INTRAFORMATIONAL STRUCTURAL FEATURES OF THE CHASE GROUP, WOLFCAMP SERIES

by

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INTRODUCTION

The area of investigation covered by this report is the western portion of Riley County as shown on Plate I and II. The formations investigated are the Winfield limestone and the upper two members of the Doyle shale, Chase group, Wolfcamp series, of the Permian system. The boundaries, confining the area of investigation are, to the east, the outcrop of the Towanda limestone of the Winfield formation, to the west the outcrop of the Cresswell limestone of the Doyle formation, and the north and south boundaries of Riley County.

The area of investigation lies within the central lowlands physiographic province as defined by Raisz.

The Abilene arch, the dominant structural feature in this area, is a prominant anticlinal fold extending to the north, from west central Dickinson County, across Riley County, into central Marshall County, where it becomes known as the Barneston anticline.

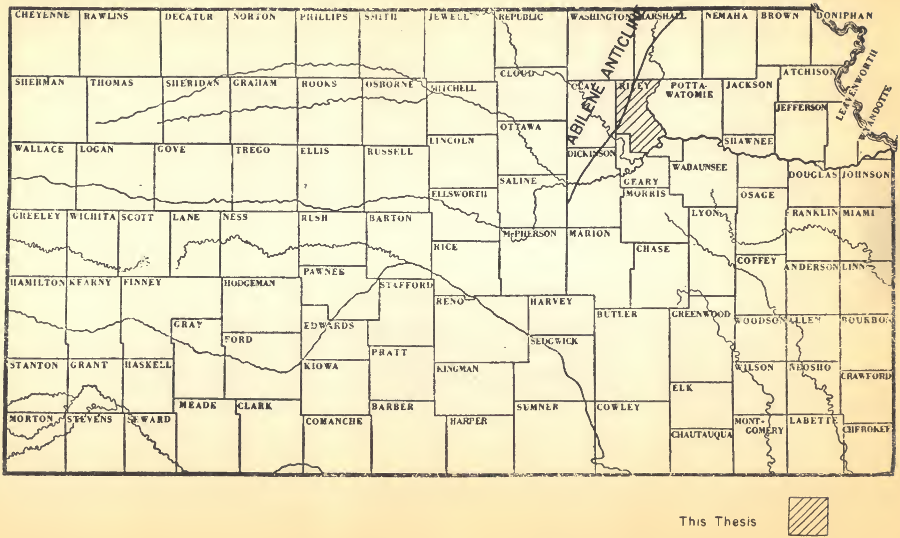
Purpose

The purpose of this report is twofold: first is the description of the intraformational structural features peculiar to the rocks of this area. Secondly, an attempt will be made to explain the causal forces which produced these features.

EXPLANATION OF PLATE I

Index map of Kansas showing area of investigation and the relationship to the Abilene anticline.

PLATE I



CHEYENNE
RAWLINS
DECATUR
NORTON
PHILLIPS
SMITH
JEWELL
REPUBLIC
WASHINGTON
MARSHALL
NEMAHA
BROWN
DONIPHAN
SHERMAN
THOMAS
SHERIDAN
GRAHAM
ROOKS
OSBORNE
MITCHELL
CLOUD
CLAY
RILEY
POTTA-WATOMIE
JACKSON
ATCHISON
JEFFERSON
LEAVENWORTH
WYANDOTTE
ABILENE ANTICLINE
WALLACE
LOGAN
GOVE
TREGO
ELLIS
RUSSELL
LINCOLN
OTTAWA
DICKINSON
SHAWNEE
WABAUNSEE
GEARY
MORRIS
SALINE
ELLSWORTH
OSAGE
DOUGLAS
JOHNSON
GREELEY
WICHITA
SCOTT
LANE
NESS
RUSH
BARTON
RICE
McPHERSON
MARION
CHASE
LYON
FRANKLIN
MIAMI
COFFEY
ANDERSON
LINN
HAMILTON
KEARNY
FINNEY
HODGEMAN
PAWNEE
STAFFORD
RENO
HARVEY
BUTLER
GREENWOOD
WOODSON
ALLEN
BOURBON
GRAY
FORD
EDWARDS
PRATT
SEDGWICK
KINGMAN
STANTON
GRANT
HASKELL
KIOWA
WILSON
NEOSHO
CRAWFORD
ELK
MEADE
CLARK
BARBER
SUMNER
COWLEY
MORTON
STEVENS
SEWARD
COMANCHE
HARPER
CHAUTAUQUA
MONT-GOMERY
LABETTE
CHEROKEE
This Thesis

EXPLANATION OF PLATE II

Index map of Riley County showing locations of outcrops investigated for this thesis and the relationship to the Abilene anticline.

PLATE II


ABILENE
ANTICLINE
WASHINGTON
CLAY COUNTY
WALSBURGH
LEONARDVILLE
STOCKDALE
BIG BLUE RIVER
Mill Creek
Wild Cat Creek
KEATS
ROCKY FORD
MANHATTAN
FT RILEY MILITARY RESERVATION
Seven Mile Creek
Three Mile Creek
OGDEN
KANSAS RIVER
U.P. R.R.
REPUBLICAN RIVER
GEARY COUNTY
77
24
40
13
16

Review of Literature

Walcott (1894), p. 192, defined an intraformational conglomerate as one that was formed within a geologic formation from material derived from and deposited within that same formation.

Intraformational conglomerates or breccias may be formed by various means. The primary requisite must be movement of some nature. The forces instigating this movement may come either from within the formation or from outside of the formation.

The forces which may originate within the formation itself are limited. The predominate forces are physical and chemical. Physical forces would include frost action. Sardeson (1906), pp. 226-332, described structural features and relates their origin to repeated freezing and thawing of springs and small streams, each freezing lowers the stream deeper into the formation leaving subrounded to angular rock fragments upfolded into broken anticlinal features. The distorted portions in many places lie between horizontal strata. He also described other similar intraformational upfolding with associated thrust faulting and related the origin to glaciation and grounding of floating objects. Sardeson suggested the floating objects could very possibly be icebergs which grounded against domed or ridged portions of the sea floors. Many other authors relate intraformational structures to the grounding of floating objects.

Campbell (1906), pp. 718-721, identified features, similar to the intraformational structures of Sardeson, near Spieberville, Arkansas, and discounted the origin of grounded glaciers. Campbell described anticlinal features measuring two feet from crest to trough within thin bedded sandstone three to four feet thick. The strata above and below were undisturbed. Campbell related the origin of such features to weathering, for no evidence of glaciers in Arkansas has been found. Campbell believed that the increase in volume due to weathering action would produce anticlinal features of this type. The structures described by Campbell are well defined anticlinal features in consolidated thin bedded sandstones which are well jointed and fractured at the structures. The increase in volume from jointing due to weathering action produced the forces necessary to originate intraformational structures, according to Campbell.

The chemical force capable of originating intraformational structure could be the process of hydration. The hydration of anhydrite to gypsum has resulted in the formation of many intraformational features. Flow lines, fracturing and faulting associated with gypsum deposits result from the increase in volume and flowage during the hydration of anhydrite.

The replacement of calcium carbonate by magnesium carbonate could also produce a chemical force capable of changing the volume within a limestone unit. Twenhofel (1950), p. 391, stated that the secondary formation of a dolomite would be attended by a 12.3 percent decrease in volume. The decrease in volume is produced by the uniting of magnesium carbonate with the already deposited calcium carbonate and a chemical equivalent quantity of calcium carbonate passes into solution. If the rock was partially lithified at the time of this replacement, there would be development of numerous cavities and collapse of parts of the rocks associated with the larger cavities. The decrease in volume in unlithified or soft rock may not necessarily produce collapse or porosity effects.

Some dolomite occurrences have been attributed to the addition of magnesium carbonate to calcium carbonate. This leads to an increase in volume. Twenhofel (1950), p. 391, concerning addition of magnesium carbonate, states that: "Addition seems unlikely in normal sea water, which, ..., is unsaturated with magnesium carbonate, but it could take place in waters of higher concentration which had been made alkaline by plant action."

In the introduction to the same article, Twenhofel (1950), p. 382, discussed previous work done with dolomitic limestones which resemble breccias. The brecciation or "pseudobrecciation" is brought about by recrystallization of an aragonite portion of a lime mud. The lighter colored, coarser textured matrix surrounds particles of irregular shapes. The matrix is more argillaceous than the fragments or particles and the carbonate of the matrix may be calcite or dolomite.

The causal forces of intraformational structures which originate outside the formation are numerous. The various authors present many logical origins in different localities and environments.

Miller (1908), pp. 428-433, described intraformational flowage and faulting within the Trenton limestone at Trenton Falls, New York. The features are traceable along two zones, for two miles within the Trenton limestone which is 270 feet thick.

Miller attributes the deformation to differential movement along less rigid zones. The features are associated with a thrust fault and show definite flowage of the limestone with small normal and thrust faults. The flowage structures in many places within the zones are highly twisted, contorted and broken where they have been pushed over one another.

In a later article Miller (1922), pp. 587-610, set up a criteria to distinguish features of subaqeous gliding from other intraformational features. Miller's criteria is as follows:

> 1. Notable variations in thickness of the contorted zone locally, even within a few feet.
>
> 2. The very irregular upper surface of the folded zone, and the rather regular under surface.
>
> 3. The bulging of the immediately overlying strata over little anticlinal folds.
>
> 4. The distinct evidence of the filling of the depressions on the upper surface of the corrigated zone before the general layers of overlying material were laid down.

