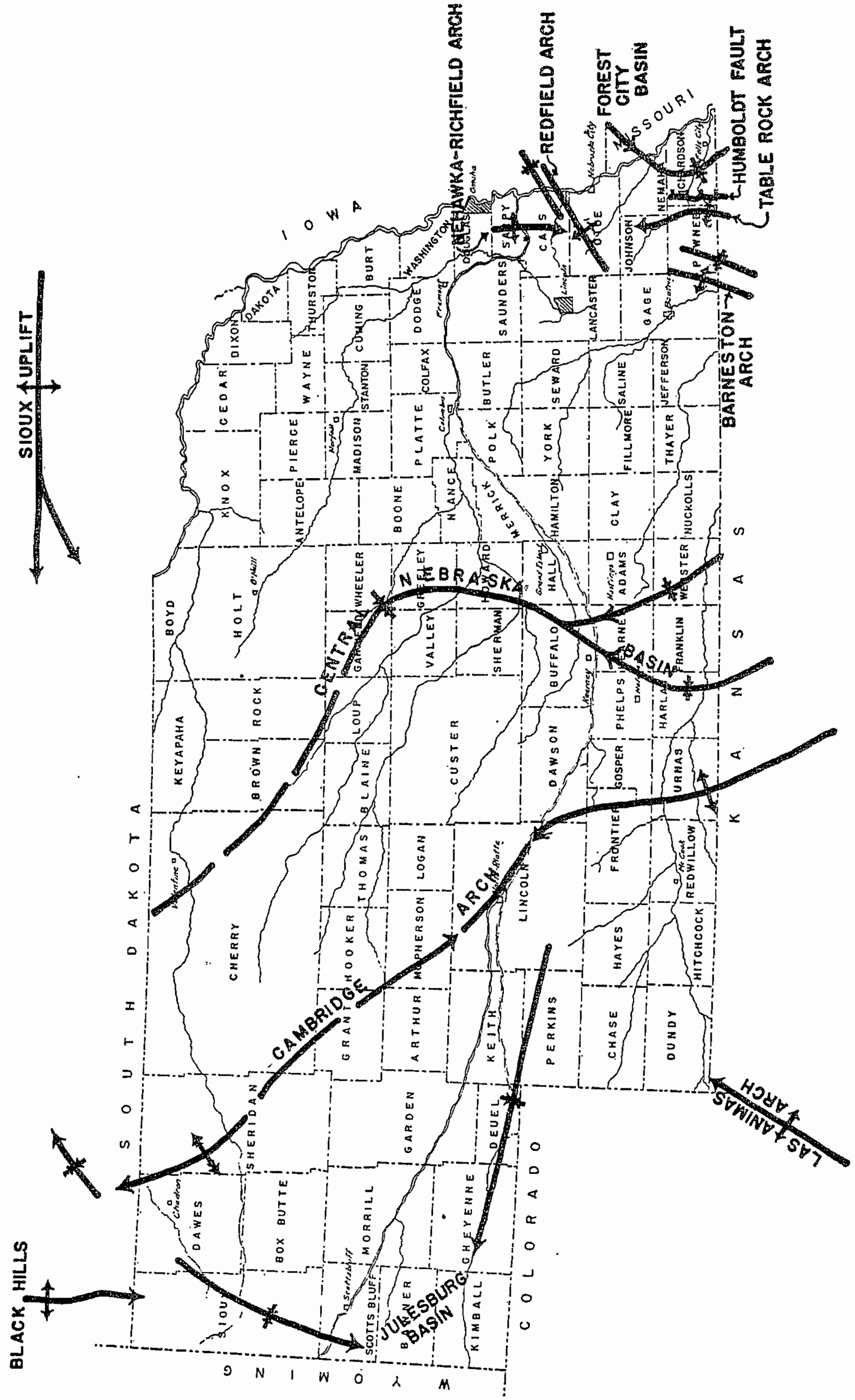

Figure 2.—Principal Structural Features of Nebraska. The heavy lines indicate the approximate axes of the arches and basins and the arrows indicate direction of regional dip. No attempt has been made to show the smaller local structures.

materials from large areas which were later depressed to below sea level and covered by younger sediments. This shift in elevation plus the accompanying erosion and deposition developed the irregularities or breaks in the regular sequence of rock deposition known as unconformities, which mark the boundaries of the systems, subsystems, series, and some groups of the rocks.

The combined thickness of the sedimentary rocks in Nebraska varies from a minimum of about 500 feet near DuBois, Pawnee County to about 9,000 feet or more in some of the western counties. The extent of the rocks of volcanic origin is very limited in Nebraska.

CLASSIFICATION AND CORRELATION

Our State Geological Survey has made a close study of the rocks which outcrop in the state and has correlated them in cooperation with the surveys of the bordering states. Since the bedrock in much of Nebraska is deeply mantled with unconsolidated materials, such as alluvium, loess, dunesand and glacial drift, the classification of the subsurface formations progressed slowly and unsatisfactorily until subsurface data were obtained by the study of the cuttings and cores of deep wells made for water supply and oil and gas exploration.

In the classification of the rocks of Nebraska, it is necessary to employ both time terms and rock terms. In other words, the rock systems, series, groups, formations, and members were deposited or formed during the units of time now generally known as periods, epochs, ages, stages and substages. The periods and systems in Nebraska, named from youngest to oldest, are the Quaternary, Tertiary, Cretaceous, Jurassic, Triassic, Permian, Carboniferous, Devonian, Silurian, Ordovician, Cambrian, and Pre-Cambrian.

We classify the rock units down to the subdivision of the formations. This is done to establish a basis for the close study involved in geology and paleontology, but those who do not wish the detailed picture of the stratigraphy, need not observe the classification and correlation below the groups and subgroups.

HISTORY OF GEOLOGIC INVESTIGATIONS

Observation and description of the formational composition of the land began along the eastern boundary of the Nebraska area with the explorations of Lewis and Clark (1806) and Major Long (1819) but the explorers and fur-traders who followed them were not much interested in geology. Then, more than 90 years ago, the first organized geological exploration was started by Meek and Hayden in the area now known as Nebraska. Since that time many persons affiliated with the State and Federal geological surveys, colleges, universities and museums or with oil companies have devoted their lives to the study of the geology of the Northern Mid-Continent Region and the Rocky Mountain Region. They contributed much to the present knowledge of the geology of Nebraska, and we acknowledge the beneficial relation their services now hold to Nebraska, as the technical background of this bulletin.

Among those who did most in their day in geological activity relating directly or indirectly to Nebraska were F. B. Meek, F. V. Hayden, C. A. White, G. C. Swallow, Robert Hay, G. C. Broadhead, C. S. Prosser, J. A. Udden, S. Calvin, F. W. Cragin, Stuart Weller, J. E. Todd, E. Haworth, David White, J. W. Beede, G. H. Girty, G. L. Smith, George I. Adams and J. L. Tilton. All these finished their work, and were succeeded by E. O. Ulrich, N. H. Darton, E. H. Barbour, E. F. Schramm, H. A. Buehler, Chas. R. Keyes, George Kay, C. N. Gould, W. H. Twenhofel, Raymond C. Moore, M. M. Leighton, Frank Leverett, W. C. Alden, G. E. Condra, E. B. Plummer, Frank C. Green, H. D. Meiser, S. H. Knight, E. B. Branson, F. M. Van Tuyl, Marvin Weller, H. Hinds, W. T. Lee, Carl O. Dunbar, N. W. Bass, J. B. Reeside, A. C. Trowbridge and others. And, during the later years, Carey Croneis, K. K. Landes, H. S. McQueen, R. H. Dott, M. E. Upson, E. C. Reed, C. W. Tomlinson, N. D. Newell, J. E. Upp, A. K. Miller, M. K. Elias, R. K. DeFord, Robert Roth, G. H. Norton, Von Russom, W. A. Ver Weibe, A. L. Lugn, H. D. Thomas, J. M. Jewett, Oliver Scherer, L. M. Cline and many others have cooperated with the older workers in various kinds of geological investigation and regional correlation.

The Pre-Pennsylvanian formations of Nebraska have been studied here from deep well logs. They extend widely through adjacent states where they have been studied, described and classified mainly from the outcrops.

COOPERATIVE SURVEY

R. C. Moore, Director of the Kansas Geological Survey, Frank C. Green of the Missouri Geological Survey and G. E. Condra of the Nebraska Geological Survey have worked together very closely for a number of years in the study and classification of the Pennsylvanian formations of the northern Mid-Continent Region. They have been ably assisted by members of state surveys and by the geologists of oil companies.

The studies of the Permian formations have been carried on cooperatively between the Texas, Oklahoma, Kansas and Nebraska surveys, and by the Kansas Geological Society. The Cretaceous formations have been studied by a number of state surveys, by federal geologists and by oil company geologists and independent workers. Nebraska has made special surveys of the Pennsylvanian, Permian, Cretaceous, Tertiary and Quaternary systems of the state and has correlated the formations of these systems with those of the bordering states. The Kansas Geological Society and the Iowa-Minnesota-Illinois Geological Society have been active in regional geological correlation for several years through annual excursions made to the states of the northern Mid-Continent and Rocky Mountain regions. Committees of these organizations and of the American Association of Petroleum Geologists and the Geological Society of America have made special investigations relating to regional problems and formational correlations.

SYSTEMS AND SUBSYSTEMS

In the classification of the major groupings of the late Paleozoic rocks, we rank the Carboniferous and Permian as systems, and the Mississippian and Pennsylvanian as subsystems. This is done because it does not disturb the series groupings now in general use and because it leaves the Mississippian and Pennsylvanian free to be classed either as systems or subsystems, otherwise, they would necessarily be called series. For example Moore (1936) in Bull. 22, p. 18, says: "The Pennsylvanian rocks of the Mid-Continent region are here regarded as constituting a geologic system, and the major subdivisions of the Pennsylvanian are classed as series." This nonmenclature, as noted above, disturbs the classification and nomenclature of those who have used the name Pennsylvanian as a series of the Carboniferous by making it necessary to change the rank of such subdivisions, as the Virgil and Missouri Series to subseries, but the rank of the Pennsylvanian subsystem does not do this.

References to authors and publications are made in the text of this bulletin, and in the lists following the discussion of each rock system. However, only the essential citations are given and complete bibliography does not seem advisable in this connection.

ORDER OF TREATMENT

We now outline the geologic section of Nebraska, beginning with the youngest rocks and ending with the deeply buried oldest formations, which is the natural order in which the formations occur and the sequence in which they are encountered in deep drilling exploration.

Columnar sections are run to visualize the features, thickness and sequence of the formation. The formations are described in condensed, summary manner, giving their names, classification, local and regional distribution, and in some cases, their economic relations.

PLEISTOCENE SYSTEM

This system includes deposits formed during the period from Tertiary to present time. Its formations were laid down during the glacial or Pleistocene period, which includes most of Quaternary time. They occur widely in the north-central states and were formed from the debris of glacial ice sheets, by stream deposition of silt, sand and gravel, and by wind erosion and deposition, as dune

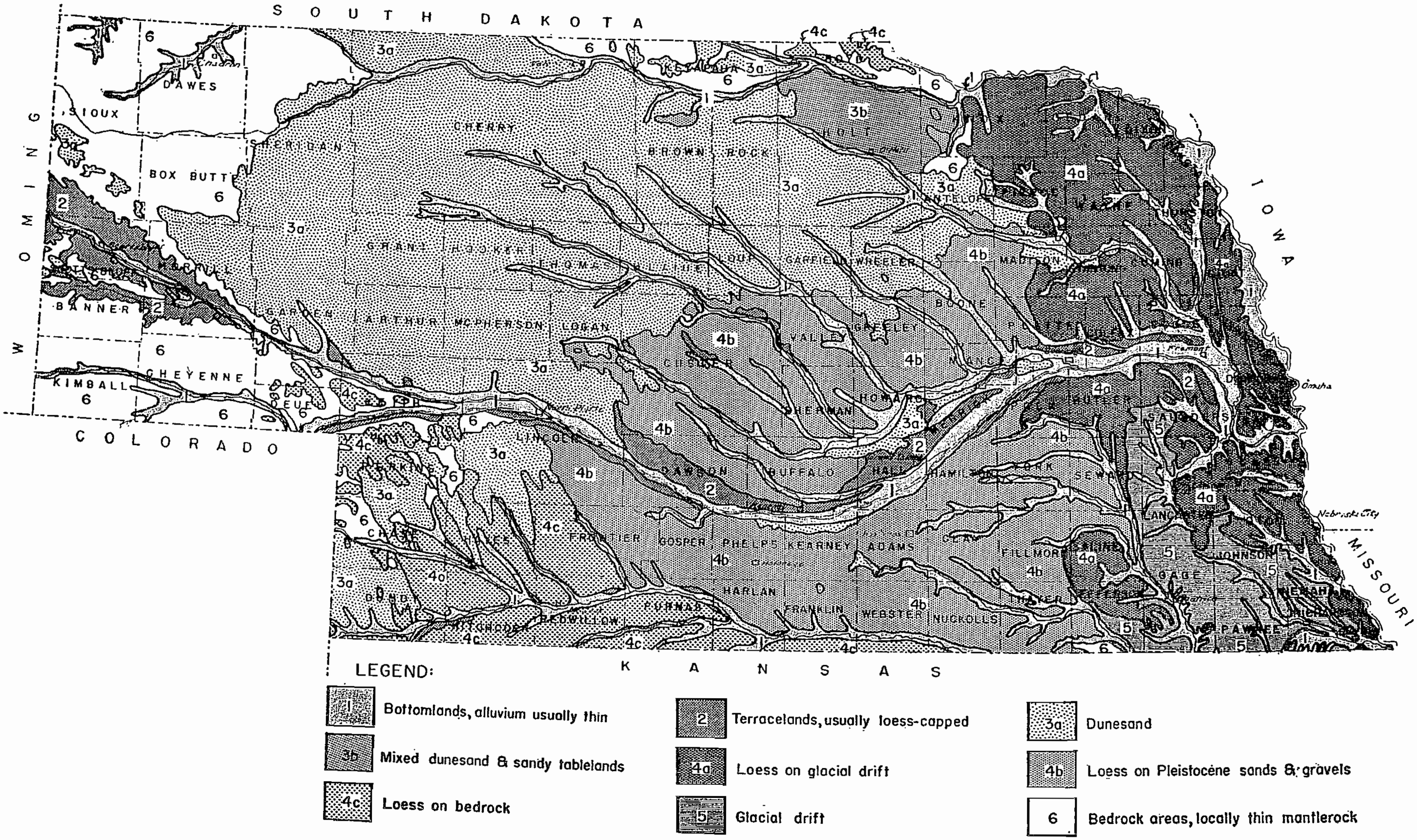

Figure 3.—Generalized Areal Mantlerock Map of Nebraska. Note that the Loess-on-glacial-drift areas include some inliers of glacial drift and the glacial drift ares includes small outliers of Loess in the higher topography. The scale of the map does not permit us to show narrow belts of terracelands or bedrock along some valley sides.

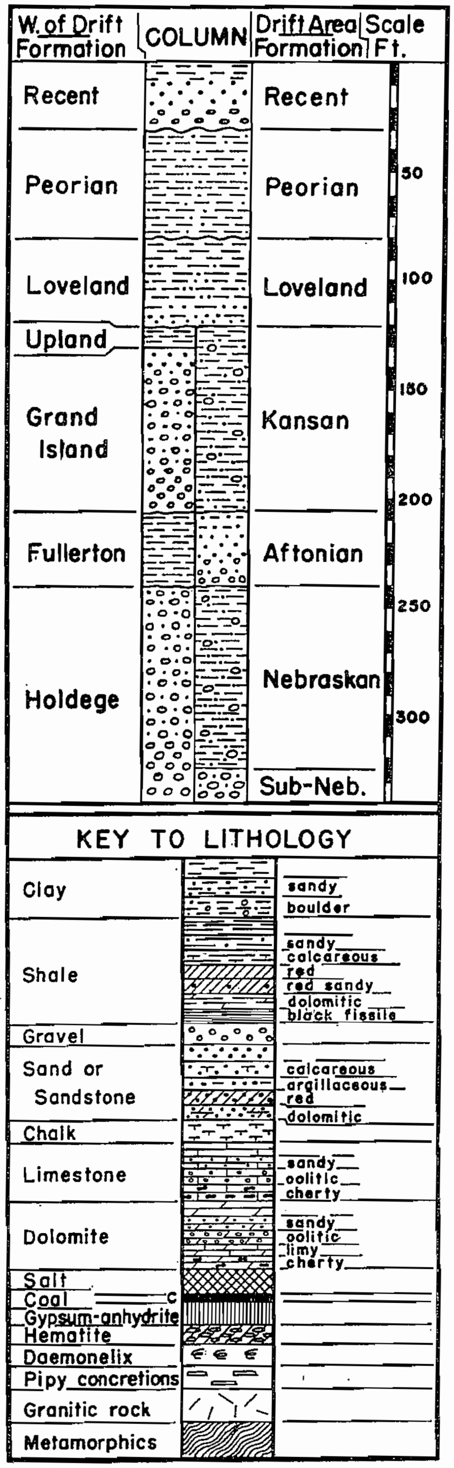

Figure 4.—Composite Columnar Section, Pleistocene System and Key to Lithology. Note: This key applies to this and succeeding columnar sections.

sand and loess. The Pleistocene deposits of Nebraska have been studied by several geologists, but with most detail by A. L. Lugn, who described them in Bulletin No. 10 of the Nebraska Geological Survey published in 1935. These deposits are largely unconsolidated, and mantle much of the state. (See Figure 3.)

OUTLINE OF THE PLEISTOCENE DEPOSITS OF NEBRASKA

(Grouped by Age, from Youngest to Oldest) *see* Figure 4.

1. *Recent deposits:* Alluvium, dune sand and the latest loess
2. *Peorian loess,* Leverett 1898, yellowish, thickness 5′–80′, and some dune sand of Peorian age
3. *Loveland loess,* Shimek 1909, thickness 5′–100′, and some dune sand, sand and gravel of Loveland age and the Loveland fossil soil
4. *Upland formation,* Lugn and Condra 1932, thickness 5′–30′+, on the Grand Island formation of the Loess Plain and Loess Hill regions west of the glacial drift border; age of the fossil soil, gumbotil and re-worked materials on the Kansan drift
5. *Kansan till,* Chamberlin 1896, boulders, till and sand of the drift region, 0–75′+; age of the Grand Island sands of the Loess Hill and Loess Plain regions west of the drift region, 50′–100′
6. *Aftonian formation,* Chamberlain 1895, consisting of gravel, silt and clay on the Kansan drift in the drift region, 0–60′; age of the Fullerton formation, Lugn and Condra 1932, of the Loess Plain and Loess Hill regions west of the drift region, 10′–70′
7. *Nebraskan till,* Shimek 1909, of the glacial area, 50′–100′, the sub-Nebraskan sands and gravels in the drift region, 9′–100′+; age of the Holdrege sand and gravel, Lugn and Condra 1932, west of the drift region, 50′–100′

Following is a review of the features and occurrences of the Pleistocene deposits of Nebraska made in the order of their development or genesis.

GEOLOGIC HISTORY

Nebraskan glacial stage.—The surface of eastern Nebraska was comparatively rough prior to glaciation. Then the Missouri River Valley and its main tributaries occupied approximately their present positions.

The Nebraskan ice sheet entered our state from the northeast, planed off the high places, filled the preglacial valleys with sand, gravel and till, and covered the land generally with a thick mantle of bluish gray till studded with pebbles and some boulders. This ice-sheet became a great dam across the eastward-trending valleys at its west border, causing the streams to fill their valleys with sand and gravel wash and aggrade a wide inwash belt of sand and gravel (Holdrege formation) over central Nebraska, extending from the ice-sheet westward to and onto the borders of the tablelands.

Aftonian interglacial stage.—With the retreat of the Kansan ice-sheet from Nebraska and adjacent states a nearly flat plain was left where the ice had been and a sand plain was left on the Holdrege formation to the west. The newly formed plains were soon invaded from the south by grasses and woody vegetation. A soil profile was developed generally in time, and by deep weathering and leaching, gumbotil was formed on the drift in the flatter areas. The surface runoff re-opened some of the pre-glacial valleys and eroded the drift plain as valleys and hills, with remnants of till plains left on the divides.

During this stage the Fullerton formation was formed on the Holdrege sand plain by the weathering and re-working of the local parent materials, and by the deposition of loess-like materials, blown in from the west. However, sub-drainage was more active here than surface drainage, consequently this area was not much eroded by streams and remained nearly flat.

Kansan glacial stage.—The advance of the Kansas ice-sheet caused changes similar to those produced by the Nebraskan invasion, i.e., the valleys were filled with glacial debris, a thick layer of drift (Kansan) was left on the Aftonian deposits of the drift region, and the sand plain to the west was capped by the Grand Island formation, which is much like the Holdrege formation.

Yarmouth interglacial stage.—With the melting northward of the Kansan ice the drift region and the sand plain to the west were again left nearly flat, with poor drainage, but like during the Aftonian stage, soil, gumbotil and re-worked till deposits were formed on the flat to rolling areas of the drift region but valleys and bold drift hills were formed where erosion was most active. During this time the Grand Island area to the west became mantled with the Upland formation by the weathering and reworking of the surface of the sand plain and by the accumulation of loess blown in from the west, but again this area remained level to rolling, due to its rapid subsurface drainage and the consequent relatively low per cent of surface runoff.

Illinoian glacial stage.—The Illinoian or third great ice-sheet advanced into Illinois and southeastern Iowa, but did not reach Nebraska. However, its presence in the states to the east caused a more humid climatic shift here, resulting in land erosion and the deposition of sand and gravel in the valleys of the central and eastern counties. This deposition, according to Dr. A. L. Lugn, is the valley phase of the Loveland formation which clogged the valleys, lifting the flood plain levels.

Sangamon interglacial stage.—This was a relatively dry cycle in the Mississippi Valley region, and the deposition of the reddish Loveland Loess which began in late Sangamon time became very active in Nebraska, but soil and gumbotil were formed on the Illinoian drift in parts of Iowa and Illinois.

Wisconsin stage.—Dr. M. M. Leighton (1931 and 1933) classes the Iowan drift with the Wisconsin stage and divides the latter in Illinois as substages, separated by loess deposits. His substages of the Wisconsin, named from the youngest to oldest, are as follows:

1. *Mankato drift*
2. *Cary drift*
3. *Tazewell drift*
4. *Iowan drift*

According to Leighton the Wisconsin drifts are relatively thin, not much weathered and leached, and represent relatively short substages. The interdrift loesses are thin boundaries of the drifts. Dr. George Kay of Iowa supports the classification by Leighton, but F. Leverett (1933) does not concur in this classification of the Wisconsin.

Although the Wisconsin ice sheets did not reach our state, the substage lobes did advance into northwestern Iowa and southeastern South Dakota, and their advances and retreats were accompanied by relatively wet and dry cycles in eastern Nebraska and adjacent areas. And it is evident that the Wisconsin substages had a close relation to the dating and development of the post-Sangamon cycles of sedimentation, erosion, loess leaching, soil formation, and terrace development in eastern Nebraska.

Outwash from the Wisconsin ice-sheets, which was deposited generally in the valleys leading from the ice, did not reach Nebraska except locally along the Missouri bordering South Dakota where erosion has removed most of this deposition.

Following are brief statements relating to some of the effects and relations of glaciation in Nebraska.

Iowan glacial substage.—The Iowan ice-sheet, as noted before, reached into Iowa from Wisconsin, and across Minnesota and eastern South Dakota to near Nebraska. It brought a humid cycle accompanied by wide-spread erosion, valley-excavation and high terrace development in much of central and eastern Nebraska and the development of a thick soil (1 to 5 feet thick) on the Loveland loess where the land was flat to moderately hilly.

Peorian loess.—A dry cycle followed the retreat of the Iowan ice and the Peorian loess proper was deposited on the Loveland loess and on the high alluvial terraces along the Missouri, Elkhorn, Loups, Platte and Republican valleys. This loess buried the Loveland soil several feet in depth, as may be observed in highway cuts in the Loess Hill Region.

LOESS DEPOSITS IN GENERAL

As noted before, the Loveland loess lies between the Illinoian and the Iowan drift sheets in Iowa, but farther west, where the Illinoian is missing, it lies on the eroded Kansan and Nebraskan drifts and locally on bedrock formations. In Nebraska where the Iowan and other Wisconsin drifts are absent, the name Peorian applies to all post-Loveland loess.

The Peorian loess of Nebraska is being studied in the hope of correlating its zones with the loess substages found between the Wisconsin drift sheets in South Dakota, Iowa and Illinois. This investigation should also result in the extension of present knowledge regarding the late Pleistocene climatic cycles.

The loess deposits of Nebraska lie nearly flat on the Yarmouth formation west of the drift border, but where they mantle the drift hills the topography is hilly. In other words, the topography of the Loess Plain, Loess Hill, and Loess-Drift Hill regions is largely an expression of the topography preceding the loess deposition, i.e., where the antecedent topography was flat the land is now nearly level, and where it was hilly, the surface is now hilly.

The loess deposits mantle more than one half the area of Nebraska. They are best represented in the Loess Plain, Loess Hill and the Loess-Drift Hill regions, but occur at places on the table lands and as small areas in the White River and Pierre Hill regions of the state.

VALLEY-FILL

Formerly most geologists dated the alluvial deposits of our large valleys as of recent origin, i.e., post-glacial. However, the hundreds of soundings recently made to bedrock in these valleys in connection with groundwater survey show that the fill is of composite age, i.e., from Nebraskan to recent. For example, the channel-fill of the ancient Missouri River Valley is composed of variable thicknesses of Nebraskan till, Holdrege-Grand Island sand and gravel, Kansan till, alluvial phase of Loveland formation, and shallow recent alluvium. The Platte Valley floor in central Nebraska is underlain by the Holdrege, Fullerton and Grand Island formations. Its terraces are capped by late Peorian loess, and there is thin recent alluvium on the flood plain, also small areas of dune sand. And, in the Platte Valley north of David City, there are boulders on the flood plain where recent alluvium was thought to occur.

As noted before, some of our rivers are in pre-glacial channels which were filled during Nebraskan time, reopened in part for considerable distance by erosion during Aftonian time, filled again during the Kansan glacial stage, opened (eroded) again in Sangamon time, refilled to considerable depth by the deposition of the alluvial phase of the Loveland formation and finally eroded to their present condition during middle and late Wisconsin time, accompanied by the deposition of Peorian loess on the terraces. These deposits do not all occur at a given place in these valleys, but their distribution is variable and quite general.

The amount of recent alluvium in the larger valleys of the state is much less than is generally supposed. It is underlain by Pleistocene deposits in most large valleys.

BURIED VALLEYS

All pre-glacial valleys of the state are not now occupied by streams. Some with fill of Nebraskan and Kansan age, as in the Sandhill, Loess Hill, Loess-Drift Hill and Loess Plain regions, are now buried beneath later Pleistocene deposits. In some cases fills of Nebraskan and Kansan age are deeply covered by Loveland wash or by Loveland loess, Peorian loess or by dune sand. Some of the buried channels extend southeastward from the Sandhill and Loess Plain regions. Their locations and characteristic features are being explained by drilling. Several buried channels have been located, as north of Dorchester and near Aurora, in which there is more than 100 feet of sand and gravel fill.

CHANGE IN SURFACE ELEVATION

The deposition of materials brought into Nebraska from other states by wind, streams and the ice-sheets has lifted the surface of the land generally from the bed rock floor upward 100 to 200 feet or more in places. But erosion by runoff water is now lowering the surface of the state generally. The major streams are cutting through the Pleistocene deposits and uncovering the bedrock in the valleys. Sheet water runoff deposits colluvial materials low on the valley-sides and streamborne sediments are being spread on the flood plains or carried down-valley beyond the borders of Nebraska. In other words the topography of the Pleistocene formations is being changed by water and wind erosion and locally there are places in the state where loess and dune sand are being formed faster than they are removed.

DUNE SAND

This, sometimes called sandhill formation, occupies the surface of more than one-fourth of Nebraska. Much of it is of Pleistocene age, blown from the Valentine and other Tertiary formations and from the Grand Island and Holdrege sand and gravel sheets. No doubt the dust blown from the sandhills during their development contributed to loess deposition east of the sandhill region. For example, the Loveland loess grades eastward from dune sand in Perkins County and other points along the border of the sandhills.

Dune sand is now forming locally as incipient sandhills along the scarps of alluvial terraces, on sandy alluvial lands, and generally on sandy land not protected by vegetative cover, and the dust from these areas is carried eastward.

PLEISTOCENE ECONOMIC RELATIONS

The sandy Pleistocene deposits of Nebraska are sources of much sand and gravel production. They also carry vast quantities of groundwater used for domestic purposes and pump irrigation. The thickest water-bearing Pleistocene deposits are the Holdrege and Grand Island sands and gravels, the valley-fills in the present large valleys, and the buried channels of the Loess Plain, Sandhill and other regions of the state. The Pleistocene terraces, being well drained and free from flood hazard, afford good locations for rural homes, railroads, highways and cities.

Some volcanic ash occurs in the Loveland formation. Formerly this had considerable economic importance, but its production is now limited.

Peorian loess, mixed with clay from bedrock formations, is used in brick and tile manufacture at Hastings and other places.

The loess formations, the till (drift) deposits, and the finer textured alluvial deposits of the state have fertile soils of great value in agricultural development. The sandy soils of the dune sand areas support grazing on the hilly land and dependable wild hay production in the valleys and basins where the water table is shallow.

BIOLOGICAL RELATIONS

The advance and retreat of the continental glaciers, and the accompanying changes in climate influenced the distribution of the plant and animal population of eastern Nebraska and adjacent areas. Many plants perished during the advances of the ice, and others migrated to non-glacial areas, but with the recessions of the ice, living conditions became more hospitable and the plants invaded the areas that had been glaciated. The shift in plant life during the glacial and inter-glacial stages was accompanied each time by a shift in the zonal distribution of the animals such as the fish, birds, and mammals.

The musk ox, mastodon, elephant and bison lived here during early glacial time. Their fossil remains collected from the Pleistocene deposits, are now in the University Museum.

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TERTIARY SYSTEM

The Tertiary rocks of Nebraska are of continental origin, and lie unconformably on Cretaceous formations in the central and western areas of the state. They have been studied and described by F. V. Hayden, J. B. Hatcher, N. H. Darton, O. A. Peterson, E. H. Barbour, H. J. Cook, A. L. Lugn, C B. Schultz and by many others. The most comprehensive study of these rocks in Nebraska was made by A. L. Lugn while connected with the Nebraska Geological Survey. A summary of the results of his survey was published in Vol. 50 of the Geol. Soc. of America, 1939, and the final report is being prepared for publication by the state survey.

CLASSIFICATION OF TERTIARY SYSTEM IN NEBRASKA

We observe that the classification of the marine and continental Tertiary rocks is not made on the same basis, and that apparently discrepancies of variable magnitude arise in the age assigned to the rock units of these origins. This means, for example, that a continental formation, said to be of a given age, may not correlate exactly in age with a formation of marine origin assigned to the same age. Consequently the ages given for the subdivisions of the Tertiary of Nebraska are only approximately the same as those of marine origin. The following table of the Tertiary formations of Nebraska and their age correlation is modified and condensed after A. L. Lugn, 1939 (Figure 5).

I. PLIOCENE

1. *Ogallala group,* Darton 1899, redefined by Lugn 1939, thickness 400′ or less:
   (1) *Kimball limestone* formation (Lugn and others 1939, gray, algal limestone, at top, 2′–3′; gray to buff shale in middle, about 20′–30′; caliche sandstone at base, 8′–10′; combined thickness 30′–50′
   (2) *Sidney gravel,* Lugn and others 1939, channel or basin deposit in southwestern Nebraska, northeastern Colorado and at places in northwestern Kansas, but not widely persistent, yellowish to dark brownish, fine to coarse, with some pebbles, thickness variable, 0–50′
   (3) *Ash Hollow formation,* Engelmann 1858, redefined by Lugn and others, 1939, known as the "mortar beds," consists of light gray to dark gray and buff to yellowish irregular beds or lenses of silt, sand and gravel and of

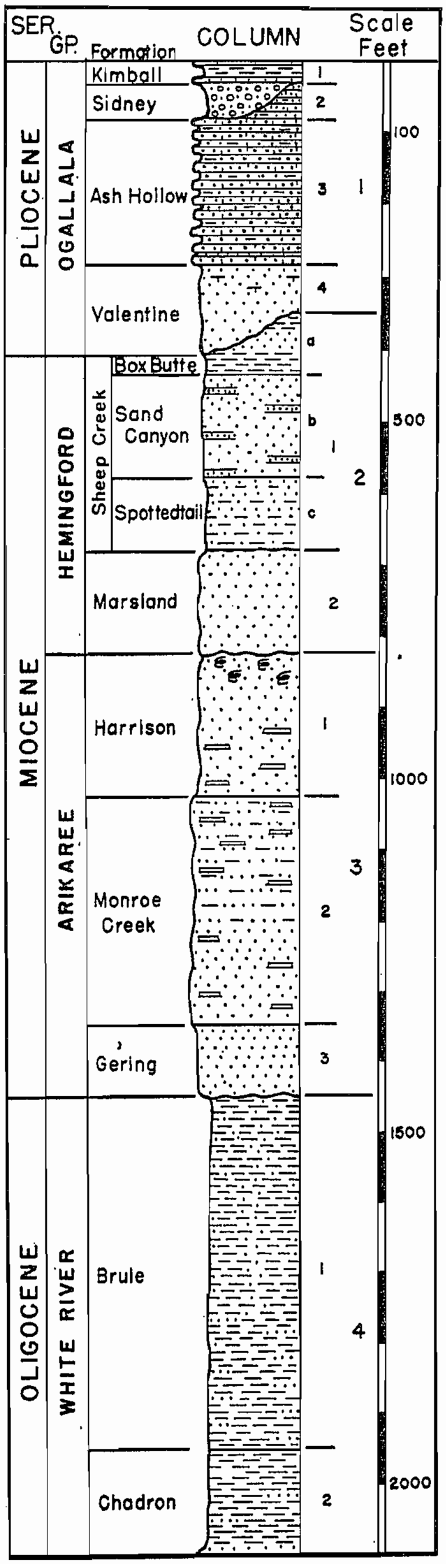

Figure 5.—Composite Columnar Section. Tertiary System.

"mortar bed" zones, also some volcanic ash; thickness, 100′–250′

(4) *Valentine formation,* Barbour and Cook 1917, light gray to slightly buff, friable sand, with some irregular indurated material, early Pliocene age, and probably in part upper Miocene, 50′–200′

UNCONFORMITY

II. MIOCENE

1. *Hemingford group,* Schultz 1939, middle Miocene age, about 500′ or less:

(1) *Sheep Creek formation,* Matthew and Cook 1909, predominantly pinkish and greenish sand and sandy clay, partially consolidated into mortar beds; divided by erosional unconformities into three members, but no complete development of all three members is observed in a single area; age, upper Miocene; combined thickness, about 400′:

a. *Box Butte member,* Cady 1940, upper zone consisting of greenish sandy clay at top and greenish to grayish sand below; lower zone largely pinkish to brownish clay, age, late upper Miocene, combined thickness about 85′

b. *Sand Canyon member,* Elias 1942, greenish above, grayish below, largely sand, with irregularly cemented mortar beds throughout the section, and a thin dark-gray volcanic ash bed at base, age, upper Miocene, combined thickness about 145′

c. *Spottedtail member,* Elias 1942, largely pinkish to greenish-gray, sand and fine sandy clay; upper part partially cemented sand as friable beds, about 105′; lower part predominantly sandy clay without concretions, about 60′; combined thickness about 165′; age, upper Miocene

(2) *Marsland formation,* Schultz 1938, the "Upper Harrison," buff to reddish brown above and more gray below, consists of soft sandstones; combined thickness, 150′ or less; age, early upper Miocene

UNCONFORMITY.

