STUDY OF THE STRUCTURAL RELATIONSHIP OF THE RILEY COUNTY INTRUSIONS TO THE ABILENE ARCH

by

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INTRODUCTION

Purpose and Location

The purpose of this paper is to describe a survey of the flexures and igneous dikes in the Abilene Arch area in Riley County, Kansas for the purpose of establishing the geologic cause of their origin.

Stratigraphic Units in Riley County

The survey was conducted entirely on rocks of Permian age. The average thickness, age and stratigraphic sequence are shown in Table 1 (5, 160-170).

Table 1. Table of stratigraphic units in Riley County.

Series	Group	Formation	Member	Average thickness in feet
		Nolan Ls.	Herington Ls.	20
			Paddock Sh.	11
			Krider Ls.	3
		Odell Sh.		30
		Winfield Ls.	Cresswell Ls.	17
			Grant Sh.	10
			Stovall Ls.	1
		Doyle Sh.	Gage Sh.	48
			Towanda Ls.	7
			Holmesville Sh.	25
		Barneston Ls.	Fort Riley Ls.	40
			Oketo Sh.	5
			Florence Ls.	40
		Matfield Sh.	Blue Springs Sh.	40
			Kinney Ls.	8
			Wymore Sh.	30
		Wreford Ls.	Schroyer Ls.	18
			Havensville Sh.	7
			Threemile Ls.	10
		Speiser Sh.		25
		Funston Ls.		8
		Blue Rapids Sh.		20
Wolf-camp	Council Grove	Crouse Ls.		12
		Easly Creek Sh.		15
		Bader Ls.	Middleburg Ls.	6
			Hooser Sh.	10
			Eiss Ls.	7
		Stearns		14
		Beattie Ls.	Morrill Ls.	5
			Florena Sh.	7
			Cottonwood Ls.	6
		Eskridge Sh.		37

Table 1 (concl.)

Series	Group	Formation	Member	Average thickness in feet
		Grenola Ls.	Neva Ls.	20
			Salem Point Sh.	8
			Burr Ls.	10
		Roca Sh.		20
		Red Eagle Ls.	Howe Ls.	3
			Bennett Sh.	7
			Glenrock Ls.	9
		Johnson Sh.		20
		Foraker Ls.	Long Creek Ls.	7
			Hughes Creek Sh.	40
			Americus Ls.	3
		Hamlin Sh.	Oaks Sh.	12
			Houchen Creek Ls.	2
			Stine Sh.	36
		Five Point Ls.		3
		West Branch Sh.		20
	Admire	Falls City Ls.		7
		Hawxby Sh.		30
		Aspinwall Ls.		5
		Towle Sh.	Unnamed Sh.	30
			Indian Cave Ss.	120

MAPPING PROCEDURE

Flexures

The strike and dip of flexures were determined by the use of a Brunton compass, hand level and stadia rod. In each area several readings were taken to insure obtaining the maximum dip and the true direction of strike. Primary interest was in steep dips, those steeper than the regional dip and steeper than those that were the results of differential compaction, in other words, tectonic folds. In several places it was impossible to make any measurements because of the lack of rock outcrops.

Each location was numerically recorded in a field notebook and also recorded on a large field map of Riley County.

Igneous Intrusion

There are three igneous intrusions that have reached the surface in Riley County, Kansas. Each intrusion is named after the closest town; that is Bala, Leonardville and Stockdale.

A magnetic survey was made on the Stockdale and Leonardville Intrusions to see whether they were elongated and if so in what direction. A survey of the Bala Intrusion (Dreyer, 1) had already been made.

In mapping the intrusions, a traverse was set up using magnetic north as the control. This was done with a Brunton compass using a one-hundred foot steel tape to control the distance between stations. A dipping needle was used in the survey of the two intrusions. The dipping needle is an instru-

ment used for the determination of the inclination. In its magnetic system, the center of gravity is coincident with the axis of revolution. The scale division of the dipping needle is in degrees.

At each station in the traverse, a plane table and tripod were set up, and the plane table was leveled with a bulls eye level. The dipping needle was than placed on the plane table and oriented by aligning the plane table to the traverse. Several readings were taken at each station with the dipping needle facing first 90 degrees west, then 90 degrees east, of magnetic north. The average of these readings was then recorded in a field notebook and on a map of the traverse.

A base station was established to allow for correction due to magnetic variations and any change of sensitivity of the dipping needle.