The theories of submarine slumping or flowage, differential movement and differential compaction are the predominate ones con-concerning the origin of intraformational features. Submarine slumping is formed under water, as the name implies, and entails the slumping down a slope of the consolidated or unconsolidated rock material. Barrington Brown's theory (Doreen, 1951), p. 1831, for submarine slumping of consolidated rock is that after a large thickness of sediments have consolidated, if for some reason the mass was to become unstable through withdrawal of support or other cause, an intrastratal plane of weakness might develop and the upper part would slide across the lower at a low angle. The slip plane would be a low angle normal fault plane. The slip plane would be a brecciated zone and have a great range in thickness ranging from one inch to several hundreds of feet. He (Barrington Brown) postulates that the slip plane can, in places, bifricate and even slope upward in places.

Fairbridge (1946), p. 84, advocated the use of the features of submarine slumping in the search for petroleum. Slumping will occur on the flanks of submarine subsiding basins or rising anticlinal features if the movement continues during sedimentation. The extremists of this theory believe that basins may even become completely filled from this process. The slumping process will occur on slopes as small as two or three degrees and slumping of normal sediments deposited on a slope of five degrees or greater is inevitable. Oil tends to follow the shelf principle of accumulation and the shelf areas possess angles of low magnitude suitable for slumping. Fairbridge (1946), p. 87, believed that the field geologist could readily use the field evidence of slumping in surface mapping, and has established a criteria to assist the geologist in recognition of slump features during field mapping.

1. Abnormal increase in thickness (stratigraphic or bedding excess).

2. Abnormal decrease in thickness (stratigraphic or bedding deficiency).

3. Superposition of slightly older on slightly younger beds.

4. Pseudo-unconformities, where horizontal beds lie on penecontemporaneous folds.

5. Pseudo-conformities, where the slip has caused a short hiatus, horizontal beds being overlain by horizontal.

Orientation of the slumps by the field geologist should give an indication of the position of the shore line or the flanks of the anticline which was rising during sedimentation. Measured sections on the flanks or crest will give no idea of the actual thickness of the strata for there is no way of knowing what amount of the material was incorporated in the slumping. The thickness of the section will have to be interpreted from adjacent areas where no slumping has occurred.

Rettger (1935), pp. 271-292, performed extensive laboratory experiments on soft rock deformation. Rettger uses the term "soft rock" rather than unconsolidated because of the ambiguous useage of the terms consolidated and unconsolidated. Unconsolidated applies also to rock which readily falls apart under the hammer. Therefore a friable sandstone could be and is termed a unconsolidated rock. Soft rock on the other hand by Rettger's definition is one which can be shaped or deformed by the hand. Soft rocks can be either coarse or fine sediments or material deposited from solution. The line of distinction between a consolidated rock and an unconsolidated rock would be difficult to distinguish.

The soft rock experiments of Rettger exemplify contemporaneous deformation and he again qualifies the definition of contemporaneous deformation to pertain to deformation any time after deposition but before the rock becomes hard. Some authors imply contemporaneous deformation must occur immediately after deposition and before overlying sediments are deposited.

Rettger conducted his experiments in galvanized iron tanks five feet long, one foot wide, with plate glass sides six inches high. The tanks had four drains in one end for regulating the water level. The sediments were all deposited when the tanks were filled with water. To attain uniform deposition of the sediments he mixed the clays and muds with water until they were soupy and poured them from the containers beneath the surface of the water. The clays, silts and muds would then be allowed to settle uniformly. The sands were of three different groups, consisting of coarse, medium, and fine elements to approach natural bedding and the mechanical analysis of each was determined. The sands were sieved into the tanks to attain more uniform distribution. Sediments of different colors were used to emphasize the stratification and to make the structures formed in the experiment more distinct for photographing. The sliding plane in all of the slump or slide structures was a layer of bentonite.

Slumping, by nature, as has been before mentioned, will occur on slopes of two or three degrees but in Rettger's experiments slopes of twenty degrees or better were needed, even with the softest material, before slumping would occur.

When slumping occurs lens like masses move down the slope forming low angle normal faults at the crest of the slope. The front end of the sliding mass is distorted the most and the folds are at right angles to the direction of movement.

The upper surface of the slumped material displayed great irregularity after it came to rest but with minor agitation of the water submarine erosion effectively beveled the distorted upper surface. Thus after subsequent deposition of new sediments a distorted layer between two undisturbed layers was attained.

Rettger in another experiment determined that the features of differential movement and subaqeous slump were similar enough that only under the most unusual cases would it be possible to determine any difference between the features. The two different processes have no separate distinguishing features, therefore Rettger set up the following criteria.

1. Folding produced solely by differential movement is apt to be regular, all folds having the same angle of dip. The bedding more over is often not disrupted.

2. Intraformational folded zones produced by slump are often beveled across the top, due to subsequent erosion, and may be beveled along the bottom due to slide.

3. Large sections of the bedding may be absent or duplicated in folded zones produced by slump due to actual migration of material.

4. A single or a very thin incompetent bed lying between two highly folded zones suggests two periods of slump with a short period of deposition between. It is believed that such a thin bed could not have existed at the time of the folding of the lower zone.

5. A bowing upward of the beds overlying the folded zone at the crests of the folds suggests slump, but the absence of such bowing does not necessarily imply differential movement, as submarine erosion may level the surface of the folded zone before the deposition of the overlying beds.

When the tanks were being tilted during the experiments and before the slumping occurred, Rettger (1935), p. 281, noticed very unusual occurrences. The bedding was disrupted by small volcanic like eruptions. These features were formed by the artesian pressures from the hydrostatic head produced by the tilting.

These features are similar to those described by Stewart (1956), pp. 153-179. The small scale structures described by Stewart were formed, in his opinion, by the entrapment of air in lagoonal, beach sand deposits protected from wave action by offshore bars. The distorted areas were only affected by tidal fluctuations. The sand at low tide would be exposed to the air and as the water table would lower the air would follow it down into the sand. The encroachment of the water at high tide would overrun the sand before the water table could rise thereby entrapping the air. The rising bubbles of air would form small scale domes and slump structures generally less than eight to ten inches across. Stewart produced identical features in the laboratory using the same principle.

Although the features of Rettger and Stewart are analagous, the features of Stewart were much more concentrated and continuous than the features formed by the volcanic like eruptions of Rettger.

From the data compiled in his experiments with soft rock Rettger set up the following criteria for soft rock deformation:

1. There is never any cleavage which bears a direct relationship to the folding or a parallel orientation of mineral particles such as is seen in gneisses and schists.

2. Deformation is in many places confined to a zone between two undisturbed zones.

3. Structures (folds) tend to be beveled due to contemporaneous erosion or to sliding, and either top or bottom may be beveled.

4. Structures are, in general, of small size (differential settling on a large scale excepted).

5. Structures do not ordinarily show any direct relationship to major diastrophism.

6. Structures and structural arrangements are usually complex, normal and reverse structures being present in the same bed within short distances.

7. There is evidence, in places, of actual migration of sediments. In some cases this migration produces a repetition or ommission of beds.

8. Evidence of cavities is entirely lacking. Structures of faulting are usually filled with material similar to the sediment, rather than cement, such as vein quartz.

9. Faults are not sharply defined, but have characteristic drag and blurred beds.

10. Joints, as such do not exist, except as tension joints exemplified by mud cracks.

11. Faults, where present, are usually associated with folded and crumpled beds.

12. It is unlikely that any shells or other rigid animal remains would be deformed. Such deformation suggests hard rock folding or movement.

Rettger's concluding experiment was to determine the effect of contained water on the competency of the beds. He conducted experiments on sediments under water, sediments which had been drained 20 minutes and on sediments which had been drained of all water for 24 hours. The sediments were distorted by a lateral compressive force. The sediments under water were deformed into an irregular anticline. The sediments drained for 20 minutes formed an anticline with irregular waves or breaks in the stratification while the sediments drained for 24 hours formed a sharp distinct thrust fault. Rettger concluded that too broad an application of the experiments was not warranted.

Proffessor Emeritus Arthur B. Sperry, of the Geology Department of Kansas State College, suggested that structural deformation of the type investigated for this report, could be caused by earthquake shock. The deformation of stratigraphic units by earthquakes has been greatly neglected in geologic literature. No reports concerning the effect of earthquakes on stratigraphic units can be found.

The U. S. Coast and Geodetic Survey (Heck), 1947, pp. 32-35, lists 156 earthquakes for the central portion of the United States. These include major and minor earthquakes from 1699 through 1946 and were listed with the precaution that the list was incomplete because accurate recording and listing of earthquakes has only been done for the last few years. Earthquakes have toppled chimneys, cracked plaster, broken water mains, etc., in the Manhattan area (Heck), 1947, p. 42. It seems that earthquakes of that severity would have some effect on geologic formations.

The application of Hutton's doctrine of uniformitarianism and multiplication of the some two hundred millions of years, since the end of the Permian period, by the average number of earthquakes per year for the central region results in 126,400,000 earthquakes that have shaken this area.