2. *Arikaree group,* Darton 1899, redefined by Lugn 1939, age, lower Miocene, thickness about 400′–500′:

(1) *Harrison formation,* Hatcher 1902, unconsolidated fine gray sand with "pipy" concretions in lower 100′, but smaller than those of the Monroe Creek; thickness about 200′. This formation has thick channel fills. It contains the Agate Springs bone fossil deposits.

(2) *Monroe Creek formation,* Hatcher 1902, upper 100′–150′ composed of pinkish to buff sandy silt and clay with layers of cemented concretions and scattered large concretions; lower 185′–220′

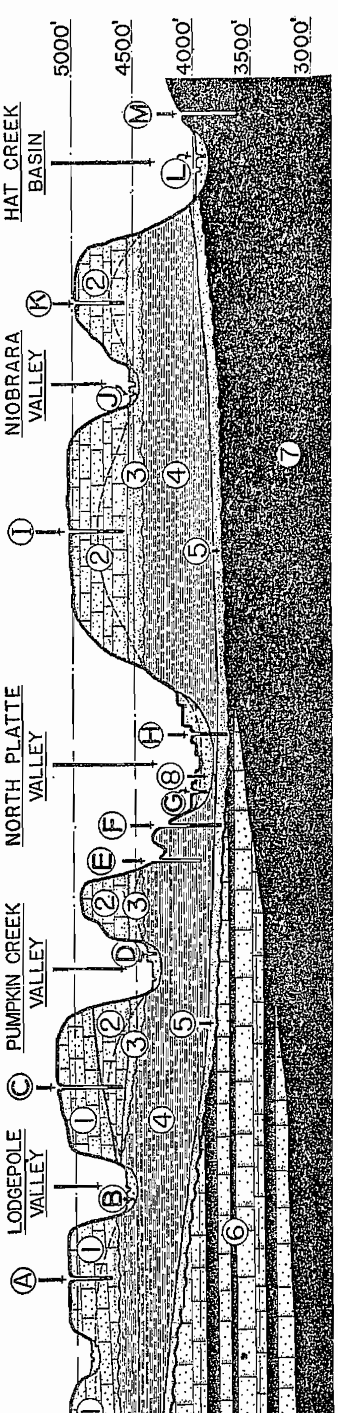

Figure 6.—Generalized north-south profile section in Western Nebraska near the Wyoming line, looking Westward. Formation: 1, *Ogallala*; 2, *Hemingford-Harrison-Monroe Creek*; 3, *Gering*; 4, *Brule*; 5, *Chadron*; 6, *Lance*; 7, *Pierre*. Note the southward wedding-out of the Harrison and Gering formations between the Ogallala and Brule formations. Dashed line in upper part of section indicates approximate position of water table and letters A to M show water well possibilities. After Nebraska Geological Survey, Paper 10, p. 15, 1935.

composed of gray medium textured, massively bedded sand with large "pipy" concretions; combined thickness, 285'–370'

(3) *Gering sand formation,* Darton 1889, upper part gray, medium fine, massive sand; lower part gray, bedded to cross-bedded channel deposits, combined thickness, 100'–230'

UNCONFORMITY.

III. OLIGOCENE

1. *White River group,* Meek and Hayden 1858, about 325'–700':
   (1) *Brule clay formation,* Darton 1899, upper member pinkish, massive silty clays with thin layers of volcanic ash and sand, 250'–500'; lower member, pink, sandy clays and channel sandstone, 125'; combined thickness, 325'–600'
   (2) *Chadron formation,* Darton 1899, composed of greenish to buff clay and silt, and a channel sandstone locally at the base, marking an unconformity, 50'–100'

IV. EOCENE, absent in Nebraska, but formations of this age occur in the adjacent areas of Wyoming, South Dakota and North Dakota.

DISTRIBUTION OF FORMATIONS

(Figure 6)

The Chadron formation outcrops north of Pine Ridge, from Wyoming eastward through Sioux and Dawes counties of Nebraska and into South Dakota, and in the North Platte Valley from the western part of Scotts Bluff County into Wyoming, and underlies the western part of the state approximately west of a line between Keith and Cherry counties.

The Brule clay is exposed widely north of Pine Ridge, and at places in the North Platte, Pumpkin Creek and Lodge Pole valleys. It underlies western Nebraska farther east than the Chadron and extends into Colorado, Wyoming, and South Dakota. Its thickness decreases southward and eastward from Sioux County.

Formations of the Arikaree group are best exposed in the Pine Ridge Escarpment of Sioux, Dawes and Sheridan counties. They reach southward from Pine Ridge to the Platte Valley beyond which there are outliers of the Monroe Creek in Wild Cat Ridge and in the north border of Cheyenne Table.

The Arikaree beds thin out to the east in Sheridan County. They change in facies northeastward in South Dakota, where it is difficult to distinguish and map their formations as such. Here they were given the name Rosebud formation by Matthew and Gidley in 1904.

The Hemingford formations are quite prominently exposed in about two-thirds of Box Butte County, extending into Sheridan County. They form a belt south of the Pine Ridge Escarpment from central Sioux County eastward past Hay Springs, Rushville and Gordon.

The Ogallala beds rest unconformably on the eroded edge of the Hemingford and Arikaree formations along a line between near Gordon, Alliance and Harrisburg and extend eastward on the Cretaceous formations to Crofton, north of Grand Island and southeast of Franklin. They occur northeastward in South Dakota to buttes located east of the Missouri River. The Kimball and Ashhollow beds reach southward through eastern Colorado, western Kansas and Oklahoma to Texas and New Mexico, but occur only a short distance westward in Wyoming.

EVOLUTION OF GRASSES

Some of our present-day grasses and larger mammals originated in the Tertiary of Nebraska. Dr. M. K. Elias (1942, pp. 1-176), Paleontologist of the Nebraska Geological Survey, prepared the following statement regarding the grasses and their relation to ancient animals.

"No fossil remains of the prairie grasses of Oligocene age are known, but the presence of hackberry seeds and silicified hickory nuts in the Brule clay indicates the wide distribution of trees and probably shrubs at that time. The appearance and rapid spread of prairie grasses soon after the beginning of Miocene time apparently caused pronounced changes in general adaptation of the horses and other herbivorous mammals from browsing to grazing habit, and correspondingly, their teeth changed from originally cuspidate to the high-crowned and heavily enameled hypsodont type. In other words the earlier horse which was small as a dog and looked somewhat like a mongrel changed rapidly into a horse-like creature of donkey size. In the course of later Miocene and in Pliocene time the originally small spear-grasses of the Tertiary time prairie evolved in the larger types and became very nearly like those now growing in our prairie, while horses, antelope and other herbivores grew in size and perfected organization to approach that of the now living genus.

"In most areas of western, central and north-central Nebraska the late Tertiary rocks contain numerous fossil seeds of grasses and forage herbs. These provide the best means now developed for the separation of the rocks from the upper part of the Harrison to the top of the Ogallala into 10 clearly recognizable biologic zones and subzones. The changes in the seeds which characterize these zones, as described by M. K. Elias, indicate apparent evolution of the herbs and successive major migrations of the prairie plant association. These fossil plant associations are comparable to the Mixed Prairie and True Prairie associations now occupying respectively the western and eastern halves of the State controlled in their geographic distribution primarily by the annual rainfall.

"Comparative analysis of the major floral changes in the late Tertiary rock indicates two major climatic cycles in the late Tertiary time in Nebraska, which roughly correspond to the Miocene and Pliocene. The Miocene cycle starts with the Gering and ends with the Box Butte clays of the Sheep Creek formation with the most favorable conditions for prairie vegetation reached at Spottedtail time. The Pliocene cycle starts with the Valentine and ends with the Kimball with the most favorable conditions in early Ash Hollow time. The leveling of the Tertiary prairie and the appearance of extensive swamps and lakes marked the end of Ogallala time, and the subsequent uplift followed by a cycle of erosion marks the beginning of the Pleistocene.

"Extinct Mammals.—The skeletons of the extinct animals from the Tertiary and Pleistocene of Nebraska can be seen at the University of Nebraska State Museum in Lincoln, where they are arranged for exhibition in the order they were found in the rock formations, from more ancient to more recent, so that their evolutionary changes are evident. Many kinds of animals which now live only in far-away lands like Africa, Asia, and South America, such as elephants, rhinoceri, camels, and many others lived in Nebraska during the Tertiary. Some of them originated here in Tertiary time but were exterminated chiefly by the severe climatic reverses in the Pleistocene."

TERTIARY ECONOMIC RELATIONS

Stone, usually of poor grade, considerable sand and gravel, and some volcanic ash, and large quantities of water of good quality occur in the Ogallala and Arikaree formations of Nebraska. There is some quarrying and sand and gravel production from these formations and much groundwater is pumped with air motor and other power for domestic and irrigation use.

The soils on the Tertiary formations vary greatly in their suitability for agricultural use. Those on the Marsland formation and the Box Butte clay are best suited to cultivation. The deep soils on the Tertiary beds are cultivated successfully during most years but the shallow sandy soils are used generally for grazing, and the rough stony lands support more or less tree growth and grazing.

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CRETACEOUS SYSTEM

(Figure 7)

Formations of this system underlie most of Nebraska, except in the southeastern counties (see Figures 1 and 7). Their combined thickness in the western counties is 4000–5000 feet, but decreases rapidly eastward, thinning by local truncation on the Cambridge Arch. The system rests unconformably on pre-Cretaceous rocks and its upper surface was peneplained in early Tertiary time, making the unconformable contact with Tertiary and later rocks.

The Cretaceous formations are of marine origin, except the main sandstones, which are fresh water continental deposits. They have been studied and described in Nebraska and adjacent areas by F. V. Hayden, N. H. Darton, C. N. Gould, E. H. Barbour, G. E. Condra, E. P. Rothrock, W. H. Twenhofel, W. T. Lee, A. C. Tester, M. V. Searight, M. K. Elias, E. C. Reed, J. P. Gries, A. L. Moxon, and others.

OUTLINE OF THE CRETACEOUS GROUPS AND FORMATIONS IN NEBRASKA

1. *Montana group,* Eldridge 1888 and 1889:
   - (1) *Lance formation,* Hatcher 1903
   - (2) *Fox Hills sandstone,* Meek and Hayden 1862, probably absent in Nebraska
   - (3) *Pierre shale formation,* Meek and Hayden 1862
2. *Colorado group,* Hayden 1876:
   - (1) *Niobrara chalk formation,* Meek and Hayden 1862
   - (2) *Carlile shale formation,* Gilbert 1906
   - (3) *Greenhorn limestone formation,* Gilbert 1906
   - (4) *Graneros shale formation,* Gilbert 1906
3. *Dakota group,* Meek and Hayden 1862:
   - (1) *Omadi formation,* new name, Condra and Reed
   - (2) *Fuson shale formation,* Darton 1901
   - (3) *Lakota sandstone formation,* Darton 1899

The Cretaceous group names, except the Dakota, are not used generally. Also the name, Benton, given by Meek and Hayden in 1862 to include the section now classed as Carlile, Greenhorn and Graneros, is no longer in use except at places where the Greenhorn is poorly developed or absent. This condition does not obtain in Nebraska and we have dropped the name Benton, which was first defined as a formation, later as a group and is now in the Colorado group.

COMPOSITE SECTION OF THE CRETACEOUS SYSTEM IN NEBRASKA

Montana Group

Lance formation.—This was named from Lance Creek in Converse County, Wyoming. It is exposed in Wyoming just west of Scotts Bluff County, Nebraska, and

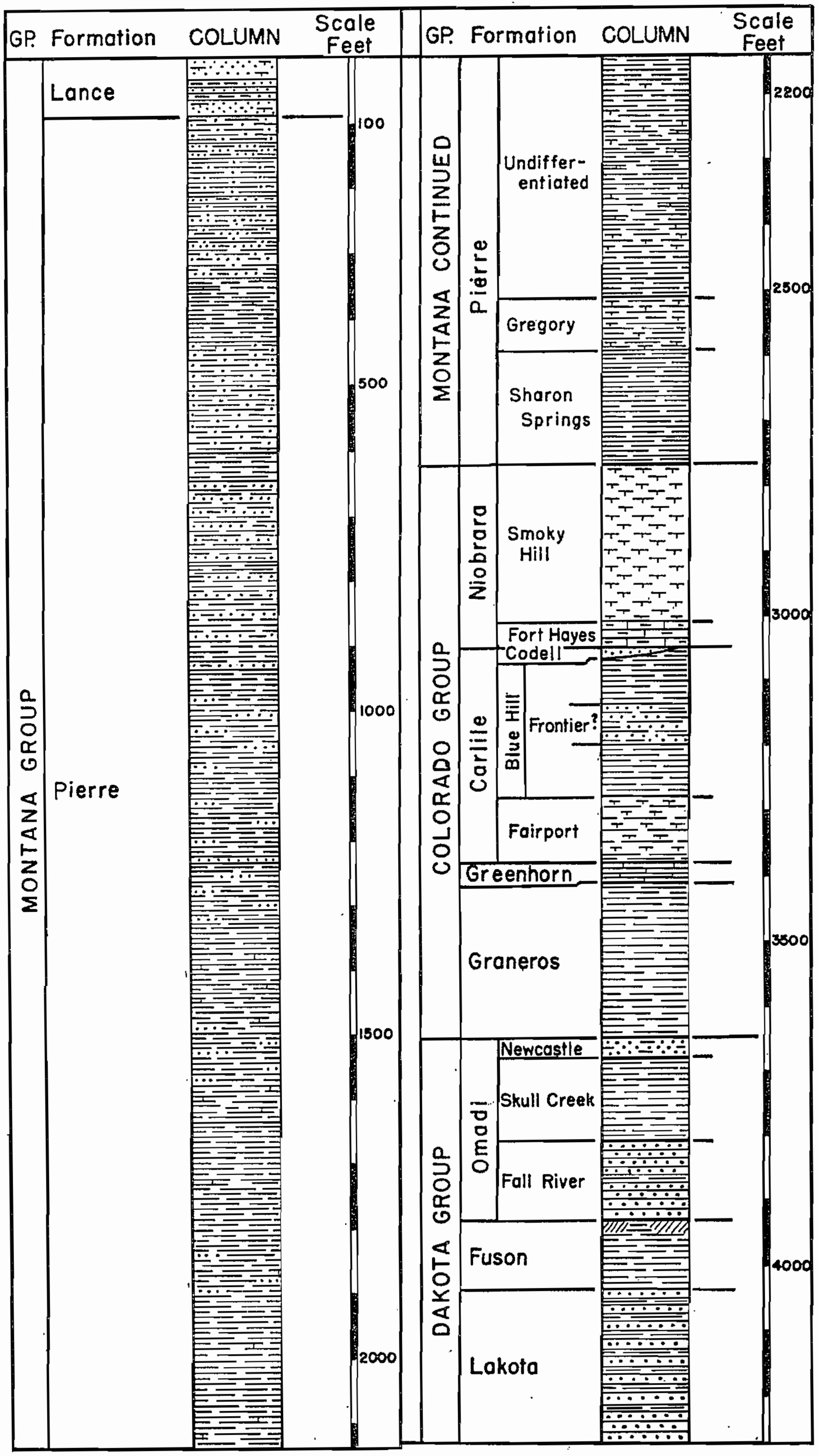

Figure 7.—Composite Columnar, Section, Cretaceous System.

in the Dakotas and other states west and northwest of Nebraska, and is composed of greenish gray argillaceous sands, some sandstone and lignite coal. It underlies western Scotts Bluff County, Banner County and probably part of Kimball County in Nebraska, in a thickness of 90–125 feet, as shown by the logs of deep wells in which no coal has been reported.

Fox Hills sandstone.—This consists of gray to yellowish sandstones and has been mapped in Colorado near the Nebraska line and at places in Wyoming, South Dakota and North Dakota, but thus far we have not found it in our deep wells, nor in the outcrops of western Nebraska. However, we do have a sandy transitional shale at the top of the Pierre which may have been correlated as the Fox Hills in adjacent states.

Pierre shale formation.—Named from Pierre, South Dakota, this consists of black, dusty gray and brownish clay shales, thin layers of bentonite and cone-in-cone structure, indurated shaly chalk, thin shaly limes, well defined concretionary zones, and thin sandstones in the upper part. The thickness of the Pierre is less than 100 feet along its easternmost outcrop in the state and increases westward to 2000 or 3000 feet in Banner and Scotts Bluff counties. However it is eroded through at places on the Cambridge Arch.

Dr. M. K. Elias (Bull. 18, Kansas Geological Survey, 1931) has separated the Pierre in northern Kansas as four well-defined members, and Searight of the South Dakota Survey has named six members of the formation in that state. The members of the Pierre are recognized by their sequence, lithology and faunal content in which species of *Baculites* are the best horizon markers.

The Pierre outcrops along the Missouri in Cedar, Knox and Boyd counties, along the Niobrara in Keyapaha, Rock and Brown counties, from northwestern Sheridan and westward through northern Dawes and Sioux counties, and along the Republican from Franklin County most of the distance to the Colorado line. It occurs widely in the Great Plains region: Its subdivisions (members) as delimited from the outcrops of east central South Dakota, east central and southern Nebraska and northwestern Kansas are as follows.

Elk Butte member.—Searight named this member in 1937 from Elk Butte located between Wakpala and Elk Butte in Carson County, South Dakota. It is missing in Kansas and southern Nebraska but occurs in northeastern Nebraska, Gregory County, South Dakota, and northwestward from there in a thickness of 300 to 400 feet. It consists of medium dark gray, fine grained argillaceous shales, thin bentonite layers and some calcareous concretions, but has not been differentiated in western Nebraska nor in southwestern South Dakota.

Mobridge member.—Erosion probably has removed this member from Kansas and southern Nebraska, but a thickness of about 350 feet of it occurs in Gregory County, South Dakota, extending into northeastern Nebraska. However, its boundaries have not been determined in the deep wells of central and western Nebraska.

This member was defined by Searight in 1937 from Mobridge, South Dakota. It consists of beds of chalk, chalky shale, sandy shale and layers of sandstone. The member changes facially within short distances and its boundaries are not well defined in some areas, and have not been delimited in western Nebraska.

Virginia Creek member.—As defined by Searight in 1937, from Virginia Creek in northeastern Dewey County, South Dakota, this includes upper and lower zones of wide occurrence. The lower zone may correlate with the Sält grass unit of the Kansas survey, which seems to be the highest division of the Pierre exposed in Kansas and southern Nebraska. The upper zone of this member consists of grayish argillaceous shale with calcareous bands and concretions near the top. Its thickness in South Dakota and northeastern Nebraska is approximately 130 to 140 feet.

The Salt grass zone, according to Elias, 1931, has a thickness of about 60 feet in northwestern Kansas and probably persists through Nebraska to South Dakota. It is a grayish shale which includes several thin layers of bentonite, numerous selenite fragments and some concretions.

The Virginia Creek member varies considerably in thickness and has not been differentiated in the subsurface section of western Nebraska.

Sully member.—This was defined by Searight in 1937, and redefined in 1938, from the western part of Sully County, South Dakota. It includes three zones, the Verendrye shale, Agency-Oacoma, and the Crow Creek. The Verendrye zone is composed of light to dark gray shale containing large, flat, ferromanganese carbonate concretions. Its thickness ranges between about 60 and 200 feet, grading into the Agency-Oacoma beds. The Oacoma beds of South Dakota, which carry manganese concretions, thin out near the Nebraska line. The basal sands and chalk beds of the Sully member are called the Crow Creek zone by the South Dakota Geological Survey. They are best developed along the Missouri River in the vicinity of Wheeler bridge located northeast of Bonesteel.

In northwestern Kansas, according to Elias, the Sully member correlates with the Lake Creek shale, 200 feet thick above, and the Weskan, 170 feet thick below. The last named of these carries scattered manganese concretions in its lower part in Kansas.

Gregory member.—Searight named this in 1937 from exposures at the Rosebud bridge section, Gregory County, South Dakota. The member correlates with the upper Sharon Springs of the Kansas Survey as defined by Elias and includes a shaly zone at the top and a chalky zone below. The combined thickness of the member in South Dakota and northeastern and southwestern Nebraska is 30 to 80 feet, and about 70 feet in northwestern Kansas.

Sharon Springs member. — This was named by Elias in 1931 from Sharon Springs, Kansas, but its concept was modified by Searight in 1937 when he defined the Gregory member. It is a dark fissile shale carrying bituminous material and the scales and other remains of fish. It caps the Niobrara formation in a wide occurrence in South Dakota, Nebraska, Kansas, and Colorado, and is a good horizon marker. Its thickness ranges between 20 and 80 feet.

Colorado Group

NIOBRARA CHALK FORMATION. — Named from Niobrara, Nebraska this well-known formation including two members, i.e., the lead-gray, shaly *Smoky Hill chalk,* Cragin 1896, thickness 160 to 460 feet in the upper and middle parts and the gray to yellowish, massive *Fort Hayes limestone,* Williston 1893, thickness 20 to 40± feet, in the basal part. The combined thickness of the Niobrara formations is about 200 feet in Knox County, 450 feet in Furnas County, 500 feet ± in Dundy County and 200 feet in Sioux County. This formation and the section down to the Dakota group are eroded from the Cambridge Arch in western Sheridan County, Nebraska.

The Niobrara formation occurs from Canada to Texas and probably to Mexico, and generally in the Great Plains. It is exposed as chalk bluffs in the Republican Valley, from Guide Rock to near Alma, and along the Missouri River from Cedar County to the Great Bend north of Chamberlain, South Dakota. Nebraska has much chalk rock, probably more than England.

CARLILE SHALE FORMATION.—This was named from Carlile Station and Carlile Springs, located 21 miles west of Pueblo, Colorado. It includes the members: *Codell sandstone,* Bass 1826, *Blue Hill shale,* Logan 1897 and 1899, and the *Fairport shale,* Rubey and Bass 1925. The combined thickness of the Carlile in Nebraska is about 150 feet in the east, 250 feet in the southwest and 400 to 500 feet in the northwest. The fine grained, grayish Codell sandstone, 5 to 10 feet thick, underlies southwestern, western and northern Nebraska a few feet below the Niobrara formation. The grayish, argillaceous Blue Hill shale is about 80 feet to the east, 100 feet to the southwest, and 400 to 500 feet under the northwestern part of the state, and the bluish gray Fairport shale, filled with fossiliferous thin limy layers, lies between the Fairport shale and the Greenhorn limestone with a thickness of 60 to 80 feet in Nebraska and adjacent areas.

GREENHORN LIMESTONE FORMATION.—This, named from Greenhorn Station, south of Pueblo, Colorado, occurs widely in the Great Plains region. It outcrops at Homer, Milford, east of Hebron and at Hubbell, Nebraska. Its average thickness is 25 to 30 feet in a wide occurrence, but some geologists have included the Fairport shale with it, making a much greater thickness.

The Greenhorn formation is composed of thin, medium soft, gray limestones interbedded with gray shales. It occurs widely in the Great Plains Region and is recognized by the presence in the upper part of many specimens of *Inoceramus labiatus,* which has some resemblance to an oyster shell.

GRANEROS SHALE FORMATION. — Named from Graneros Creek in Pueblo County, Colorado, it consists of dark gray plastic shale with thin calcareous layers, some sand and sandy shale, and carbonaceous material in the basal part. The thickness is 60 to 70 feet in northeastern Nebraska (near Ponca and Homer) and 40 to 90 feet subsurface in the Republican Valley, increasing northwestward to 550 to 700 feet or more in northern Dawes County and about 900 feet in its exposures around the Black Hills. This formation changes facially westward becoming the argillaceous *Belle Fourche shale* above and gray calcareous *Mowry shale* below, in western Nebraska, eastern Wyoming and southwestern South Dakota.

Dakota Group

As noted before, this group was named by Meek and Hayden in 1862 from Dakota County, Nebraska. Since that time it has been separated as three formations, the upper one of which is yet called the Dakota sandstone, a usage conflicting with the name of the group.

Lee, 1927, p. 29, correlates the subdivisions of the Dakota group at the east side of the Laramie Range in Wyoming, in a section near the Greenacre Ranch, as follows:

Newcastle sand, Hancock 1920, thickness 82′
Skull Creek shale, Collier 1922, thickness 118′
Fall River sandstone, Russell 1927, thickness 15′±
Fuson shale, 25′±
Lakota sandstone, 75′±

Our study of the Dakota group in the Laramie Range, Black Hills, in the outcrop areas across Nebraska, and from the cuttings and logs of many wells in the area between has led to the conclusion that the New Castle sandstone, Skull Creek shale, and the Fall River sandstones correlate collectively with the so-called Dakota sandstone or top formation of the Dakota group in eastern Nebraska, which means that these divisions may be members of the upper formation of the Dakota group.

The use of the name Dakota both for a formation and a group leads to confusion, and since this name is now established for the well-defined lithologic group, we believe that an appropriate name should be selected for the formation, hence we propose the name Omadi sandstone, for the so-called Dakota formation, to include the section lying between the Fuson and Graneros shales. The formation is named from Omadi township in southeastern Dakota County, Nebraska and the type section is in the Missouri River Bluffs extending through this township. The term Omadi relates back to an abandoned town, Omaha Creek and the Omaha Indians. It is an apropriate substitution for the name Dakota sandstone.

Meek and Hayden used the name Dakota for what they classed as a formation and described its type locality as follows: "Hills back of the town of Dakota; also extensively developed in the surrounding country in Dakota County below the mouth of Big Sioux River,—thence extending southward into northeastern Kansas and beyond." Evidently they did not locate a very definite type locality, nor did they refer to the older horizons of the Dakota group, as now generally understood, but they must have observed the occurrence of these lower beds southward to Kansas. Evidently they applied the name Dakota to the section now classed as the Dakota group, but a specific section and type locality of this group has not been established. So, it seems that such type locality should be selected for this group, and that the location should be made in conformance with the purposes of Meek and Hayden, i.e., in Dakota County. Fortunately this can be done by the use of surface and subsurface data. Consequently we select a type location in the Missouri River Bluffs of Dakota County, located one mile southeast of Homer, Nebraska, in the NE ¼ of Section 13, T. 27 N., R. 4 E.

Following is a section of the Dakota group made in the vicinity of the proposed type locality, on the outcrop and from well logs, thickness 392 feet:

1. *Omadi sandstone formation* (new name), 147′ 4″:
   (1) Sandstone, massive, indurated, with some ironstone, 3′
   (2) Interbedded shales and sandstone, 22′ or more
   (3) Sandstone, medium light gray to brown-gray, medium-grained, in part friable, in part indurated, about 30′
   (4) Interbedded yellow to rusty sandstones and gray, slightly sandy clay shales, with four zones of ironstone, 11′ or more
   (5) Sandstone, rusty, friable, 2′ 2″
   (6) Interbedded gray, sandy, clay shales and yellow, unconsolidated sandstones, 2′ 2″
   (7) Sandstone, massive, crossbedded, with an ironstone zone at top, 3′
   (8) Sandstone, buff to yellow, massive, friable, with an ironstone zone at top, 16′
   (9) Interbedded rusty yellow sandstone with ironstone zones and gray, sandy, clay shale, 38′
   (10) Sandstone, buff to rusty, massive, crossbedded, 11′
   (11) Sandstone, light gray, fine to medium grained, about 9′
2. *Fuson shale,* drilled in well northwest of Homer, about 75′
   (1) Shale, varicolored red and light gray, argillaceous to slightly sandy, 10′
   (2) Shale, medium dark gray, with some red mottling, argillaceous to sandy, 15′
   (3) Shale, medium light gray, part brown and red tinged, sandy, 50′
3. *Lakota sandstone,* thickness 170′ in well northwest of Homer:
   (1) Sandstone, light gray and brown-gray, in part coarse-grained, and friable, in part fine-grained and dense, 15′ (Fuson ?)
   (2) Shale, gray, red brown and yellow varicolored, sandy, with common spherulitic siderite concretions, 20′ (Fuson ?)
   (3) Sandstone, light gray, fine-grained, some spherulitic siderite, some interbedded dark gray, carbonaceous shale, 10′
   (4) Sandy shale and argillaceous sandstone, light gray, with much spherulitic siderite, 15′
   (5) Sandstone, light gray, fine-grained, friable, with much spherulitic siderite, 15′
   (6) Sandstone, light gray, medium to coarse-grained, friable, 8′
   (7) Sandy shale, red and light gray, varicolored, 12′
   (8) Sandstone, light brownish gray, fine-grained, friable and spherulitic siderite concretions, 15′
   (9) Sandstone, argillaceous, light gray, grading to sandy shale, 5′
   (10) Sandstone, light gray, fine-grained, friable, 20′
   (11) Argillaceous sandstone to sandy shale, gray to pink, micaceous, 5′
   (12) Sandstone, light gray, fine to medium grained, micaceous, spherulitic, friable, 20′
   (13) Sandstone, light pinkish gray, medium to coarse-grained with some chert pebbles, 10′

NOTE: The beds above numbered 3 (1) and 3 (2) were measured on outcrop located 3¼ mi. SE of Ponca (Middle east side, sec. 31, T. 30 N., R. 7 E); number 3 (3) is from the record of a well in NW–NE Sec. 33, T. 28 N., R. 8 E); numbers 3 (4)–(10) on outcrops in SW ¼ Sec. 23, T. 27 N., R. 8 E.; number 3 (11) and lower are from the record of the well in the NW–NE, Sec. 33, T. 28 N., R. 8 E.

Further discussion of the formations of the Dakota group is not given here because their features are shown in the preceding section. But it remains to be stated that the Dakota group at the type locality probably lies on the lower Pennsylvanian and is overlain by the Graneros, but at places westward in the State, it rests in succession on the eroded surface of the Pennsylvanian, Permian, Triassic and Jurassic rocks. A few miles southeast of the type locality it is thought to lie on the Mississippian and northward in South Dakota, Minnesota and northwestern Iowa it overlaps the Pre-Cambrian rocks.

The Dakota group underlies most of Nebraska, except parts of Douglas, Sarpy, Cass, Otoe, and Gage counties and all of Nemaha, Richardson, Johnson, and Pawnee counties. It underlies the northern Great Plains generally and outcrops in the foothills of the Rocky Mountains, Laramie Range and the Black Hills, and has outliers in western Iowa. Its thickness averages between 350 and 400 feet in eastern and central Nebraska and increases to between 600 and 700 feet in northwestern part of the State and adjacent areas of Wyoming and South Dakota, where the Skull Creek shale becomes quite thick. The thickness in the southeast flanks of the Black Hills, as shown by the following section, is not much greater than it is in northwestern Nebraska.

OUTLINE OF THE CRETACEOUS FORMATIONS IN THE VICINITY OF RAPID CITY, SOUTH DAKOTA

Abridged and modified after E. F. Miller (1929) Conference Kansas Geol. Soc. Field Trip.

1. *Niobrara formation,* 200′
2. *Carlile shale formation* and *Frontier member,* Knight 1902, thickness 524′
3. *Greenhorn limestone,* 45′
4. *Graneros shale,* 941′:
   (1) *Belle Fourche shale,* Collier 1920, 401′
   (2) *Mowry shale,* Darton 1904, thickness 540′
5. *Dakota group,* 649.5′:
   (1) *Omadi* (Dakota) *formation,* 275′:
      a. *Newcastle* sand, 15′
      b. *Skull Creek shale,* with large calcareous and iron concretions, 213′
      c. *Fall River sandstone,* 47′
   (2) *Fuson shale,* 129′
   (3) *Lakota sandstone,* 245.5′

CRETACEOUS ECONOMIC RELATIONS

Oil and gas are produced in Wyoming from the Shannon sands of the Pierre shale and from the Omadi and Lakota sandstones, but their occurrence in economic quantities at these horizons has not been found in Nebraska.

Coal occurs in the Lance, Fox Hills, Omadi and Lakota formations, in Colorado, Wyoming, and South Dakota. In Nebraska it has been found in the Omadi and Lakota and under conditions not now favorable for economic production.

Bentonite is produced from the middle Cretaceous shales of Wyoming and South Dakota in areas adjacent to the Black Hills, but only small quantities of it are produced in Nebraska, from the Pierre shale.

The Codell, Omadi and Lakota sandstones are important sources of water supply. In Nebraska many wells yield artesian water from the Omadi and Lakota formations.

Stone for structural and road-building purposes is produced from the Niobrara, Greenhorn, Omadi and Lakota formations. Some of the Greenhorn limestone is sawed as fence posts. Portland cement is manufactured at Superior from Niobrara chalk and Carlile shale. Clay from the Fuson shale is used in brick and tile manufacturing at Lincoln and Hastings. Some sand from the Dakota group is used as moulding sand.

The Cretaceous formations have important relations to soil development and agricultural land use. Soils on the Pierre and Carlile shales are very heavy as a rule and the land on which they occur is used chiefly for grazing. The Niobrara, Omadi and Lakota formations have rough topography in most places and support grazing and considerable tree growth. Deep soils developed at places on all of the Cretaceous formations are cultivated.

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JURASSIC SYSTEM

(Figure 8)

The upper part of this system (Morrison) was formerly classed with the Cretaceous, but is now included with the Jurassic by most geologists. Among those who have studied the Jurassic in outcrop areas adjacent to western Nebraska are F. V. Hayden, Henry Newton, R. P. Whitfield, W. C. Knight, N. H. Darton, W. T. Lee, J. G. Bartram, J. B. Reeside, W. W. Rubey, A. K. Baker, C. H. Crickmay and Joseph Neely. E. C. Reed has made most of the subsurface study of this system in Nebraska.

OCCURRENCE OF JURASSIC ROCKS IN NEBRASKA

Jurassic rocks do not outcrop in Nebraska but they are present in the subsurface in much of the western one-half of the state, occurring next below the oldest Cretaceous sandstones and resting unconformably on Triassic and Permian beds. The thickness of the Jurassic formations encountered in the deep wells of the southern and western counties varies from ten feet in southeastern Franklin County to 542 feet in northwestern Sioux County near the Wyoming and South Dakota lines. The average thickness drilled in the state is slightly more than 200 feet, the greater thickness being almost entirely in the panhandle region.

In northwestern Nebraska, the Jurassic rocks can be satisfactorily correlated with the Morrison and Sundance formations but farther to the east and southeast, where a thinner section is involved, detailed correlations are difficult. It is believed, however, that the thinner Jurassic intervals to the east include all or most of the Morrison formation and only the upper parts of the Sundance formation.