REVIEW OF PREVIOUS WORK CONCERNING THE ABILENE ARCH AREA

Winkler Anticline

Jewett (2) wrote:

> There is a noticeable arching of beds in the vicinity of Winkler, in northern Riley County in the southeast part T. 6 S., R. 6 E. Near the town, exposures of Florence limestone in the Barneston formation show that the Wreford limestone beds must lie well below the surface of the alluvium of the flood plain of Fancy Creek; but only a short distance westward the Wreford formation lies well above the almost flat flood plain, and still farther westward it dips below the stream again. The same reversal of dips can be plainly seen in the bluffs forming the walls of Fancy Creek valley and even more plainly along streams tributary to Fancy Creek on the north. The fold described here is a part of the Abilene anticline, which extends from a point near Kingman in Kingman County in the south central

part of Kansas northward into Nebraska. In Nebraska it is commonly called the Barneston Arch. Probably it is no more acute near Winkler than elsewhere along its axis, although elsewhere the flat topography may not reveal the arching so well.

The writer made a careful field study of the Winkler Anticline area in an effort to determine whether tectonic forces, differential compaction, or a combination of factors produced the structure which is expressed along the Abilene Arch in that area.

Recognition of Abilene Arch

Lee, Leatherock and Botinelly (3) wrote:

> The prominent Abilene anticline on the northeast side of the Salina basin is recognized in the surface rocks in Riley County. It resembles the Nemaha anticline in that the beds dip steeply on its southeastern side and very gently to the northwest. Not many subsurface data are available on the Abilene anticline and the thickness lines have been drawn to conform with the scanty data and with the structure of the surface formations. The Abilene anticline is interrupted on the south by the Salina basin syncline.

Evidence of Deformation Along Abilene Arch

Lee, Leatherock, and Botinelly (3) found in their work that in Pennsylvanian times, between Hertha limestone and the Topeka limestone, that the available wells along the Abilene anticline suggest some activity of this structural feature.

They also found that between the Topeka limestone, Pennsylvanian in age, and the Barneston limestone, Permian in age, that:

> Deformation is suggested vaguely by a few wells and abrupt deformation of more than fifty feet in surface

formations on its east side a short interval above the tops of this sequence.

Activity is suggested along the Abilene Arch as early as Pennsylvanian times and seems to carry through Permian times at least. This would be expected because a buried hill is a line of weakness and any movement in the area would be taken up along this buried hill. Minor amounts of tectonic movement, probably taking place at all times throughout the geologic history of a belt of weakness are due to adjustments the Earth's crust makes in its attempt to establish isostasy.

Discussion of Southern Extension of Mono Craters

Mayo, Conant and Chelikowsky (4) found in their survey of the southern extensions of the Mono Craters in California, that there was a definite alignment of the rhyolite protrusions. These protrusions covered a distance of approximately seven miles. Sets of joints and gaping fissures in the crystalline basement, and in the volcanic platform, appear to be the avenues of escape, and explains the alignment of the volcanic extrusions.

The intrusions in Riley County, Kansas were studied to determine whether they had any definite alignment with respect to the Abilene Arch, and if so, to see if they would fit in as gash fractures.

Open Gash Fractures

Nevin (7) states that:

> Oblique fractures are at various angles; they always diverge to the right of one looking along the trace of the fault zone. In other words, the direction of differential

movement is into the acute angle made by the oblique cracks and the trend of the fault zone.

Since these features occupy a position of active tension, they are rightly termed gash fractures, as they tend to keep open. One result is that they are commonly mineralized and appear as gash veins, which distinction may be used to separate them from any associated closed compression fracture, which in turn are seldom filled with vein material.

A Buried Hill as a Zone of Weakness

In all places, where a buried hill is surrounded by a compressible material, a compaction structure will be formed, and this structure will have its influence in any later rejuvenation.

Rejuvenation of a buried structural hill is not only possible, but it is the normal thing to expect. Rejuvenation of a buried structural hill would be reflected in a refolding of the underlying structure; and if the hill is surrounded by compactable sediments, the fold above it, as seen at the surface, would be the composite result of differential compaction and dynamic movements. Any later folding would tend to follow the line of weakness established during differential compaction.

The Abilene Arch, having been formed by a buried hill, is a zone of weakness along which any movement in the region would be reflected by deformation of the rock layers.

Bala Intrusion

A magnetic survey had already been done on the Bala intrusion by Dreyer (1). "The survey was undertaken to supplement drill-hole data and to see whether relatively large amounts of this rock could be obtained at or near the surface."

The magnetic survey was taken with a vertical magnetometer which indicated that the intrusion is a plunging dike, plunging much steeper eastwardly. The axis of elongation of the intrusion is approximately N68W-S68E.

ANALYSIS OF SURVEY

Flexures

The flexures found in northern Riley County were pitching anticlines and plunging synclines. The axis of these flexures run parallel to the axis of the Abilene Arch. The size of these flexures and the amount of dip present is indicated on Fig. 2.