STRATIGRAPHY

The stratigraphic units investigated in this report are of the Paleozoic sequence, Permian system and Wolfcamp series. The term Wolfcamp replaces the previously used term Big Blue (Adams, 1939) as the name of the lowest series of the Permian system. The Wolfcamp series as now defined contains the following groups, in ascending order: the Admire, Council Grove and Chase groups.

Chase Group

The Chase group, upper group of the Wolfcamp series, was named from Chase County by Prosser (1902), pp. 713-714. Flint bearing limestones are characteristic of the lower portion of this group. The lower boundary of the Chase group is, the basal member of the Wreford limestone formation, the Threemile limestone and the upper boundary is the Herington limestone, the upper member of the Nolans limestone formation. The formations of the Chase group are, in ascending order: the Wreford limestone, Matfield shale, Barneston limestone, Doyle shale, Winfield limestone, Odell shale and the Nolans limestone formations. A geologic column of the Chase group is shown on Plate III.

The formations of the Chase group investigated for this report are the Doyle shale and the Winfield limestone formations.

Doyle Shale Formation. The Doyle shale was named from exposures on Doyle creek, southwest of Florence, Marion County, Kansas. The name was given by Prosser (1902), p. 715. The Doyle shale overlies the Barneston limestone and underlies the Winfield limestone. Later Moore (1936), p. 12, stated that the Doyle shale was divisible into three units which could be given formational rank. Moore's redefinition was not accepted and the tendency now is to retain Prosser's original definition giving the three units the rank of member. The members of the Doyle shale formation are in ascending order: the Holmesville shale, the Towanda limestone and Gage shale. The Doyle shale ranges in thickness from 85 to 90 feet throughout the area of investigation.

Holmesville Shale Member. The Holmesville shale is defined as the basal member of the Doyle shale formation, overlying the Fort Riley limestone member of the Barneston limestone formation and underlying the Towanda limestone. The type locality is one and one-half miles west and one-half mile north of Holmesville, Gage County, ~~Kansas~~ Nebraska. The Holmesville shale is predominately gray but also it is yellow, red and green in parts. The uppermost portion is predominately green to the base of the overlying Towanda limestone. The thickness ranges from 20 to 25 feet.

Towanda Limestone Member. Prosser (1902), p. 715, recognized the existence of a middle member as what is now the Doyle formation. Fath (1926), p. 54, later named this member the Towanda limestone from exposures near Towanda, Butler County, Kansas. The Towanda limestone is the middle member of the Doyle formation overlying the Holmesville shale and underlying the Gage shale. The Towanda limestone is defined as a persistent but irregular unit. Within the area of investigation it varies from a soft yellow limestone to a gray lithographic limestone in many exposures. i.e. west center boundary section 28, T 9 S, R 6 E. The outcrop character of the Towanda limestone ranges from bold to moderate and is readily traceable on the landscape. Identification of the Towanda limestone is enhanced by the characteristic absence of fossils and the thick shale sections above and below. In the area of investigation the Towanda has a range in thickness from 8.5 feet to a little over 15 feet.

Gage Shale Member. The Gage shale is the upper member of the Doyle formation. It was named from type exposures in Gage County, Nebraska. The lower two-thirds of the Gage is predominately a red shale up to within 10-15 feet of the top where a calcareous zone is encountered which locally contains a unit bedded limestone lens generally less than one foot thick. From the calcareous zone to the base of the Stovall the Gage shale is yellowish-gray with abundant fossils. The portion of the Gage shale immediately below the Stovall limestone locally is similar to a coquinoid shale and is everywhere abundantly fossiliferous. The Gage shale averages about 50 feet thick over the underlying Towanda limestone. Accurate measurement of this shale section in certain localities is difficult due to irregularities associated with the intraformational structures of the overlying and underlying limestone members.

Winfield Limestone Formation. The Winfield limestone formation (Prosser, 1897), p. 64, was formerly named the Marion concretionary limestone (Jewett, 1941), p. 83, from the type locality near Marion in Marion County, Kansas. The name Winfield was applied from exposures near Winfield in Cowley County, Kansas. The Winfield limestone formation contains three members in ascending order: (1) The Stovall limestone, (2) Grant shale, and (3) Cresswell limestone including the "Luta" beds in the upper portion.

The Winfield limestone formation was renamed, as was previously mentioned, from the Marion limestone. The renaming changed the type locality to Cowley County, this in Jewett's opinion (1941, p. 83) should be relocated farther north than Cowley County or to the original type locality of the previous name. The present location of the type locality occurs where the lower two members of this formation begin to "pinch out".

The Luta beds, in many previous descriptions, have been given the rank of a member in either the Winfield or the overlying Odell shale formation. The recent trend is to refer to this unit as the Luta beds of the Cresswell limestone member. The latter designation will be used in this report.

Stovall Limestone Member. The Stovall limestone is the basal member of the Winfield limestone formation. It was named from exposures on the Stovall farm, seven miles southwest of Florence, Marion County, Kansas (Condra and Upp, 1931), p. 49. The Stovall limestone in the area investigated for this report contains an abundance of chert arranged in nodular, irregular bands which locally coalesce to form one thick irregular band comprising up to two-thirds of the member. The limestone is generally light gray in color and contains silicified fossils. The fossil content is variable and on well weathered exposures they are conspicuous because of their resistance to weathering. The Stovall varies from one foot to two and two-tenths feet throughout the area of investigation.

Grant Shale Member. The Grant shale was named from exposures five to six miles north of Florence, Marion County, Kansas in Grant township (Condra and Upp, 1931), p. 50. The shale is bluish gray and highly calcareous. The Grant shale ranges in thickness from nine to twelve feet and again, as in the case of the Gage shale, accurate measurements locally are difficult because of the irregularities associated with the intraformational structures of the overlying and underlying limestone members. Fossils are present in the Grant shale.

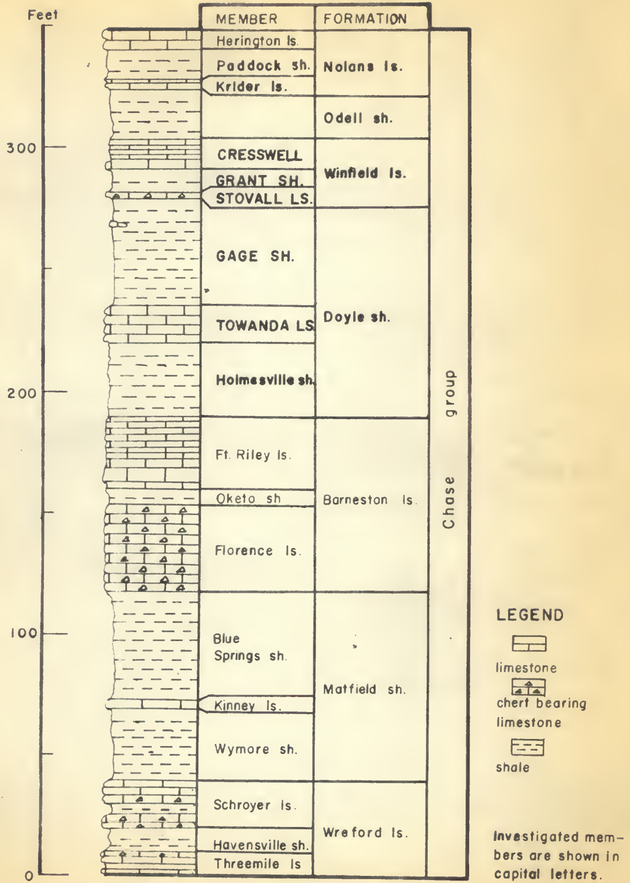
Cresswell Limestone Member. The Cresswell limestone is the upper member of the Winfield formation. The Cresswell was formerly called the "concretionary limestone". The name Cresswell was given by Condra and Upp (1931), p. 51, from exposures in Cresswell township, Cowley County, Kansas. They (Condra and Upp) describe it as a persistant massive limestone varying from four to eleven feet in thickness from Oklahoma to Nebraska. The Luta limestone was named by J. W. Beede from type exposures near Luta brooks north of Marion, Marion County, Kansas (Condra and Upp, 1931), p. 57, and was considered as the basal member of the Sumner group for many years. R. C. Moore, in 1936, (p. 12) treated the Luta limestone as the upper member of the Winfield limestone.

The base of the Cresswell limestone consists of a unit bedded persistent limestone generally less than three feet thick. The basal "unit" is persistent, resistant to weathering and contains abundant fossil fragments. The abundance of echinoid spines is a diagnostic feature but the fossils may be absent locally. The limestone is a light bluish gray to buff and has a white, smooth appearance on the weathered portions. Locally the basal unit bedded portion of the Cresswell limestone contains nodular chert. The basal limestone is overlain by thinner bedded limestones grading into the platy beds of the Luta limestone. The Luta beds are composed predominately of a light grayish white, platy limestone but locally may be a shale containing abundant geodes and concretions, or, as in southwestern Riley County, the Luta beds are a white powdery, calcareous marl used by the farmers for agricultural lime. The Luta beds are characteristically nonfossiliferous. The Cresswell limestone within this area ranges from twelve to fifteen feet in thickness.

EXPLANATION OF PLATE III

Generalized stratigraphic section of the Chase group, Wolf-camp series, Permian system.