The thickest Jurassic section (Figure 8) drilled in the state to date, was penetrated between 2,770 and 3,312 feet in a well drilled by the J. M. Huber Corporation in northwestern Sioux County, where the record of the section is as follows:

1. *Morrison formation,* Eldrige 1896, thickness, 120′:
   (1) Shale, dark chocolate gray and brown-gray, in part pale green with some phosphatic nodules, 25′
   (2) Shale, medium gray to light green-gray, in part silty, with some dark, limy, pyritic seams, 15′
   (3) Shale, dark green and lavender, indurated, in part almost a non-calcareous mudstone, 23′
   (4) Limestone, medium light gray, finely granular, in part brownish-gray, and interbedded shale, greenish-gray, part calcareous, 45′
   (5) Shale, greenish gray, calcareous and sandstone, light gray to white, 12′
2. *Sundance formation,* Darton 1899, thickness 401–422′:
   (1) *Upper Marine member,* 85–106′:
      a. Shale, dark green, calcareous, with some interbeds of green, glauconitic siltstone to fine sandstone, 5′
      b. Shale, blue-green to dark gray, argillaceous, thinbedded, with some thin beds of fine-grained sandstone, 25′
      c. Shale, dark blue-gray, argillaceous, indurated, in part calcareous, in part silty, 55′
      d. Sample missing, 21′ (At this place the tools were changed from cable to rotary and the lower beds were cored. When the rotary tools were run in the hole for coring the depth was found to be 2996 feet

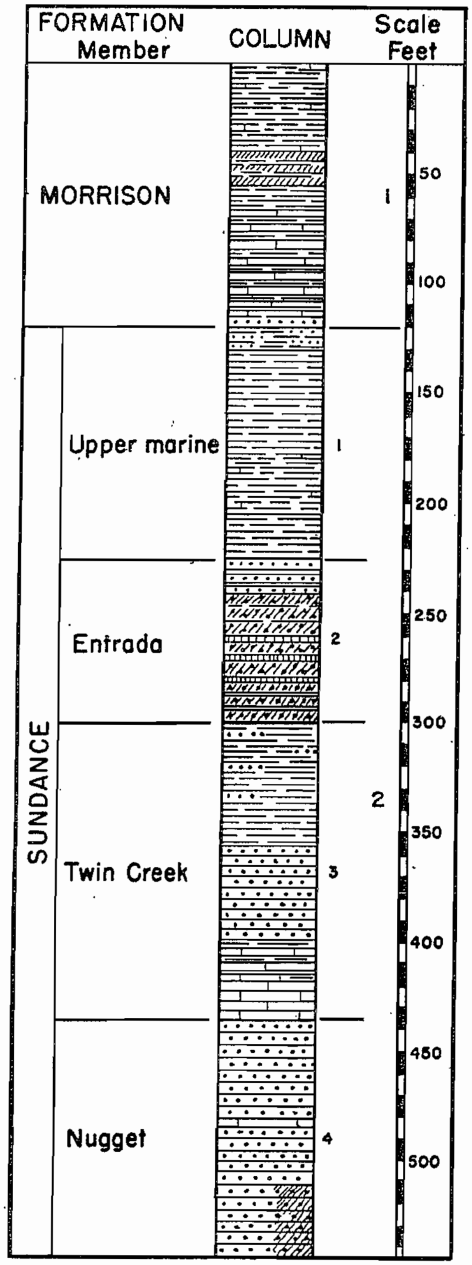

Figure 8.—Composite Columnar Section, Jurassic System.

while the previously reported cable tool depth was 2975 feet.)

(2) *Entrada sandstone member,* Gilluly and Reeside 1896, thickness, 74':
   a. Sandstone, light green-gray, fine-grained, subangular, calcareous-cemented, in part clayey, with thin green shale partings, 8'
   b. Sandstone, light gray and pinkish gray, fine-grained, 9'
   c. Sandstone, pinkish gray, fine-grained, with thin green shale partings, 20'
   d. Sandstone, pinkish gray, in part green-gray mottled, with thin partings of chocolate to maroon shale, 18'

(3) *Twin Creek limestone,* Veach 1907, thickness, 137':
   a. Shale, dark green-gray, thin-bedded, with irregular laminae of light green-gray, fine-grained sandstone, 34'
   b. Shale, dark green-gray, argillaceous to calcareous, in part sandy, with many siderite spherules at base, 19'
   c. Sandstone, medium dark with dark streaks, calcareous, indurated and limestone, dark gray, spherulitic, 2'
   d. Sandstone, light gray to white, fine to medium-grained, calcareous and thin-bedded at base, 45'
   e. Shale, dark green-gray and dark gray, argillaceous and limestone, dark brown-gray, finely crystalline, dense, slightly fossiliferous, 18'
   f. Limestone, dark brown-gray to dark gray, more or less argillaceous, 19'

(4) *Nugget sandstone,* Veach 1907, thickness 105':
   a. Sandstone, light gray, fine to medium grained, in part brownish, 43'
   b. Limestone, dark gray, 1'
   c. Sandstone, light gray to white, fine to medium-grained, 29'
   d. Sandstone, light brownish gray to pinkish gray, indurated, slightly calcareous, 32'

NOTE: The preceding correlation of the members of the Sundance formation with outcrop equivalents in Wyoming is believed to be accurate and in keeping with the four-fold divisions as used in that state, but the bed correlated as Twin Creek limestone is not entirely in accord with the stratigraphy of this interval in Wyoming.

ECONOMIC RELATIONS

The Sundance formation is an important oil-producer in the Lance Creek Field of Wyoming, where the discovery horizon is sometimes referred to as the Upper Sundance sandstone, which is believed to correlate with the interval classified as the Entrada, while the more productive "Basal Sundance" sandstone is equivalent to rocks herein classified as the Nugget.

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THE TRIASSIC SYSTEM

PERMIAN-TRIASSIC BOUNDARY

The exact lower limit of the Triassic system and the upper limit of the Permian system are still in doubt in the Rocky Mountain Region and the Black Hills. Darton in 1899 classified all of the red bed section above the Minnekahta limestone and below the Sundance formation in the Black Hills as Triassic and called this interval the Spearfish formation. Thomas, 1934, traced the Permian Phosphoria from the Wind River Mountains into the Laramie Basin and found that the Phosphoria interfingers with red shales in the lower part of the "Chugwater formation" which had previously been classified as Triassic in age. Condra, Reed and Scherer in 1940, continued the eastward tracing of the upper part of the Phosphoria into the Hartville Uplift of Eastern Wyoming and into the Black Hills of South Dakota. They found that the lower part of the Spearfish formation in these areas is Phosphoria in age, and restricted the Spearfish to the red bed section above the eastern Phosphoria equivalents.

The term *Jelm formation,* Knight 1917, has been given to rocks in the Laramie Basin of Wyoming which unconformably underlie the Jurassic Sundance formation and unconformably rest upon "red beds" which are believed to correlate with the restricted orange-colored, cross-bedded sandstone, classified as Upper Triassic. A massive, orange-colored, cross-bedded sandstone, occurring along the Laramie and Rocky Mountain Fronts has been tentatively correlated with the Jelm by W. T. Lee (1927, pp. 14, 15). This formation is not believed to be present in the subsurface of Nebraska.

OCCURRENCE OF TRIASSIC ROCKS IN NEBRASKA

Rocks believed to correlate with the restricted Spearfish formation have been drilled in several wells in northwestern Nebraska and probably are present in the subsurface of a large part of the "panhandle" area of the state. The maximum thickness of the Spearfish formation drilled in western Nebraska is about 125 feet in the vicinity of Agate Springs, Sioux County, from which the formation thins out eastward, either by truncation or non-deposition, and is absent over the top of the Cambridge Arch and is not known to occur farther to the east. However, it is probably present in the subsurface of eastern Colorado.

Our best record of the Triassic, i.e., the Spearfish (restricted) in Nebraska is from a well located about ten miles southwest of Alliance. This record is as follows: *Spearfish formation,* Darton 1899, thickness, 118 feet:

1. Shale, brownish red, silty to sandy, indurated, gypsiferous, 22′
2. Shale, brownish red and greenish gray, silty, gypsiferous, 17′
3. Shale, brownish red, silty, slightly gypsiferous, 27′
4. Shale, brownish red, in part greenish gray, part sandy, gypsiferous, 16′
5. Sandstone, brownish red, fine-grained, argillaceous, 17′
6. Shale, brownish red to maroon, argillaceous to silty, 19′

NOTE: The Triassic rocks have no special economic importance in Wyoming and South Dakota, except for the use of the land for grazing and cultivation. The gypsiferous zones formerly included with the Spearfish Triassic are now classed as upper Permian.

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PERMIAN SYSTEM

The tendency now among geologists of the Mid-Continent region, is to class the Permian rocks as a system rather than a series. The series and groups of this system in the Kansas-Nebraska area were established by F. W. Cragin, Charles Prosser, and G. I. Adams as follows:

1. *Cimarron series,* Cragin 1896:
   (1) *Kiger group,* Cragin 1896
   (2) *Salt Fork group,* Cragin 1896
2. *Big Blue series,* Cragin 1896
   (1) *Sumner group,* Cragin 1896
   (2) *Chase group,* Prosser 1895
   (3) *Council Grove group,* Prosser 1902
   (4) *Admire Group,* Adams 1903

DISCUSSION OF PERMIAN PROBLEMS

The Permian was named in Russia by Murchison in 1841 for rocks of the approximate age of our Cimarron series. But in the Permian Excursion and the Permian Sessions of the International Geological Congress held in Russia in 1937, many Russian and American geologists and paleontologists were in favor of placing the base of the system lower in the section, to include formations of the approximate age of our Cimarron and Big Blue series, but since that time some of the Russians have changed their opinion and would now place the lower boundary of the system higher, probably at the base of the Artinskian as originally defined stratigraphically in Russia. This means that the Russians have not agreed on the position of the base of the Permian in their country.

Marked progress has been made in the United States the past few years in the study and correlation of the Permian rocks, especially in the northern and southern areas of the Mid-Continent region. The Kansas, Oklahoma and Nebraska geological surveys have made special studies of the system in their states, the Geological Society of America has subsidized special researches on the Permian, and a special committee of the American Association of Petroleum Geologists has been very active in the attempt to establish a standard Permian section for North America, in West Texas and Southeastern New Mexico. The report of this Permian committee is found in A.A.P.G. Bull., Vol. 23, No. 11, Nov. 1939, pp. 1673-1681. The committee advocates the classification of the American Permian as a system, based on the exposed and subsurface section adjacent to the Delaware basin, and proposes series names for the system, named from youngest to oldest, as follows: Ochoa, Guadalupe, Leonard, and Wolfcamp.

Evidently the Kansas and Oklahoma Geological Surveys have accepted the proposed national section and have discontinued the use of such well established terms as the Big Blue and Cimarron series. However, the Nebraska Geological Survey hesitates to accept this shift in nomenclature except as it applies to correlative age, and recognizes the age relations of the so-called standard series as follows:

1. *Ochoa*=Permian above the Day Creek horizon
2. *Guadalupe*=Whitehorse and Day Creek
3. *Leonard*=the section from top of Herington limestone to top of the Dog Creek
4. *Wolfcamp*=approximately the Big Blue Series (revised)

Although the above age relations are apparent it does not mean that the lithologic units of the proposed national section are the same as those in Kansas and Nebraska. For example the Big Blue and Wolfcamp series are separated by a red bed facies and represent distinct regional lithologic series, i.e., formationally they are not correlative.

Our subsurface study indicates that an important unconformity is present at the base of the Ninnescah in Nebraska, and the subsurface sections made by Norton in 1939 seem to indicate the same situation in Kansas. Therefore, the Leonard series, if accepted here, would have this unconformity in its middle. This means that we are not yet ready to apply the name Leonard lithologically in the northern part of the Mid-Continent region. Furthermore the name Guadalupe is objectionable on a lithologic basis for this region, but its age relation is acceptable. The section of Ochoa age is thin in Kansas and Nebraska.

THE OCCURRENCE OF PERMIAN ROCKS IN NEBRASKA AND ADJACENT AREAS

The Nebraska Geological Survey continues the current formational classification and nomenclature of the Permian subdivisions employed in the Northern Mid-Continent region and cooperates with other surveys and agencies in the regional and interregional age correlation of the Permian System. We believe that the natural common boundary of the Wellington formation and the Chase Group is at the top of the Herington limestone, but we do not follow the Kansas survey in placing the Ninnescah and Stone Corral formation in the revised Sumner group, but leave the latter as correlative with the Wellington. This means that we class the Wellington formation or group, as it may be, of post Big Blue-pre-Cimarron age. It has been classed with the Big Blue for a number of years but is a transitional development upward from the latter and probably should not be classed with either the Cimarron or the Big Blue series as they are now understood. The more precise classification of the Wellington is deferred until after its relations are better established and cooperative correlation can be made by the state and federal surveys having direct relations to the problem.

CIMARRON SERIES

The formations of this series are quite well developed and exposed in northern Oklahoma and southern Kansas from which some of them extend subsurface to southern and western Nebraska and grade into the Permian redbed section of the Rocky Mountain, Laramie Range, Hartville and Black Hills regions, where their correlation is given following that of Kansas and southern Nebraska.

Cragin, Gould, Russom, Norton and

others have studied the Cimarron series of Kansas quite closely. The following outline has been compiled from the publications of Cragin (1896) and Norton (1939).

Outline of the Cimarron Series in Southern Kansas

Thickness 1810 feet or less

I. *Kiger group,* Cragin 1896, about 377′:
   1. *Big Basin* ("Hackberry") *formation,* Cragin 1896, thickness 65′ or less
      (1) Sandstone, massive, cross-bedded, and sandy shale, 40′
      (2) Shale, 18′
      (3) Shale, gray and green, 7′
   2. *Day Creek dolomite,* Cragin 1896, gray, fine textured, dense, 2′+
   3. *White Horse sandstone formation,* Gould 1905, thickness 310′ or less:
      (1) *Cloud Chief,* Gould 1925, thickness, 30′±
      (2) *Rush Springs,* Sawyer 1924, thickness, 138′:
         a. Shale, red, with layers of dolomite at base, 38′
         b. Sandstone, evenly bedded, with shale partings, 100′
      (3) *Relay Creek dolomite,* Evans 1931, bluish at top and base; sandstone in middle, 22′
      (4) *Marlow sandstone,* Sawyer 1924, bright red, soft, fine grained, cross-bedded, 110′–120′

II. *Salt Fork group,* Cragin 1896, about 1433′ or less:
   1. *Dog Creek shale formation,* Cragin 1896, red, with indurated sandstone and some shale, 15′–53′
   2. *Blaine* (Cave Creek) *formation,* Gould 1902, red shales and gypsum, 84′ or less:
      (1) *Shimer gypsum,* 0–24′
      (2) *Jenkins shale and gypsum,* 10′ or more
      (3) *Medicine Lodge gypsum,* 25′–30′
   3. *Flower Pot shale formation,* Cragin 1896, reddish, with selenite veins, 165′–190′
   4. *Cedar Hills sandstone formation,* Cragin 1896, red, 180′
   5. *Salt Plains formation,* Cragin 1896, red sandstone and siltstone, 275′
   6. *Harper sandstone formation,* Cragin 1896, restricted by Norton, 1939, thickness, 220′ or less:
      (1) *Kingman sandstone,* Norton 1939, red, 80′
      (2) *Chikaskia sandstone,* Norton 1939, largely red, 100′–140′
   7. *Stone Corral dolomite formation,* Koesler 1935, gray, 6′±
   8. *Ninnescah shale formation,* Norton 1939, largely red sands and shales, sandy limes, sandstone, with the thin Melon limestone at the base; combined thickness, 425′ at the Oklahoma line and about 350′ at places about 50 miles northward in Kansas

NOTE: Most of the Cimarron formations have been correlated with units of the Upper and Middle Permian in Oklahoma and Texas and their age relations are fairly well known. However, it should be noted here, that the Harper sandstone as defined by Cragin in 1896 includes the Stone Corral of Koesler (1935) and the Ninnescah of Norton (1939). This means that the base of the Cimarron as defined by Cragin is at the base of the Ninnescah or top of the Wellington.

According to age relations, the divisions of the Cimarron in southern Kansas correlate with the proposed national section about as follows:

1. *Big Basin* (Hackberry) *formation* = basal *Ochoa series*
2. *Day Creek* and *Whitehorse* = Guadalupe *series*
3. *Salt Fork Group* = *Upper* and *Middle Leonard series*

Composite Section of the Cimarron Series in Southern Nebraska and Northeastern Colorado. Figure 9.

This section is based on subsurface data obtained from the records of deep wells in southern Nebraska and in the vicinity of Wray, Colorado, where the upper beds of the series have been truncated leaving a thickness of 500 feet or more in Hitchcock and Dundy counties of Nebraska and adjacent parts of Colorado and resulting in an eastward thinning to forty feet or less in Franklin County and complete absence farther to the east. The section from the record of a well drilled about 8 miles southeast of Trenton, is the most complete of this series in southern Nebraska. Following is the composite section of the Cimarron beds from the Trenton well and the Colorado wells, thickness 633 feet:

1. *Kiger group,* absent, probably due to truncation
2. *Salt Fork group,* top eroded, 633′:
   (1) *Dog Creek-Blaine formations* absent in Nebraska wells, thickness of Blaine in adjacent part of eastern Colorado, 50′ or more
   (2) *Flowerpot shale formation,* total thickness in adjacent part of eastern Colorado about 120 feet, upper part eroded in Nebraska leaving a thickness of 65′ as follows:
      a. Shale, maroon to chocolate, with some green-gray mottling, 30′

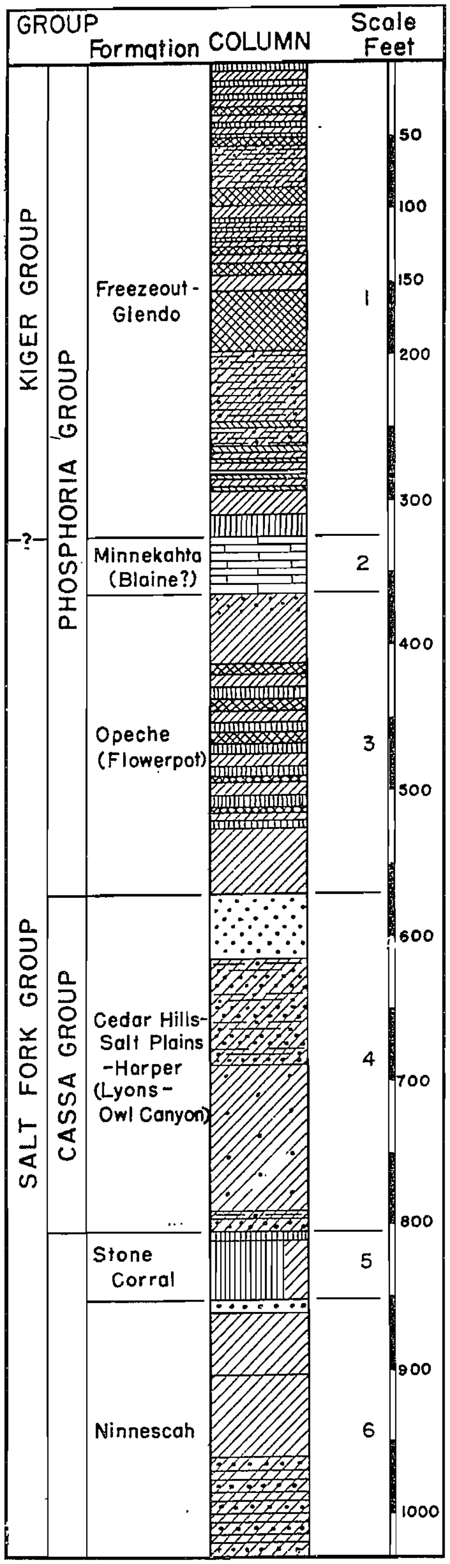

Figure 9.—Composite Columnar Section, Cimarron Series, Permian System.

b. Shale, brick red, silty, massive, 30′
c. Shale, maroon, argillaceous, with some thin beds of gypsum and dolomite, 5′

(3) *Cedar Hills-Salt Plains-Harper section,* 237′:
a. Sandstone, pinkish gray, medium-grained, subangular to subrounded, with some red shale, 45′
b. Sandstone, pinkish gray, interbedded with shale, red, silty, 76′
c. Shale, red to maroon, in part greenish gray mottled, silty to argillaceous, 102′
d. Shale, red, silty, gypsiferous, 6′
e. Shale, red, gypsiferous, and sandstone, pinkish gray, fine to medium coarse-grained, friable, 8′

(4) *Stone Corral formation,* 48′:
a. Anhydrite, light gray to white, 5′
b. Anhydrite, white to pink, with some interbedded pink and red silty shale, 43′

(5) *Ninnescah formation,* 178′:
a. Sandstone, gray, fine to medium-grained, in part orange-stained, 7′
b. Shale, dark red, argillaceous, massive, with some light gray streaks, 43′
c. Shale, red, silty, in part argillaceous, in part gypsiferous, 57′
d. Sandstone, pink, fine-grained, friable, interbedded with shale, maroon to pink, argillaceous to silty, 71′

Permian of Cimarron Age in Eastern Wyoming

The study of outcrops in the Hartville and Laramie Range Regions of Eastern Wyoming and in the Black Hills of South Dakota has been of material assistance in the correlation of the subsurface in western Nebraska which has become a critical area in that a study of the subsurface contributes much to a sound correlation between the outcrop areas of the Mid-Continent and Rocky Mountain regions.

The following composite section of rock units based on a study of outcrops in the Laramie Range and the Hartville Uplift, is thought to be of Cimarron age:

1. *Phosphoria group,* Richards and Mansfield 1912, thickness 240′–268′:

(1) *Freezeout beds,* Thomas 1934, thickness 102′:
a. Limestone, gray, gypsiferous, interbedded with red shale, 8′–10′
b. Shale, red, about 45′
c. Limestone, gray to pink, 2′ or more
d. Shale, red, with thin layers of red sandstone, 45′

(2) *Forelle limestone,* Darton 1908, gray to pink, in two beds separated by shale, 8′–12′

(3) *Glendo shale,* Condra, Reed and Scherer 1940, thickness 50′ or more:
   a. Shale, red, 8′–10′
   b. Sandstone, yellowish, 1′ or more
   c. Shale, red, with some gypsum, 39′–40′

(4) *Minnekahta limestone,* Darton 1901, gray to purple, fossiliferous, in thin beds, 20′6″–25′

(5) *Opeche shale,* Darton 1901, thickness, 60′–79′:
   a. Shale, lavender, argillaceous to sandy, 1′–2′
   b. Sandstone, red, sandy, with gypsum, 1′
   c. Shale, red, sandy, 2′ or more
   d. Sandstone, red, argillaceous, massive to bedded, 10′
   e. Shale, red, part sandy, with gypsum seams, 19′ or more
   f. Gypsum, with thin red shale seams in upper part, 18′–20′
   g. Limestone, gray to yellowish, finely granular, sandy, slightly dolomitic, gypsiferous, 6″
   h. Shale, red to yellowish, 4′6″

2. *Cassa group,* Condra, Reed and Scherer 1940, thickness 208′8″:
   (1) *Lyons sandstone* (Fenneman 1905), redefined by Lee 1927. Stone, yellow-buff, massive but thinbedded at top and base, 20′
   (2) *Owl Canyon formation,* Condra, Reed and Scherer 1940, thickness 188′8″:
      a. Shale, medium gray, weathers yellow-buff, concretionary, 4′9″
      b. Sandstone, yellow-buff, part red-stained, fine-grained, in three beds separated by thin shale partings, 9′
      c. Sandstone, red, massive, soft, with a 2′2″ resistant bed below top, 15′2″
      d. Sandstone, red, mottled with light gray, forms a rounded ledge, 1′
      e. Sandstone, red, massive, soft, 2′9″
      f. Sandstone, red, forms a ledge, 3′
      g. Sandstone, red, argillaceous, in part covered, 33′
      h. Limestone, medium gray to lavender, dense, dolomitic, sandy at top, 8′
      i. Sandstone, red, friable, badly covered in base of slope, 36′
      j. Siltstone, light gray to pink and red-stained, calcareous, massive, heterogeneous, grades from limestone to sandstone, locally cavernous, with angular cobbles of limestone and siltstone, 30′
      k. Siltstone-sandstone, gray, with limestone cobbles, 22′
      l. Sandstone-siltstone, pink to red, calcareous, massive, with scattered limestone cobbles, 14′

Permian of Cimarron Age in Northwestern Nebraska. Figure 9.

This section is based on subsurface data obtained from the records of deep wells. The amount of truncation of the upper part of the Cimarron lessens in a northwestward direction so that all of the Cimarron is represented in central and southern Dawes and Sioux Counties, in northern Morrill County and probably in the remaining southern part of the Panhandle region of Nebraska. Eastern Wyoming formation and group names, as well as Kansas and Oklahoma names, are used in this section because of the proximity of Wyoming. The regional correlation of units is discussed later.

The following composite section of beds of Cimarron age is taken from the records of wells drilled near Dakota Junction and Agate Springs, Nebraska. The beds of this age thin northwestward from 860 to 900 feet at Agate Springs to 565 feet in the northwest corner of Sioux County. Section:

1. *Phosphoria group* (*Kiger group* and *Upper Salt Fork group*), 570′–580′ (thins to 364′ in NW corner of Sioux County):
   (1) *Freezeout - Forelle - Glendo formations* (Probably largely equivalent to Kiger group), 214′ in NW Sioux County, 285′–322′ in Agate Springs and Dakota Junction
      a. Gypsum-anhydrite and red shale, 25′
      b. Gypsum and red shale, some salt, 27′
      c. Salt, 6′
      d. Shale, red, silty, gypsiferous, in part salty, 28′
      e. Salt, 12′
      f. Shale, red, in part greenish gray, gypsiferous, 8′
      g. Anhydrite, pinkish gray, and shale, red, silty, 14′
      h. Salt and red shale, interbedded, 34′
      i. Salt, 42′
      j. Shale, red, silty, 48′
      k. Shale, red, silty, interbedded with some salt, 21′
      l. Shale, red, silty, gypsiferous, 14′
      m. Salt and red shale, 10′
      n. Shale, red, gypsiferous, 18′
      o. Anhydrite and gypsum, 15′
   (2) *Minnekahta limestone,* probably equivalent to Blaine, light gray to pinkish-gray, fine-grained, dense, 40′–44′
   (3) *Opeche* (*Flowerpot*) shale, 88′ in NW corner of Sioux County and 208′–225′ at Agate Springs and Dakota Junction
      a. Shale, red, silty to sandy in upper

part, more argillaceous and gypsiferous below, 48′
b. Salt, red shale, and gypsum, 57′
c. Gypsum, common red shale, some salt, 7′
d. Shale, red, gypsiferous, with common thin beds of salt, 51′
e. Shale, red, gypsiferous, 45′

2. *Cassa group* (*Cedar Hills-Harper*), thickness 157′ in NW corner of Sioux County and 215′–220′ at Agate Springs and Dakota Junction:
   (1) Sandstone, pinkish gray to red, fine-grained, interbedded with red silty shale and some orange with medium coarse sand grains, 35′
   (2) Shale, red, argillaceous to silty and siltstone, red, 46′
   (3) Shale, maroon, argillaceous to silty, 17′
   (4) Shale, red, gypsiferous, and sandstone, red, argillaceous, fine-grained, 42′
   (5) Shale, maroon, argillaceous to silty, 7′
   (6) Sandstone, pink to red, fine to medium-grained, subangular, 22′
   (7) Shale, maroon, argillaceous to silty, 8′
   (8) Sandstone, pinkish gray, fine-grained, subangular, 18′
   (9) Shale, dark maroon, silty, 5′
   (10) Sandstone, pinkish gray, fine-grained, with some maroon shale, 20′
3. *Lower Salt Fork group,* probably absent in outcrop area of eastern Wyoming, thickness at Agate Springs and Dakota Junction, 75′–100′:
   (1) *Stone Corral formation;* anhydrite and dolomite, 15′–56′
   (2) *Ninnescah formation;* shale, and fine-grained, red sandstone, 34′–61′

Correlation of the Cimarron from the Mid-Continent Region Northwestward

The purpose here is to outline as completely as we know, the relations the Cimarron units of Kansas and southern Nebraska hold to the red bed sections of western Nebraska, eastern Wyoming, and the Black Hills Region. Factual data obtained from deep well records and from surveys of the outcrops of the Permian in eastern Wyoming and southwest South Dakota were used in this correlation and for the compilation of Figure 10.

Formerly most geologists classed the Spearfish of the Black Hills and Hartville areas with the Triassic, but as noted before, Condra, Reed and Scherer, 1941, show that approximately the lower 100 feet or more of the Spearfish shale of these areas and in the foothills of the Laramie Range in Wyoming, is of Permian age, classed with the Phosphoria of western Wyoming. Figure 10 shows that these basal "Spearfish" beds, i.e., the Freezeout shale, Forelle limestone, Glendo shale, Minnekahta limestone, and the Opeche shale, extend into western Nebraska, correlating with certain divisions of the Cimarron of the Northern Mid-Continent Region.

Geologists have not agreed regarding the age of the Minnekahta limestone and its relation to the Kansas-Oklahoma Section. Some of them correlate the Minnekahta provisionally with the Day Creek and others with the Stone Corral. Our investigation leads to the following correlations of the Cimarron northwestward from Kansas.

1. The Kiger group of Kansas appears to correlate with the Freezeout formation and probably with the Forelle and Glendo formations.

2. The Salt Fork group of Kansas is believed to be equivalent to the lower part of the Phosphoria group and all of the Cassa group of Wyoming.

3. The Day Creek dolomite of Kansas and Oklahoma is approximately equivalent to the top of the Freezeout formation of Wyoming and the Black Hills.

4. The Whitehorse formation probably correlates with the main part of the Freezeout formation in these areas.

5. The Dog Creek-Blaine section is probably equal to the Forelle, Glendo and Minnekahta and there is a strong suggestion that the Medicine Lodge Gypsum member of the Blaine is correlative with the Minnekahta limestone.

6. The Minnekahta limestone formation can be carried subsurface from the Hartville and Black Hills regions into Nebraska as far southeast as Lakeside in Sheridan County. The truncation of the upper beds of the Cimarron series farther to the southeast in Nebraska prevents actual tracing of the Minnekahta into the Blaine of Kansas although this correlation is suggested by the relatively few deep wells in the Julesburg Basin region of western Nebraska and northeastern Colorado. The Minnekahta limestone is exposed southward along Laramie Range from south of Douglas, Wyoming to the vicinity of Fort Collins,

Figure 10.—Correlation of Permian Rocks from Eastern Wyoming to Southeast Nebraska and Kansas through Nebraska Deep Wells.

Colorado and probably occurs under the Cretaceous overlap yet farther to the south.

7. The Flowerpot shale formation becomes the Opeche shale in Wyoming and South Dakota.

8. The Cedar Hills, Salt Plains and Harper (Kingman-Chikaskia) cannot be separated accurately in the subsurface but the Cedar Hills-Harper interval can be carried through the subsurface of western Nebraska and appears to correlate with the Cassa group of Wyoming.

9. The top of the Cedar Hills sandstone and the top of the Lyons sandstone appear to be about the same horizon.

10. The Stone Corral dolomite or anhydrite cannot be carried into the Wyoming outcrop area with any assurance and it may be overlapped by the Cedar Hills-Harper formation northwestwardly. However we are able to carry it through to the vicinity of Hay Springs, Nebraska and it occurs in the lower part of the Cimarron Series in the subsurface of Dawes and Sioux counties. This division is carried westward across southern Nebraska to the vicinity of Wray, Colorado and probably is present in much of the Julesburg Basin region.

11. The Ninnescah formation is in general coextensive with the Stone Corral although it is generally thinner in Nebraska than in Kansas and appears to be overlapped by the Stone Corral and higher Cimarron formations to the east of the Cambridge arch and in northwestern Nebraska and adjacent parts of eastern Wyoming.

WELLINGTON BEDS

The salt in the Wellington formation is an end product of evaporite deposition and more suggestive of the Cimarron type of deposition than of any part of the Big Blue series, but evaporites such as gypsum and anhydrite occur in formations of the Big Blue Series and seem to increase in importance upward, so the presence of salt in the Geuda member of the Wellington is not sufficient evidence for including the latter with the Cimarron. Also color cannot be relied upon in the establishment of this correlation because of the regional facial changes.

Subsurface studies in Nebraska indicate a marked westward overlap of the lower formations of the Cimarron on the Wellington and older formations. This overlap is suggestive of unconformity and it appears that the subdivisions of the Wellington are more conformable to the Hollenberg, Herington, and lower beds than they are to the Stone Corral and other Cimarron beds. However, G. H. Norton (1941), in his study of the Ninnescah-Wellington contact on the outcrop in southern Kansas, reports that there is no evidence of unconformity between the Wellington and Ninnescah, although his subsurface sections seem to show the same overlap relations in Kansas that obtain in the subsurface of Nebraska.

Wellington Formation or Group in Southern Kansas

After Cragin (1896), Ver Wiebe (1937) and Moore (1936).

We use the term Wellington for the section between the top of the Herington limestone and the base of the Ninnescah formation, thickness, 568′. Section:

1. *Afton limestone,* Ver Wiebe 1937, composed of zones of green and red, indurated claystones, 75′
2. Shale, red, part greenish, argillaceous, probably 50′
3. *Slate Creek limestone,* Ver Wiebe 1937, two gray chalky claystones separated by green and red shales, 12′
4. *Highland shale,* Ver Wiebe 1937, mostly greenish, largely argillaceous, with gray claystone layers, about 40′
5. *Carlton limestone,* Moore 1936, gray to dark clay shales separated by chalky claystones, about 60′
6. *Chisholm Creek shale,* Ver Wiebe 1937, drab, argillaceous, with local red layers, about 50′
7. *Annelly gypsum,* Ver Wiebe 1937, interbedded gypsum and greenish clay about 15′
8. *Geuda Salt measures,* Cragin 1896, varicolored, argillaceous shales, gypsum and salt, about 128′
9. *Donegal limestone,* Moore 1935, thickness 15′–18′:
   (1) *Strickler limestone,* Moore 1936, gray, 1′
   (2) *Newbern shale,* Moore 1936, thickness 8′–10′
   (3) *Hollenberg limestone,* Condra and Upp 1931, thickness, 2′–4′+
10. *Pearl shale* (Beede 1908), restricted by Condra and Upp 1931, gray and red beds of shale, largely argillaceous, 35′–40′

NOTE: Of the five names introduced by Ver Wiebe in 1937, two may be preoccupied. However, we find that the zones described by him are more widely persistent than had been expected. The Strickler limestone and the Newbern shale named by Moore in 1936 are not very persistent. Consequently, the name Donegal limestone formation is not well founded.

Composite Section of the Wellington Formation in Southern Nebraska. Figure 11.

Based on well records in Webster, Franklin and Harlan counties, thickness about 350 feet.

1. *Afton limestone,* light gray, granular, argillaceous, dolomitic, in part white and crystalline, 5′–20′
2. Shale, brownish-red and dark greenish-gray, 30′
3. *Slate Creek-Carlton shale* and mudstones, 40′
   (1) Mudstones and shale, greenish gray, calcareous, 5′

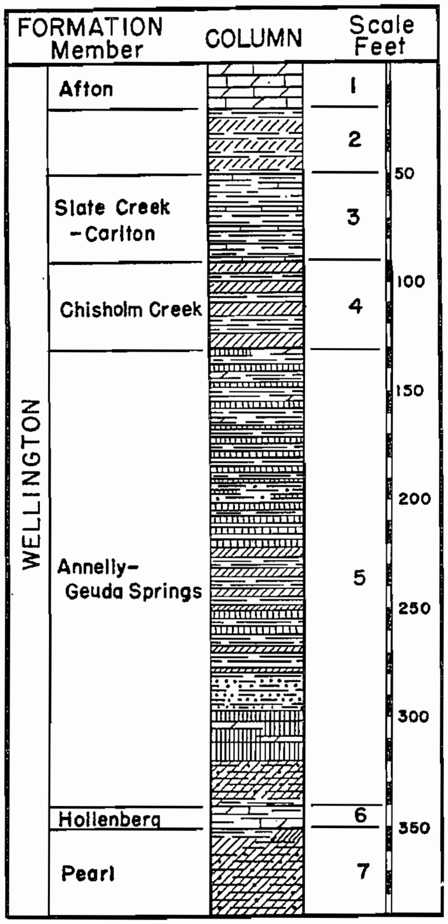

Figure 11.—Composite Columnar Section, Wellington Beds, Permian System.