Most of the survey was made on the Fort Riley limestone which outcrops boldly in that area.

Each strike and dip symbol on Fig. 2 represents an average of several readings in that one location. Due to a thick covering of mantle in some of the locations, it was impossible to take any readings.

Throughout the Abilene Arch in Riley County, Kansas, the Stovall limestone is folded and in some locations, it is faulted. The folds are small but have a high angle of dip. Some of the folds are even overturned. The faults are small as a rule, usually the amount of displacement is not more than a few feet. Most of the faults are thrust faults and are thrust toward eroded valleys.

The Stovall limestone, which is a foot thick, is located between two shales, the Grant and the Gage. These two shales are incompetent beds which are rather thick; therefore the thin

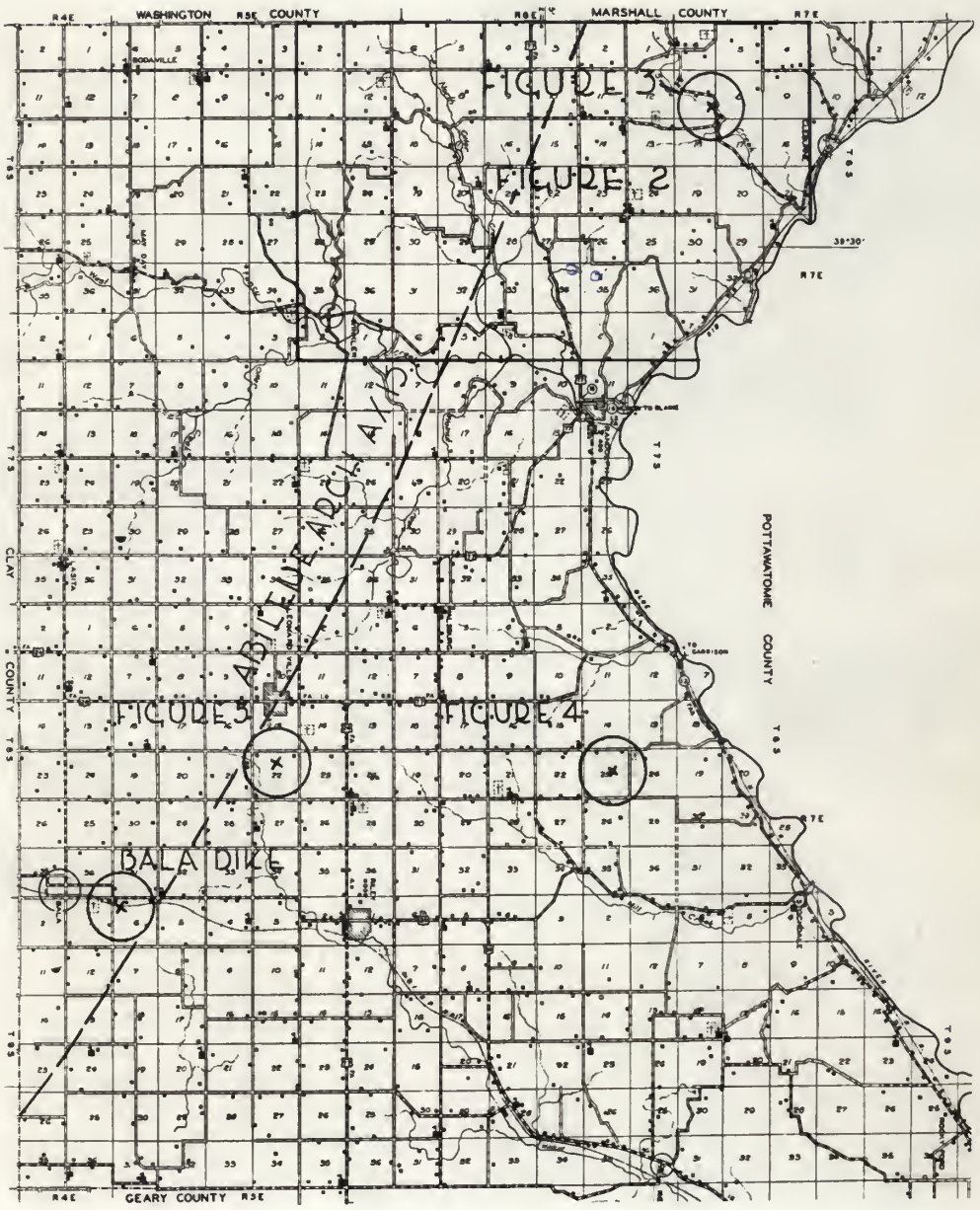

Fig. 1. Index map of the Abilene Arch area in Riley County, Kansas.