PLATE III


Feet
300
200
100
0
MEMBER
FORMATION
Herington ls.
Paddock sh.
Krider ls.
Nolans ls.
Odell sh.
CRESSWELL
GRANT SH.
STOVALL LS.
Winfield ls.
GAGE SH.
TOWANDA LS.
Holmesville sh.
Doyle sh.
Ft. Riley ls.
Oketo sh
Florence ls.
Barneston ls.
Blue Springs sh.
Kinney ls.
Wymore sh.
Matfield sh.
Schroyer ls.
Havensville sh.
Threemile ls
Wreford ls.
Chase group
LEGEND
limestone
chert bearing limestone
shale
Investigated members are shown in capital letters.

STRUCTURE

The Abilene anticline, the dominant structural feature of this area, was named by Barwick, (1928), p. 179. He described it as a fold of considerable size paralleling the larger Nemaha anticline farther to the east and bordering the Salina Basin to the west. The Abilene anticline, or Abilene arch, as it is commonly referred to, trends north northeast through Riley County. The northern extension into northern Kansas and Nebraska is called the Barneston anticline. The southern extremity of the Abilene arch extends into west central Dickinson County and terminates in the Salina Basin syncline (Lee, et al., 1948), p. 136.

The Abilene arch is a pronounced asymetrical plunging anticlinal fold. The dips on the western flank are but a little more than the regional dip of this area but on the eastern flank some of the steepest dips to be found in the surface rocks in Kansas are expressed. The crest of the anticline plunges to the southwest 22 feet per mile (Nelson, 1952), p. 25.

The Abilene anticline was formed at the same time as the Nemaha anticline and the Salina Basin. The period of deformation which formed these features began in Mississippian time and terminated in Permian time (Lee, et al., 1948), p. 136. The deformation reaches its peak at the end of Mississippian and continued diminishingly into Permian time.

The Abilene arch is believed by many to be the surface expression of a fault in the Pre-Cambrian basement complex. The subsurface of the Abilene arch is virtually unexplored and consequently little information is available. Nelson (1952), p. 20, prepared a structural contour map on the Pre-Cambrian surface and inferred a fault with as much as 400 feet of displacement. The name Big Blue fault was proposed by him for this fault.

The outcrop of the rock units investigated for this report surround the surface expression of the Abilene arch. The structural distortion, the intraformational deformation and facies changes combine to make stratigraphic correlation difficult at times.

The surface structure of the Abilene anticline depicts ideal structural conditions for the subsurface accumulation of oil. Prolific oil production has been obtained from the central Kansas uplift, forming the western boundary of the Salina Basin. This suggests the Abilene anticline, forming the eastern boundary may be equally as prolific, but it has been virtually unexplored. The author believes that the future potential for oil production of the Abilene anticline is very good.

INVESTIGATION PROCEDURES

Field Procedure

The field work incurred extensive investigation of the surface expression of the formations in question. The samples were collected from various locations and at each location the outcrop sampled was measured and described in detail. The locations were recorded in a field book to the nearest ten acre tract, using the government land grid system, whenever possible. The majority of the locations described, measured and sampled display unusual characteristics either facies changes or structures peculiar to the area. The remainder of the detailed outcrop descriptions pertain to the areas displaying typical, undisturbed characteristics.

Laboratory Procedure

The laboratory procedures were applied in an attempt to determine the origin of the intraformational structural features.

The insoluble residue technique was applied to determine if the sink holes could possibly have originated in the Grant shale.

The calcium-magnesium ratio of the Cresswell limestone was used to determine if the distortions of the limestones could be attributed to the change of volume which accompanies the dolomitization process.

Insoluble Residue. The samples of the Grant shale, obtained in the field at sink hole structures, were collected in a set consisting of three samples from each location. The sink hole structures that could be sampled were displayed in road cuts or stream banks revealing a cross-sectional view of the structure. The set of three samples consisted of one sample from each side of the structure at approximately the same elevation within the shale member and one sample taken from the base of the depression. Samples were taken from each side of the sink hole to increase the accuracy of the results. The sample taken from the base of the depression was obtained from .5 to 1 foot below the severely weathered portion to eliminate, as much as possible, sampling the zone of most recent solution action. The samples were then crushed to facilitate the leaching by hydrochloric acid. Ten grams of the crushed shale sample was weighed on filter paper on an analytical balance. The sample was then put into a container and to it was added hydrochloric acid in sparing amounts while stirring alternately until all effervescing had ceased. The mixture was then filtered and washed until all hydrochloric acid was washed out and all the soluble compounds were filtered out. The residue was then put, with the filter paper, into a drying oven until it was completely dry and then weighed. The final weight after treatment was then subtracted from the original weight resulting in the amount of leachable material in the shale sample. The percentage of leached element was then computed.

Table 1. Results of the insoluble residue of the grant shale

Sample No.	Weight digested with filter paper	Dry weight after digestion	Weight lost	Percentage lost
1a	10 grams	5.18	4.82	48.2
1b	10 grams	4.00	6.00	60.0
1c	10 grams	5.37	4.63	46.3
2a	10 grams	5.42	4.58	45.8
2b	10 grams	5.88	4.12	41.2
2c	10 grams	5.22	4.78	47.8

Sample numbers correlate with location 24 of Plate II, fig. 1.
1b and 2b were collected at the base of the sink holes.

<u>Calcium-Magnesium Determination</u>. The analysis to determine the content of calcium-magnesium carbonates of the Cresswell limestone was undertaken to see if the zones of distortion or brecciation contained a high content of magnesium.

Theory of Analysis. This analysis concerns titrations of a standard calcium solution of known concentration and sample limestone solutions of unknown concentrations. The aliquots obtained from titrating solutions of known concentration are compared to the aliquots obtained from titrating solutions of unknown concentrations.

Two titrations are needed. The first titration determines the content of calcium plus magnesium and the second determines the content of calcium alone.

Preliminary Procedures. The samples of limestone used in this process were collected from outcrops of the Cresswell limestone. Every outcrop from which a sample was taken was measured, described and located geographically to the nearest ten acres whenever possible. Each sample was made up of from seven to ten pieces, all of uniform size, approximately the size of a golf ball is satisfactory. Care was taken to get unweathered samples. The pieces composing each sample were taken at random from the Cresswell outcrops in an attempt to prevent the introduction of biased samples.

The samples were ground to less than ten mesh, but the size to which the samples are ground is dependent upon the time available for the digestion by hydrochloric acid. The ground sample was placed on a large smooth sheet of paper, approximately two feet by two feet, and rolled back and forth from corner to corner fifty times. This was done to thoroughly mix the sample and to keep the powdered fraction mixed with the coarse material. From the well mixed sample about 50 grams was taken at random to fill a sample bottle. The sample bottle was filled so that no separation of the coarse and fine fractions would occur before the analysis was completed. From the sample 2.5 grams were weighed out on an analytical balance. The weighed samples were then put into individual beakers. A small amount of water was added to moisten the powdered sample so there would be no loss by fluffing when the hydrochloric acid is added. Only distilled water must be used in this analysis. A two to one solution of water and hydrochloric acid was added in small quantities so the sample would not effervesce too violently. When the sample stops effervescing upon stirring, add small amounts of hydrochloric acid. Care was taken not to add an excess of hydrochloric acid because this would necessitate later adding an excess of base to neutralize the solution. When the sample no longer effervesces when hydrochloric acid is added, pour it into a 250 milliliter flask and allow it to cool to room temperature. The beaker was rinsed with water several times to insure that all of the solution and insoluble residue was washed from the beakers. A minimum of three hours should be allowed for cooling the solutions.

While the sample solutions are cooling prepare a standard calcium solution. This solution may be prepared by accurately weighing 25.0000 grams of chemically pure calcium carbonate, dissolving it in a minimum amount of hydrochloric acid and carefully diluting to a volume of one liter with water. This solution contains 2.5000 grams of calcium carbonate equivalent or 1.0000 gram of calcium per 100 milliliters. The standard calcium solution gives a known calcium content on which to base the computations and was prepared in this concentration for ease of computations.

Determination of the Content of Calcium plus Magnesium. The preparation and uses of the various reagents used in the determination of the content of calcium plus magnesium were as follows:

The sample limestone solutions may be prepared in the concentration of 2.5 grams of limestone sample per 250 milliliters. The 25 milliliters of sample solution used for this process contains .25 grams of limestone equivalent.

The buffer may be prepared by dissolving one liter of ammonium hydroxide and 500 grams of ammonium chloride in 8 liters of water. This solution has a pH value of 9.5 and when used in the amounts specified by the analysis will maintain the pH value of the solutions at approximately 9.5 during the "Versene" titrations.

The Erio Chrome Black T indicator is made by dissolving 0.2 grams of Erio Chrome Black T indicator (Eastman #P 6361) plus 2 grams of hydroxylamine hydrochloride in 50 milliliters of methyol alcohol. This indicator should be kept in a refrigerator or be used freshly made up. A stabilized indicator that can be used for a long period without refrigeration may be purchased from the Bersworth Chemical Company. The Erio Chrome Black T indicator combines with the magnesium of the solutions.

Dilute magnesium sulphate is useful in detecting the end point when the solution contains no magnesium. Only one drop was used to avoid introducing a significant error into the true magnesium content.

Potassium cyanide was added to stabilize the indicator by combining with any interferring elements which may be present in the solutions. Care should be taken not to add the potassium cyanide to an acid solution.