   (2) Shale, greenish gray, in part calcareous, with some brownish-red shale, 10′
   (3) Shale, greenish-gray, and brownish-red, with thin calcareous mudstone seams, 25′
4. *Chisholm Creek shale,* brownish-red and greenish-gray, 40′
5. *Annelly gypsum-Geuda Salt measures,* 210′:
   (1) Shale, green-gray, thinbedded and gypsum, white, amorphous, some thin dolomitic seams, 40′
   (2) Gypsum, white, amorphous, and greenish gray shale, 20′
   (3) Siltstone, light greenish gray, granular, with some interbedded greenish shale and gypsum, 10′
   (4) Gypsum and anhydrite, light gray to white, with some interbedded siltsone and greenish shale, 20′
   (5) Shale, brownish red to maroon and greenish gray, gypsiferous, 30′
   (6) Anhydrite, light gray, with some interbedded greenish gray and red shale, 10′
   (7) Shale, greenish gray, in part brownish red to maroon, gypsiferous, 20′
   (8) Siltstone-sandstone, greenish-gray and red, with some interbedded greenish gray and red shale, 15′
   (9) Anhydrite and gypsum, 5′
   (10) Dolomite, medium light gray, finely granular, gypsiferous, interbedded with gypsum and anhydrite, 10′
   (11) Anhydrite and gypsum, 8′
   (12) Shale, maroon, argillaceous to silty, with common greenish gray shale in lower part, 22′
6. Limestone, dolomitic lime, shale and the *Hollenberg limestone,* combined thickness about 10′
7. *Pearl shale,* about 40′:
   (1) Shale, greenish gray and red, gypsiferous, 10′
   (2) Shale, maroon silty to sandy, massive, in part gypsiferous, 30′, with the basal few feet exposed southwest of Odell, Gage County.

NOTE: West of Harlan County the upper beds of the Wellington formation are truncated and overlapped by Cimarron sediments. West of the Cambridge Arch in southern Nebraska practically all of the Wellington and some lower beds have been eroded.

BIG BLUE SERIES

As here considered this series includes the section between the top of the Herington limestone and the unconformity at the horizon of the Brownville limestone. The series includes the redefined Chase group, Prosser 1895; Council Grove group, Prosser 1902; and the Admire group, Adams 1903.

The upper boundary of the Big Blue series has been in question, because varying criteria have been relied upon by different workers in suggesting its position, as at the top of the Herington, at the top of the Hollenberg, or as most generally accepted, at the top of the Wellington formation.

Local faunal evidence would favor the placement of the top of the Big Blue Series at the top of the Herington or at the top of the Hollenberg limestone because of the scarcity or absence of invertebrate fossil remains above these horizons. Regionally, however, the upward disappearance of a diagnostic fauna occurs at various stratigraphic levels depending upon the local environmental conditions. Therefore, undue reliance should not be placed upon this criterion.

R. C. Moore and W. P. Hayes (1917, Kansas Geol. Survey Bull. 3) raise the rank of the Big Blue formation to that of a group, to include the section from the top of the Wellington to the base of the Cottonwood limestone. Moore and Condra (1932) place the base of the Big Blue at the base of the Americus limestone, but Condra (1935, Nebraska G. S. Paper No. 8) and Moore (1935, Kansas G. S. Bull. 22) add older beds, i.e., down to the unconformity at the Brownville limestone horizon, and recently the Kansas survey places the top of the series at the top of the Herington limestone, which is a good regional marker.

The U. S. Geol. Survey has not adopted the name, Big Blue Series, nor has it established the boundary between the Permian and Pennsylvanian in the northern Mid-Continent region, except provisionally at the base of the Cottonwood limestone. However, the lower contact of the series, established by Moore and Condra is recognized generally by the geologists of this region and is approximately at the horizon of the base of the Wolfcamp series of the Permian in Texas.

Some of the lowest and highest beds of the Big Blue series, as now recognized, are not exposed in the Big Blue Valley but they do outcrop just below the mouth of the Big Blue Valley. Consequently the series has a well selected regional name.

The Big Blue series has been studied quite closely by the Kansas and Nebraska surveys. Its groups, formations and most members, persist with unusual uniformity in thickness and physical features from Oklahoma to Nebraska. The series is overlapped by Cretaceous formations in north-central Kansas and southeastern Nebraska, but is quite well exposed in southern Kansas where the section of the Wellington formation at the top of the series is as follows:

Chase Group in Southern Nebraska. Figure 12.

This group was recently redefined by the Kansas Geological Survey to include the section from the base of the Wreford formation to the top of the Herington limestone. Its thickness in southern Gage County is about 292 feet as follows:

1. *Nolans limestone formation,* Moore 1936, about 30′ in wells. The thickness measured on outcrops southwest of Odell and south of Krider is 28′:
   (1) *Herington limestone,* Beede 1909, gray to buff, massive, to bedded, 8′ or more
   (2) *Paddock shale,* Condra and Upp 1931, grayish, largely argillaceous with much platy material, 14′
   (3) *Krider limestone,* Condra and Upp 1931, consists of upper and lower dark gray impure limes separated by 4′6″–5′ of gray shale; combined thickness about 6′
2. *Odell shale formation,* Condra and Upp 1931, measured on outcrop south of Krider, in gray, greenish-gray and chocolate and red bands, about 34′
3. *Winfield limestone formation,* Prosser 1897, south of Krider, about 21′:
   (1) *Cresswell limestone,* Condra and Upp 1931, 3′6″±:
      a. Limestone-sandstone, gray, soft, massive, geodal, pitted, weathers buff, 1′
      b. Shale, bluish-gray, blocky, geodal, 2′
      c. Limestone-mudstone, gray, massive, geodal, weathers buff, 1′
   (2) *Grant shale,* Condra and Upp 1931, about 16′:
      a. Bluish-gray to olive, geodal, fossiliferous in basal portion, with *Derbya, Compositas, Dictyoclostus, Rhombopora,* and echinoid spines; weathers dark gray, thickness, 11′3″
   (3) *Stovall limestone,* Condra and Upp 1931, dark gray, granular, very cherty, with *Dictyoclostus americanus, Derbya,* crinoid joints, *Rhombopora,* etc., 1′6″
4. *Gage shale formation,* Condra and Upp 1931, 1½ miles south of the west side of Wymore. Consists of thin beds of gray,

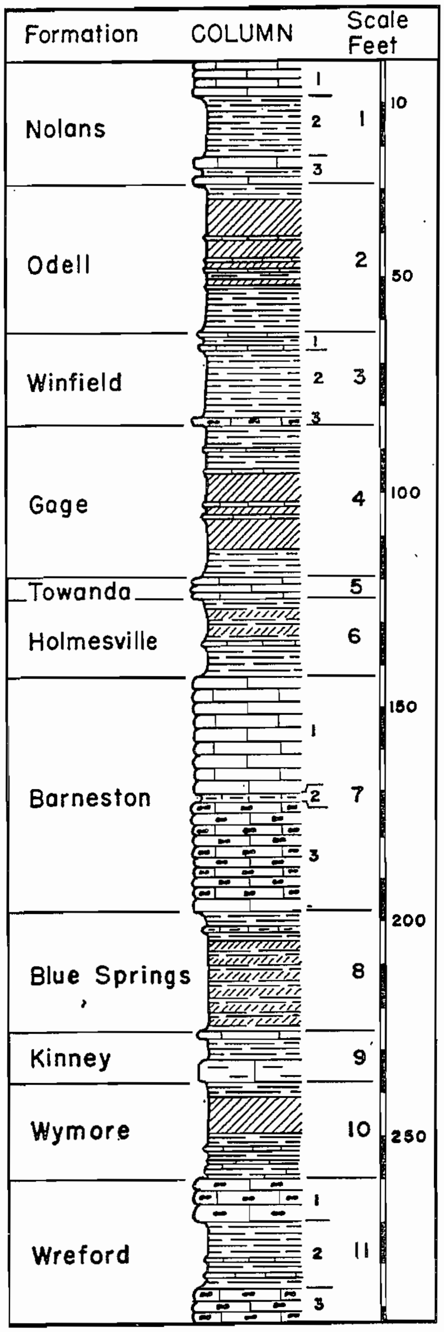

Figure 12.—Composite Columnar Section, Chase Group, Big Blue Series, Permian System.

buff, greenish-gray and chocolate-red argillaceous to calcareous, massive to bedded shales and gray to buff mudstones, about 35′

5. *Towanda limestone formation,* Moore 1921, southwest of Wymore and a few miles southeast of Barneston, gray to buff, bedded to massive, very irregular in places, arenaceous, about 5′±. This formation outcrops across Kansas where its thickness is 8′ or more locally
6. *Holmesville shale formation,* Condra and Upp 1931, 1½ miles west and ½ mile north of Holmesville, about 18′–19′
   (1) Shale, in argillaceous bands of gray, red and gray, about 10′–11′
   (2) Limestone, gray, blocky, 1′
   (3) Shale, gray, 7′
7. *Barneston limestone formation,* Condra and Upp 1931, about 60′ or less:
   (1) *Fort Riley limestone,* Swallow 1866, gray, largely massive, broken by shales, quite fossiliferous; thickness in the Big Blue Valley, 27′–30′
   (2) *Oketo shale,* Moore 1936, gray, calcareous, 0–3′ in Nebraska and Kansas
   (3) *Florence limestone,* Prosser 1895, gray, irregularly bedded, very cherty, quite fossiliferous, weathers buff; thickness west of Barneston, 27′6″
8. *Blue Springs shale formation,* Condra and Upp 1931, east of Wymore, about 28′:
   (1) Shale-sandstone, dark gray, limy, 9″–1′
   (2) Dark gray, massive, 1′9″–2′
   (3) Shale, olive, argillaceous, 8″–9″
   (4) Mudstone-shale, dark gray, massive, 1′6″–2′
   (5) Shale, olive, massive, 2′
   (6) Shale, red and olive bands, largely argillaceous, part sandy, massive, loosely indurated, 19′–20′
   (7) Shale, olive, argillaceous, 1′6″
9. *Kinney limestone formation,* Condra and Upp 1931, three miles southeast of Wymore and at Kinney, about 12′+:
   (1) Limestone-sandstone, gray, soft, weathers buff, separated by olive colored shale, 1′8″
   (2) Shale, gray, massive, 4′9″
   (3) Limestone, gray, soft, fossiliferous, 5′–7′
10. *Wymore shale formation,* Condra and Upp 1931, about 2 miles east of Wymore, i.e., in ravine and west bank of creek north of railroad and highway, in NE ¼ of Section 27, T. 2 N., R. 7 E., about 22′6″:
    (1) Shale, gray, argillaceous, 3′,
    (2) Shale, largely red, part olive, 9′
    (3) Shale, olive-gray, argillaceous, 3′
    (4) Mudstone, gray, limy, massive, weathers buff with vertical breaks, 1′
    (5) Shale, dark olive colored, 2′
    (6) Mudstone, gray, weathers buff, 6″
    (7) Shale, dark olive colored, crumbly, 6″
    (8) Mudstone, dark gray, 2′9″
    (9) Shale, bluish-gray, crumbly, 9″
11. *Wreford limestone formation,* Hays 1893, about 29′6″:
    (1) *Schroyer limestone,* Condra and Upp 1931, three miles southeast of Wymore, gray, cherty, about 10′
    (2) *Havensville shale,* Condra and Upp 1931, badly covered in Nebraska, thickness about 15′–20′ in southern

Nebraska and northern Kansas, thinning southward

(3) *Threemile limestone,* Moore 1936, stone gray, cherty, 7′–7′6″. This member was named by Condra and Upp 1931, from Fourmile Creek 10½ miles south and ½ mile east of Humboldt, in Richardson County, Nebraska. The name was passed upon by the U. S. Geological Survey, but was later found to be preoccupied. Then Moore gave the name, from Three Mile Creek in Central Kansas.

Discussion.—The Holmesville shale varies considerably in thickness and physical features between Nebraska and Oklahoma due primarily to the local gradation of the top of the Fort Riley limestone from limestone to shale. The apparent thickness of the Holmesville in this distribution ranges between 11 and 25 feet.

A local thickening of the upper Winfield at Luta station north of Marion, Kansas was named the Luta limestone by Beede in 1908. This is a top zone in the member named the Cresswell limestone by Condra and Upp in 1931. In southern Kansas and northern Oklahoma the Cresswell includes three zones, viz., limestone at the top, locally with large chert-like concretions, about 4 or 5 feet of shale in the middle, and a thin limestone at the base.

The Havensville shale member of the Wreford formation varies markedly in thickness in northern Kansas, varying between 12 and 26 feet, due to limestone-shale gradation at the base of the Schroyer limestone and the top of the Three Mile limestone.

Council Grove Group in Nebraska. Figure 13.

Measured on outcrops in southern Richardson County, 311 feet or less:

1. *Speiser shale formation,* Condra 1927, near state line about 10 miles south and 2 miles east of Humboldt, Nebraska, 19′+:
   (1) Shale, olive colored, with thin limy-sandy seams, 2′+
   (2) Limestone, gray, blocky, 6″+
   (3) Shale, gray to olive colored, argillaceous, 3′–4′
   (4) Shale, gray, pink-gray, or largely red, argillaceous, 6′
   (5) Shale, gray, argillaceous, 2′–3′
   (6) Shale, gray-red or red, argillaceous, 2′–3′
   (7) Shale, gray to olive, argillaceous, 1′+
2. *Funston limestone,* Condra and Upp 1931, about 8′:
   (1) Limestone, light gray, massive, dense, blocky, forms rounded boulders, 1′6″
   (2) Shale, greenish-gray, argillaceous, 1′
   (3) Limestone, gray, massive, fossiliferous, 1′6″
   (4) Shale, greenish, 6″–1′
   (5) Limestone, medium dark gray, massive, blocky, arenaceous locally, 3′

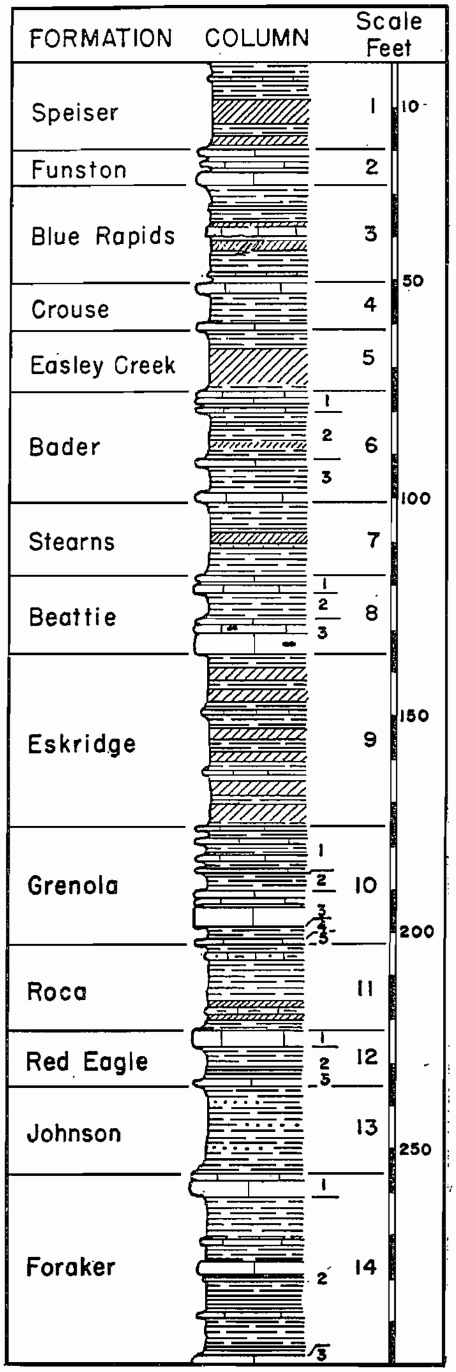

Figure 13.—Composite Columnar Section, Council Grove Group, Big Blue Series, Permian System.

3. *Blue Rapids shale formation,* Condra and Upp 1931, section ¾ mile south of the state line, about 9¼ miles south and 1 mile west of Dawson, 22′:
   (1) Shale, greenish-gray, massive, argillaceous, 4′–5′

(2) Sandy-limy, weathered buff and irregular, 7″–9″
(3) Shale, olive colored, massive, argillaceous, with chocolate-red seam near base, 4′+
(4) Mudstone, light gray to buff, somewhat arenaceous, weathers bedded, 2′
(5) Shale, grey, bedded, argillaceous, 1′ 1″+
(6) Shale, chocolate-maroon, massive, blocky, argillaceous, 2′6″
(7) Shale, greenish-gray, largely bedded, argillaceous and crumbly with some mudstone and vesicular boxwork at places, 5′–6′
(8) Mudstone, greenish-gray, limy, arenaceous, indurated, weathers light gray, 1′
(9) Shale, dark gray, 1′+

4. *Crouse limestone formation,* Heald 1917, thickness 11′:
(1) Limestone, light gray but dark gray on surface, massive, granular, weathering gray-buff and at places pitted, 2′–3′
(2) Shale, olive colored, with some sandy seams and calcareous bodies, 7′
(3) Limestone, dark gray, earthy, shattered, or slabby, quite fossiliferous, 1–2′

5. *Easly Creek shale formation,* Condra 1927, about 10 miles south and 2 miles east of Humboldt, 14′:
(1) Shale, olive, argillaceous, weathers grayish, 4′
(2) Shale, maroon-gray, more or less mixed, about 10′

6. *Bader limestone formation,* Moore and Condra 1935 and 1936, location 10 miles south and 2 miles east of Humboldt, about 24′6″:
(1) *Middleburg limestone,* Condra and Upp 1931, thickness, 4′+:
a. Limestone, gray, massive, granular, dense, weathers buff-gray, about 1′ 4″
b. Limestone, variegated light to dark gray, massive, tough, with many small dark-colored, high-spired gastropods, 1′6″
c. Shale, olive, argillaceous, 6″–1′
d. Limestone, dark gray, blocky, dense, 3″–4″
(2) *Hooser shale,* Condra and Upp 1931, about 11′:
a. Olive, calcareous-argillaceous, fossiliferous, weathers buff, 2′
b. Shale weathered buff, with boxwork at places, 1′
c. Grayish, with calcareous concretionary subzone near the base and a reddish subzone below the middle, about 8′
(3) *Eiss limestone,* Condra and Upp 1931, about 9′6″:
a. Limestone, grayish, massive, siliceous, granular, dense; weathers gray-buff, 1′3″–2′
b. Shale, olive, argillaceous, massive, with some lime aggregate, fossiliferous at base, 5′–7′
c. Limestone, dark gray, shaly especially so at top, very fossiliferous, 1′6″–2′

5. *Stearns shale formation,* Condra 1927, about 17′:
(1) Shale, olive, massive, crumbly, largely argillaceous, with some calcareous aggregate, weathers gray, 5′–6′
(2) Mudstone, not well developed, 4″
(3) Shale, lavendar-maroon, about 3′
(4) Shale, gray, irregular, weathers buff with intersecting bladed material giving a box-like appearance, 1′
(5) Shale, olive with some calcareous material, 5′ or more

6. *Beattie limestone formation,* Moore and Condra 1935 and 1936, 10 miles south and 2 miles east of Humboldt, about 18′:
(1) *Morrill limestone,* Condra 1927, two gray limestones separated by a thin shale; stone weathers brownish and irregular; thickness about 3′–4′+
(2) *Florena shale,* Prosser 1902, olive colored at top; middle and base light gray with much calcic material, quite fossiliferous, with *Chonetes granulifer var. meekanus* abundant, 5′–8′;average thickness 6′
(3) *Cottonwood limestone,* Haworth and Kirk 1894, light gray, massive to slabby with some small bodies of gray chert; quite fossiliferous at places, thickness 6′–11′; average 8′

7. *Eskridge shale formation,* Beede 1902, average thickness in Nebraska about 38′; section after C. E. Busby, in the W ½, Sec. 3, T. 1 N., R. 13 E., south of Humboldt, with a maximum thickness of about 50′:
(1) Shale, 16′:
a. Green-gray, calcareous, 3′6″
b. Orange-red, crumbly, 4′
c. Green, argillaceous, 2′
d. Orange-red, nodular, 3′6″
e. Blue, argillaceous, 3′
(2) Limestone, light gray, earthy, with pelecypods and some gastropods, 9″
(3) Shale, 17′:
a. Green, calcareous, 4′
b. Orange-red, micaceous, 4′
c. Blue-gray, argillaceous, 3′
d. Orange-red, micaceous, 3′
(4) Limestone, light gray, conglomeratic, weathers pitted, with fragments of pelecypods, 6″–9″
(5) Shale, about 16′:
a. Green, argillaceous, 6″–1′
b. Orange-red, nodular, 4′–6′
c. Green, calcareous, nodular, 2′
d. Light orange-red, crumbly, 8′

NOTE: The Eskridge is about 50′ thick in Ranges 13, 14, and 15 east and 34′ in Ranges 7, 8, 9 and 10 east, and thins southward in Kansas. Its limestones become more largely orange-red westward and southward across Kansas.

8. *Grenola limestone formation*, Condra and Busby 1933, in the vicinity of Roca, Nebraska, about 26′+:
   (1) *Neva limestone* (Beede 1902), redefined by Condra and Busby 1933, top now covered, 10′8″:
      a. Limestone, poorly exposed in the Warner quarry, light gray, shaly, fossiliferous, 6″
      b. Shale, light gray, calcareous, slabby, 2′
      c. Limestone, light gray, shaly in middle, with crinoid joints, *Punctospirifer, Composita,* etc., 1′6″
      d. Shale, gray, calcareous, bedded, papery, weathers yellowish, with crinoid joints, brachiopods, *Lophyophyllum profundum,* etc., 2′8″
      e. Limestone, buff-gray, silty, nodular at base, slabby at top, reentrant in middle, with *Triticites, Ambocoelia, Marginifera, Wellerella,* echinoid spines, bryozoa, etc., 1′3″
      f. Shale, dark gray, calcareous, bedded, weathers buff-gray, with *Chonetes, Marginifera, Ambocoelia, Derbya,* 1′6″
      g. Limestone, gray, argillaceous, with crinoids, *Dictyoclostus americanus, Marginifera, Meekopora, Rhombopora, Cystodictya, Polypora, Fenestella,* etc., 9″–1′
   (2) *Salem Point shale,* Condra and Busby 1933, bluish gray, argillaceous, 4′
   (3) *Burr limestone,* Condra and Busby 1933, best shown in a new quarry, 1½ miles northeast of Roca, 8′6″:
      a. Limestone, light blue-gray, massive, fine-grained, laminated, weathers light gray, platy, with ostracod layer at top carrying *Bairdia, Hollinella, Geisina,* etc., 3′. The ostracods appear to have been coated by secondary calcite.
      b. Shale, gray, calcareous, forms a reentrant, 3″
      c. Limestone, gray, coarse-grained, granular, with fragmentary fossils, 5′3″
   (4) *Legion shale,* Condra and Busby 1933, exposed in road cut ¾ mile east and ½ mile south of Roca, olive-colored, calcareous, with platy seams, weathers yellowish, 2′+
   (5) *Sallyards limestone,* Condra and Busby 1933, in road cut one mile northeast of Roca, gray, massive, wavy-bedded, weathers yellowish, with pelecypods, crinoid joints, etc., 1′+. This is fusuline-bearing in southern Kansas.

NOTE: The Kansas Geological Survey correlates (4) and (5) of the above with the Roca shale.

8. *Roca shale formation,* Condra 1927, measured near the P.W.A. quarry northeast of Roca, about 20′:
   (1) Shale, bluish gray, argillaceous, with some limy material, about 2′
   (2) Siltstone, massive, with calcite in joints and cavities, weathers buff, 1′1″–2′
   (3) Shale, largely olive colored and bedded, with a thin fossiliferous lime seam at places, 5′–6′
   (4) Shale, bluish-gray, argillaceous, with three limy bands weathered yellowish and a faint band of purple shale, about 4′
   (5) Shale, maroon-mottled, with some fine gypsum, 1′6″
   (6) Limestone-shale, bluish gray, massive, argillaceous-calcareous, 1′6″
   (7) Shale, maroon, massive, argillaceous, 1′3″
   (8) Shale, bluish gray, massive, weathers yellowish, 1′6″–2′

NOTE: The limy zone (6) of the Roca becomes more prominent near the Kansas-Nebraska line.

10. *Red Eagle formation,* Heald 1916, southeast of Bennett, about 11′6″:
   (1) *Howe limestone,* Condra 1927, color and texture variable, usually with some silt and sand; stone weathers yellowish and dark gray, granular and porous; thickness about 4′
   (2) *Bennett shale,* Condra 1927, about 7′–8′:
      a. Shale, bluish-gray, largely argillaceous, with some arenaceous material and fossiliferous limy seams in the middle at places, 3′
      b. Shale, dark gray, argillaceous, quite fossiliferous, Compositas abundant, pelecypods in places, 2′
      c. Shale, largely black, with subzones of dark gray, contains *Orbiculoidea missouriensis,* 2′–3′
   (3) *Glenrock limestone,* Condra 1927, dark gray, dense, blocky, top argillaceous, weathers light gray and buff-gray, with *Triticites ventricosus var. medialis,* 6″–1′8″

NOTE: The Glenrock becomes less well developed and loses its fusulinids eastward in Nebraska, but then increases in thickness southward to central Kansas.

11. *Johnson shale formation,* Condra 1927, northwest of Johnson, blue-gray and blue-green, argillaceous to calcareous, with zones of limy sandstone which weather gray to yellowish; few or no fossils, 18′–20′
12. *Foraker limestone formation,* Heald 1916, thickness 43′–50′:
   (1) *Long Creek limestone,* Condra 1927, gray to yellowish, texture variable, irregular, sometimes bedded, weathers vesicular, 3′–7′
   (2) *Hughes Creek shale,* Condra 1927, near Auburn, 37′:
      a. Shale, dark gray on fresh exposure, slightly calcareous, weathers buff, with a light gray fusulinid lime-

stone below the middle; thickness 15′. With *Triticites ventricosus, Septopora, Polypora, Thamniscus, Fenestella, Meekopora prosseri, Cyclotrypa barberi, Rhombopora lepidodendroides, Chonetes granulifer, Linoproductus, Ambocoelia planoconvexa,* etc.

b. Limestone, gray-buff to blue, mottled black, contains Bellerophons, 2′6″

c. Shale, dark gray, argillaceous, with *Chonetes granulifer, Ambocoelia planoconvexa, Ambocoelia expansa,* weathers buff, 8″

d. Limestone, dark gray to buff, with *Ambocoelia planoconvexa, Ambocoelia expansa,* etc, 9″

e. Shale, 7′:
   (a) Olive-drab to black, micaceous, blocky, 3′
   (b) Black, weathers fissile, with *Orbiculoidea* and *Lingula,* 4′

f. Limestone, bluish gray, crystalline, with *Rhombopora lepidodendroides, Neospirifer, Meekopora prosseri,* etc., weathers brown to buff, 1′6″

g. Shale, bluish-gray to black, with *Orbiculoidea,* weathers fissile, about 8′–10′

(3) *Americus limestone,* Kirk 1896. In NE ¼ Sec. 22, T. 1 N. R. 13 E., eight miles south of Humboldt; stone dull blue, dense, weathers gray-blue, with *Meekella striatocostata, Marginifera* sp., *Ambocoelia planoconvexa,* 1′6″

NOTE: The Hughes Creek shale becomes nearly solid limestone southward in Oklahoma, north of Foraker.

Admire Group in Nebraska. Figure 14.

Thickness in Richardson and Pawnee counties about 115 feet, not including the basal Indian Cave channel deposits.

1. *Hamlin shale formation,* Moore and Condra 1935 and 1936, about 48′–50′+:
   (1) *Oaks shale,* Moore and Condra 1932, at type locality just southwest of Salem, bluish gray, argillaceous, with some calcareous material and a thin zone of yellowish "box-work" near top, 14′–20′. This has crystals of celestite in places, as on the Yoder farm north of Morrill, Kansas
   (2) *Houchens Creek limestone,* Condra 1927, gray, porous, weathers gray-orange, and vesicular, 1′–4′. Separated in places by gray-green, argillaceous layers of shale. This member is characterized by its lobulate bedding.
   (3) *Stine shale,* Condra 1927, 23′–30′; section in NE ¼ Sec. 23, T. 4 N., R. 15 E., 2½ miles southwest of Nemaha City, about 26′:

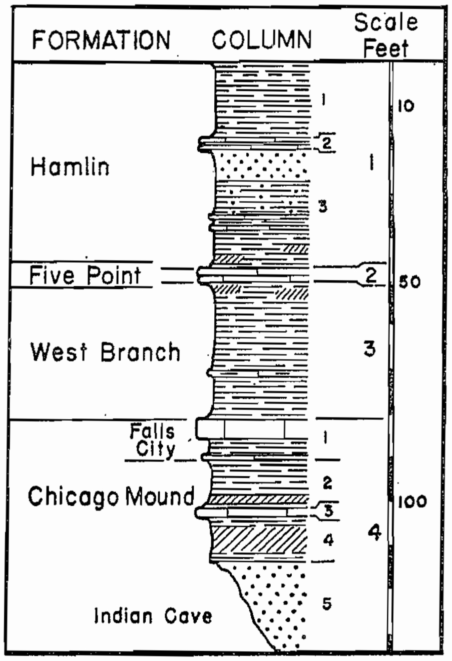

Figure 14.—Composite Columnar Section, Admire Group, Big Blue Series, Permian System.

a. Shale and sandstone, 12′–18′:
   (a) Sandstone, greenish, fine-grained, micaceous, 10′ or less
   (b) Shale, gray and greenish, arenaceous, 8′+

b. Limestone, 5′+:
   (a) Limestone, gray, argillaceous, with gastropods, 3″
   (b) Shale, brown, drab, brittle, 2′1″
   (c) Limestone, bluish-gray, ironstained, dense, wavy-bedded, brittle, pelecypodal, 10″
   (d) Shale, brownish-drab to black, 3′

c. Shale, zones of blue-gray, dark and mottled-red, 7′

2. *Five Point limestone,* Condra 1935, light gray, nodular, locally conglomeratic, with *Osagia,* small high and low coiled gastropods, and bryozoa, thickness 1′–5′. This unit is fairly uniform in Nebraska and Kansas and becomes two dense limestones separated by shale in Oklahoma a few miles southeast of Foraker

3. *West Branch shale,* Condra 1927, in N. ½ Sec. 11, T. 5 N., R. 15 E., 2 miles northwest of Brownville, about 30′:
   (1) Shale, buff, gray, green, red and brown, argillaceous to earthy, 5′
   (2) Shale, blue to green, argillaceous, 15′
   (3) Limestone, light gray to brown, crystalline to argillaceous, 3″–1′
   (4) Shale, blue, argillaceous, massive, 10′

NOTE: Division (3) above thickens northward from Richardson County.

4. *Chicago Mound formation* (new name, Condra and Reed), about 22′:
   (1) *Falls City limestone,* Moore and Condra 1932, at the old Lehmer quarry four miles southwest of Falls City, 9′:
      a. *Lehmer limestone,* Condra 1935, brown, porous, soft, pelecypodal, with small, thin lenses or concretions of light gray, dense, limy material, 4′
      b. *Reserve shale,* Condra 1935, blue-gray, argillaceous to calcareous, flaky, 4′
      c. *Miles limestone,* Condra 1935, blue-gray, argillaceous, nodular and slabby, with *Myalina subquadrata, Osagia, Derbya crassa,* and *Ambocoelia planoconvexa,* 1′
   (2) *Hawxby shale,* Condra 1935, four miles southwest of Nemaha City, upper 8′ light gray, calcareous, with thin calcareous blades in joints, weathers crumbly; middle and lower zones argillaceous, with subzones of blue-gray and dark orange-red; combined thickness, 10′–12′
   (3) *Aspinwall limestone,* Condra and Bengtson 1915, a bluish gray limestone or two limestones separated by shale; locally a calcareous shale; thickness, 1′–3′ or more
5. *Towle shale formation,* Condra 1927, gray at top and base; middle zone red; largely argillaceous; locally sandy; combined thickness, 10′, thickening southward:
   (1) *Indian Cave sandstone,* Moore 1936, thickness 0–50′+. This occurs at Peru, in southeastern Nemaha County (at Indian Cave), near Falls City and at places in Kansas where it is sandy, continental deposition filling pre-Permian Valleys, and grades upward into the Towle formation

NOTE: The names Falls City, Hawxby and Aspinwall were given originally for what were supposed to be members, but Moore ranked them on a cyclothemal basis as formations in Kansas. We believe, however, that they are members of a formation in Nebraska and Kansas and apply to them the formational name Chicago Mound. The formation outcrops in the slopes and cuts along Highway No. 10, southeast of Chicago Mound, a well known topographic feature southwest of Maple Hill, Kansas. The formation includes the section between the West Branch and Towle shales.