The "Versene" solution was made by dissolving 500 grams of disodium, dihydrogen "Versene" in 10 liters of the ammonium hydroxide ammonium chloride buffer solution. The "Versene" will combine with the calcium of the solution before it combines with the magnesium.

When the sample solutions have cooled to room temperature, adjust the individual solutions to 250 milliliters with water and the first process for the content of calcium plus mangesium may be started.

Beakers for the standard and unknown samples should be obtained, washed and rinsed in water.

The process for the determination of the calcium plus magnesium content of each solution should be as follows:

To the beakers add;

25 ml of sample solution

50 ml of buffer

½ ml of indicator

1 drop of $MgSO_4$

1 pinch (approx. the size of a pea) of KCN (The KCN must only be added to a basic solution.)

After stirring the mixture is ready for the "Versene" titration.

The "Versene" titration should be done slowly and the solution should be stirred continuously during titration. The solutions may be titrated over a daylight fluorescent bulb thus they may be viewed by transmitted light, in which slight color changes are most easily seen.

The burette reading is made at the point when the color change is complete. The solution changes from a wine red to a sky blue color.

Three titrations are carried out with the standard calcium solution to make sure that there is no variation in the quantity of "Versene" used in titration of the three standard calcium solutions. One of the solutions should be kept for color comparison. The titration of the standard calcium solutions should be done first and must be done with absolute accuracy because the results of the complete analysis depends upon the accuracy of the standard titrations. The sample solution titrations should be done in duplicate and if any variation of the "Versene" content is noted, then additional titrations should be made until equal quantities of "Versene" are used in at least two samples.

The computation of the results of this process gives the content of calcium plus magnesium carbonates.

Determination of the Content of Calcium. The preparation and uses of the various reagents used in the determination of the content of calcium alone is as follows:

The sample solution is the same as prepared for the calcium plus magnesium determination.

The standard calcium solution is the same as prepared under preliminary procedures. The process for the calcium content requires titration with the standard calcium solution.

The "Versene" is the same as prepared for the determination of the content of calcium plus magnesium.

The potassium hydroxide - potassium chloride buffer was prepared by adding 250 grams of potassium hydroxide and 50 grams of potassium chloride to 4 liters of water. The pH value of this buffer is about 12. The buffer, as in the determination of the calcium plus magnesium content, adjusts the pH value of the solutions.

The potassium cyanide is the same as stated for the determination of the content of calcium plus magnesium.

The murexide indicator was made by mixing one gram of murexide with 200 grams of potassium sulphate and grinding to pass a 40 mesh screen. The murexide will combine with calcium but only after the "Versene" is satisfied. When the calcium added by titration from the standard calcium solution, is equivalent to the "Versene" content the indicator will combine with the excess calcium and change color.

The process for the determination of the content of the calcium solutions is done with murexide as the indicator and titrated with the standard calcium solution prepared for this analysis. The "Versene" must be standardized with the murexide indicator for the process of determining the calcium content of the solutions. The standardizing of the "Versene" should be done in triplicate, as was done for the previous determination of the content of calcium plus magnesium. The standardizing titrations of the second process should be accomplished first and again it should be done with extreme accuracy.

The procedure for determining the content of calcium in the solutions is as follows:

To each beaker add;

25 ml of sample solution

25 ml of "Versene"

25 ml of KOH buffer

1 pinch* of KCN

1 pinch* of Murexide indicator

*(Approx. the size of a pea)

If the "Versene" is added before the KOH buffer the precipitation of the calcium is prevented and the time for the resolution of the calcium by the "Versene" is saved.

The color change for the second titration is from purple to red and again the burette reading is taken at the point where complete color change is accomplished.

The computations for the above process results in the content of calcium in the solutions.

Computations of the Calcium plus Magnesium Carbonate Content. The standardization of the "Versene" against the indicator took X milliliters of "Versene". The aliquot of standard calcium solution contained 0.25 gram of $CaCO_3$ (25 gms per liter concentration), therefore; 0.25 gram of $CaCO_3$ is equivalent to X ml of "Versene" and 1 ml of "Versene" is equivalent to .25/X gms. $CaCO_3$ plus $MgCO_3$ ($MgCO_3$ is calculated as $CaCO_3$).

(.25/X) X (4) X (100) = % per gm of $CaCO_3$ plus $MgCO_3$ equivalent to 1 ml "Versene".

The above computations obtain a constant factor which may be multiplied times the "Versene" aliquots of the sample titrations. The product is the percentage content of the $CaCO_3$ plus $MgCO_3$.

The finished equation for sample titrations would be:

Y ml "Versene" X (100/X) = % $CaCO_3$ plus $MgCO_3$

X = ml "Versene" in standard solution

Y = ml "Versene" used in individual sample solutions.

Computation of the Calcium Carbonate Content. The standardizing of the "Versene" solution found that 25 ml of "Versene" was equivalent to A ml of standard calcium solution which contains 0.025 gms $CaCO_3$ per ml.

B ml of standard calcium solution, obtained in titration of each individual sample solution, subtracted from A ml, found above, results in C ml of standard calcium solution which is equivalent to the $CaCO_3$ of each sample. Therefore, if the sample solution contains .25 gram of limestone and the standard calcium solution contains .025 gram of pure $CaCO_3$, multiplying each amount by four, to bring the amount of limestone sample to one gram, then by 100, to obtain percentage would place the decimal one place to the right transforming the C ml, obtained by subtraction, into the percentage content of $CaCO_3$.

The completed equation would be:

A - B = C

(C) X (4) X (100) = % $CaCO_3$ by weight

A = milliliters of standard calcium solution equivalent to 25 milliliters of "Versene".

B = milliliters of standard calcium solution added to each sample solution.

C = milliliters of standard calcium solution equivalent to the $CaCO_3$ of each sample.

Computation of the True Magnesium Carbonate Content. The $CaCO_3$ content of each individual sample subtracted from the $CaCO_3$ plus $MgCO_3$ content, of its respective sample, results in the $MgCO_3$ content of each sample. The $MgCO_3$ must be corrected by multiplying the computed $MgCO_3$ content by the ratio of the molecular weights of $MgCO_3$ to $CaCO_3$ which is .84.

Table 2. Tabulation of the results of the calcium magnesium determination.

Sample Number	Location Number	$CaCO_3$ % Content	$MgCO_3$ % Content	Outcrop Characteristic	Fossil Content
1	8	79.25	1.60	Undistorted	Fossiliferous
2	9	76.00	3.97	Undistorted	Fossiliferous
3	12a	85.76	.79	Undistorted (Normal Fault)	Fossiliferous
4	12b	77.79	4.21	Distorted	Non-fossiliferous
5	12c	81.12	3.47	Distorted	Non-fossiliferous
6	15	86.50	1.52	Undistorted	Fossiliferous
7	5	81.12	5.40	Distorted	Non-fossiliferous
8	17	72.50	7.52	Distorted	Non-fossiliferous
9	18	44.50	37.56	Undistorted	Non-fossiliferous
10	19	77.50	3.125	Undistorted	Non-fossiliferous
11	20	50.50	38.68	Distorted (no inclusions)	Non-fossiliferous
12	21	77.00	3.35	Undistorted (Normal Fault)	Fossiliferous
13	22	82.50	2.19	Undistorted	Non-fossiliferous
14	23	83.50	2.89	Undistorted (sink hole?)	Non-fossiliferous
15	24	85.50	2.75	Undistorted (sink hole)	Fossiliferous

DESCRIPTION OF INTRAFORMATIONAL STRUCTURAL FEATURES

Faults

The faulting of the limestone strata of this area is very complex. Normal and reverse faults are found adjacent to each other with no obvious arrangement.

Normal Faults. High angle normal faults are numerous in the Cresswell limestone and Stovall limestones but not as many are found in the Towanda limestone. The fault displacement ranges from four feet to a few inches with an average displacement of three feet. Plate IV shows a typical normal fault of the Cresswell limestone. These two limestones are separated by the Grant shale which has a normal thickness of between nine and ten feet but at the faulted structures the displacement is adjusted in the shale resulting in irregular thicknesses of the shale section. The extreme stratigraphic thickness separating the Cresswell and Towanda limestones prevented determining if the fault at any one location extended downward to the Towanda limestone. The author believes that the thick Gage shale absorbed the displacing forces.

Thrust Faults. The thrust or low angle reverse faults occur in the Stovall limestone (Plate V). The abundance of chert in the member makes it an extremely brittle unit which does not seem to yield plastically to deforming forces. Thrust faults in the Stovall are numerous. The faults, as has been previously reported, usually display heave of four to six feet and throw from two to three feet (Neff, 1949). The reverse faults are generally displayed with heave twice that of the throw (Nelson, 1952), p. 15.

EXPLANATION OF PLATE IV

Normal fault of the Cresswell limestone member. SW¼ SW¼ Sec. 31., T. 9 S., R. 5 E.

PLATE IV

EXPLANATION OF PLATE V

Fig. 1. Thrust fault of the Stovall limestone member. SW¼ SW¼ SE¼ Sec. 36, T. 8 S., R. 4 E.

Fig. 2. A sketch of the thrust fault of Fig. 1., showing the possible fault plane.

PLATE V

Fig. 1

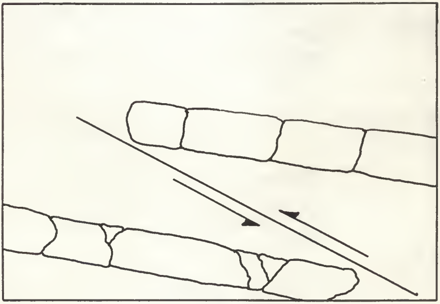


Fig. 2

The Stovall also in many places displays a peculiar feature. This unit has been bent and crumbled with no, or very little dislocation, of the bedding planes as they conform to the fold resulting in a small scale monoclinal feature (Plate VI). The amplitude of the feature is usually about two feet varying from one to three and covering a horizontal distance usually not exceeding twelve feet.

Intraformational Brecciation

The most unusual feature of the investigation is the intraformational brecciation displayed in the Towanda and the Cresswell limestones (Plate VII). The brecciation is observed at random heights within each unit displaying no stratigraphic level preference. The brecciation is predominately in the Towanda but an almost comparable amount occurs in the Cresswell. Inclusions which obviously must have come from the red basal portions of the shales overlying the Towanda and Cresswell occur incorporated into the brecciated zones and have been cemented with calcite.

The brecciation consists of angular fragments of limestone surrounded by a matrix of cemented red shale. The equally puzzling fact is that in many localities the exact opposite, where the angular fragments are found to be red shale inclusions with a matrix of limestone, is found. The latter case is not as prevalent as the first and the fragments are more isolated and less abundant. This occurence is found more often in the Cresswell than in the Towanda.

The brecciated zones vary in thickness from minute zones or

EXPLANATION OF PLATE VI

Fig. 1. Monoclinal feature of the Stovall limestone. NW¼ NE¼ NE¼ Sec. 20, T. 7 S., R. 6 E.

Fig. 2. Partially developed thrust fault in the Stovall limestone. Across the road south from Fig. 1.

PLATE VI

Fig. 1

Fig. 2

EXPLANATION OF PLATE VII

Fig. 1. Intraformational brecciation of the Cresswell limestone. C. W. line Sec. 16, T. 9 S., R. 6 E.

Fig. 2. Intraformational brecciation of the Towanda limestone. SW¼ SW¼ SW¼ Sec. 16, T. 9 S., R. 6 E.

PLATE VII

Fig. 1

Fig. 2

layers only inches thick to zones as much as six or eight feet thick. The limestone within the thin brecciated zones in some cases depicts possible incomplete brecciation of the limestone or mud cracks. The features are analagous to well formed mud cracks which retain their angularity. The individual limestone fragments within all of the brecciated zones generally range in size from two and one-half to one-tenth of an inch measured across the long dimension. The red shale inclusions have been observed in rectangular chunks as long as three feet. The larger chunks are usually found at the base of the Cresswell limestone with no visible means of reaching that position, although a joint in the Cresswell is usually observed immediately above them.

Slump Structures

The term slump structure used in this report refers to small scale structural features with a partial appearance of a syncline with nearly vertical flanks, the lower portion of which has completely lost its stratification planes in the base of the slump area. The slump structures occur in areas of horizontal stratification where the support in a small area appears to have been removed while the limestone was in the soft rock stage. Slump structures (Plate VIII) occur associated with the brecciated zones within the Cresswell and Towanda limestones. These are small structural features with the horizontal dimension, generally three to four feet, greater than the vertical dimension. In places the stratification planes are folded almost ninety degrees without associated fracturing within a horizontal distance of less

EXPLANATION OF PLATE VIII

Slump structure within the Towanda limestone. NW¼ NW¼ SW¼ Sec. 28, T. 9 S., R. 6 E.

PLATE VIII

than one foot. Stratification planes are visible near the edges of slump structures but the planes become indistinguishable in the lower part of the slump area. Slump structures appear to have a random distribution throughout the limestone unit but occur more often near the middle.

Sink Holes

Sink holes are a common feature of the Cresswell limestone but are more prevalent further south in Marion County. An excellent cross-sectional exposure of a sink hole is shown on Plate IX. The sink hole in this case, and others in various parts of Riley County, occurs where only the lower, unit bedded, two to three foot portion of the Cresswell limestone remains, although the depression extends well into the basal portion of the underlying Grant shale.

The sink holes create topographic depressions ranging from approximately ten feet long and six feet wide to circular depressions a hundred feet and greater in diameter.

Mud Cracks

The Towanda limestone displays a sedimentary structure which is identical in appearance to well formed mud cracks (Plate X). The mud cracks are formed in material of the same type as the limestone surrounding them. The mud cracks occur, wherever found, associated with the brecciated zones. The mud cracks bound characteristic polygons of irregular size, ranging from three inches to one-tenth of an inch, measured along the long dimension and

EXPLANATION OF PLATE IX

Fig. 1. Cross sectional view of a sink hole in the Grant shale and Cresswell limestone. SE¼ NW¼ Sec. 2, T. 9 S., R. 4 E.

Fig. 2. Sink hole in the Grant shale and Cresswell limestone. The stick is five feet long. NE¼ SW¼ SW¼ Sec. 6, T. 9 S., R. 6 E.

PLATE IX

Fig. 1

Fig. 2

EXPLANATION OF PLATE X

Fig. 1. Pseudo-mud cracks found within the Towanda limestone. NW¼ NW¼ SW¼ Sec. 28, T. 9 S., R. 6 E.

Fig. 2. Location within the Towanda limestone where the Pseudo-mud cracks of Fig. 1., were found.

PLATE X

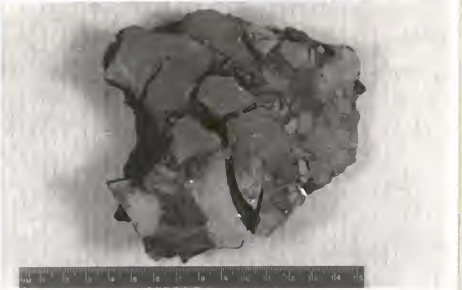


Fig. 1

Fig. 2

are found in most cases near the middle of the limestone unit.

CONCLUSIONS

The structural distortion of the area investigated is extremely complex and apparently is the result of a complicated geologic history which is not immediately recognizable. The occurence of structural features of soft and hard rock deformation in close association is very unusual.

The knowledge gained from the previous reports of structural deformation of this type and the complexity of the structural features found indicate that there had to be at least two phases of structural deformation. The characteristic hard rock faulting of the thin Stovall limestone could occur between the soft rock deformation of the Towanda and Cresswell limestones only by the exertion of two separate deforming forces.

The presence of mud cracks or "pseudo-mudcracks" is another indication that suggests soft rock deformation. Mud cracks may form in soft rocks as a result of tension. This mode of formation of the mud cracks is the only plausible one, for it would be impossible for the area to be elevated above water level for a sufficient length of time to develop the mud cracks and then subside without leaving some evidence of wave action.

The intraformational brecciation in places shows distinct evidence of soft or a partially lithified condition, of the rock during induration. The particles are subangular to angular. The emplacement of the fragments of red shale into a matrix of limestone had to be accomplished during the soft rock stage. The random orientation of the brecciated zones within the two limestones also discounts the possibility of one period of deformation. The analysis for the content of calcium plus magnesium carbonates of the Cresswell was determined in an attempt to correlate the brecciated and distorted zones to a high magnesium carbonate content. This attempt at correlation proved unsuccessful but the high magnesium content did prove to correlate with the absence of fossils in the Cresswell limestone. In all cases where non-fossiliferous zones were sampled they proved to be high in magnesium carbonate. This indicated the dolomitic zones were primary and not secondary for fossils could not have lived in a high magnesium environment.

The sink holes of the Cresswell limestone and Grant shale have originated from recent erosion at the surface. Though contradictory to geologic thinking the sink holes have obviously formed in the Grant shale and the overlying Cresswell has collapsed into the cavities. The soluble portion of the Grant shale ranged from 41.2 percent to 60 percent by weight. The soluble portion plus the fine fraction of the shale which could be carried away by suspension would be sufficient to form sink holes once an open system along a joint or fracture has developed.

The deforming or distorting forces, seem to have been primarily instigated by earthquakes or some similar agent capable of shaking up the limestones in their soft rock state. Some agent of this type would have been needed to form the severe brecciation and to incorporate the shales from the overlying units into the limestone to a maximum depth of fifteen feet. The complete lack of stratification at some localities suggests that the subaqueous slump or differential compaction initiated by earthquake shock, was sufficient to destroy stratification planes but not of sufficient intensity to produce flow structures.

The geologic history of this area has long been a problem and much more geologic investigation will be needed before it is solved.

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To all others in the Department of Geology and Geography at Kansas State College, who have assisted the writer in the preparation of this report, the writer gives his thanks.

APPENDIX

The following measured sections of the Chase group, Wolfcamp series, Permian system, in Riley County are numbered to correspond to the locations shown in Plate II.

(1) SW¼ SW¼ SW¼ Sec. 16, T. 9 S., R. 6 E.

Doyle shale formation

Towanda limestone member (incomplete)

Zone 1, 1.1 feet	limestone; finely crystalline; blocky to unit bedded; light gray; weathers gray with limonite stains; non-fossiliferous.
Zone 2, 5 feet	limestone; finely crystalline; platy to blocky, fragmental in part; light gray; weathers gray with limonite stains; non-fossiliferous; contains inclusions of red shale.

(2) NW¼ NW¼ Sec. 20, T. 9 S., R. 6 E.