Broom Creek Group in Eastern Wyoming

Rocks which are believed to be equivalent to the Big Blue Series outcrop in the Laramie Range, Hartville Uplift of Wyoming and in Black Hills of eastern Wyoming and southwestern South Dakota. These rocks rest unconformably upon Pennsylvanian strata and unconformably underlie rocks which are believed to be of Cimarron age. Condra, Reed, and Scherer named this interval the *Broom Creek group* in 1940 and classified it provisionally as "age uncertain" (p. 45), but we now expand the Broom Creek group to include a few higher beds than were included in the original definition, placing its top at an unconformity which was located in the overlying Cassa group. The group is exposed on Broom Creek in the Hartville area, where its thickness is 85 to 101 feet as follows:

1. Limestone, light gray, in part mudstone-like, 5′–7′
2. Sandstone, red, massive, in part cross-bedded, in part pebbly, 11′–20′
3. Limestone, with some interbedded shale, 20′–26′:
   (1) Limestone-mudstone and interbedded shale, 4′6″
   (2) Limestone, bluish gray, massive to bedded, 10′6″
   (3) Shale, gray, 4′
   (4) Limestone, gray with reddish tint, with some gray to reddish chert, some brachiopods and crinoid joints, pebbly at top, 7′
4. Sandstone, gray, red and pink, and shale, gray, red, and greenish gray, poorly exposed, 30′
5. Limestone, light gray to red-stained, irregular in texture, dolomitic, 2′6″
6. Sandstone, shale, and some limestone, 10′–16′6″:
   (1) Sandstone, gray to pinkish, soft, friable, 1′8″
   (2) Sandstone and shale, red, sandy, 2′4″
   (3) Siltstone, red, calcareous, pitted, 8″
   (4) Limestone, light gray, dense, pitted, with some small crinoid joints, thin shale seam at top, 9″
   (5) Shale, gray to red, with silty lenses, 2″–3″
   (6) Siltstone, yellowish gray, calcareous, 1′4″
   (7) Shale, red, sandy, laminated, with some red and gray sandstone at top, 3′

The Broom Creek Group in Northwestern Nebraska

The following section, present in the subsurface of the Julesburg Basin of the "panhandle" region of western Nebraska, is taken from the record of a deep well drilled at

Agate Springs, in Sioux County. Figure 15. Broom Creek Group, 367 feet:

1. Limestone, medium to dark gray, argillaceous to dolomitic in upper part and at base, with some thin black shale partings, 30′
2. Anhydrite, light and dark gray mottled, in part light greenish gray, 26′
3. Shale, green-gray, indurated with thin seams of light gray to greenish, dolomitic limestone at top and base, 3′
4. Sandstone, light gray to greenish, indurated, slightly calcareous, 4′
5. Limestone, black shale, and some anhydrite, 17′

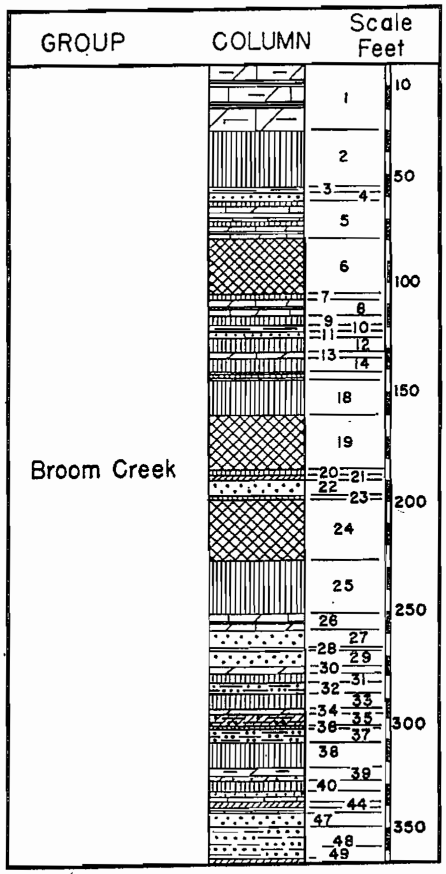

Figure 15.—Columnar Section, Broom Creek Group, Permian System, Agate Springs Well.

a. Anhydrite, 2′
b. Limestone, medium gray to greenish, dolomitic, 3′
c. Shale, black, indurated, 1′
d. Limestone, medium gray, dolomitic, 1′
e. Anhydrite, 1′
f. Shale dark gray to black, indurated, 1′
g. Anhydrite, 2′6″
h. Limestone, dolomitic, 2′
i. Shale, black, indurated, 1′
j. Limestone, dolomitic, 2′6″

6. Salt, 25′
7. Anhydrite, with dark shale at base, 3′
8. Limestone, medium gray, dolomitic, with a dark gray to black shale seam at top and two feet below top, 7′
9. Anhydrite, light gray and greenish, 4′6″
10. Shale, greenish gray above, grades to black below, micaceous, indurated, 2′4″
11. Sandstone, light greenish gray, fine-grained, 3′
12. Anhydrite, with some seams of limestone in lower part, 7′2″
13. Limestone, medium light gray, dolomitic, 2′
14. Anhydrite, 7′4″
15. Shale, greenish gray to dark gray, 1′
16. Anhydrite, with thin seams of argillaceous limestone, 1′
17. Shale, dark green-gray, calcareous, indurated, with seams of anhydrite, 1′8″
18. Anhydrite, 16′
19. Salt, 25′
20. Anhydrite, 2′
21. Shale, dark chocolate, sandy, becomes lighter colored and limy at base, 3′6″
22. Sandstone, brownish gray, fine-grained, indurated, 6′6″
23. Anhydrite, 1′
24. Salt, 28′6″
25. Anhydrite, 25′
26. Limestone, medium dark gray, dolomitic, with thin seams of anhydrite and black shale in middle part, 7′6″
27. Sandstone, light gray, dolomitic, indurated, 8′
28. Shale, dark green-gray, sandy, finely micaceous, indurated, 6″
29. Sandstone, light gray, with some thin dark shale streaks, 8′
30. Dolomite, medium gray to brownish gray, with some anhydrite areas, 3′6″
31. Anhydrite, light gray to white, 3′6″
32. Siltstone to sandy shale, dark greenish, micaceous, calcareous, with pink anhydrite areas, 5′
33. Anhydrite, light gray to white, 7′6″
34. Dolomite, brownish gray, dense, in part argillaceous, some fossill fragments, 1′4″
35. Siltstone, greenish above and below, red in middle, indurated, 6′5″
36. Anhydrite, light gray to white, 10″
37. Siltstone, greenish, indurated, with some anhydrite areas in lower part, 6′5″
38. Anhydrite, light and medium dark mottled, 12′
39. Dolomite, medium dark gray, argillaceous, grades to calcareous, indurated siltstone, 6′3″
40. Anhydrite, light and dark gray mottled, 4′9″
41. Siltstone-sandstone, light gray to greenish, calcareous, 3′
42. Limestone, medium dark gray, dolomitic, 1′
43. Siltstone-sandstone, light green-gray, calcareous, 1′

44. Shale, maroon, argillaceous, 3′
45. Shale, green-gray, maroon and yellowish, 1′
46. Mudstone, green-gray, calcareous, 1′
47. Sandstone, green-gray and maroon mottled, micaceous, thin bedded to massive, 6′
48. Soft shale and sandstone, poor core recovery, 15′
49. Shale, dark maroon, argillaceous, indurated, 2′

CORRELATION OF BIG BLUE SERIES FROM SOUTHERN NEBRASKA NORTHWESTWARD TO EASTERN WYOMING

The Big Blue Series of the outcrop area in southeastern Nebraska can be correlated across Nebraska into the eastern Wyoming outcrop areas by means of the records of deep wells in southern, central and western Nebraska (see Figure 10). However, the tracing of individual units is difficult because of facial changes and our understanding of exact correlatives is not as complete now as it will be after more drilling is done in strategic areas.

Three distinct facies are recognized in the Big Blue Series of the region under discussion. They are (1) the Nebraska-Kansas outcrop area where the section is composed of well-defined fossiliferous limestone formations separated by red and somber-colored shales with only minor amounts of evaporites; (2) the subsurface section of the panhandle region of western Nebraska where the limestone horizons are generally nonfossiliferous and usually dolomitic and are separated by relatively thick evaporites as well as by sandstones and shales; and (3) the outcrop area of eastern Wyoming where the correlative interval is composed of sparsely fossiliferous to non-fossiliferous, often dolomitic limestones, interbedded with red sandstones and minor amounts of shale. Subsurface studies indicate a progressive gradation between these three facial types.

It is our purpose here to indicate to what extent the individual formations of the Big Blue Series of southeastern Nebraska may be traced northwestward. Our studies permit the following conclusions:

1. The upper formations of the Big Blue Series appear to be successively cut out along the Cimarron-Big Blue unconformity in a northwest direction.

2. The Nolans limestone formation can be traced in the subsurface from the outcrop area in Gage County westward and northwestward to the vicinity of Lexington in Dawson County. It appears to be absent farther to the west.

3. The Winfield limestone formation, because of the relative thinness of the indurated beds is not a good marker in the subsurface of Nebraska.

4. The Barneston limestone formation can be traced from the outcrop areas northwestward to near North Platte in Lincoln County but appears to be missing farther to the northwest. It is interesting to note that the chert in the lower part of the Barneston (Florence flint) can be traced only as far westward as western Jefferson County and farther west the formation is non-cherty.

5. The Wreford formation can be followed from the outcrop area northwestward to the vicinity of Hyannis and it is noncherty west and northwest of Franklin County.

6. The Beattie formation is an excellent subsurface marker in central and eastern Nebraska and may continue northwestward into the outcrop area of eastern Wyoming but it is difficult to trace through western Nebraska.

7. The Grenola formation appears to be one of the most persistent and easily traced formations of the Big Blue series. Although it is non-cherty in the outcrop area it becomes cherty in Webster County and northwestward and is believed to correlate with bed number 3 of the Broom Creek outcrop section in eastern Wyoming.

8. The Foraker formation can be traced northwestward to near Lexington in Dawson County where it seems to lose its identity. However, it is probably represented in the subsurface of much of western Nebraska by lithologic units which are nondistinctive.

9. The Admire group, at the base of the Big Blue series can be traced from the outcrop area northwestward across Nebraska, although its upper limit is uncertain to the northwest. It is usually typified by a large amount of red shale and quite often contains a sandstone zone at its base, probably the equivalent of the Indian Cave sandstone.

The zone of red shale in the Lance Creek Oilfield which is locally called the "Red Marker" and which occurs approximately 100 feet above the "Leo" producing sands seems to represent at least part of the Admire. It is also likely that the red shale near the base of the Broom Creek Group of the Eastern Wyoming outcrop area is correlative with a part of the Admire and with the "Red Marker."

PERMIAN ECONOMIC RELATIONS

Rock salt is produced from the Permian formations of Kansas; gysum from Kansas, Oklahoma, Colorado, Wyoming and South Dakota and potash from New Mexico. We produce considerable stone from ten or eleven limestones of the Big Blue series and have thick deposits of salt and gypsum at a depth of a mile or more in Sioux and other western counties, and we may yet find potash in the cuttings and cores of deep wells drilled in that area.

Permian dolomites and limestones are important reservoir rocks in the production of oil and gas in Kansas, Oklahoma and New Mexico and the Permian sandstones produce oil and gas in Wyoming. Some of the Permian horizons in the subsurface of parts of Nebraska are possible sources of oil and gas production.

Certain limestones of the Big Blue series in our southeastern counties carry ground water used for rural supplies. The red bed soils of Oklahoma, southern Kansas and along the border of the Mountains of South Dakota, Wyoming and Colorado were developed on the red bed Permian formations and the Flint Hill rough lands of east central Kansas were eroded from the Wreford, Barneston and Winfield cherty limestone. They are used chiefly for grazing, whereas much of the red bed land is cultivated. Fortunately from the standpoint of agricultural land use, the cherty limestones and the red bed formations are deeply covered by mantle rock formations in Nebraska on which are more productive soils than occur generally on the Permian formations under the same climatic conditions.

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CARBONIFEROUS SYSTEM

Rocks of this system are thought to underlie all of Nebraska except a few square miles in the northeastern part, and outcrop only in the southeastern counties. However, much of the thickness of the system is absent at places on the Cambridge arch and the Table Rock Arch. The major subdivisions of this system in Nebraska are as follows:

1. Pennsylvanian subsystem, Williams 1891 (Upper Carboniferous)
2. Mississippian subsystem, Winchell 1896 (Lower Carboniferous)

PENNSYLVANIAN SUBSYSTEM

This has been classed as a system, as a subsystem and as a series, but is now ranked as a subsytem by many geologists, with its upper boundary at the unconformity at the base of the Big Blue Series and its base at the marked unconformity at the top of the Mississippian subsystem. It includes the following series:

1. *Virgil series,* Moore 1932
2. *Missouri series,* Keyes 1893, redefined by Moore 1932
3. *Des Moines series,* Keyes 1893, redefined by Moore 1932
4. *Morrow group,* Adams and Ulrich 1904, absent in Nebraska.

VIRGIL SERIES

The groups of this series are as follows:

1. *Wabaunsee group,* Prosser 1895, redefined by Moore 1932
2. *Shawnee group,* Haworth 1896, redefined by Moore 1932
3. *Douglas group,* Haworth 1898, redefined by Moore 1932

Wabaunsee Group. Figure 16.

This group extends from Iowa through northwestern Missouri, southeastern Nebraska and Kansas into Oklahoma and correlates in age with beds in Texas. The Nebraska Survey separates it into these subgroups, as follows:

1. Richardson subgroup, Condra 1935
2. Nemaha subgroup, Condra and Bengtson 1915
3. Sac-Fox subgroup, Condra 1935

Richardson Subgroup. — This subgroup lies between the unconformity at the top of the Brownville limestone and the slight unconformity at the top of the Tarkio limestone. Most of its formations and members outcrop from southwestern Iowa through southeast Nebraska and east-central Kansas to Oklahoma. Its Brownville, Nebraska City, Jim Creek, Palmyra, Morton and Dover limestones are very good horizon markers in Nebraska.

Discussion.—The Pony Creek shale formation at the top of this subgroup was named by Condra in 1927 to include too much section. It was redefined by Moore in 1935 on a local cyclothemal basis and reduced to a thickness of only about 6 feet, which at places does not represent a natural formation, and probably not a good member. Consequently we now apply the name Wood Siding formation to include the section between the base of the Brownville limestone and the base of the Nebraska City limestone. This is done because the Nebraska City limestone, with the Lorton coal below it, is a persistent recognizable marker, because the non-persistent Gray Horse limestone, named from Oklahoma, is not a good boundary marker between the so-called Caneyville formation and the Pony Creek as restricted by Moore, because the restricted Pony Creek and the Caneyville are not good formations in Nebraska, and because the section between the Brownville limestone and the base of the Nebraska City limestone is a natural, mapable formation in Nebraska and Kansas.

The units of the Richardson subgroup down to the base of the Jim Creek limestone are recognizable in Nebraska and Kansas, but the correlations of the lower units of the Richardson subgroup are not certain in north-central Kansas where the Palmyra and Grandhaven limestones seem to be absent in the Friedrich-Dry shale interval.

Evidently the Otoe shale member, named by Condra and Reed in 1938, from Otoe County, Nebraska is at the top of the Friedrich shale formation of Kansas, but the relations the Palmyra limestone, Minersville shale and the Morton limestone (new name) hold to the lower part of the central Kansas section, where the Grandhaven limestone is present, are not known to us.

We give the name Morton to a limestone which outcrops in a ravine on the Morton farm southwest of Nebraska City. It is the first limestone above the Dover in Ne-

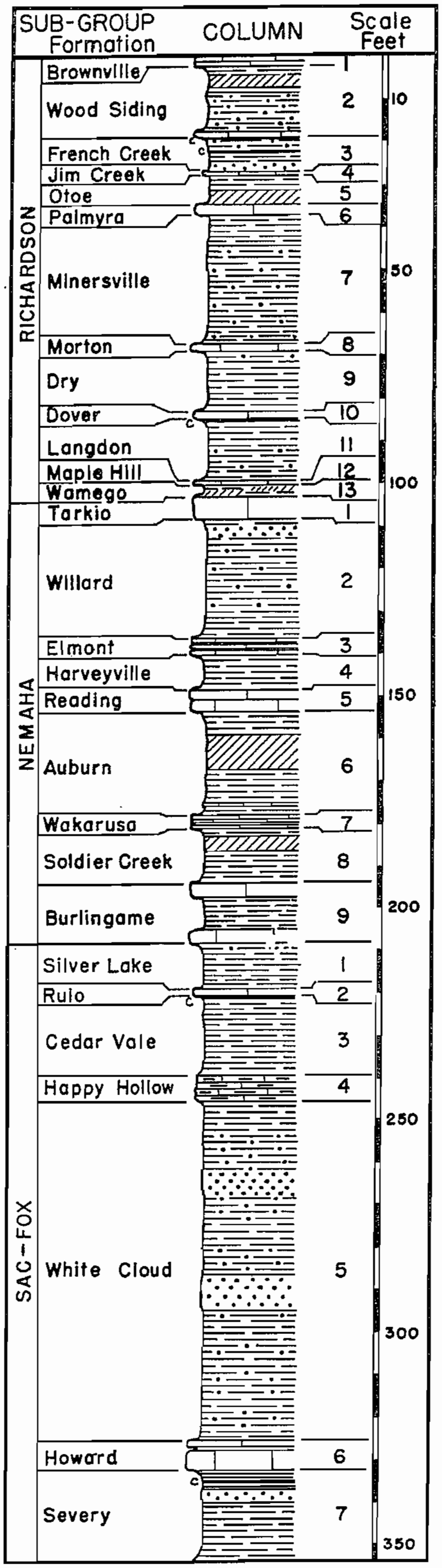

Figure 16.—Composite Columnar Section, Wabaunsee Group, Pennsylvanian Subsystem.

braska and lies between the Minersville and what seems to be the Dry shale. The name Minersville was given by Condra and Reed in 1938 for the shale and sandy beds lying between the Palmyra and Morton limestones, with the type locality at Minersville, Nebraska.

Condra named the "Table Creek" shale from Table Creek at Nebraska City in 1927 to include the beds between the Dover limestone and what was supposed to be the Tarkio limestone, but it was later found that the lower boundary of the "Table Creek" at this place is the top of the Elmont limestone, and that the Tarkio is represented higher in the section here by a sandstone located about 15 feet below the Dover, all of which means that the so-called "Table Creek shale" represents three formations, i.e., the shale below the Dover (with the Maple Hill limestone missing), plus the sandstone equivalent of the Tarkio, plus the Willard shale. Consequently we discard the name "Table Creek" and propose the name Langdon for the shale between the base of the Dover limestone and the top of the Maple Hill limestone. The type locality of this division, with a thickness about 19 feet, is in the Missouri River Valley bluffs southeast of Langdon, Missouri or northwest of Craig, Missouri. The Langdon formation becomes thinner in parts of southeastern Nebraska and much thicker, up to 50 feet or more, in north central Kansas, as near Maple Hill and Dover.

The "Pierson Point" shale, as defined by Condra in 1927, includes at its type locality, the section between the Dover and Tarkio limestones, and not from the Maple Hill limestone to the Tarkio as was originally supposed. This makes it part of the "Table Creek shale," however, the Maple Hill limestone is missing at the "Pierson Point" type locality leaving the latter without an upper boundary marker, but the Maple Hill is well developed at other places. So we drop the name "Pierson Point" and give the name Wamego to the shale between the Maple Hill and Tarkio limestones, the type locality being in the bluffs north of Highway No. 40 about four miles west of Wamego, Kansas, where the thickness of the shale is 15 to 18 feet.

As noted before, there is some question regarding the correlation of the Morton limestone of Nebraska with the Grandhaven of Kansas, hence the Nebraska name is used in this report. This question in correlation is raised because we have not been able to trace the Grandhaven from its type locality to Nebraska. It has been suggested that the limestone exposed low in the Kaw Valley bluffs about three miles east of St. Marys, Kansas is the Grandhaven. However, we have traced this unit into the Jim Creek limestone and northward to Nebraska City where it lies 7 to 8 feet above the Palmyra limestone which persists southward to the Kansas line, but is considerably higher in the section than the Morton limestone.

The Palmyra limestone is well developed at Nebraska City and Minersville but thins out south of the Kansas line and disappears in northern Kansas. The Morton limestone lies in about the same horizon as the Grandhaven of central Kansas but plays out in northern central Kansas, where the section between the Jim Creek and Dover limestones in the vicinity of St. Marys, Kansas is shale with no limestone separations. Consequently the Morton and Grandhaven limestones are not connected and probably not correlative, but they lie about the same distance above the Dover limestone and both may be at the top of the Dry shale. The relations of the beds of the Richardson Subgroup are shown by the following sections made near Nebraska City and Pawnee City in Nebraska and east of St. Marys, Kansas.

Composite Section of the Richardson Subgroup

At Nebraska City, thickness about 106 feet; Figure 16.

1. *Brownville limestone,* Condra and Bengston 1915, southwest of Nebraska City, two gray to yellowish fossiliferous limestones separated by fossiliferous shale, *Marginifera osagensis* common, 2′
2. *Wood Siding shale formation* (new name), about 17′:
   (1) *Pony Creek shale* (Condra 1927), restricted by Moore 1934, bluish gray above, maroon below, 5′±
   (2) Sandstone, gray to brownish, limy, locally conglomeratic, not persistent, 6″–11″
   (3) Shale, greenish-gray, sandy, locally with sandstone in upper part, 9′–10′
   (4) *Nebraska City limestone,* Condra 1927, dark gray, firm to shattered, with many *Myalina, Derbya, Chonetes,* etc., 1′–2′

   This is the Caneyville formation of the Kansas Survey by Moore, 1934.
3. *French Creek shale formation,* Moore 1934, about 8′:
   (1) Shale, bluish-gray, fossiliferous at top, 6″±
   (2) Lorton coal, 2″+
   (3) Shale, greenish-gray, argillaceous, with sandy seams, 2′9″–3′6″
   (4) Coal smut, 1″
   (5) Shale, gray, top indurated, middle argillaceous, base sandy, 1′11″
   (6) Sandstone, gray-brown, irregular, concretionary, 1′4″–2′
4. *Jim Creek limestone,* Moore 1934, dark gray, massive, impure, with abundant *Chonetes granulifer,* etc., 1′+
5. *Otoe shale,* Condra and Reed 1938, upper part bluish gray, calcareous, with many *Chonetes granulifer,* lower part red; combined thickness, 7′
6. *Palmyra limestone,* Condra and Reed 1938, bluish gray, stained reddish from shale above, firm or shattered, with many small *Triticites acutus* and other fossils, 2′–3′
7. *Minersville shale,* Condra and Reed 1938, largely bluish gray shale, with thin zones of red, argillaceous to sandy shale and some sandstone, about 30′–32′
8. *Morton limestone formation* (new name), dark gray to yellowish or brownish, locally irregular, sandy to conglomeratic, and quite fossiliferous, 2′
9. *Dry shale formation,* Moore 1935, largely grayish, with thin zones of red locally, argillaceous to sandy, part calcareous, fossiliferous in places, thickness 14′
10. *Dover limestone formation,* Beede 1898, grayish to bluish-gray, massive to irregular, quite fossiliferous, with brachiopods, bryozoa, fusulines, etc., 2′–5′
11. *Langdon-Wamego shale,* with the *Maple Hill limestone,* Condra 1927, absent; consisting of gray, argillaceous to calcareous shales and sands, Nyman coal near top, 15′

NOTE: The Otoe shale, Palmyra limestone and the Minersville shale may occupy the horizon of the Friedrich shale and the Morton limestone that of the Grandhaven limestone of Moore, 1935.

Composite Section Richardson Subgroup

South and southwest of Pawnee City, Nebraska, thickness about 111 feet.

1. *Brownville limestone,* measured 4½ miles south and 2 miles west of Pawnee City, 2′+:
   (1) Limestone, gray, weathered yellowish, with *Marginifera osagensis,* crinoid joints, etc., 8″
   (2) Shale, green gray, calcareous, fossiliferous, 6″
   (3) Limestone, greenish gray, blocky, firm, weathers yellowish, carries *Marginifera* and other fossils, 6″–1′
2. *Wood Siding formation,* 18′6″:
   (1) Shale, greenish gray, compact, micaceous, 9″
   (2) Shale, greenish, with limy pebbles, 3″–4″
   (3) Shale, greenish, friable, sandy, micaceous, laminated, 9′6″
   (4) Limestone, dark gray, impure, 2″–3″
   (5) Shale, greenish, sandy, micaceous, laminated, 1′6″
   (6) Shale, dark bluish-gray, very fossiliferous, about 2′
   (7) Nebraska City limestone, dark bluish-gray, very fossiliferous, about 2′
3. *French Creek shale,* measured at road crossing on Highway 99, 7 miles south of Pawnee City, composed of grayish argillaceous to sandy shale with rusty plates in upper, with the Lorton coal near top and a coal smut 2′8″ lower; combined thickness 27′
4. *Jim Creek limestone,* measured in road gutter north of above (3), upper 4″–5″ bluish gray and dense; lower 1′6″ yellowish, calcareous, fossiliferous shale, with abundant *Chonetes granulifer* and other fossils, combined thickness about 2′+
5. *Friedrich shale,* Moore 1934, thickness 19′–21′:
   (1) *Otoe shale,* gray above, red below, about 5′–7′
   (2) *Palmyra limestone,* gray-brownish, a nodular zone, 2′±
   (3) *Minersville shale,* gray, and sandstone, locally with some red near top, 10′–12′
6. *Morton limestone,* bluish-gray, dense, fossiliferous, 1′±
7. *Dry shale,* gray, with sandstone at top, 18′–19′
8. *Dover limestone,* on bed of creek east of road, about 2′
9. *Langdon-Wamego shale,* best exposed east side of Turkey Creek, one mile south of State line and one mile east of Highway 99, combined thickness 18′6″. The Maple Hill limestone is present locally in this area 2′ to 5′ above the Tarkio limestone.

Composite Section of the Richardson Subgroup

Between St. Marys and north of Rossville, Kansas, thickness about 140 feet.

1. *Brownville limestone* in road cut on N-S road north of Highway 40 and 3 miles east of St. Marys. Stone gray to yellowish, massive, top uneven, with *Marginifera wabashensis, Chonetes granulifer, Dictyoclostus, Ambocoelia, Meekopora, Rhombopora,* crinoid joints, etc., 2′2″+
2. *Wood Siding shale formation,* exposed in road cut, 21′:
   (1) Shale, greenish-gray, 2′3″+
   (2) Coal smut, 1″+
   (3) Shale, greenish-gray, argillaceous, 5′–6′
   (4) Shale, bands of red and gray, sandy, micaceous, 7′5″
   (5) Shale, gray, with yellow sandy plates, micaceous, 3′7″
   (6) Nebraska City limestone, dark gray, impure, shattered, with several kinds of fossils, as *Myalina,* crinoid joints, *Chonetes, Neospirifer,* etc., 1′6″–1′10″
3. *French Creek shale,* in road cut, 28′–29′:
   (1) Shale and "coal blossom," 2½″
   (2) Lorton coal, 4″
   (3) Shale, gray, with yellow, sandy, micaceous plates, 3′4″
   (4) Coal smut, 1″
   (5) Sandstone, gray to buff, thin-bedded, micaceous, 2′11″
   (6) Shale, bluish-gray, argillaceous, with micaceous, yellow sandy plates, part now covered, 21′–22′
4. *Jim Creek limestone,* low in gutter of N-S road east of St. Marys. Stone bluish gray, massive, dense, 1′2″, but 2′+ at farm lot ⅜ mile east where it weathers brownish and contains several kinds of fossils but not in large numbers
5. *Friedrich-Dry shale,* at foot of slope along N-S road, 22′ exposed; thickness probably 28′; Grandhaven absent here
6. *Dover limestone,* 2 miles north of Rossville, gray, fossiliferous, massive, 2′+
7. *Langdon shale,* north of Rossville Kansas, composed of gray sands and shales, 45′+
8. *Maple Hill limestone,* in road cut north of Rossville, gray, fossiliferous, 1′4″–1′6″+
9. *Wamego shale,* in road cut north of Rossville, gray, argillaceous to sandy-limy, about 15′

Note: The thickness of the preceding section above the Dover limestone compares quite closely with the same interval south of Pawnee City, Nebraska, but the Langdon and Wamego shales and the Maple Hill limestone are thicker here than in Nebraska. Pony Creek equals 2(1) to 2(5)

Nemaha Subgroup

This includes the formations from the top of the Tarkio limestone down to the base of the Burlingame limestone. It persists in the outcrops from southwestern Iowa southward through northwestern Missouri, southeastern Nebraska and Kansas to Oklahoma.

The Tarkio limestone was defined by Calvin (1896) to include thin limestones and shales exposed in the Tarkio Valley in Page County, Iowa from a few miles northwest of Clarinda southward to Missouri. Hinds and Green (1915) and Dr. Geol. L. Smith (1909) classed the topmost bed of this subgroup, in exposures along the Missouri Valley in northwest Missouri, as the Tarkio limestone and later Condra traced this unit through the sections of Richardson and Pawnee counties of Nebraska and southward to beyond Dover, Kansas. Reed, however, proved that the zone correlated as the Tarkio at McKissick and Nebraska by Hinds, Green, Smith and Condra is the Elmont and not the Tarkio. And finally Condra found that the Tarkio grades into sandstone at Nebraska City and McKissick Grove and is an impure limestone in the Missouri River bluffs west of Tarkio River north and northeast of Corning, Missouri, which location he selected as the type locality or cotype locality of the Tarkio limestone formation. Also Moore, in 1936, designated a type locality of this formation in the vicinity of Maple Hill, Kansas.

Condra and Bengston (1915) named the Preston limestone formation from the vicinity of Preston, Nebraska to include two limestones separated by a shale. This formation lies between the Willard and Auburn shales, but when it was found that these beds represent the "Emporia" of the older Kansas surveys, the Nebraska Survey accepted and usëd the name Emporia for a few years, i.e., until it was discarded by Moore in 1936, when he revived the names Elmont (Beede, 1903), and Reading (Smith, 1905), and gave the name Harveyville to the shale located between these limestones, and ranked the three divisions each as formations. Although we believe that these units represent only members of the Preston limestone their formational rank is accepted, and the name Preston limestone is dropped.

Composite Section of the Nemaha Subgroup in Southeastern Nebraska

Figure 16; thickness about 110 feet:

1. *Tarkio limestone formation* (Calvin 1900), Condra 1927, gray to buff, massive, with *Triticites ventricosus* and *Osagia* abundant, 3′–7′
2. *Willard shale formation,* Beede 1898, composed of gray to dark gray shales, thin shaly limes, sands and thin sandstones, and some reddish shale near base in places, about 28′–30′+
3. *Elmont limestone formation,* Beede 1898, gray separated by thin shales, with *Triticites acutus* and other fossils abundant in places, 2′6″–4′
4. *Harveyville shale formation,* Moore 1934, greenish, blue or buff, with calcareous layers in places, contains *Chonetes granulifer,* crinoid joints, etc., 4′+ in Pawnee County; thickening eastward to 12′–20′ in southeastern Richardson County.
5. *Reading limestone formation,* Smith 1905, blue-gray, weathers brownish, irregular, becomes sandy locally, about 3′–5′.... ....
6. *Auburn shale formation* (Beede 1898), Condra 1927, with zones of gray, red and bluish gray; locally calcareous, slabby and quite fossiliferous near base with *Chonetes, Rhombopora, Dictyoclostus* and crinoid joints abundant. This faunal horizon becomes well developed in central and southern Kansas and in northern Oklahoma; thickness of formation, 14′–30′
7. *Wakarusa limestone* (Beede 1898), Condra 1927, usually three limestones separated by shale, 2′6″–6′; stone bluish gray, weathering yellowish brown, quite fossiliferous. Section 4 miles northwest of DuBois, about 3′:
   (1) Limestone, bluish gray, dense, weathers brownish, with *Triticites ventricosus* abundant, 7″–1′
   (2) Limestone, brownish, irregular, carries many large crinoid joints, 8″–1′
   (3) Shale, gray, argillaceous, fossiliferous, 2″–1′
   (4) Limestone, light blue, weathers light gray, 6″+
8. *Soldier Creek shale formation* (Beede 1898), Condra, 1927, bluish gray, usually with a red zone near top, locally micaceous, arenaceous or very sandy, 12′–14′ or more. This formation contains a thin, limy seam at places.
9. *Burlingame limestone formation,* Hall 1896, thickness about 20′ in southern Richardson County:
   (1) *South Fork limestone,* Condra 1935, one massive bluish bed or 2 or 3 beds separated by shale, 2′–6′
   (2) *Winnebago shale,* Condra 1935, bluish, argillaceous, with some limy seams, 8′–12′+ in southeastern Nebraska and much thinner northward.

(3) *Taylor Branch limestone,* Condra 1935, bluish-gray, massive, weathers brownish, 2′–4′6″ to the south and about 5′ northward

SAC-FOX SUBGROUP

This subdivision outcrops in part in the Weepingwater Valley below Wabash and near Union, also at Jones Point, and in whole near DuBois and in the extreme southeastern corner of the state. It reaches northeastward into Iowa and Missouri and southward through Kansas to Oklahoma. In the early survey of Kansas the section of this subgroup above the Howard limestone was classed as the Scranton shale.

Composite Section of the Sac-Fox Subgroup in Nebraska

Measured on exposures and in the subsurface in southeastern Richardson County, Figure 16, thickness about 175 feet:

1. *Silver Lake shale* (Beede 1898), Condra 1927, bluish gray, argillaceous to sandy, 10′–12′
2. *Rulo limestone,* Condra and Bengston 1915, dark gray, earthy, 1′–2′
3. *Cedar Vale shale formation,* Condra 1930, gray, largely argillaceous, bedded near top, indurated and yellowish near base, 19′–20′+ The Elmo coal occurs near the top of this member
4. *Happy Hollow limestone formation,* Condra 1927, gray to yellowish beds of calcareous mudstone; 6′–8′. This grades into a well-defined limestone across Kansas
5. *White Cloud shale formation,* Condra 1927, exposed and subsurface, gray to gray-green, argillaceous and sandy with lenses and beds of sandstone and a thin coal seam near middle, 80′ south of the mouth of Big Nemaha River
6. *Howard limestone formation,* Haworth 1898, in NE ¼ Sec. 27, T. 1 N., R. 12 E., ½ mile southeast of DuBois, 7′:
   (1) *Utopia limestone,* Moore 1932, dark gray, massive, weathers brownish, 1′–2′. Locally this carries abundant *Triticites* and bryozoa
   (2) *Winzeler shale,* Moore 1932, blue to black, part calcareous, with *Ambocoelia, Lingula,* pelecypods and ostracods, 6″–1′
   (3) *Church limestone,* Condra 1927, bluish gray, massive, with crinoid joints, brachiopods, etc., weathers brownish, 2′–4′+
7. *Severy shale formation,* Haworth 1898, thickness 29′, subsurface southeastern, thickness 22′ exposed at or near state line southeast of DuBois and 10′ north:
   (1) Shale, exposed below waterfall south of DuBois, 2′ or more:
      a. Calcareous, fossiliferous, 6″
      b. Black, massive to bedded, with many Lingula, 4″–7″
      c. Grayish, fossiliferous, 3″–6″
      d. Black, silty above, massive below, 6″
      e. Rotted, fossiliferous, 2″–4″
   (2) *Nodaway coal,* exposed east of waterfall on Lore's Branch south of DuBois, at the old mill site on Turkey Creek at Cincinnati (abandoned), and southward in Kansas, 1′2″–1′4″
   (3) Shale, at site of old mill dam on Turkey Creek near Cincinnati (abandoned), 17′–18′:
      a. Gray, argillaceous, 6″
      b. Black, fissile, 6″
      c. Bedded, sandy, micaceous, with ripple marks at base, 3′6″
      d. Bluish, bedded to massive, unfossiliferous, argillaceous, 13′–14′

NOTE: The Severy shale, thickness 25 feet, is well exposed in Kansas southeast of DuBois where its middle and lower zones are bluish and argillaceous and there is a thin limestone seam near the base. This formation decreases in thickness northward to 10 feet in the Jones Point section east of Union, Nebraska.

Shawnee Group

This group extends from Iowa to Oklahoma. Its units outcrop in whole or in part in the Weepingwater Valley, at Jones Point and Plattsmouth, southeast of DuBois, and in the extreme southeastern corner of the state.

The Topeka and Deer Creek formations nearly coalesce in the Weepingwater Valley area of Nebraska, making the Calhoun shale very thin. Some have classed the Wolf River limestone and the Iowa Point shale under the Calhoun, but our study of these beds in northeastern Kansas and southeastern Nebraska shows that they are members of the Topeka formation.

Composite Section of the Shawnee Group in Nebraska

Thickness 250 feet southeast and 175 feet north, Figure 17.

1. *Topeka limestone formation,* Bennett 1896, about 27′ in Weepingwater Valley, part exposed at Jones Point and southeast of DuBois, thickness subsurface southeastern Richardson County, about 39′+:
   (1) *Coal Creek limestone,* Condra 1927, 4′:
      a. Limestone, dark gray, somewhat siliceous, forms large flat blocks, car-

ries many fusulines and bryozoa, 1′ 6″

b. Shale, bluish, argillaceous to calcareous, weathers buff, 1′6″

c. Limestone, blue, dense, massive, fossiliferous, weathers brownish, 1′+

d. Shale seam, 6″

e. Limestone, dark blue, massive, forms rectangular blocks, with *Myalina*, crinoid joints and bryozoa, 6″

(2) *Holt shale,* Condra 1927, upper portion bluish gray, argillaceous, with some calcareous material; lower portion black, fissile; combined thickness, 2′3″

(3) *DuBois limestone,* Condra 1927, about 2′9″:

a. Limestone, dark blue, massive, with *Myalina* on upper surface, 1′2″

b. Shale seam, calcareous, 5″

c. Limestone, separated by shale seams, dark blue, dense, quite fossiliferous, with small *Myalina*, 1′2″

(4) *Turner Creek shale,* Condra 1927, bluish gray, calcareous, with lime seam near top, 2′8″

(5) *Sheldon limestone,* Condra 1933, gray, 2′6″–4′

(6) *Jones Point shale,* Condra 1927, bluish green, argillaceous, somewhat calcareous, 7′–8′

(7) *Curzon limestone* (Galleher 1898), Condra 1927, bluish gray, massive, weathers buff or brownish, 4′ or more in the subsurface southeast and north

(8) *Iowa Point shale,* Condra 1927, upper portion bluish and argillaceous; lower portion bluish gray, bedded to massive, with thin seams or layers of lime, quite fossiliferous, combined thickness 10′ subsurface southeast, and 1+ to the north

(9) *Wolf River limestone,* Condra and Reed 1937, gray, massive, brittle, breaks irregularly, with some chert in middle, weathers brownish, 3′ subsurface southeast, less to the north

2. *Calhoun shale formation,* Beede 1898, bluish gray, weathers yellowish, calcareous, dark at base, thickness, 2′6″ subsurface south, much less north. This thinning northward brings the Topeka and Deer Creek formations close together in Nebraska.

3. *Deer Creek limestone formation,* Bennett 1896, thickness 32′4″ subsurface southeast and 23′ exposed north:

(1) *Ervine Creek limestone,* Condra 1927, 16′–17′ subsurface southeast and about 14′-15′ in Weeping Water Valley:

a. Limestone, light gray to white, oolitic, massive, 1′5″–2′

b. Limestone, light gray to white, finely crystalline, dense, locally with numerous incipient fractures and hackly fracture, extensively quarried in vicinity of Weeping Water, 5′6″–7′

c. Shale, bluish gray, very calcareous, locally grades to limestone, 6″–1′6″

d. Limestone, gray, massive, dense, weathers yellowish, fossiliferous with two or three species of fusulines near middle and upper part, crinoid stems and brachiopods throughout,

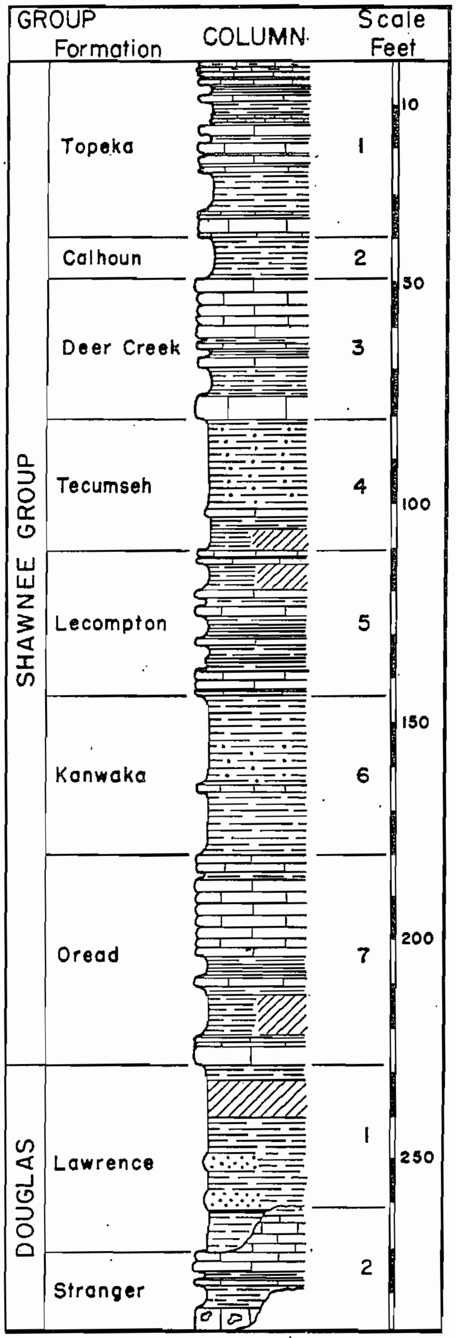

Figure 17.—Composite Section, Shawnee and Douglas Groups, Pennsylvanian Subsystem.

Fistulipora, and *Amblysiphonella* in lower part, 5′–6′

(2) *Burroak shale,* Condra and Reed 1937, bluish gray and black, very persistent north, pinches out south, 2′6″ or less

(3) *Haynies limestone,* Condra 1927, blue, fine-grained, dense, with sharp fracture, crinoids common, thickness 1′ north; united with the Ervine Creek limestone in the subsurface southeast

(4) *Larsh shale,* Condra 1927, upper portion bluish gray and argillaceous; lower portion dark to black and carbonaceous, thickness, 1′6″–2′6″

(5) *Rock Bluff limestone,* Condra 1927, light bluish gray, massive, blocky, weathers yellowish, locally pitted with vugs of iron oxide, 1′6″–2′

(6) *Oskaloosa shale,* Moore 1936, bluish gray, argillaceous, 4′–5′ subsurface southeast, poorly developed or absent north

(7) *Ozawkie limestone,* Moore 1936, bluish gray, subsurface southeast, 5′; absent north

NOTE: The Burroak shale pinches out in southeastern Nebraska where the Haynies limestone unites with the Ervine Creek. In east-central Kansas, the Oskaloosa and Ozawkie members come in below the Rock Bluff limestone and persist northward to Nebraska.

4. *Tecumseh shale formation,* Beede 1898, about 50′ subsurface southeast, 36′ exposed north. Section along the road in middle Sec. 7, T. 10 N., R. 12 E., 2 miles southeast of Weepingwater:

(1) *Rakes Creek shale,* Condra 1930, gray to buff, sandy to sandstone, about 25′

(2) *Ost limestone,* Condra 1930, light gray to dark gray, irregular, argillaceous to sandy and locally conglomeratic, 2′–3′+

(3) *Kenosha shale,* Condra 1930, maroon, argillaceous to sandy, with gray layer at top, 7′–8′

NOTE: The Tecumseh thickens southward from Nebraska to central Kansas, but we do not differentiate its members in the subsurface section of southeastern Nebraska.

5. *Lecompton limestone formation,* Bennett 1896, thickness 36′ subsurface south and 30′ north. The members of this formation persist from Iowa and Nebraska to southern Kansas. Section in Cascade Creek Valley, in Sec. 12, T. 10 N., R. 11 E., near Weepingwater, about 30′

(1) *Avoca limestone,* Condra 1927, bluish gray, usually in two beds separated by shale, with *Triticites, Rhombopora,* brachiopods, etc., 2′+

(2) *King Hill shale,* Condra 1927, upper portion gray, lower portion maroon and at places arenaceous, about 6′. Fauna: *Allorisma terminale, Aviculopecten occidentalis, Myalina subquadrata, Myalina swallowi,* etc.

(3) *Beil limestone,* Condra 1930, section 100 feet west of Highway 75, 6½ miles north of the road junction east of Union, Cass County, about 5′6″:

a. Limestone, light yellow, massive, coarse-grained, with *Syringopora,* etc., 1′6″–2′

b. Shale, light yellow to gray, calcareous, with *Campophyllum torquium* abundant, 1′–2′

c. Limestone, light brown, silty, with *Syringopora* on top, 2′

(4) *Queen Hill shale,* Condra 1927, upper portion bluish, argillaceous, lower portion black, carbonaceous, platy to fissile, combined thickness, 5′. Fauna: *Chonetes granulifer, Ambocoelia planoconvexa* and *Derbya crassa*

(5) *Big Springs limestone,* Condra 1927, light bluish gray, dense, argillaceous, massive, with *Triticites,* 1′+

(6) *Doniphan shale,* Condra 1927, bluish-gray, argillaceous, part sandy, thickness 8′–9′ subsurface southeast and about 4′–5′ north

(7) *Spring Branch limestone,* Condra 1927, gray to buff, massive in upper part, less firm below, 3′–5′

6. *Kanwaka shale formation,* Adams 1903, about 37′ subsurface southeast and probably 7′–9′ exposed north:

(1) *Stull shale,* Moore 1932, bluish, argillaceous to sandy, thickness subsurface southeast, probably 13′–15′; thickness in Weepingwater Valley, 2′–3′

(2) *Clay Creek limestone,* Moore 1932, subsurface southeast, 2′–3′, about 6″–1′ exposed north

(3) *Jackson Park shale,* Moore 1932, dark gray, very calcareous, argillaceous to sandy, with some lime seams, thickness probably 14′ subsurface southeast and about 3′ on exposures north

NOTE: In the early reports on the Pennsylvanian of Nebraska the Spring Branch limestone of the Lecompton and the Stull shale, Clay Creek limestone and Jackson Park shale of the Kanwaka at the Snyderville quarry in the Weepingwater Valley were classed with the Plattsmouth limestone. However, a cyclothemal regional study of these beds made by Dr. Moore and the senior author lead to the present correlation.

7. *Oread limestone formation,* Haworth 1894-1895, about 54′ subsurface southeast and 47′ exposed north:

(1) *Kereford limestone,* Condra 1927, dark gray, massive, dense, locally oolitic, with conchoidal fracture, 6′–8′ subsurface south, 3′–4′ exposed north

(2) *Heumader shale,* Moore 1932, bluish to dark gray, mostly argillaceous, with *Chonetes, Composita, Neospirifer,* bryozoa, etc., 0–2′ north

(3) *Plattsmouth limestone,* (Keyes 1899), Condra 1927, in Weepingwater Valley, thickness 17′–18′ subsurface southeast and 15′ or more exposed north:
  a. Limestone, dark gray, massive, 2′
  b. Shale, bluish gray, 1′6″
  c. Limestone, light gray, massive, with chalky appearance, forms very large blocks, 4′. Fauna: Many fusulinids
  d. Shale and weathered limestone, mostly dark gray, argillaceous to calcareous, 6″–1′. Fauna: *Neospirifer triplicatus* common
  e. Limestone, dark gray, massive to unevenly bedded, irregularly jointed, compact, brittle, with considerable free calcite, 8′–9′, upper 3′ with two zones of chert. Thin seams of clay may occur at places in the stone below the chert. Fauna: Many horn corals occur in basal portion; fusulinids rare and more slender than those in the higher zones; brachiopods common, and a few specimens of *Enteletes hemiplicatus*

(4) *Heebner shale,* Condra 1927, along Heebner Creek four miles west of Nehawka, thickness 4′–6′; upper 3′ bluish gray and argillaceous, basal part black and fissile

(5) *Leavenworth limestone,* Condra 1927, along Heebner Creek, blue, brittle, massive, one or two beds, forms rectangular blocks, 1′6″

(6) *Snyderville shale,* Condra 1927, along Heebner Creek, bluish at top and base, maroon in middle, largely argillaceous, 11′–14′

(7) *Weepingwater limestone,* Condra and Bengston 1915, forms small waterfall in Heebner Creek. Stone light bluish gray, massive in upper portion, slabby below, and somewhat shaly along the middle, 6′–8′. Fauna: Crinoid joints, brachiopods, bryozoa, etc. This member occasionally thins to nodular limestone in the subsurface of Richardson County, but has been traced on outcrop to southern Kansas.

Douglas Group

This group has an unconformable base, a slight unconformity near the middle and an uneven top. It has wide occurrence from Iowa to Oklahoma and reaches a considerable distance westward in Nebraska and Kansas. Its top and bottom are readily recognized in the logging of deep wells, because this formation differs in color and texture from the overlying and underlying formations.

The thickness of this group, composed of the Lawrence and Stranger formations, varies between 110 and 150 feet in the well records of Richardson County where it is composed of red shales, sandstones and gray to bluish gray shales with a calcareous zone, probably in the horizon of the Haskell limestone, near the base. The thickness is only about 66 feet in the Weepingwater Valley northwest of Nehawka and about 38 feet in the Platte Valley between Ashland and South Bend.

Composite Section of the Douglas Group in Southeastern Nebraska

Figure 17.

1. *Lawrence shale formation* (Haworth 1894), Moore and Newell 1936, thickness in Richardson County, where not differentiated from the Stranger formation, about 110′–150′. Its thickness is only about 19′ northwest of South Bend, and northwest of Nehawka it is 40 to 42 feet as follows:
   (1) Shale, bluish-gray, argillaceous, 3′
   (2) Shale, red, argillaceous to arenaceous, 8′–10′
   (3) Shale, bluish-gray, argillaceous, part bedded, 7′–10′
   (4) Limestone-sandstone, dark gray, 4′–5′
   (5) Shale, bluish to dark gray, 4′–5′
   (6) Limestone-sandstone, dark gray, 4′–5′
   (7) Coal, and black shale, 6″–1′
   (8) Shale, bluish-gray, about 9′–10′
   (9) Shale, pebbly, exposed at places in Weepingwater and Platte valleys, marks an unconformity, about 5′

NOTE: The basal part of divison 3 above and all of divisions 4 to 8 inclusive do not occur in the Weepingwater Valley northwest of Nehawka, due to removal by erosion.

2. *Stranger formation,* Moore 1931, not differentiated from the Lawrence shale in the subsurface southeast; thickness in Weepingwater Valley northwest of Nehawka, 17′–19′, and 19′–24′ in the Platte Valley northwest of South Bend, as follows:
   (1) Shale, bluish-gray, argillaceous, pelecypodal, 1′6″–2′
   (2) Cass (Haskell?) limestone, Condra 1927, top eroded in Weepingwater Valley with about 7′–8′ of the member remaining, thickness of member in Platte Valley northwest of South Bend, 15′–16′, as follows:
      a. Limestone, bluish-gray, massive, fossiliferous, 1′6″
      b. Shale, gray, uneven, calcareous, 6″–1′
      c. Limestone, largely mottled blue-gray, with free calcite, quite fossiliferous, with thin wavy shale seams, 10′6″

d. Shale, thickness, 1′6″; upper portion bluish and argillaceous; middle portion black, becoming fissile on drying; lower portion blue and quite fossiliferous, with *Neospirifer, Chonetes, Rhombopora, Polypora,* etc.
e. Limestone, blue-gray, dense, one bed or two beds separated by a thin shale seam, 1′4″

(3) Shale, bluish gray, thickness about 2′ in Weepingwater Valley and 1′ or less in the Platte Valley

(4) *Nehawka limestone,* Condra and Bengtson 1915, in North Branch of Weepingwater Valley, northwest of Nehawka, variegated, light to dark gray; conglomeratic-brecciated, massive, grading upward into about 2′ of bluish gray, pebbly shale; thickness of massive bed 4′–5′, combined thickness 6′–7′

MISSOURI SERIES

This series was named by Keyes in 1893, and redefined by R. C. Moore in 1932. Its thickness is about 350 feet subsurface in southeastern Nebraska and 266 feet to the north. According to the Kansas Survey it includes the following groups:

1. *Pedee group,* Moore 1932
2. *Lansing group* (Hinds 1912), Moore 1932
3. *Kansas City group* (Hinds and Green 1915), Moore 1936
4. *Bronson group,* Adams 1904
5. *Bourbon group* or *formation,* Moore 1932

The Missouri Geological Survey includes the Bronson group with the Kansas City group and applies the name Pleasanton to the Bourbon part of the section.

Formerly the base of the Kansas City group and of the Missouri Series was placed at the base of the Hertha limestone, but later an unconformity located at the base of the Pleasanton-Bourbon was accepted by the Oklahoma, Kansas, Missouri, Iowa and Nebraska surveys as marking the base of the Missouri series, and it would seem that this unconformity would also mark the base of the Bronson group and that the Bourbon-Pleasanton interval should be classed as the basal formation of the Bronson group if it is accepted by the state surveys.

Pedee Group

The correlation of this is not certain. The uneroded thickness exposed in the lower Platte and Weepingwater valley is about 13 feet; and its subsurface thickness in the southeastern corner of the state probably is about 59 feet.

1. *Iatan limestone formation,* Keyes 1899, probably 6′–9′ subsurface southeast, eroded from sections north if ever deposited there
2. *Weston* (Plattford) *shale formation,* Keyes 1899, probably 50 feet subsurface in southeastern Richardson County; eroded from the Weepingwater Valley section, but 13 feet remaining in the Platte Valley northwest of South Bend where it is largely purplish red shale with thin zones of gray shale at the top and base

UNCONFORMITY

Lansing Group

Thickness about 58 feet subsurface southeast and 52 feet exposed to the north. Top eroded in places. Composite section of the Lansing group (Figure 18) in southeastern Nebraska:

1. *Stanton limestone formation* (Swallow 1865), Haworth and Bennett, 1908, subsurface thickness about 40′ feet southeastern Richardson County and 35 feet exposed in the Platte Valley near South Bend and Louisville:

(1) *South Bend* ("Little Kaw") *limestone,* Condra and Bengston 1915, northwest of South Bend, 9′6″:
a. Limestone, gray, massive, with chert, forms large blocks, 2′9″. Fauna: Many *Rhombopora lepidodendroides* occur on the upper surface, fusulinids and brachiopods common
b. Shale, bluish to bluish gray, average thickness, 9″–1′
c. Limestone, gray, oolitic, massive, 5′. This weathers along the middle, forming a shale seam 2″–3″ thick at places, but the freshly quarried rock is solid
d. Shale, gray, a seam on weathered surfaces, but not shown in fresh openings, 3″
e. Limestone, gray, massive, quite fossiliferous, not very hard, 7″–9″

(2) *Rock Lake* ("Victory Junction") *shale,* Condra 1927, thickness 4′ in Weepingwater Valley and 6′ at the old Burlington Quarry northwest of South Bend:
a. Shale, bluish, argillaceous, 1′
b. Shale, maroon, tough, argillaceous, with calcareous bodies in the basal portion, 5′

(3) *Stoner* ("Olathe") *limestone,* Condra 1930, at quarry west of Meadow Station, Nebraska, 15′–16′:
a. Limestone, gray to buff, clayey to sandy, irregularly weathered in places, 2′6″–3′

b. Limestone, medium light gray, dense, massive, with free calcite, brachiopods and *Triticites,* about 8′+
c. Shale, gray, calcareous, with many *Tricites,* 3″–6″
d. Limestone, gray, one bed, fossiliferous, 6″–8″
e. Shale, gray, very limy and fossiliferous, 2′9″
f. Limestone, bluish, dense, weathers brownish, 1′7″–1′9″

(4) *Eudora shale,* Condra 1930, subsurface thickness 3′ or more southeast and about 2′ exposed north; upper portion gray, argillaceous, lower 6″ dark, coal-like

(5) *Capitan Creek limestone,* Newell 1936, thickness subsurface southeast, 3′–5′; thickness exposed north 1′6″; bluish gray

The South Bend limestone, Rock Lake shale, and Stoner limestone were named in Nebraska but soon thereafter they were given the names Little Kaw, Victory Junction and Olathe by Newell (1932) from the Kaw Valley area of Kansas. However, we have studied these members very closely in their outcrops and subsurface and it is now generally agreed that the original names are valid. The South Bend limestone is eroded from the section locally in the North Branch of the Weepingwater Valley northwest of Nehawka.

2. *Vilas shale formation,* Adams 1898, thickness subsurface southeast probably 6′–10′; thickness north at the quarry west of the Meadow Station, about 6′:
   (1) Shale, blue to black, bedded, argillaceous, 1′
   (2) Limestone seam, 2″
   (3) Shale, bluish, bedded, with limy seams, 1′
   (4) Limestone, bluish, earthy, arenaceous, 3″–3′
   (5) Shale, blue, bottom uneven with some reddish shale at base, 3′6″
3. *Plattsburg limestone formation,* Broadhead 1865, thickness 15′ subsurface south and about 10 feet at quarry west of Meadow Station:
   (1) *Springhill limestone,* Newell 1932, gray, top uneven, weathers buff to irregular, 3′–4′
   (2) *Hickory Creek shale,* Newell 1932, blue, argillaceous, 1′–3′
   (3) *Meadow limestone,* Condra and Bengston 1915, bluish gray, massive quite fossiliferous, *Polypora* abundant, weathers yellowish, 2′6″–3′

Kansas City Group

Thickness subsurface southeast, 210 feet; exposed thickness in Platte Valley in Sarpy and Cass counties (Figure 18) about 100 feet:

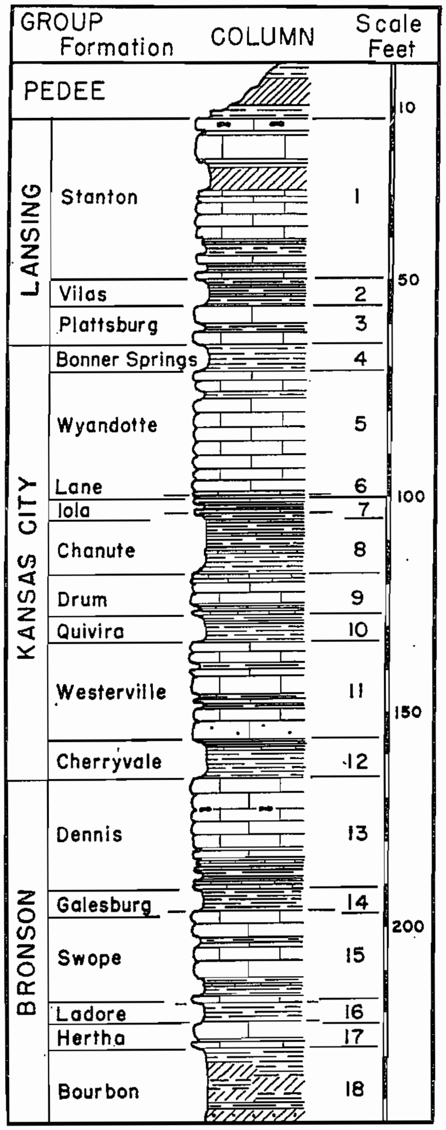

Figure 18.—Composite Section, Missouri Series, Pennsylvanian Subsystem.

1. *Bonner Springs shale formation,* Newell 1932, bluish gray, argillaceous, massive to bedded, with an irregular zone of red shale and thin seams of fossiliferous limestone in upper portion, thickness, 6′–8′
2. *Wyandotte limestone formation,* Newell 1932, about 56′ thick subsurface southeast and 30′ north, at the National quarries near Louisville:
   (1) *Farley limestone,* Hinds and Green 1915, gray, massive, weathers yellowish in places, about 5′ subsurface southeast and 4′–5′ exposed north. This forms the roof of the quarry tunnels at the Kiewitz and National quarries near Louisville

(2) *Island Creek shale,* Newell 1932, bluish gray, massive, argillaceous, thickness subsurface southeast about 4′, and 1′–3′ exposed north
(3) *Argentine limestone,* Newell 1932, gray, compact, in upper portion, broken by thin, wavy shale seams, softer in lower portion, thickness 21′6″ at Louisville quarry and 15′–16′ subsurface southeast
(4) *Quindaro-Frisbie,* Newell 1932, dark, about 10′ subsurface southeast and only 1′ north, on the floor of the National quarry near Louisville.

3. *Lane shale formation,* Haworth and Kirk 1895, thickness subsurface southeast, 17′–18′; thins markedly from Kansas to Nebraska and Iowa, becoming only 6″ thick at the National quarry near Louisville
4. *Iola limestone formation,* Haworth and Kirk 1894, about 12′ subsurface southeast and 3′–4′ at the National quarry northeast of Louisville, as follows:
   (1) *Raytown limestone,* Hinds and Greene 1915, impure, 6″–8″
   (2) *Muncie Creek shale,* Newell 1932, bluish above, dark below, 1′6″–2′
   (3) *Paola limestone, Newell* 1932, impure, 8″
5. *Chanute shale formation* (Haworth and Kirk 1894), Haworth and Bennett, 1908, 16′ or more subsurface southeast and 14′ exposed at the National quarry (abandoned) two miles northeast of Louisville:
   (1) Shale, bluish, argillaceous, 8″–10″
   (2) Claystone, light gray mottled, calcareous, 6″
   (3) Shale and thin claystone seams, 2′6″
   (4) Claystone, gray, mottled, calcareous, 10″
   (5) Shale, gray, argillaceous, 3′6″
   (6) Limestone, gray, very fossiliferous, with *Derbya crassa* common, 6″ or more
   (7) Shale, olive green with yellowish brown mottlings in lower portion, 5′6″
6. *Drum limestone formation,* Adams 1903, thickness 10′–12′ subsurface southeast and 9′ feet at the old National quarry E. of Louisville:
   (1) Limestone, weathered yellowish and somewhat slabby, 1′6″ or more
   (2) Limestone, in gray, dense, massive layers, with crinoid joints and a few other fossils, 5′
   (3) Shale, calcareous, about 4″
   (4) Limestone, 4″
   (5) Shale, calcareous, 8″ or more
   (6) Limestone, dense, forms large blocks, with crinoid joints and a few brachiopods, 10″–1′
7. *Quivira shale formation,* Newell 1932, thickness 35′ subsurface southeast, and 6′ at PWA quarry in Platte River bluffs south of Richfield:
   (1) Shale, olive green, argillaceous, with some fossils, 10″–1′
   (2) Shale, black, argillaceous to carbonaceous, 1′
   (3) Shale, dark gray, argillaceous, 4″
   (4) Shale, bluish green, argillaceous, 4′ or more
8. *Westerville limestone formation,* Bain 1898, about 26′ subsurface southeast and 18′ at PWA quarry south of Richfield:
   (1) Limestone, gray, massive with dark gray limestone pebbles in upper portion, weathers yellowish, with small fuslinids and small gastropods, 2′
   (2) Limestone, gray, massive or separated in irregular beds, with small fusulinids in lower portion and *Myalina subquadrata* in upper portion, 2′–3′
   (3) Shale, bluish gray, argillaceous to calcareous, with fossil fragments, 1″–8″
   (4) Limestone, dark gray, dense, resembles buhrstone, has small weathered vertical channels, 2′. Fauna: *Pinna,* brachipods
   (5) Limestone, gray, massive, with shale seams near middle, forms large blocks, carries dwarfed fusulinids, 4′
   (6) Shale, bluish gray, bedded, argillaceous, with dwarfed fusulinids, fenestrated bryozoa, crinoid joints, *Obiculoidea, Chonetes,* etc., 1′6″
   (7) Limestone, dark gray, impure, irregular, 6″–1′
   (8) Shale bluish green, massive, argillaceous, 1′
   (9) Limestone, medium dark gray, massive, pseudo-oolitic, top irregular, forms large blocks, with fusulines in places, 3′4″. The base of this bed is uneven.
9. *Cherryvale shale formation,* Haworth and Bennett 1908, thickness 10′–20′ subsurface southeast, 13′6″ feet at the PWA quarry south of Richfield:
   (1) Stone, gray to buff, massive, very sandy, loosely indurated, forms large blocks, varies from claystone to very fine grained limy sandstone, 4′6″. This is a transition zone betwen the Cherryvale and the Westerville.
   (2) Shale seam, bluish, crumbly, 3″–6″
   (3) Shale, black, finely blotched dark gray, fissile, 1′6″
   (4) Limestone, earthy-calcareous, separated by shale seam, 7″. This a very persistent thin bed
   (5) Shale, bluish to bluish green, argillaceous, crumbly, 6′6″

Bronson Group

Thickness subsurface southeast, 85 feet; thickness exposed and subsurface north, 79′ feet:

1. *Dennis limestone formation,* Adams 1903, about 25′ subsurface southeast and 21′6″ exposed in PWA quarry south of Richfield (Figure 18):
   (1) *Winterset limestone formation,* Tilton and Bain 1897, about 18′6″:

a. Limestone, gray, very massive, forms large blocks, 7'. This is quite fossiliferous, with *Composita subtilita* as the most noticeable species
b. Limestone, similar to above but not so massive, with dark chert near the top, 6' or more
c. Limestone, weathers cream-colored, 3' or more
d. Shale, calcareous, 5"
e. Limestone, cream-colored, soft, 2'

(2) *Stark shale,* Jewett 1932, about 1'10":
a. Shale, calcareous above, fossiliferous at base, 8"–9"
b. Limestone, bluish gray, 7"
c. Shale, 6"

(3) *Canville limestone,* Jewett 1932, dark blue, dense, hard, 10"

2. *Galesburg shale formation,* Adams 1903, thickness 11' subsurface southeast, and 7'4" in Amerada well northwest of Nehawka, and about 10'6" exposed in Platte Valley east of PWA quarry, south of Richfield as follows:
(1) Shale, 1'8", upper part bluish, argillaceous, 1'2"; lower part black calcareous, with small worm burrows in top, 6"
(2) Limestone, dark blue, massive, 5"–6"
(3) Shale, 1'; upper part greenish-blue, argillaceous, with *Ambocoelia, Chonetes, Rhombopora,* etc., lower part black
(4) Limestone, dark blue, dense, 6"
(5) Shale, black, fissile, 10"
(6) Claystone, bluish, forms small waterfall in Dyson Hollow, 9"
(7) Shale, 5'6"; top transitional, bluish, argillaceous; second sub-zone dark, bedded; basal subzone, greenish-blue, irregular, argillaceous

3. *Swope limestone,* Moore and Newell 1933 and 1936, thickness 20' subsurface southeast and 21' surface and subsurface in Platte Valley, as follows:
(1) *Bethany Falls limestone,* Broadhead 1865, thickness exposed east of PWA quarry south of Richfield and 14'10" in the core-drilled Amerada well northwest of Nehawka, as follows:
a. Limestone, dark gray, dense, nodular, earthy, stylolitic with algal growth, some pyrite and poorly preserved fossils, 6'
b. Limestone, light gray to dark gray, clouded, fine texture, brittle, dense, fractures with sharp edges, contains some unfossiliferous shale in upper portion, 8'10"; depth 336'10"

(2) *Hushpuckney shale,* Newell 1932, in core of Amerada well, northwest of Nehawka, 4'7"
a. Shale, dark gray, with some calcareous material, *Lingula, Wellerella,* and *Orbiculoidea,* 1'2"
b. Limestone, dark gray, dense, 2"
c. Shale, gray, argillaceous, massive, lumpy, 3'3"; depth 341'5"

(3) *Middle Creek limestone,* Newell 1932, in core of Amerada well, dark gray, fine textured, with some pyrite, fossil fragments and algal growth, 1'7"; depth, 343'

4. *Ladore shale,* Adams 1904, subsurface north, bluish gray to dark gray, calcareous, with pyrite, fine light colored mica, and small limy concretions, 5'

5. *Hertha limestone formation,* Adams 1903, subsurface north, 5':
(1) Limestone, dark gray, part with brownish tinge, massive, cavernous, reticulate, stylolitic, fossiliferous, 3'
(2) Shale, bluish gray, with *Orbiculoidea* and *Composita,* 8"
(3) Limestone, upper portion dark gray to brownish gray, semicrystalline, stylolitic, with some pyrite, scattered fine mica and brachipoda fragments, lower portion dark gray, with *Ambocoelia,* crinoid joints, and some fusulines; thickness, 1'4"; depth, 353'

6. *Bourbon formation,* Moore 1932, in core of Amerada well, 17'8":
(1) Shale, bluish, argillaceous, massive, with many small calcareous concretions, 3'6"
(2) Shale, bluish to reddish, silty or sandy, lumpy, 9'6"
(3) Shale, dark gray, argillaceous-arenaceous, 1'
(4) Shale, reddish, arenaceous-argillaceous, with small flakes of mica, 3'8"; depth, 370'8"

UNCONFORMITY, with the basal Bourbon and upper beds of the Marmaton group missing.

NOTE: The Bourbon formation or group of the Kansas survey is essentially the Pleasanton formation or group of the Missouri Geological Survey.

DES MOINES SERIES
(Middle Carboniferous)

Thickness about 900 feet + subsurface in Richardson County and 230 feet at Omaha. This series includes the following major subdivisions:

Marmaton (Henrietta) *group* (Haworth 1898), Moore 1932
Cherokee group, Haworth and Kirk 1894

Marmaton (Henrietta) Group

This group has been studied quite closely by Jewett, Cline, Green and others in its outcrop areas from south-central Iowa, through Missouri to southeastern Kansas and northeastern Oklahoma. Its formations and members persist more uniformly in this distribution than is generally supposed. The sequence of formations, from youngest to oldest in this outcrop area, is as follows:

1. *Memorial shale,* Dott 1936
2. *Lenapah limestone,* Ohern 1919, one, two or three members
3. *Nowata shale,* Ohern 1910
4. *Altamont limestone,* Adams 1896, one, two or three members
5. *Bandera shale,* Adams 1903, thick in southeastern Kansas; thins southward into Oklahoma
6. *Pawnee limestone,* Swallow 1866, with three or more members
7. *Labette shale,* Haworth 1898, with three or four members
8. *Fort Scott Limestone* (Swallow 1866), Bennett 1896, with three or more members

The Marmaton group in Nebraska, as classified from the logs of deep wells, includes the interval from a sandstone zone which is believed to be at the base of the Bourbon, to the base of a limestone which is thought to correlate with the Lower Fort Scott limestone. However, there is considerable difficulty in determining the details, and in some cases the exact limits of the group cannot be determined because many of the individual beds are thin and cannot always be placed accurately within the ten-foot samples from the rotary-drilled wells. The thickness of the Marmaton group varies from 142 to 205 feet in southeastern Nebraska. The average thickness in 57 wells in Richardson County is about 160 feet, varying from 150 to 170 feet.

A detailed study made by Reed of the samples from the Marmaton group in two cable-tool wells drilled in Richardson County indicates the following sequence of beds from top to base, with suggested correlations in terms of the Kansas outcrop section:

Composite Section, Marmaton Group Southeastern Nebraska

Figure 19. Thickness about 176 feet:

1. *Memorial shale* and *Lenapah limestone*; absent, probably removed by erosion
2. *Nowata shale,* blue-gray, and dark gray to black, 10′
3. *Altamont limestone,* medium dark gray to medium light gray, finely granular to finely crystalline, with chonetids and some other fossils, about 20′
4. *Bandera shale,* about 55′:
   (1) Shale, greenish gray and dark gray to

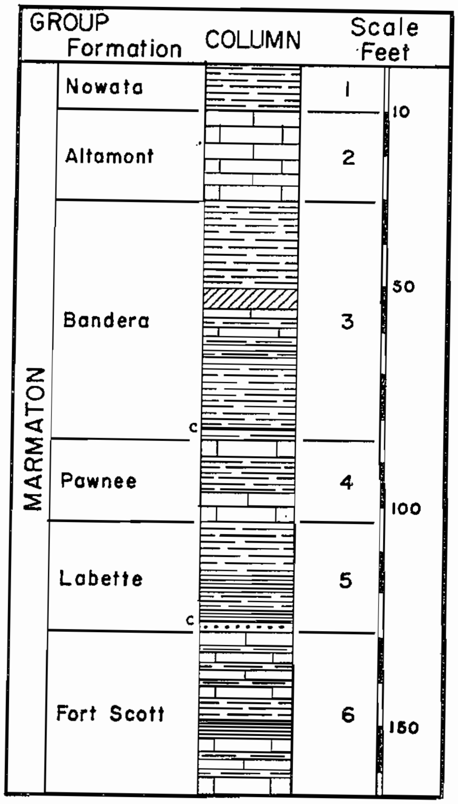

Figure 19.—Composite Columnar Section, Marmaton Group, Des Moines Series, Pennsylvanian Subsystem; from Richardson county Subsurface.

   black, with some red shale in lower part, 25′
   (2) Limestone, light gray, finely granular, interbedded with greenish-gray, and dark gray shale, about 12′
   (3) Shale, blue-gray and green-gray, in part yellowish, with a relatively persistent thin coal seam near the base, about 18′
5. *Pawnee limestone,* about 19′
   (1) Limestone, light gray, granular to finely crystalline, about 4′
   (2) Shale, blue-gray and dark gray, about 8′
   (3) Limestone, light gray to cream, crystalline to granular, fossiliferous, with brachiopods and fusulinids, about 7′
6. *Labette shale,* largely dark gray to black, with a thin coal seam in lower part, occasionally underlain by about 5 feet of sandstone, thickness 21′–29′
7. *Fort Scott limestone,* 35′–38′
   (1) *Higginsville limestone,* Jewett 1941, light gray, finely granular with some interbedded blue-gray and dark gray shale, 15′
   (2) *Little Osage shale,* Jewett 1941, blue-gray and dark gray to black, 8′–10′

(3) *Black Jack Creek limestone*, Cline 1941, medium and light gray, granular to lithographic, in part crystalline, with some interbedded blue-gray and dark gray shale, 12′–14′

The above tentative correlation agrees quite closely with that made on the outcrop areas of the Marmaton group in Iowa and Missouri, and if our correlation of individual beds and formations in this area is correct, the thicknesses are approximately the same as those in the outcrop area of southeastern Kansas, as described by Jewett (1941), with two exceptions. In our subsurface sections there is a limestone in the middle part of the Bandera shale which is not described by Jewett in southeast Kansas and we find a thin coal seam in the lower part of the Bandera shale which is not mentioned by Jewett.