Winfield limestone formation

Cresswell limestone member (indistinct, no accurately measurable section)

14 ± feet	limestone; finely crystalline; platy to unit bedded; light buff; weathers buff to white; echinoid spines and plates; inclusions of red shale and chert nodules.

(3) C. W. line Sec. 18, T. 9 S., R. 6 E.

Winfield limestone formation

Cresswell limestone member (incomplete, no accurately measurable section)

6 ± feet	limestone; finely crystalline; platy to unit bedded; light buff; weathers buff to white; non-fossiliferous; agricultural lime excavated from the upper portion.

(3) Continued

Grant shale member

10 ± feet	shale, calcareous, blocky to platy; light gray; weathers gray; derbyia abundant.

Stovall limestone member (indistinct)

Nodular gray chert debris.

Doyle shale formation

Gage shale member (incomplete)

20 ± feet	shale, calcareous; platy to fissle; gray in upper to red in lower; echinoid spines, crinoid columnals.

(4) NW¼ NW¼ NW¼ Sec. 12, T. 9 S., R. 5 E.

Winfield limestone formation

Cresswell limestone member (incomplete)

Zone 1, 4.5 feet	limestone; finely crystalline; platy; light buff; weathers buff; non-fossiliferous.
Zone 2, .75 feet	limestone; finely crystalline; unit bedded; light buff; weathers buff; non-fossiliferous.
Zone 3, .75 feet	limestone; finely crystalline; unit bedded; light buff; weathers buff; non-fossiliferous.
Zone 4, 2.5 feet	limestone; finely crystalline to dense; light buff; weathers buff; echinoid spines and test plates.

(5) NW¼ SW¼ SW¼ Sec. 1, T. 9 S., R. 6 E.

Winfield limestone formation

Cresswell limestone member (incomplete)

4.2 feet	limestone; finely crystalline to dense; amorphous, honeycombed, red shale inclusions; gray; weathers light gray and smooth; echinoid spines and plates in isolated groups.

(5) Continued

Grant shale member (distortion of limestones results in inaccruate thickness)

15 feet — shale, calcareous; platy to blocky; white to buff; weathers buff; derbyia abundant.

Stovall limestone member

1.5 feet — limestone, cherty; unit bedded; light gray; weathers gray to buff; dictyoclostus.

(5a) NE¼ SW¼ SW¼ Sec. 6, T. 9 S., R. 6 E.

Winfield limestone formation

Cresswell limestone member

Sink hole, no measurable section.

(6) SE¼ SE¼ SW¼ Sec. 19, T. 9 S., R. 6 E.

Doyle shale formation

Gage shale member (incomplete)

shale; platy to fissle; upper gray to buff, red in lower portion; echinoid spines and test plates and crinoid columnals in upper portion.

(7) N½ NW¼ NE¼ Sec. 25, T. 9 S., R. 5 E.

Winfield shale formation

Stovall limestone member (distorted)

1.2 feet — limestone, cherty; unit bedded; light gray; weathers gray; dictyoclestus.

(8) NE¼ NE¼ SW¼ Sec. 4, T. 9 S., R. 6 E.

Winfield limestone formation

Grant shale member

9 feet — shale, calcareous; platy to blocky; light gray to buff; weathers buff; derbyia abundant.

(9) NW¼ SE¼ NE¼ Sec. 4, T. 9 S., R. 6 E.

Winfield limestone formation

Cresswell limestone member (incomplete)

Zone 1, 17 feet	limestone; finely crystalline; unit bedded; light gray; weathers buff; echinoid spines and test plates abundant.
Zone 2, 1.5 feet	limestone; finely crystalline; unit bedded; light gray to buff; weathers buff; echinoid spines and test plates.

(10) NW¼ SW¼ Sec. 19, T. 9 S., R. 6 E.

Winfield limestone formation

Grant shale member (incomplete)

shale calcareous; platy to blocky; light gray; weathers light gray to buff; derbyia; white nodules of marl?

(11) NW¼ NW¼ SW¼ Sec. 28, T. 9 S., R. 6 E.

Doyle shale formation

Towanda limestone member (incomplete)

Zone 1, 5.3 feet	limestone; lithographic; platy to blocky in lower to blocky in upper portion; gray to yellowish gray; weathers gray to buff with dark limonite staining; non-fossiliferous; moderately vuggy.
Zone 2, 1.3 feet	limestone; finely crystalline; angular gray and pink fragments; gray fragments weather gray to buff, pink weather to dark reddish brown; non-fossiliferous; slightly vuggy at upper and lower contacts.
Zone 3, 1.2 feet	limestone; finely crystalline; unit bedded; gray to brown; weathers dark brown, abundant limonite staining; non-fossiliferous.

(12a, b & c) W. C. Sec. 33, T. 8 S., R. 6 E.

Winfield limestone formation

Cresswell limestone member (incomplete, faulted)

2 feet	limestone; finely crystalline; unit bedded; light gray; weathers light buff; echinoid spines and test plates abundant.

Grant shale member

9.5 feet	shale, calcareous, platy to blocky; gray to buff; weathers buff; derbyia abundant.

Stovall limestone member (faulted)

1.3 feet	limestone, cherty; unit bedded; light gray to buff; weathers gray; dictyoclostus.

(13) SE¼ SW¼ SW¼ Sec. 28, T. 8 S., R. 6 E.

Winfield limestone formation

Cresswell limestone member (incomplete)

2 feet	limestone, sparsely cherty; finely crystalline; unit bedded; light buff; weathers buff; echinoid spines and test plates.

(15) NW¼ NE¼ NE¼ Sec. 20, T. 7 S., R. 6 E.

Winfield limestone formation

Cresswell limestone member (incomplete)

Zone 1, 1.4 feet	limestone; finely crystalline; platy; light buff to white; weathers buff; non-fossiliferous.
Zone 2, 1.2 feet	limestone; finely crystalline; unit bedded; shale break near middle; gray to buff; weathers buff; echinoid spines and test plates.

Grant shale member

9.25 feet	shale, calcareous; platy to fissile; buff; weathers buff; derbyia abundant.

(15) Continued

Stovall limestone member

1.5 feet	limestone, cherty; finely crystalline; unit bedded, gray; weathers buff; dictyoclostus.

Doyle shale formation

Gage shale member (incomplete)

3.75 feet	shale, calcareous; platy to fissile; gray weathers buff; echinoid spines and test plates, crinoid columnals.

(16) NW¼ NW¼ Sec. 31, T. 9 S., R. 5 E.

Winfield limestone formation

Cresswell limestone member (incomplete)

2 feet	limestone; finely crystalline; unit bedded; light gray to buff; weathers buff; echinoid spines and test plates.

Grant shale member

10.2 feet	shale, calcareous; platy to fissile; buff; weathers buff; derbyia.

Stovall limestone member

2.2 feet	limestone; finely crystalline; unit bedded; gray; weathers buff; dictyoclostus.

Doyle shale formation

Gage shale member (incomplete)

6 feet	shale, calcareous; platy to fissile; gray; weathers buff; echinoid spines and test plates.

(17) C. W. line Sec. 16, T. 9 S., R. 6 E.

Winfield limestone formation

Cresswell limestone member (incomplete)

3.6 feet	limestone; finely crystalline; fragmental with red shale inclusion;

(17) Continued

yellowish brown; weathers buff; non-fossiliferous; white chert nodules.

(18) NE¼ SE¼ NE¼ Sec. 30, T. 8 S., R. 6 E.

Winfield limestone formation

Cresswell limestone member (incomplete)

Zone 1, 1.3 feet	limestone finely crystalline; platy; gray to buff; weathers gray; non-fossiliferous.
Zone 2, 1.8 feet	limestone; finely crystalline; blocky to platy; buff to light gray; weathers buff; non-fossiliferous; sparse white chert nodules.

(19) SW¼ SW¼ SE¼ Sec. 36, T. 8 S., R. 4 E.

Winfield limestone formation

Cresswell limestone member (incomplete)

Zone 1, 4 feet	limestone; finely crystalline; platy; white to gray; weathers gray to buff; non-fossiliferous.
Zone 2, 2.6 feet	limestone; finely crystalline; unit bedded; light gray; weathers buff; echinoid spines and test plates.

Grant shale member

11.2 feet	shale, calcareous; platy to blocky; light gray; weathers light buff; derbyia abundant.

Stovall limestone member

1.6 feet	limestone, cherty; finely crystalline; unit bedded; light gray; weathers gray; dictyoclostus.

(20) NW¼ SW¼ SW¼ Sec. 35, T. 9 S., R. 4 E.

Winfield limestone formation

(20) Continued

Cresswell limestone member (incomplete)

5 feet	limestone; finely crystalline; amorphous, vuggy; light gray; weathers gray; non-fossiliferous.

(21) SW¼ SW¼ Sec. 31, T. 9 S., R. 5 E.

Winfield limestone formation

Cresswell limestone member (incomplete)

Zone 1, 3 feet	limestone; finely crystalline; platy; gray to light gray; weathers gray; non-fossiliferous.
Zone 2, 4 feet	limestone; finely crystalline; unit bedded to blocky; gray; weathers buff; echinoid spines and test plates.

Grant shale member

10 feet	shale, calcareous; platy to blocky; gray to buff; weathers buff; derbyia.

Stovall limestone member

1.6 feet	limestone, cherty; finely crystalline; unit bedded; light gray; weathers gray; dictyoclostus.