The Cherokee group in Nebraska

The best development of the Cherokee group in the state occurs in the lower parts of the "Forest City Basin" region of Richardson County. The following section is taken from the record of a deep well located about 5 miles west of Falls City where the top of the Cherokee was drilled at 1396 feet and its base was reached at 2096 feet. Figure 20.

Cherokee group, 700′:

1. Shale, black, fissile, coaly, with some thin seams of dark brown, siliceous, concretionary limestone, 11′
2. Shale, blue-gray, finely micaceous, argillaceous to silty, 28′
3. Sandstone, blue-gray, calcareous, indurated, 7′
4. Shale, dark gray, argillaceous, laminated, 8′
5. Sandstone, blue-gray, micaceous, medium-grained, 4′
6. Shale, dark gray and black, laminated, coaly in upper part, greenish-gray in lower part, 21′
7. Ardmore limestone, brownish gray to tan, crystalline, dense, fossiliferous (brachiopods), 8′
8. Shale, black and fissile in upper part, blue-gray to dark gray below, 29′
9. Sandstone, medium and dark gray, micaceous in upper part, arkosic to conglomeratic below, 19′
10. Shale, black, fissile, and dark gray, with some coal, 5′
11. Shale, blue-gray to green-gray, part silty, and shale, dark gray to black, laminated,

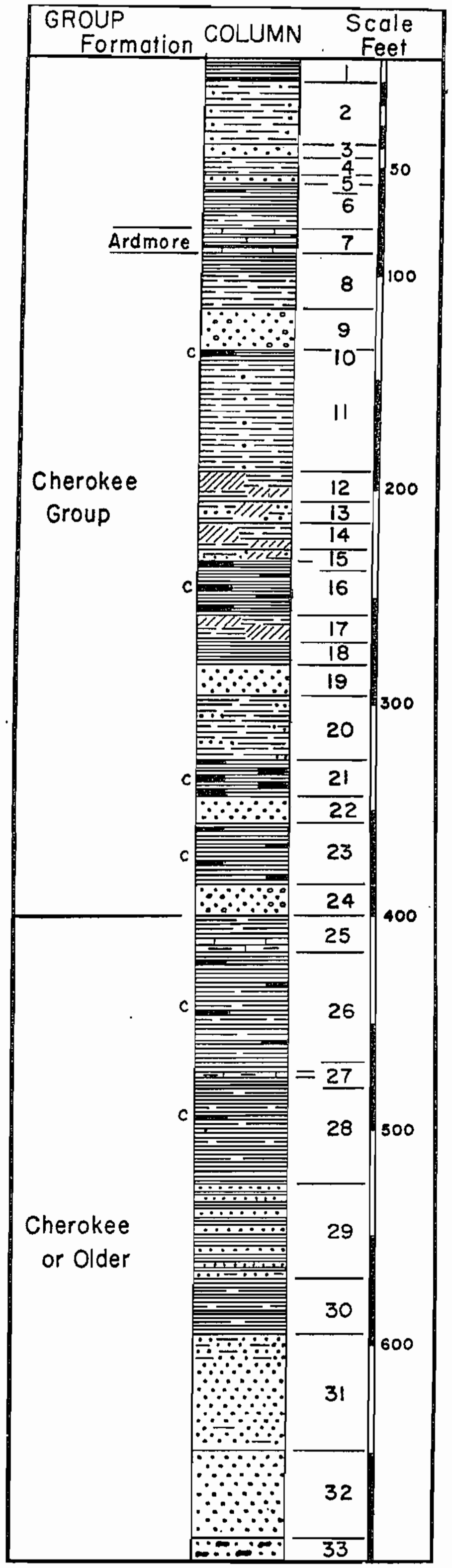

Figure 20.—Composite Columnar Section, Cherokee Group, Des Moines Series, Pennsylvanian Subsystem, from Richardson County Subsurface.

PENNSYLVANIAN SUBSYSTEM IN EASTERN WYOMING

Rocks of Pennsylvanian age outcrop in the Black Hills of South Dakota, in the Hartville Uplift of Eastern Wyoming and along the Rocky Mountain and Laramie Mountain Fronts in Colorado and Wyoming. The best development of these rocks occurs in the Hartville Uplift, northwest of Guernsey, Wyoming, where the following sequence has been measured (for details see Nebr. Geol. Surv. Bull. 13, pp. 24-35):

1. *Wendover group,* Condra, Reed and Scherer 1940 (Virgil Series), 106'–117'
2. *Meek group,* Condra, Reed and Scherer 1940 (Missouri Series), 109'–130'
3. *Hayden group,* Condra, Reed and Scherer 1940 (Des Moines Series), 121'6"
4. *Roundtop group,* Condra, Reed and Scherer 1940 (Des Moines Series), 142'6"
5. *Reclamation group,* Condra, Reed and Scherer 1940 (Des Moines Series), 82'
6. *Fairbank formation,* Condra, Reed and Scherer 1940 (Des Moines Series), 30'–100'

Rocks of equivalent age in the Black Hills of South Dakota were formerly included in the *Minnelusa formation,* Winchell 1875 and Darton 1901. At places along the Rocky Mountain Front in Colorado these rocks are represented, in large part, by arkosic sandstones which are known as the *Fountain formation,* Cross 1894. However, in the northern part of the Rocky Mountain Front the upper part of the Pennsylvanian is represented by interbedded limestones, dolomites and sandstones, which are classified as *Ingleside formation,* Butters 1913, and similar strata in the Laramie Range of Wyoming are included in the *Casper formation,* Darton 1908, and Knight 1929.

CORRELATION WESTWARD FROM SOUTHEAST NEBRASKA

The major subdivisions of the Pennsylvanian of the Nebraska-Kansas-Missouri outcrop areas can be satisfactorily carried through the subsurface of central and southern Nebraska and correlated with sediments in the subsurface of the Panhandle Region of Western Nebraska which are quite similar lithologically to the eastern Wyoming Pennsylvanian. The facial changes involved present some difficulties which will probably be removed when additional information is secured as the result of deep drilling in strategic areas. The following conclusions can now be made:

1. The Virgil Series can be carried through satisfactorily but the Wabaunsee group (Richardson, Nemaha and Sac-Fox subgroups) thins westward and may be missing along the Permian-Pennsylvanian unconformity in the western part of the state. The Shawnee and Douglas groups are believed to persist across the state but are increasingly less fossiliferous in a northwestern direction.

2. The Missouri Series persists westward and northwestward with some thinning, especially over the top of the Cambridge arch but the individual groups and formations of this series cannot be traced through very satisfactorily at the present time.

3. The Des Moines Series can be traced across the state but it is very thin and may be absent in places over the top of the Cambridge Arch. A satisfactory subdivision into Marmaton and Cherokee groups can usually be made but individual formations in the Marmaton cannot now be carried very far from eastern Nebraska with much satisfaction.

4. Certain difficulties arise in the westward subsurface correlation of units of the Pennsylvanian. Many of the formations near the outcrop areas are very distinctive and may be easily recognized in well samples but there is a strong westward tendency toward loss of identity in individual beds and a marked westward decrease in fossil content. Under these conditions it is necessary to depend too largely upon intervals between limestone and shale zones and resultant correlations may be only approximate.

ECONOMIC RELATIONS, PENNSYLVANIAN SUBSYSTEM

Clay and shale for brick and tile manufacture, stone for structural purposes and road building; limestone and shale for Portland cement manufacture, also, coal, oil and gas are produced from the Pennsylvanian formations in states bordering Nebraska. Some of the limestone and sandstone formations carry ground water used for domestic purposes and the land farmed on the rocks of this subsystem varies greatly with the nature of the rocks on which the soils were developed. Consequently the lands of this system of rocks differ much in their use capabilities.

Brick, tile and cement are manufactured from the Pennsylvanian formations in Nebraska and about thirty of the limestones are quarried for various uses as for road work, river control work and other purposes. Thus far we have made no economic discoveries of oil and gas in the formations of this age in Nebraska but drilling explorations are being made to determine the potentialities.

Coals known as the Lorton, under the Nebraska City limestone; the Nyman, under the Dover limestone; Elmo, under the Rulo limestone; and Nodaway, under the Howard limestone have been mined in a limited way from the Wabaunsee group in Nebraska, and various older beds, as the Lexington (Mystic) and the Summit of the Marmaton (Henrietta) group, are mined in Iowa and Missouri and thin out under our southeastern counties, as do the Mulky, Bevier, Tebo, Jordon and other coal horizons found in the Cherokee group. Unfortunately the chance for economic production of coal from the Pennsylvanian subsystem in Nebraska is not promising.

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MISSISSIPPIAN SUBSYSTEM

This subsytem outcrops prominently in south and southwest Illinois, southeast Iowa, northeast Missouri, the Ozark region of Arkansas, Oklahoma and southwest Missouri and in the Black Hills and Hartville uplifts of South Dakota and Wyoming. It underlies most of Nebraska, except in the with occasional thin coaly seams and concretionary zones, 52′

12. Shale, varicolored blue-gray, green-gray, red, and black, in part nodular, 14′
13. Shale, green-gray and maroon, laminated with common thin beds of sandstone, 7′
14. Shale, varicolored blue-gray, green-gray, and red, mostly laminated, 16′
15. Shale, green-gray and blue-gray, in part red, with some thin beds of fine-grained sandstone, 5′
16. Shale, blue-gray and black, fissile, with fairly common seams of coal, 25′
17. Shale, varicolored blue-gray, dark gray, maroon and yellowish, 13′
18. Shale, dark gray to black, laminated to fissile, 11′
19. Sandstone, medium light gray, fine to medium grained, micaceous, 14′
20. Shale, blue-gray, dark gray and black, in part sandy grading to argillaceous sandstone, 30′
21. Shale, black, fissile, common seams of coal, 17′
22. Sandstone, medium gray, micaceous, medium grained, 12′
23. Shale, black, fissile, some thin coal seams, 29′
24. Sandstone, in part arkosic and conglomeratic, 15′
25. Shale, dark gray to black, grading downward to argillaceous, fossiliferous limestone, 17′
26. Shale, black, in part gray, laminated to fissile, with some thin seams of coal, 56′
27. Limestone, dark gray to black, argillaceous, fossiliferous, 2′
28. Shale, black, in part gray, laminated to fissile, a thin coal seam about 19′ below top, 50′
29. Shale, black, fissile, and sandstone, light gray, medium grained and friable above, fine grained and argillaceous below, 43′
30. Shale, black, in part gray to yellowish, laminated, 27′
31. Sandstone, gray, fine-grained and argillaceous above, medium grained and friable in middle, fine grained and calcareous below, 54′
32. Sandstone, light gray, medium coarse, subangular, friable, 40′
33. Chert, light gray to white, largely weathered, and sandstone, as above, 11′

The thickness of the Cherokee group in the deeper parts of the Forest City Basin is variable depending upon the structural position of the wells drilled, the thicknesses varying from about 600 feet to more than 800 feet. This group is absent over the top of the Table Rock arch, west of the Forest City Basin and thins northward from its maximum development in Richardson and Nemaha counties to about 115 feet near Nebraska City, about 26 feet near Nehawka, about 100 feet at Omaha (structurally low), and it is absent in the vicinity of Sioux City, Iowa. It is only about 20 to 30 feet thick at Lincoln and thickens to 200 feet or more in the deeper parts of the Central Nebraska Basin. It is absent in many wells which are located structurally high on the Cambridge arch and probably thickens to several hundred feet or more in the deeper parts of the Julesburg Basin of western Nebraska.

The approximate upper 400 feet of the Cherokee in southeastern Nebraska, northwestern Missouri and eastern Kansas is thought to correlate with the upper part of the thick Cherokee section of Oklahoma. However, the age of the lower 300 feet classed as Cherokee in the Forest City Basin is not certain. It may be of the age of the lower beds of the group in Oklahoma but not as old as beds of the Morrow series. However, McQueen and Greene (1938, p. 30), suggest that this part of the section may, by further study, prove to be of Chester age. We hesitate to concur in this suggestion.

In regions where the Cherokee is thin it is usually represented largely by red and varicolored shales, with occasional thin limy seams, and often includes a basal detrital zone which may be sandstone or reworked chert or both. The record about 5 miles northwest of Nehawka is as follows:

Cherokee shale, 26′6″

1. Shale, reddish, mottled yellowish green, argillaceous, indurated, lumpy, brachiopodal, 5′
2. Shale, buff above, red below, argillaceous, finely micaceous, with a thin carbonaceous seam 1′6″ below top, 3′
3. Limestone (Ardmore?), dark gray, semi-crystalline, porous, brachiopodal, part brownish, 8″
4. Shale, buff at top, reddish in middle, dark gray at base, arenaceous, micaceous, laminated, 10′4″
5. Shale, dark blue-gray, silty, massive, 2′9″
6. Limestone, bluish gray to dark gray, dense, 6″
7. Shale, bluish gray, massive, with nodular calcareous material, 1′4″
8. Reworked material, dark gray and limy, indurated and conglomeratic, 2′
9. Shale, gray, argillaceous, with scattered pebbles, 1′

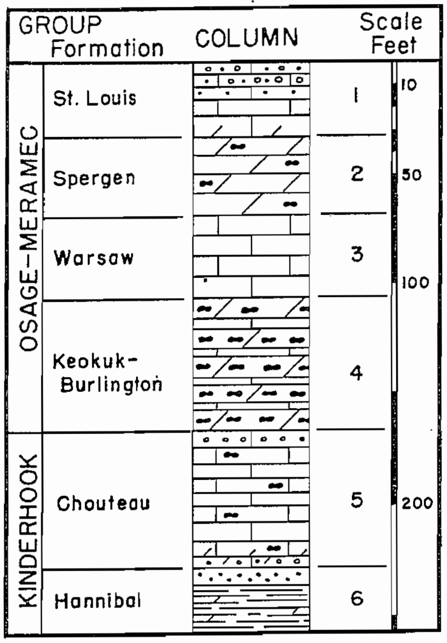

Figure 21.—Composite Columnar Section, Mississippian Subsystem, Subsurface Southeast Nebraska.

b. Limestone, light gray to white, cryptocrystalline, dense to lithographic, with occasional grains of embedded sand in upper part; grades downward into medium dark gray dense limestone, in part dolomitic, 23′

(2) *Spergen* (Salem) *dolomite,* brownish-gray, crystalline, vesicular, with some chert, in part light gray and conchoidal, in part dark and brown mottled, fossiliferous, 36′

(3) *Warsaw* (?) limestone, light gray to white, moderately coarsely crystalline, crinoidal, 36′–40′

(4) *Keokuk-Burlington* dolomite and limestone, light brown-gray to buff, crystalline, vesicular to sucrose, fossiliferous, with medium dark gray to light gray chert; thickness 56′–65′

2. *Kinderhook group,* 88′–110′:

(1) *Chouteau limestone,* light gray, medium light gray, and brownish gray, in part dark mottled, finely crystalline to lithographic; in part moderately coarsely crystalline and fossiliferous; occasionally with a dark mottled oolitic limestone at top and a white oolite at base; a small amount of gray-speckled granular chert; occasionally grades to dolomite as at Omaha; thickness, 52′–71′

(2) *Hannibal formation,* usually with a thin, fine-grained sandstone at the top, underlain by interbedded greenish-gray, finely micaceous shales and medium dark gray impure pyritic dolomites; in some localities includes brownish flattened oolitic limonite concretions embedded in the shale; combined thickness 20′–48′

NOTE: In this composite section the base of the Mississippian is placed at the top of a red hematite zone in the upper part of a thick greenish-gray shale sequence. The hematite and the shale below it are believed to be Upper Devonian in age.

SOUTH-CENTRAL NEBRASKA

The Mississippian has been drilled in a few wells in south-central Nebraska where the correlation of its subdivisions is not satisfactory, except to show that the uppermost beds may be as young as Warsaw and the oldest are correlative with the Hannibal. The Mississippian of this area is thought to extend northward and northwestward in the Central Nebraska Basin, playing out westward in the east flank of the Cambridge arch, probably as a result of truncation.

WESTERN NEBRASKA

The *Englewood,* Darton 1901, and *Pahasapa,* Darton 1901, limestones of Mississippian age outcrop in the Hartville and Black Hills uplifts and the *Madison,* Peale 1893, limestone, which probably is about correlative in age with the Pahasapa, is exposed at places in the Rocky Mountain region. However, wells have not been drilled to the Mississippian in the panhandle area of Nebraska west of the Cambridge arch, but a well near Wray, Colorado is logged as penetrating 175 feet of cherty, dolomitic Mississippian rock between 5270 and 5445 feet in depth. So, because of the position and attitude of their outcrops near the north and west borders of our state and because of the occurrence near Wray, Colorado, it seems safe to conclude that the Pahasapa and probably the Englewood limestone may extend from the Black Hills and Hartville Uplifts eastward for some distance into western Nebraska in a thickness decreasing from about 225 feet, and playing out by truncation in the west flank of the Cambridge Arch. And it can be noted with some assurance that the Mississippian formations were formerly connected across the axis of the Cambridge Arch but were eroded away and disconnected there sometime after the arch was formed.

ECONOMIC RELATIONS

The Mississippian horizons are sources of oil and gas production in Montana and Wyoming and, though deep, are potential sources in Nebraska.

Stone from the Pahasapa near Guernsey, Wyoming runs very high in calcium carbonate content and is used in large amounts by the Nebraska beet sugar factories. Some stone for this purpose is quarried from the Pennsylvanian formations at Horse Creek station and Granite Canyon located along the east flank of Laramie Range in Wyoming.

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DEVONIAN SYSTEM

Rocks of this system are well exposed in northeastern Iowa and adjacent areas and underlie most of the southeastern third of Nebraska, except in the Table Rock arch where Pennsylvanian rocks overly pre-Cambrian. They are most completely represented in Richardson, Nemaha and Otoe counties. Thicknesses vary from a few feet to a maximum of 560 feet near Nebraska City.

There has been much difference of opinion in regard to the position of the Devonian-Mississippian contact on the outcrop in the Upper Mississippi Valley region and complete agreement has not been reached to date. At least part and, in some cases, practically all of divisions 1 and 2 of the type section given below has been classified with the Mississippian by many geologists and paleontologists. We believe, however, that the present concensus of opinion is to regard these divisions as Devonian in age and we classify them accordingly, especially in view of the fact that there seems to be better evidence for a regional uncomfority at their top rather than at their base. The widespread occurrence of a zone of oolitic hematic at the top of these rocks in the subsurface of the Forest City Basin is strongly suggestive of uncomformity.

TYPE SECTION, NORTHEASTERN IOWA

According to Stainbrook, 1935, the Devonian System includes the following formations and members in northeastern Iowa:

1. *Sheffield shale* formation (Fenton 1919, blue to gray, soft shale, with thin interbeds of brown dolomite in lower part, large brown dolomite in upper part with thin interbeds of green and brown shale and thin-bedded gray limestone, 0–135′.

UNCONFORMITY.

2. *Lime Creek formation,* Williams 1883, 165′-190′
   (1) *Owen member,* Calvin 1897, limestone, buff, soft, subdomolitic, fossiliferous, 45′
   (2) *Cerro Gordo member,* Fenton, 1919, shale, bluish or buff, calcareous, fossiliferous, 30′–45′
   (3) *Juniper Hill shale,* Thomas, 1925, dark blue, plastic, sparsely fossiliferous, 90′–100′

UNCONFORMITY.

3. *Shellrock formation* (Thomas 1924), Balenski 1927, thickness, 4′–66′:

(1) *Nora member,* Thomas 1913, consists of limestone, with magnesium and shaly phases, *Stromotopora* common, 6′–20′
(2) *Rock Grove member,* Balenski 1926, consists of shaly limestones, impure dolomites and dolomitic shales, 16′–35′
(3) *Mason City member* (Calvin 1897), Balenski 1927, blue-gray limestone, lithographic limestone with dolomite, some shale layers, 10′–34′

UNCONFORMITY.

4. *Cedar Valley limestone formation,* McGee 1891, 90′–150′:
   (1) *Coralville member,* Keyes 1912, limestone gray to white, largely lithographic, in places dolomitic, sparingly fossiliferous, 12′–40′
   (2) *Littleton member* (Fenton and Fenton 1930), Stainbrook 1935, largely limestones, often argillaceous and shaly, fossiliferous, 21′–67′
   (3) *Linwood member,* Stainbrook 1935, composed of limestone, gray, resistant, coralliferous in upper part, middle part massive, lower beds gray, softer, fossiliferous, combined thickness, 21′–67′
5. *Independence shale,* Calvin 1878, bluish gray, soft, plastic, sparingly fossiliferous, with interbeds of blue or buff argillaceous limestone, 7′–20′

UNCONFORMITY.

6. *Wapsipinicon formation,* Norton 1895, 95′–140′:
   (1) *Davenport limestone* (Norton 1894), Stainbrook 1935, gray, lithographic, thin-bedded, more or less brecciated, 11′–45′

UNCONFORMITY.

   (2) *Spring Grove limestone,* Stainbrook 1935, subdolomitic, fine-grained, massive to finely laminated, 18′
   (3) *Kenwood shale,* Norton 1894, blue, soft, with intercalated blue, hard, argillaceous limestone, 18′
   (4) *Otis limestone,* Norton 1894, thin-bedded, fine-grained, sublithographic, 30′±
   (5) *Coggon member,* Norton 1894, dolomitic limestone, buff-colored, seams of dark chert in upper part, cavernous below, argillaceous and thin-bedded at base, 20′±.

NOTE: Thomas (1925) and Moore (1935) class the Sheffield shale with the Mississippian while Laudon (1929) and Branson (1941) place it in the Upper Devonian.

OCCURRENCE OF DEVONIAN IN EASTERN NEBRASKA

The Devonian rocks of Nebraska's subsurface may be separated into four natural parts. The upper part, consisting of blue-gray to green-gray shale with a zone of oolitic hematite at the top and with some thin dolomites or limestones in both the upper and lower parts and locally sandy at the base, is classified as Sheffield-Lime Creek. This is approximately the same zone that has been called Chattanooga in some areas and Kinderhook shale in others and it is probably the equivalent of the Grassy Creek-Saverton shale of Missouri. In some Nebraska wells a marked limestone development in the upper part is suggestive of the Louisiana limestone of Missouri. The thickness of this upper division at Forest City, Missouri is 77 feet, it increases to between 200 and 250 feet in much of Richardson and Nemaha Counties and thins northward to 100 feet at Nebraska City and 40 feet or less at Omaha. It is absent over the Table Rock-Nehawka arch and has not been recognized west of this line of folding. In areas where this shale division is relatively thick the underlying division is relatively thin and where it is thin the next lower division is relatively thick. There is some evidence that this condition is caused more by facial change than by unconformity.

The second division (from top) of the Devonian consists of dolomites and limestones which increase in thickness from a minimum of about 70 feet near Falls City to 150 feet in southeastern Nemaha County and a maximum of 240 feet near Nebraska City. Equivalent rocks at Forest City, Missouri may be over 200 feet in thickness.* In our opinion this division is, at least in part, equivalent to the Shellrock-Cedar Valley formation of Iowa and its upper part where thick, may be a time equivalent of at least a part of the overlying shale division.

The third division consists of greenish shales with some interbedded dolomites which usually vary in thickness from 10 to 30 feet but which locally increase to about 53 feet near Nehawka. We correlate this interval as the Independence shale of Iowa.**

The fourth and lowest division of the Devonian is quite widespread in Nebraska. Along the northwest and west margins of the occurrence of Devonian rocks in the

* Near Nehawka the division is 117 feet thick as the result of the removal of some of the upper beds by pre-Pennsylvanian erosion.

** Occasionally this shale is either very thin or absent, but usually it is well developed.

subsurface of the state it is very thin, and only the lower part is represented, the younger Devonian rocks having been removed by pre-Mississippian erosion. In eastern Nebraska it varies in thickness from 127 feet or less in southern Richardson County, to 190 feet at Nebraska City and 220 feet at Omaha. It consists of dolomite, in large part, with some interbedded limestones and a very distinctive zone of dolomitic sand or sand-embedded dolomite at its base. It is believed to be correlative with the Wapsipinicon formation of Iowa.

The term *Hunton* (Taff, 1902, 1903), has wide useage among the drillers and oil-operators in southeast Nebraska and, as now used by the geologists of most companies operating in the area, is restricted to the Devonian part of the Devonian-Silurian dolomite section. However, Hunton as originally defined, included rocks of both Devonian and Silurian age. Therefore we hesitate to follow the oil company geologists redefinition of Hunton and prefer to use the Iowa nomenclature for this interval in Nebraska.

It is difficult to construct one composite section of the Devonian that would be representative of the state. Therefore two detailed sections are given, the first being a partial record of a well drilled near Nebraska City, where we have the maximum dolomite and lime development, and the second is from a well located about two miles west of Falls City.

Section from Record of Well two miles north of Nebraska City.

1. *Sheffield-Lime Creek shale,* light green-gray, finely micaceous, 50′±
2. *Shellrock-Cedar Valley formation,* 240′:
   (1) Limestone, medium light and medium dark gray, moderately crystalline, crinoidal, 40′
   (2) Limestone, medium light and medium dark gray, finely granular to lithographic, 25′
   (3) Dolomite, light brown-gray, finely crystalline, dense, in part rhombic, 55′
   (4) Dolomite, brownish gray and medium gray, finely crystalline, dense, 80′
   (5) Dolomite, medium light and medium dark gray, in part brownish, finely crystalline, with some interbedded greenish-gray shale, 40′
3. *Independence shale,* 30′:
   (1) Shale, green to greenish-gray, calcareous, 10′
   (2) Dolomite, brownish gray and chocolate, finely crystalline, 10′
   (3) Shale, green and green-gray with some dolomite, 10′
4. *Wapsipinicon formation,* 193′:
   (1) Dolomite, chocolate-brown to brownish-gray, finely crystalline, 15′
   (2) Dolomite, medium light gray, finely crystalline, dense, some dark areas, in part vesicular, 40′
   (3) Dolomite, light gray to white, finely granular to sucrosic, with common rock crystal (clear crystalline quartz) in lower part, 25′
   (4) Dolomite, light gray and medium gray, finely granular and finely crystalline, some thin green shale seams, 30′
   (5) Dolomite, as above, with common quartzose chert, 7′
   (6) Dolomite, light gray to white, finely crystalline, 28′
   (7) Dolomite, light gray to white, finely granular, 7′
   (8) Dolomite, light gray to cream-colored, crystalline, 12′
   (9) Dolomite, light brown-gray to cream, crystalline, with common white, conchoidal to quartzose chert, 16′
   (10) Dolomite, white finely granular, with embedded rounded and frosted sand, 10′

Devonian Section from Well located 2½ miles West of Falls City. Figure 22.

Thickness about 422 feet:

1. *Sheffield-Lime Creek shale,* 214′:
   (1) Shale, rouge-red, with flattened hematite oolites, 10′
   (2) Shale, greenish, indurated, 9′
   (3) Limestones, light gray to yellowish, granular; some shale, as above, 14′
   (4) Shale, blue-gray to green gray, argillaceous, finely micaceous, in part dolomitic, 168′
   (5) Dolomite, medium dark blue-gray, argillaceous, pyritic, part silty; with common shale, as above, 13′
2. *Shellrock-Cedar Valley formation,* 74′
   (1) Dolomite, medium light gray, finely crystalline, dense, part oil-stained; some light gray, quartzose chert, 5′
   (2) Samples missing, dolomite reported, 17′
   (3) Dolomite, medium light gray and light brown-gray, finely crystalline; rare quartzose chert, 8′
   (4) Dolomite, brown-gray, crystalline, part vesicular, 20′
   (5) Dolomite, light gray to white, crystalline, dense, 12′

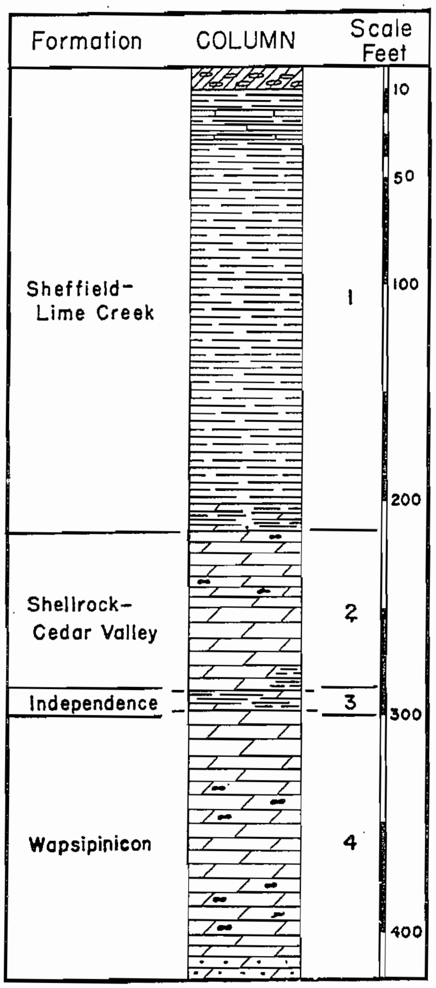

Figure 22.—Composite Columnar Section, Devonian System, Subsurface Southeast Nebraska.

(6) Dolomite, brownish gray to tan, crystalline, in part light gray to white, with a trace of green shale, 12′

3. *Independence formation,* dolomite, dark brown, in part light gray, crystalline; common shale, dark green, 10′

4. *Wapsipinicon formation,* 124′:
   (1) Dolomite, brown-gray to light gray, crystalline, 21′
   (2) Dolomite, light gray to white, coarsely crystalline, 11′
   (3) Dolomite, medium gray, finely crystalline to sucrose, part light gray to white; common white conchoidal chert and light gray quartzose chert, 20′
   (4) Dolomite, brownish gray, finely crystalline, dense to sucrose, 18′
   (5) Dolomite, light gray to white, moderately coarsely crystalline to rhombic; part brownish-gray, 7′
   (6) Dolomite, light gray to white, crystalline, part limy; some rock crystal (crystalline quartz), 26′
   (7) Dolomite, light brown-gray, finely crystalline, dense, common rounded and frosted sand in basal 10′, thickness 21′

CORRELATION NORTHWESTWARD

The Devonian rocks are found to thin rapidly westward and northwestward from the deeper parts of the Forest City Basin. The lowest division (Wapsipinicon) is the most extensive and the upper division (Sheffield-Lime Creek) is the most restricted, suggesting some tilting and westward truncation of these formations by post-Devonian erosion.

Devonian rocks are absent over the Cambridge Arch and may be found to be missing in the subsurface of the Julesburg Basin of Western Nebraska. Rocks tentatively assigned to the Devonian (*Williams Canyon formation,* Brainerd et al, 1933) occur at places along the Rocky Mountain front in Colorado, as at Canyon City, but have not been reported in the north part of the Rocky Mountain front nor in the Laramie Range, Hartville Uplifts and Black Hills. However, they outcrop in the Wind River Mountains and are believed to be present subsurface in eastern Montana and adjacent areas.

ECONOMIC RELATIONS

The Shellrock-Cedar Valley formation is the source of most of the oil production in Richardson County, Nebraska and Devonian dolomites and limestones also produce oil and gas in parts of Kansas, Oklahoma, Michigan, Illinois, and other states. The lowest production in the Falls City Field probably comes from the upper part of the Wapsipinicon. The Devonian dolomites are sources of groundwater in central and western Iowa and in the vicinity of Omaha, Nebraska.

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SILURIAN SYSTEM

The Silurian rocks occur widely in the region from New York to Nebraska. For example, beds of the Niagaran Series, named from Niagara County, New York, have been identified from their fossil content in eastern Nebraska. They lie at a depth of about 1200 feet at Lincoln.

TYPE SECTION, NORTHEASTERN IOWA

Silurian rocks are well exposed in northeast Iowa where they constitute two series, the Niagaran above and the Alexandrian below, and are classed under the following formations:

1. *Niagaran Series,* Hall 1842:
   (1) *Port Byron,* Savage 1926
   (2) *Racine dolomite,* Hill 1861
   (3) *Waukesha limestone,* Lapham 1851
   (4) *Joliet limestone,* Shufeldt, Jr. 1865
2. *Alexandrian Series,* Savage 1908:
   (1) *Kankakee limestone,* Savage 1916
   (2) *Edgewood limestone,* Savage 1909

OCCURRENCE IN NEBRASKA

Silurian rocks do not outcrop in Nebraska but occur in the subsurface of the east and southeast fourth of the state. Their greatest thickness is in Richardson and Nemaha counties, immediately east of the Table Rock Arch, and in Gage County, on the west flank of the Table Rock Arch, indicating that the Table Rock Arch was a geosynclinal area during the Silurian and received deposition. However, pre-Pennsylvanian erosion has removed all of the Silurian rocks from the higher parts of the Table Rock Arch. Thicknesses penetrated in these areas range from 375 to 450 feet. These rocks thin generally in a west and northwest direction by the disappearance of their upper layers, the result of tilting, truncation by post Silurian erosion, and overlap of Devonian strata. It is reported that a similar thinning occurs in a southerly direction in Kansas and southeastwardly in Missouri.

Much of the Silurian in the subsurface of Nebraska has been dolomitized to the extent that fossil structure has been largely altered thus preventing detailed correlations with the type section of Iowa. However, some cores of Silurian rocks have yielded coral remains which establish a Niagaran age for at least the upper and middle parts of these dolomites. Therefore we classify them as Niagaran although there is some possibility that the lowermost Silurian in Nebraska may correlate with the Alexandrian of Iowa.

An aggregate thickness of 423 feet of Silurian rocks, herein classified as Niagaran, was drilled in a well located about three miles southwest of Falls City. Figure 23. This record is as follows:

1. Dolomite, light gray to white, crystalline, part limy, 131′
2. Dolomite, as above, with interbedded shale, pale green, waxy, 2′
3. Dolomite, light gray to white, crystalline, 35′
4. Dolomite, as above, with some thin interbeds of blue-gray and pale green shale, 10′
5. Dolomite, light brownish gray, crystalline, 50′
6. Dolomite, light gray to white, finely to moderately crystalline, with some crystalline secondary quartz, 136′

7. Dolomite, as above, with common chert, white, tripolitic, conchoidal to irregular, 14′
8. Dolomite, light gray, moderately crystalline, in part very porous, in part pinkish to salmon-colored, with fairly common conchoidal to tripolitic chert in lower part. (Many other wells show a typical zone of oolitic dolomite at the base of this interval), 44′

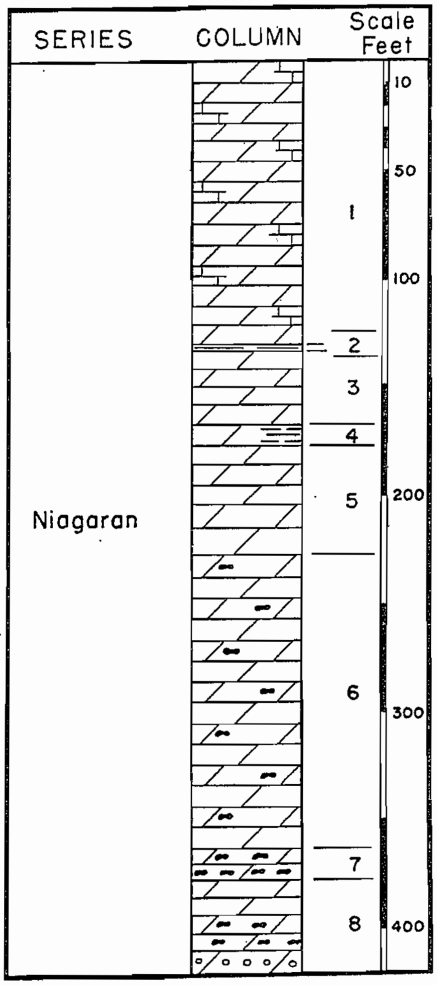

Figure 23.—Composite Section, Silurian System, Subsurface Southeast Nebraska.

The northward thinning of the Silurian is indicated by the following record from the core-drilled well of the Amerada Petroleum Company, located northwest of Nehawka in Cass County, where 262 feet 6 inches of Silurian rocks were drilled:

1. Dolomite, grayish, part brownish- mottled, crystalline, mostly vitreous, pyritiferous, pitted, with the fossils *Favosites niagarensis*, and *Halysites catenulatus*, thickness, 187′6″
2. Dolomite, light gray, fine-grained to amorphous, with small scattered bodies of broken-down silica, and some pyrite, 28′6″
3. Dolomite, light gray and light bluish gray, amorphous to fine-grained, with some broken-down silica and pyrite, 38′
4. Broken-down silica, nearly white, soft, 1′1″
5. Chert, bluish to brownish, 5″
6. Broken-down silica, nearly white, soft, 7′6″

Note: We do not try to correlate the Nebraska Silurian as groups and formations, yet it appears that the section here, though truncated at the top, is largely of Niagaran age.

CORRELATION WESTWARD

The Silurian thins progressively westward in the subsurface of Nebraska from its maximum development in Richardson, Nemaha and Gage counties and is absent on the higher parts of the east flank and over the top of the Cambridge Arch. The occurrence of Silurian rocks in the Julesburg Basin region of western Nebraska has not been proven by drilling. However, no wells in Nebraska and only a few wells in northeastern Colorado have been drilled deeply enough to penetrate the Silurian if it does occur in the panhandle area. Subsurface studies in eastern Nebraska indicate a northwestward and northward thinning and disappearance of Silurian rocks in these directions.

SILURIAN ECONOMIC RELATIONS

Silurian rocks are utilized for building purposes, for the manufacture of rock wool, etc., in their area of outcrop, but they are too deeply buried in Nebraska for utilizations of this nature under present conditions. These rocks, however, form an important groundwater reservoir in Iowa and in the vicinity of Omaha, Nebraska. However, the southwestward increase in dissolved mineral matter away from the region of outcrop results in too high mineralization for many uses in eastern Nebraska, especially in view of the availability of shallower sources of better quality groundwater.

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ORDOVICIAN SYSTEM

TYPE SECTION, NORTHEASTERN IOWA

Ordovician rocks outcrop in northeastern Iowa and adjacent areas and underlie central and western Iowa and eastern Nebraska, except over the top of the Table Rock Arch. They are classified in northeastern Iowa as follows:

1. *Cincinnattian Series*, Schuchert and Twenhofel, 1910:
   (1) *Richmond group*, Winchell and Ulrich 1897:
      a. *Maquoketa formation*, White 1870
2. *Mohawkian Series*, Clarke and Schuchert 1899:
   (1) *Trenton group*, Vanuxem 1838 (*Galena*, Hall 1851):
      a. *Dubuque formation*, Sardeson 1907
      b. *Stewartville dolomite*, Ulrich 1911
      c. *Prosser limestone*, Ulrich 1911
      d. *Decorah shale*, Calvin 1906
         (a) *Ion member*, Kay 1928
         (b) *Guttenberg limestone*, Kay 1928
   (2) *Black River group*, Vanuxem 1842:
      a. *Platteville formation*, Bain 1905:
         (a) *Spechts Ferry member*, Kay 1928
         (b) *McGregor member*, Trowbridge 1935
         (c) *Pecatonica member*, Hershey 1894, Trowbridge 1935
         (d) *Glenwood member*, Calvin 1906
3. *Chazyan Series*, Emmons 1842
   a. *St. Peter sandstone*, Dake 1918

UNCONFORMITY.

4. *Beekmantownian Series*, Clarke and Schuchert 1899:
   (1) *Prairie du Chien group*, Bain 1906:
      a. *Willow River limestone*, Wooster 1882 (*Shakopee dolomite*, Winchell 1874)
      b. *New Richmond sandstone*, Wooster 1878
      c. *Oneota dolomite*, McGee 1891

ORDOVICIAN IN THE BLACK HILLS OF SOUTH DAKOTA AND THE ROCKY MOUNTAIN FRONT OF COLORADO

Formations of this age have been described in the Black Hills of South Dakota and along the Rocky Mountain Front in Colorado. They are generally absent in the southern Black Hills, but the Whitewood dolomite (Darton 1904) of the Upper Ordovician (Trenton or Richmond) age occurs here in a maximum thickness of about 80 feet. According to Furnish, Barragy, and Miller (1936) the upper 70 feet of the Deadwood formation (Darton 1901) of the type locality which underlies the Whitewood has been found to be Ordovician, probably Black River in age. The Deadwood formation was originally classified as Cambrian.

Two formations, which outcrop in places along the Rocky Mountain Front, are classified as Ordovician. The uppermost of these, the *Fremont limestone* (Walcott 1892) is 250 to 370 feet in thickness and is believed to be Richmond and Trenton in age. It is underlain by the *Harding sandstone* (Walcott 1892), 85 to 150 feet thick, which is believed to be late Black River or early Trenton in age.

SUBSURFACE OCCURRENCE IN NEBRASKA

(See Figure 24)

Upper Ordovician (*Cincinnattian* to *Chazyan* Series) rocks underlie southeastern Nebraska and are readily divisible into three zones of which the upper one is correlated with the Maquoketa (*Sylvan*, Taff 1902, of Oklahoma) the middle one is referred to the *Stewartville-Prosser* or "Galena" of the Upper Mississippi Valley and correlates at least in part, with the *Kimmswick*, Ulrich 1904, of Missouri and the *Viola*, Taff 1902, of Oklahoma, and the fourth is equivalent to the *Simpson*, Taff 1902, of Oklahoma and to the *Platteville-St. Peter* of the Upper Mississippi Valley region. The upper Ordovician rocks immediately underlie the Silurian dolomite or unconformably underlie yet younger rocks and rest with unconformity on Lower Ordovician (*Prairie du Chien group*), Upper Cambrian or pre-Cambrian rocks.

The *Maquoketa* (Richmond) interval varies in thickness from 25 to 90 or more feet and is known to occur only in the subsurface of the southeast one-fourth of the state. It is characterized by a variable lithology, in some occurrences being represented almost entirely by greenish-gray shale and in other occurrences it consists predominantly

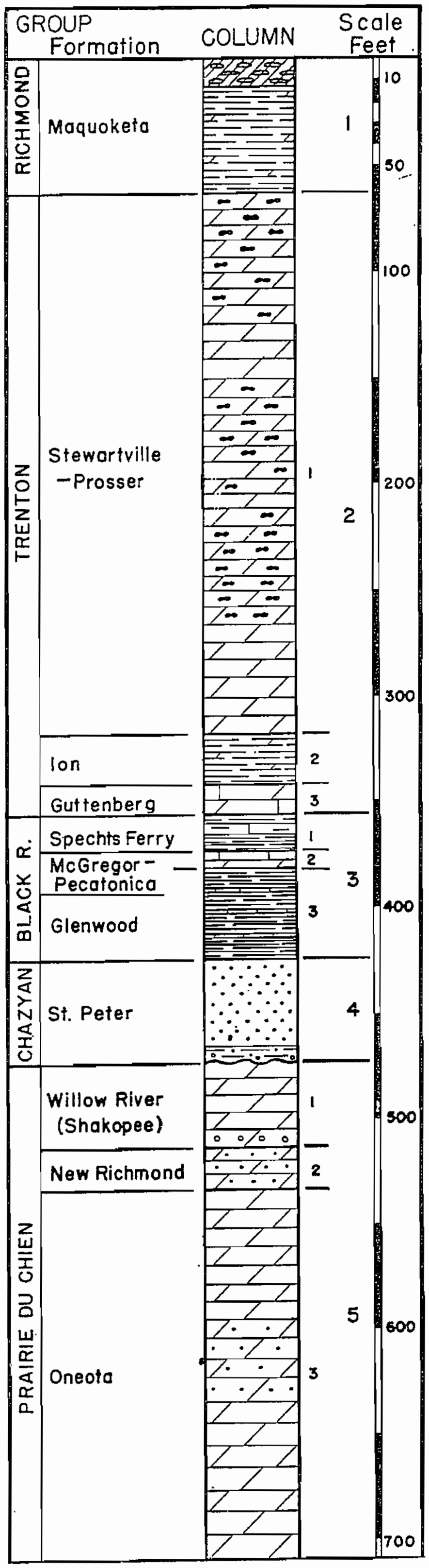

Figure 24.—Composite Columnar Section, Ordovician System, Subsurface Southeast Nebraska.

of light gray to white, granular, limy dolomites with minor amounts of shale. Its top is often marked by a zone of oolitic hematite concretions which are believed to be equivalent to the *Neda formation* (Savage and Ross 1916) of southeast Wisconsin and northeast Iowa. The shale phase, as drilled in a well located five miles south of Dawson, Richardson County is as follows.

1. Shale, deep maroon, with common oolitic, hematite concretions, 13′
2. Shale, dark greenish gray, dolomitic, 50′

The dolomite phase, as drilled in a well located 2 miles northwest of Nebraska City, Otoe County, is as follows:

1. Shale, red, with embedded oolitic hematite and some pink-stained dolomite, 9′
2. Shale, bluish gray, about 1′
3. Dolomite, light gray, in part pinkish, finely granular, part calcareous, with some interbedded dark gray-blue to green gray shale, 12′
4. Dolomite, as above, and greenish gray shale, 16′
5. Dolomite, light gray, finely granular, in part finely crystalline, wtih fairly common interbedded dark gray shale, 15′
6. Shale, dark gray, with common dolomite, as above, 10′
7. Dolomite, light gray, finely crystalline to finely granular, with common dark gray shale and some white conchoidal chert, about 15′

The *Trenton group* is well represented in the subsurface of eastern Nebraska and is more extensive in its occurrence than the overlying *Maquoketa formation*. We do not attempt to subdivide the *Trenton* into all of the formations recognized on the outcrop in Iowa but divide the Trenton into three divisions, i.e., an upper dolomite which probably represents both the *Stewartville* and the *Prosser* and which may include some rocks equivalent to the *Dubuque formation* where a thick section is represented; a middle division which is correlated with the *Ion member* of the *Decorah formation;* and a lower division which is classified as the *Guttenberg*. In some wells the *Ion* and *Guttenberg* cannot be satisfactorily separated from the higher beds of the Trenton group.

The *Dubuque-Stewartville-Prosser,* where it is overlain by *Maquoketa* shale, usually varies in thickness from about 250 feet, as at Kansas-Nebraska line in Richardson County, to about 370 feet, as at South Omaha, Douglas County. This northward thickening appears to result from the addition of higher beds of the Trenton. The Dubuque-Stewartville-Prosser thins and disappears westward and northwestward in the subsurface of eastern Nebraska where rocks younger than Maquoketa rest upon it. Two sections of these rocks are given for the purpose of comparison.

Dubuque-Stewartville-Prosser in well at South Omaha, Douglas County. Thickness about 370 feet:

1. Dolomite, light gray, coarsely crystalline, pyritic, with much white conchoidal chert, 130′
2. Dolomite, light gray to white, crystalline to rhombic, friable, 70′
3. Dolomite, light gray, finely crystalline, slightly pyritic, with much white, conchoidal chert, 55′
4. Dolomite, medium dark gray, coarsely crystalline, and chert, white conchoidal, some olive green, indurated, finely micaceous shale, 35′
5. Dolomite, brownish gray to buff, finely to moderately crystalline, pyritic, iron-stained, 80′

A thinner section correlated as Stewartville-Prosser, which is typical in the area farther to the south, is taken from the record of a well located 4 miles southwest of Falls City, Richardson County, as follows:

1. Dolomite, medium gray, crystalline, sandy-appearing, and chert, medium light gray and dark speckled, conchoidal, 30′
2. Dolomite, light gray and moderately dark gray mottled, moderately coarsely crystalline, some chert as above, 32′
3. Dolomite, light gray, moderately coarsely crystalline, part iron-stained, 23′
4. Dolomite, as above, and chert, light gray to white, conchoidal to slightly tripolitic, 38′
5. Dolomite, as above, small amount of chert, 30′
6. Chert, white, conchoidal, dark speckled, underlain by medium gray dolomite, crystalline, combined thickness 46′
7. Dolomite, medium gray, moderately coarsely crystalline to rhombic, in part pyritic, 35′
8. Dolomite, medium dark gray mottled to dark brown in lower part, moderately coarsely crystalline, pyritic, 17′

The most detailed record of the Upper Ordovician in Nebraska is from the record of a core-drilled well located about four miles northwest of Nehawka, Cass County, as follows:

1. *Cincinnattian Series,* Richmond Group, Maquoketa formation absent
2. *Mohawkian Series,* 338′7″:
   (1) *Trenton group,* 271′7″:
      a. *Stewartville-Prosser formation,* 233′-1″:
         (a) Dolomite, medium dark gray, largely crystalline, fine-grained, pyritic, with clay in cavities and some broken down silica, 74′7″
         (b) Dolomite, medium dark gray, argillaceous, with *Escharopora,* 21′
         (c) Dolomite, grayish, crystalline, part pitted, 16′
         (d) Dolomite, medium light gray, fine grained, with some light siliceous material, 51′
         (e) Dolomite, gray to brownish, vitreous, pyritic, pitted in places, 70′6″
      b. *Ion shale formation,* dark gray, with some dolomitic layers in middle, with *Isotelus* sp., *Plectambonites sericeus,* and *Dalmanella* sp., 23′10″
      c. *Guttenberg formation,* limestone or dolomite, brownish to dark gray, argillaceous at top and bottom, 14′8″
   (2) *Black River group,* 67′:
      a. *Platteville formation,* 67′:
         (a) *Spechts Ferry shale,* 17′
            ((a)) Shale, dark gray to greenish, some calcareous material, with *Rhinidictya, Homotrypa, Monticulopora, Rhynchotrema, Plectambonites,* etc., 3′4″
            ((b)) Limestone, dark gray to brownish, shaly at base, 5′1″
            ((c)) Shale, dark gray to greenish, with thin limestone seams at top and base, 8′7″
         (b) *McGregor-Pecatonica limestone,* brownish, fine-grained, dense, with *Rafinesquina* sp., *Trematis ottawaensis,* 7′2″
         (c) *Glenwood shale,* dark gray to dark greenish gray, with thin seams of light gray limestone, upper 9′4″ fossiliferous, with *Rafinesquina, Dalmanella* and *Pionodema subaequata,* 42′10″
3. *Chazyan Series,* 49′:
   (1) *St. Peter group,* 49′:
      a. *St. Peter sandstone formation,* 49′:
         (a) Sandstone, dark gray to light mottled, pyritic, 18′
         (b) Sandstone, gray to buff, fine-grained, pyritic, friable, 22′10″

(c) Shale, dark gray, sandy, 1′4″
(d) Shale, dark gray, argillaceous, 6″
(e) Conglomeratic, dark pebbles in gray sand, 2′
(f) Conglomerate, like above, with fragments of oboloid brachiopods and some petroleum residue, 6″
(g) Sandstone and sandy shale, dark gray-mottled, with some poorly preserved fossil fragments, 1′3″
(h) Shale, dark indurated, argillaceous 10″
(i) Conglomerate, with dark pebbles and fragments of oboloid brachiopods, 1′3″
(j) Conglomerate, with dark pebbles and fragments of oboloid brachiopods, 3½″

UNCONFORMITY ON PRE-CAMBRIAN.

NOTE: The Prairie du Chien group (Beekmantownian) is missing at Nehawka due to non-deposition or erosion.

The Prairie du Chien group *Beekmantownian* is most completely represented in the central Nebraska Basin where the following composite section, with a thickness of 236 feet, was penetrated in wells south of Riverton, Franklin County, and northwest of Holdrege, Phelps County:

1. *Beekmantownian Series, 236′:*
   (1) *Prairie du Chien group, 236′:*
      a. *Shakopee (Willow River) dolomite,* light gray to cream-colored, with oolitic chert and silicified oolites at the base, 41′. Probably equivalent to *Jefferson City* (Winslow 1894)-*Cotter* (Purdue and Miser 1916) of Missouri
      b. *New Richmond sandstone,* fine-grained, dolomitic, grades to sandy dolomite, 20′. Probably the *Roubidoux* (Nason 1892) of Missouri
      c. *Oneota dolomite,* light gray to white, in part cream-colored, crystalline (fine-cuttings), in part ferruginous; includes a forty foot zone of somewhat sandy dolomite 60 feet below the top; thickness 175′. Probably the *Gasconade* (Nason 1892)-*Van Buren* (McQueen 1930) of Missouri

CORRELATION WESTWARD

Ordovician rocks occur extensively in the subsurface of southeastern Nebraska except over the higher parts of the Table Rock Arch. The Upper Ordovician (Cincinnattian to Chazyan) rocks are present in the upper flanks of the Table Rock Arch and occur over the higher parts of the Redfield and Nehawka arches while the Beekmantownian is limited in its occurrence to the basin regions and lower flanks of the important uplifts. The result is that the Chazyan and, in some cases the Black River groups, rests upon Beekmantownian rocks in part, on Cambrian sediments in part, and on pre-Cambrian in part.

Ordovician rocks are missing over the Cambridge Arch where they appear to have been uplifted and eroded from the structurally higher areas and have been thinned by truncation on the flanks. They are believed to occur to some extent in the subsurface of the Julesburg basin region of western Nebraska although no wells have been drilled deeply enough to prove or disprove its occurrence there. Some northeastern Colorado wells have drilled Ordovician rocks and their occurrence at places along the Rocky Mountain Front and in the Northern Black Hills supports an opinion that they will be found to be present in parts of the Panhandle area of western Nebraska.

ECONOMIC RELATIONS

The more permeable formations of the Ordovician are important sources of groundwater in Iowa and they produce some water in deep wells at Omaha and South Omaha. Mineralization of the Ordovician groundwater increases to the west to the extent that these groundwaters in Nebraska are not well suited to extensive use.

Ordovician rocks are important producers of oil and gas in Kansas, Oklahoma, and other states. The Viola, Simpson, and rocks in part equivalent to Prairie du Chien, are the principal oil producing formations of the Ordovician in Kansas and Oklahoma. The Stewartville-Prosser dolomite (Viola) produces some oil in the Dawson Field in Richardson County, Nebraska but only small oil shows have been found in these rocks in the Falls City Field.

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CAMBRIAN SYSTEM

This system is exposed in northeastern Iowa and adjacent areas and continues in the subsurface southwestward across Iowa into Nebraska. It is known to occur quite widely in the eastern part of the state except in the structurally high areas.

All of the Cambrian rocks in this general region are referred to the Upper Cambrian, the Middle and Lower Cambrian being absent. The uppermost division of the following type section, the Madison sandstone, is most generally included with the Cambrian but Ulrich (1911) places it in his "Ozarkian System" which he sets up to include the lower part of the Beekmantown (Oneota) which we classify here as Ordovician.

TYPE SECTION, UPPER MISSISSIPPI VALLEY

The type section of the Upper Cambrian in the Upper Mississippi Valley region, according to G. O. Raasch 1935, is as follows:

I. *St. Croixan Series,* Walcott 1914:
   1. *Madison formation,* Irving 1875, Ulrich 1936, thickness up to 60′, (included by some with underlying Trempealeau formation)
   2. *Trempealeau formation,* Thwaites 1923:
      (1) *Jordan sandstone,* Winchell 1872, thickness 60′–90′
      (2) *Lodi shale,* Thwaites 1923, thickness 2′–40′
      (3) *St. Lawrence dolomite,* Thwaites 1923, thickness ½′–20′
   3. *Franconia formation,* Berkey 1897, thickness 125′–180′:
      (1) *Bad Axe member,* Raasch, 1935
      (2) *Hudson member,* Wooster 1878
      (3) *Goodenough member,* Raasch 1935
      (4) *Ironton member,* Thwaites 1923, 3′–45′
   4. *Dresbach formation,* Winchell 1886, about 400′:
      (1) *Galesville member,* Trowbridge and Atwater 1934
      (2) *Eau Claire member,* Walcott 1914
      (3) *Mt. Simon member,* Walcott 1914

The Upper Cambrian section in Missouri is well known and the Missouri terminology is widely used in subsurface work in northwestern Missouri and Kansas. Therefore, the approximate equivalency of the Missouri terms to those of the above type section is given here. The *Davis formation,* Buckley 1907, is probably in part equivalent to the Jordan sandstone; the *Bonneterre dolomite,* Ulrich and Bain 1905, is probably equal to the Franconia formation and may include the lower part of the Trempealeau formation; and the *LaMotte,* Winslow 1894, is equivalent to the Dresbach formation. The term *Arbuckle,* Taff 1902, has wide usage among oil company geologists but includes not only Cambrian rocks but also the overlying Beekmantownian dolomites of the Ordovician.

THE CAMBRIAN IN EASTERN NEBRASKA

The following section of Cambrian rocks, (Figure 25) taken from the record of a well located 4 miles southwest of Falls City, Richardson County, is representative of these rocks in the Forest City Basin region of the state:

I. Upper Cambrian (*St. Croixan*) Series, 153′+:
  1. *Madison* or *Jordan sandstone,* light gray, fine-grained, angular, interbedded with dolomite, 24′
  2. *Trempealeau* (?)-*Franconia formation,* 110′:
     (1) Dolomite, light gray, crystalline, non-glauconitic, 31′
     (2) Dolomite, light gray and medium dark gray mottled, moderately crystalline, glauconitic, 59′
     (3) Dolomite, light gray, moderately crystalline, 20′
  3. *Dresbach sandstone,* light gray, subangular, in part rounded and frosted, medium coarse in upper part, fine to coarse-grained below, 19′ drilled, base not reached

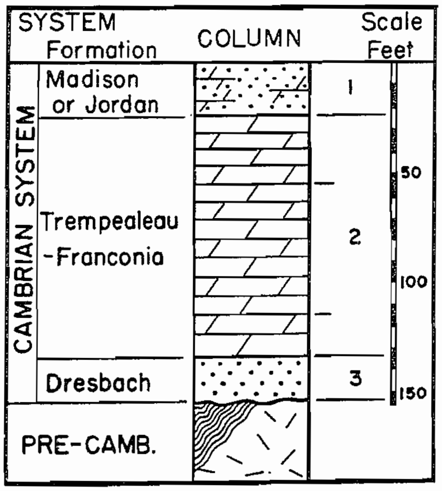

Figure 25.—Composite Columnar Section, Cambrian System, Subsurface Southeast Nebraska.

Equivalent rocks in the Central Nebraska Basin region are shown by the following composite section, made from the records of wells drilled 5 miles southwest of Riverton, Franklin County, and 4 miles northwest of Holdrege, Phelps County, as follows:

I. Upper Cambrian (*St. Croixan*) Series, 150′:
  1. *Madison* or *Jordan sandstone,* light gray, fine to medium grained, largely subangular, in part rounded and frosted, dolomitic, ferruginous, 59′–65′
  2. *Trempealeau* (?)-*Franconia dolomite,* light gray to buff, crystalline, very sandy, glauconitic, 70′
  3. *Dresbach sandstone,* moderately coarse-grained, subrounded to subangular, glauconitic, about 15′

UPPER CAMBRIAN IN EASTERN COLORADO, EASTERN WYOMING AND THE BLACK HILLS OF SOUTH DAKOTA

Several formations of Cambrian age have been recognized in parts of Colorado, Wyoming and South Dakota. The *Sawatch sandstone,* Eldridge 1894, is mapped at places along the Rocky Mountain Front in Colorado but appears to be completely overlapped by younger formations along the northern part of the Rocky Mountain Front and on the east flank of the Laramie Mountains in Wyoming. However, sandstones which are believed to be upper Cambrian in age, occur in the Hartville area near Guernsey, Wyoming and these have been correlated with the Upper Cambrian *Deadwood formation,* Darton 1901, of the Black Hills of South Dakota.

CORRELATION WESTWARD ACROSS NEBRASKA

Cambrian rocks occur widely in the subsurface of eastern Nebraska except over the top of structurally high areas such as Table Rock, Redfield, and Nehawka-Richfleld arches. They thin westward and northwestward usually by the absence of their upper formations and are missing over the top of the Cambridge Arch. West of the Cambridge Arch their occurrence has been proven by a well drilled 8 miles southeast of Trenton, Hitchcock County, where 140 feet of Cambrian dolomites and sandstones were found below Pennsylvanian beds resting on pre-Cambrian rocks. Drilling in the Julesburg Basin region of western Nebraska has not been deep enough to date to reach Cambrian rocks so we are not sure of the presence of Cambrian formations in that area, but we may expect to find a transition from the dolomite and sandstone phase such as is common in the subsurface of central and eastern Nebraska into the dominant sandstone phase of the Deadwood and Sawatch sandstones.

ECONOMIC RELATIONS

Cambrian rocks are too deeply buried in Nebraska to be available for the usual stone uses under present conditions. Although the Cambrian is not as important a producer of oil and gas as the Ordovician, some production in central Kansas is credited to these formations. Cambrian sandstones and dolomites are important groundwater reservoirs in Iowa and they yield some water to deep wells at Omaha, and their Black Hills equivalent, the Deadwood sandstone, is an important water producer around the Black Hills of South Dakota, where it is not too deeply buried.

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PRE-CAMBRIAN SYSTEM

OCCURRENCE IN NEBRASKA

The rocks of sedimentary origin in the subsurface of Nebraska, ranging in age from Cambrian to Pennsylvanian, rest upon a complex of igneous and metamorphic rocks which are classed together as pre-Cambrian. Relatively little is known regarding the pre-Cambrian of the state because relatively few deep wells have reached these horizons and because there is no particular incentive to penetrate sufficient thicknesses of them to establish their succession and relationships. They probably continue to indefinite depth and are not likely sources of important water supplies or commercial accumulations of oil and gas. Wells drilled in Nebraska which have reached pre-Cambrian rocks have encountered the following lithologic types: granites, quartzites, schists and related rocks.

The depth to pre-Cambrian rocks is variable in Nebraska, depending upon geologic structure. These old rocks are only slightly more than 500 feet in depth under the Table Rock Arch in southeastern Pawnee County in what was named in Kansas the buried "Nemaha Mountains." In the deeper parts of the "Forest City Basin" in central Richardson County the depth to pre-Cambrian is about 3800 feet or more and the pre-Cambrian surface lifts northward to a depth of 1567 feet at Nehawka, 1313 feet near Louisville and 1030 feet near Sioux City, Iowa. At Omaha it is about 2000 feet in depth. Immediately east of Lincoln the pre-Cambrian was reached at 1805 feet and west of the city it was found at about 2193 feet. The maximum drilled depth in the Central Nebraska Basin is 4526 feet near Holdrege, the surface generally rising northward to Bassett where it was reached at about 2800 feet and probably occurs at still shallower depths to the north and northeast as the Sioux Uplift is approached. It has been drilled along the crest of the Cambridge Arch at the following depths: 3490 feet, 8 miles southwest of Beaver City; 3185 feet, 10 miles northwest of Cambridge; 3320 feet, 5 miles northwest of Lexington; 3825 feet, 9 miles north of North Platte; 4030 feet, 4 miles northeast of Hyannis; 2805 feet, 2 miles south of Hay Springs; and 2840 feet, 15 miles northeast of Chadron. No wells have been drilled to the pre-Cambrian in the deeper parts of the Julesburg Basin but it was reached at a depth of 4460 feet, 8 miles southeast of Trenton, at 5580 feet near Wray, Colorado, at 6930 feet, 14 miles southwest of Yuma, Colorado, and is believed to occur at a depth of 7500 feet or more in the southwestern part of the panhandle region of western Nebraska.

The interrelations of the granitic and metamorphic rocks, which comprise our pre-Cambrian, is not clearly understood because of insufficient information. To date there is no record of any well in Nebraska which has drilled through metamorphic rocks into granitic rocks or vice versa so that we cannot establish the relative ages of these two classes of material although a well near Table Rock penetrated the granite about 750 feet, a well near Jefferson, South Dakota drilled over 500 feet of granite, one at Wagner, South Dakota, more than 3500 feet of quartzite and similar rocks, and more than 1100 feet of schistose rocks were drilled near Holdrege, Nebraska. The depth of penetration of the pre-Cambrian in the other Nebraska records is relatively small. The quartzites drilled seem to be lithologically similar to the *Sioux quartzite formation,* White 1870, of eastern South Dakota and adjacent areas. All information to date seems to indicate that granitic rocks generally underlie the structurally higher areas and that metamorphic rocks occur in the structurally lower areas. The pre-Cambrian material drilled in the deep well just east of Lincoln seems to be quartzite with some intruded basic igneous rocks.

In adjoining states pre-Cambrian rocks outcrop in the Ozark Mountains of southeast Missouri, in the Sioux uplift of southeastern South Dakota, in the Black Hills of South Dakota, at places in the Hartville Uplift and adjacent areas, in the Laramie Mountains of Wyoming and in the Rocky Mountains of Colorado. They are believed to occur at variable depths under the entire state of Nebraska.

PRE-CAMBRIAN ECONOMIC RELATIONS

Although the pre-Cambrian rocks are sources of much stone in states where they outcrop, they are too deep for mining in Nebraska under present conditions. However, use is made of Sioux quartzite and granite boulders which were brought in from the north by glaciers and occur in the drift deposits.

With the search for strategic minerals in the rocks of pre-Cambrian age, an incentive has been created for the analyses of the cuttings and cores of all deep wells, and should a discovery of such minerals be made in a well ending in the pre-Cambrian rocks of Nebraska it probably would result in extended exploration.

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CONCLUSIONS AND PRACTICAL RELATIONSHIPS

Studies of the surface and subsurface formations of Nebraska indicate that rocks ranging in age from Pre-Cambrian to Recent are present in Nebraska and that they correlate with rocks of the same age in adjacent states.

The pre-Cambrian rocks, of igneous or metamorphic origin, are believed to continue to indefinite depth but the top of these old rocks is found at variable depth in the state depending upon geologic structure.

Rocks of sedimentary origin, ranging in age from Cambrian to Recent, rest upon the pre-Cambrian and aggregate in thickness more than 13,000 feet of shale, sandstone, limestone, dolomite, gypsum, anhydrite, salt, clay, coal, sand and gravel. However, all of the thickness of these rocks is not present at any one locality in the state because many subdivisions were either not deposited in certain areas or were removed by erosion after deposition. The result is a complicated picture controlled by geologic history and resulting in a range in total thickness of sedimentary rocks from a minimum of about 500 feet, as in southeast Pawnee County, to a maximum of probably

8000 feet or more, as in the structurally deeper parts of the Julesburg Basin region of Western Nebraska.

The study of the classification and correlation of the rocks of our state has a definite practical value to all of our citizens and it is equally as important to know the materials under the land, as it is to be familiar with the surface materials.

The kind of rock material which occurs at or near the surface controls the shape and nature of the land forms that result from the erosion of these materials as well as the types of soil which are developed upon them by weathering processes. The form of the land and the nature of the soil, along with the climatic factor, influence the vegetation, land use and, to some degree, agricultural procedure. Furthermore, the study of the surface formations has revealed the economic possibilities of the outcropping and near surface materials and has contributed much to the development of our rock, sand and gravel, clay and shale, pumicite and other mineral resources. Likewise this study has assisted materially in discouraging futile attempts to develop non-economic deposits.

The practical value of knowing what materials occur at depth in various parts of the state is not generally appreciated. The nature of the subsurface formations determines the possibility of developing groundwater for farm, municipal, irrigation and industrial use. We need to know the underlying formations to evaluate the possibilities of developing buried deposits of economic value, such as salt, gypsum, coal, oil, gas and the metallic minerals. For example, if we know that certain geologic horizons produce commercial amounts of oil and gas in adjoining states, we can advise as to the probable depth at which these formations will be encountered in deep wells in Nebraska and can carefully examine samples from these horizons for evidences of petroleum. Continual vigilance is used in studying deep well samples to determine what may be present which is economically valuable or may ultimately be economically valuable.

We are very fortunate in Nebraska because we have had a law for a number of years which requires that samples, cores, and records of all deep wells drilled in the state be saved and turned over to the State Geological Survey for study and preservation. Our knowledge of the subsurface conditions is based largely upon information secured in this manner. All of this type of information eventually becomes available to the general public although information concerning active operations is held confidential until drilling is completed and records released by the operators. The State Legislature recently passed a law requiring the State Geological Survey to regulate the plugging of abandoned deep wells for the protection of potable water supplies and commercial deposits of oil and gas. The Survey's knowledge of subsurface formations and conditions, gained through the study of deep well samples, permits the regulation of plugging operations with the minimum expense to the operator and the maximum safety to the general public in the conservation of water supplies and oil deposits and prevents the injury of agricultural land through salt water pollution.

It has not been found possible in this summary of the geological column of Nebraska to indicate specifically the sequence and thickness of the subdivisions which may be present at depth under any particular place in the state, but the reader can approximate this information by studying the maps and sections and consulting the text in regard to distribution and thickness of the various subdivisions. This may be done in the following manner:

(1) Consult the Mantle Rock Map (Figure 3) to determine the nature and approximate thickness of Pleistocene deposits which are at or near the surface.

(2) Examine the bedrock map (Figure 1) to find out what the youngest bedrock will be. For example, if the location in question is midway across the band of Niobrara formation it is logical to assume that only the lower one-half of the Niobrara will be present and that the underlying Cretaceous formations will be found in regular order as indicated by the maps, sections and text.

(3) Study the chapters on all successively older systems of rocks for information as to the occurrence and probable thickness and

nature of the rocks of each System believed to occur in the subsurface of that locality.

(4) Keep in mind that a number of unconformities exist and that parts or in some cases all of certain formations and systems of rocks are absent along these unconformities.

(5) In cases where more exact information on the subsurface of a certain locality is necessary for a special purpose consult the Nebraska Geological Survey for the records of wells in the neighborhood and for more exact estimates of the section to be encountered in deep drilling.

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