(22) C. S. line Sec. 30, T. 9 S., R. 5 E.

Winfield limestone formation

Cresswell limestone member

15 feet	limestone; finely crystalline to lithographic in part; platy in upper to blocky in lower part; gray; weathers buff; non-fossiliferous.

(23) SE¼ SE¼ NW¼ Sec. 30, T. 9 S., R. 5 E.

Winfield limestone formation

Cresswell limestone member (incomplete)

Zone 1, 3 feet	limestone; finely crystalline; blocky; to platy; gray; weathers gray to buff; non-fossiliferous.

(23) Continued

Zone 2, 5.2 feet — limestone; lithographic; blocky; gray; weathers buff; sparse echinoid spines and test plates.

(24) SE¼ NW¼ Sec. 2, T. 9 S., R. 4 E.

Winfield limestone formation

Cresswell limestone member (incomplete)

Zone 1, 2.5 feet — limestone; finely crystalline; platy; gray; weathers buff; nonfossiliferous.

Zone 2, 3.5 feet — limestone; finely crystalline; unit bedded; gray; weathers buff; echinoid spines and test plates.

Grant shale member (incomplete. Sink hole)

6.5 feet — shale, calcareous; platy to blocky; light gray; weathers buff; derbyia.

BIBLIOGRAPHY

Adams, J. E., and others.
Standard Permian section of North America. Am. Assoc. Petrol. Geol. Bull. No. 23. pp. 1675-1681. 1939.

Barrell, J.
Relative geological importance of continental, littoral and marine sedimentation. Jour. of Geol. Vol. 14. pp. 524-568. 1906.

Barwick, J. S.
Salina basin of North-Central Kansas. Am. Assoc. Petrol. Geol. Bull. Vol. 12. No. 2. pp. 77-199. 1928.

Beede, J. W.
Formations of the Marion stage of the Kansas Permian. Kansas Acad. of Sci. Trans. Vol. 22. pp. 248-256. 1908.

Bucher, W. H.
Key to papers published by an institute for the study of modern sediments in shallow seas. Jour. Geol. Vol. 46. pp. 726-755. 1938.

Campbell, M. R.
Rock folds due to weathering. Jour. of Geol. Vol. 14. pp. 718-721. 1906.

Condra, G. E., and J. E. Upp.
Correlation of the big blue series. Nebr. Geol. Surv. Bull. No. 6. 2nd Ser. 1931.

Doreen, J. M.
Rubble bedding and graded bedding in Talora formation of north-western Peru. Am. Assoc. Petrol. Geol. Bull. Vol. 35. No. 8. pp. 1829-1849. (August) 1951.

Dunbar, C. O.
Historical Geology. John Wiley and Sons, Inc. New York. 1952.

Fairbridge, R. W.
Submarine slumping and location of oil bodies. Am. Assoc. Petrol. Geol. Bull. Vol. 30. pp. 84-92. 1946.

________________.
Possible causes of intraformational disturbances in the carboniferous varve rocks of Australia. Jour. and Proc. Royal Soc. New South Wales. Vol. 81. pp. 99-121. 1947.

Fath, A. E.
Geology of the El Dorado oil and gas field. Kansas Geol. Surv. Bull. 7. pp. 1-187. 1921.

Grater, R. K.
Some features of Navajo formation in Zion National Park, Utah. Am. Jour. Sci. 4th Ser. Vol. 246. pp. 317-318. 1948.

Heck, N. H.
Earthquake history of the United States and Alaska. U. S. Dept. of Comm., Coast and Geodectic Survey, Part I. Ser. No. 609. 1947.

Henderson, S. M. K.
Ordivician submarine disturbances in the Girvan district (Scotland). Trans. Royal Soc. Edinburgh. Vol. 58. pp. 487-509. 1935.

Jewett, J. M.
The geology of Riley and Geary counties. State Geol. Surv. of Kans. Bull. 90, Part 6. 1941.

__________.
Geologic structures in Kansas. State Geol. Surv. of Kans. Bull. 90, Part 6. 1951.

Jodry, R. L.
Rapid method of determining magnesium-calcium ratios of well samples and its use in predicting structures and secondary porosity in calcareous formations. Am. Assoc. Petrol. Geol. Bull. Vol. 39, No. 4. (April) 1955.

Jones, O. T.
On the sliding and slumping of submarine sediments in Denbynshire, North Wales, during the Ludlow Period. Quart. Jour. Geol. Soc. No. 93, pp. 241-283. 1930

Kiersch, G. A.
Small scale structures and other features of Navajo sandstone, northern part of San Rafael Swell, Utah. Am. Assoc. Petrol. Geol. Bull. Vol. 34. No. 5. pp. 923-942. 1950.

Krumbein, W. C., and L. L. Sloss.
Stratigraphy and sedimentation. W. H. Freeman and Company, San Francisco, California. 1953.

Lee, and others.
The stratigraphy and structural development of the Salina basin of Kansas. State Geol. Surv. of Kans. Bull. 74. 1948.

Miller, W. J.
Highly folded between nonfolded strata at Trenton Falls, New York. Jour. Geol. Vol. 16. pp. 428-433. 1908.

__________.
Intraformational corrugated rocks. Jour. Geol. Vol. 30. pp. 587-600. 1922.

Moore, R. C., J. C. Frye and J. M. Jewett.
Tabular description of outcropping rocks in Kansas. State Geol. Surv. of Kans. Bull. 52, Part 4. pp. 1-212. 1944.

__________, and others.
Kansas geological society tenth annual field conference guide book. p. 12. 1936.

__________, and others.
The Kansas rock column. Kans. Geol. Surv. Bull. 89. pp. 1-132. 1951.

Mudge, M. R.
The pre-Quaternary stratigraphy of Riley County. Kansas. Unpublished M. S. thesis, Kansas State College, Manhattan, Kansas. 1949.

Neff, A. W.
A study of the fracture pattern of Riley County, Kansas. Unpublished M. S. thesis, Kansas State College, Manhattan, Kansas. 1949.

Nelson, P. D.
The reflection of the basement complex in the surface structures of the Marshall-Riley County area of Kansas. Unpublished M. S. thesis, Kansas State College, Manhattan, Kansas. 1952.

Nevin, C. M.
Principles of structural geology. John Wiley and Sons, Inc. New York. 1953.

Pettijohn, F. J.
Sedimentary rocks. Harper and Brothers, New York. 1949.

Prosser, C. S.
Revised classification of the upper Paleozoic formations of Kansas. Jour. Geol. Vol. 10, pp. 700-737. 1902.

Rettger, R. E.
Experiments on soft rock deformation. Am. Assoc. Petrol. Geol. Bull. Vol. 19, No. 2. pp. 271-292. (February) 1950.

Rich, J. L.
Flow markings, groovings, and intra-stratal crumplings as criteria for recognition of slop deposits with illustrations from Silurian rocks. Am. Assoc. Petrol. Geol. Bull. Vol. 34. No. 4. pp. 717-741. (April) 1950.

Sardeson, F. W.
The folding of subjacent strata by glacial action. Jour. Geol. Vol. 14. pp. 226-232. 1906.

Stewart, H. B., Jr.
Contorted sediments in modern coastal lagoon explained by laboratory experiments. Am. Assoc. Petrol. Geol. Bull. Vol. 40. No. 1. pp. 153-161. (January) 1956.

Twenhofel, W. H.
Principles of sedimentation. 2nd Ed. McGraw-Hill Book Co., Inc. New York, Toronto and London. 1950.

______________.
Treatise on sedimentation. 2nd Ed. Baltimore and Wilkins Co. pp. 668-685. 1932.

Walcott, C. D.
Paleozoic intraformational conglomerates. Geol. Soc. Am. Bull. Vol. 5. pp. 191-198. 1894.

Woolnough, W. G.
Pseudo-tectonic structures. Am. Assoc. Petrol. Geol. Bull. Vol. 17, Part 2. pp. 1098-1106. 1933.

INTRAFORMATIONAL STRUCTURAL FEATURES OF THE CHASE GROUP, WOLFCAMP SERIES

by

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The intraformational structural features of the Doyle and Winfield formations, Chase group, Wolfcamp series, Permian system of western Riley County are the result of a complex geologic history. The intraformational structural features observed in these rocks include, normal faults, thrust faults, intraformational brecciation, slump structures, sink holes, and mud cracks. These features may all be found in close association and with no orientation.

An explanation of the origin of the structural features was sought by extensive field investigation and laboratory procedures. The laboratory procedures undertaken were: (1) insoluble residues of the Grant shale, Winfield formation, to obtain a percentage by weight of the leachable fraction, and (2) a rapid method of analysis for the determination of the content of calcium-magnesium carbonates of the Cresswell limestone, also of the Winfield formation. The information gained from the laboratory procedures along with the field evidence supported the following conclusions:

1. That sink holes may be formed in the Grant shale.

2. The high magnesium content of the Cresswell limestone correlated with nonfossiliferous areas.

3. The magnesium content of the Cresswell limestone was syngenetic.

The intraformational structural features of the area under investigation display characteristics of both soft and hard rock deformation. This indicates a minimum of two phases of structural deformation.

The origin of the intraformational structural features of this area was interpreted to be primarily from the effect of earthquake action with minor amounts of subaqeous slumping or differential compaction.