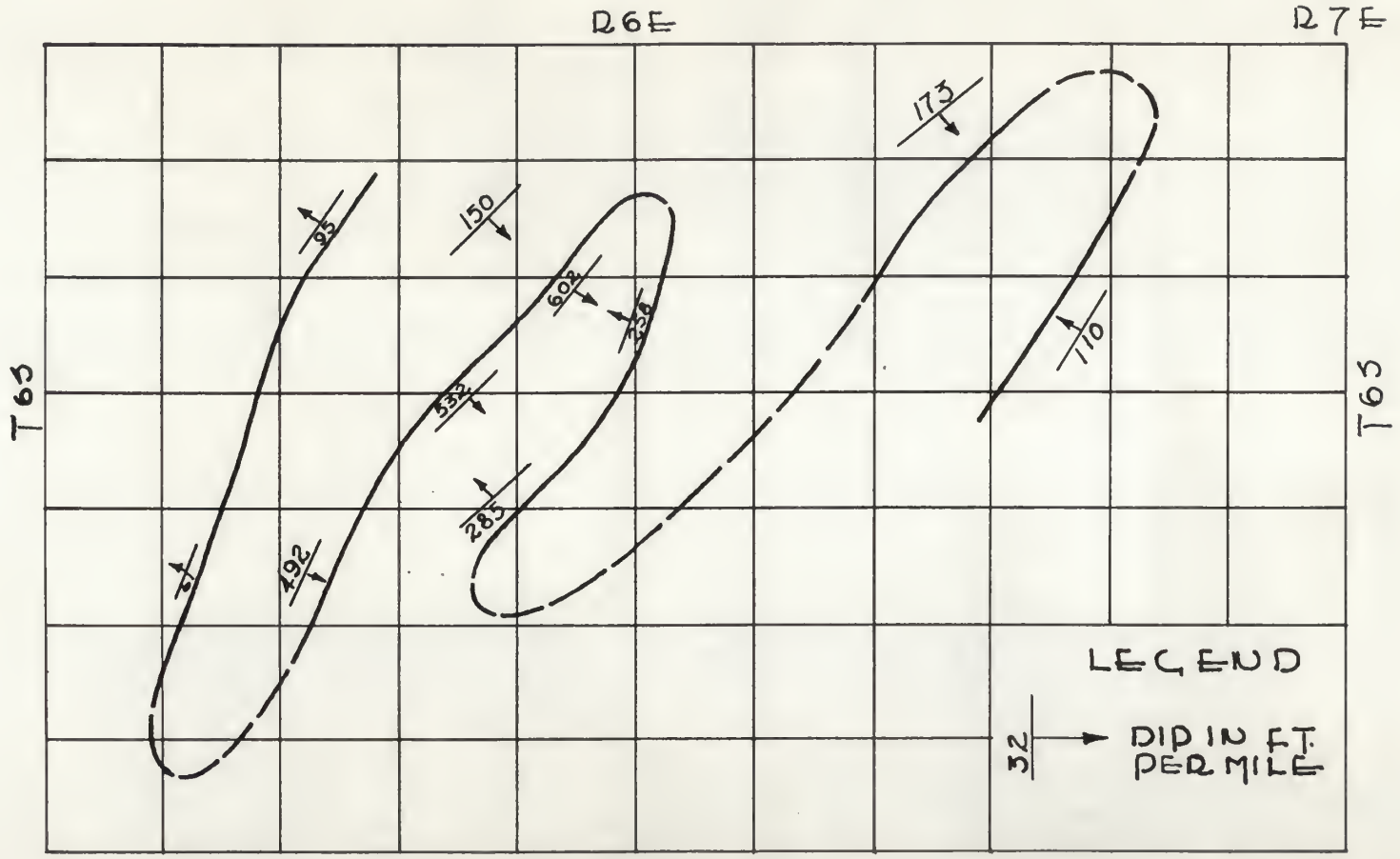

Fig. 2. Detail map of flexures in northern Riley County, Kansas.

Fig. 3. Nondeposition of non-cherty limestone zones. Inked line shows contact between the cherty zone of the Schroyer limestone and the bottom of the Wymore shale.

Stovall limestone is at their mercy.

A local period of non deposition of the non-cherty limestone zone at the top of the Schroyer limestone, was found in a deep creek cut just west of the bridge in sec. 7, T. 6 S., R. 7 E. This indicated that this immediate area was raised up just after the cherty zone had been deposited, so that the non-cherty limestone zone was not deposited. This also indicated that tectonic forces were at work during those times.

Igneous Intrusions

In the survey of the two igneous intrusions, it was found that they are elongated. This elongation is in a general east-west direction in both cases. Figures 4 and 5 show this elongation which was determined with the dipping needle.

The magnetic contours are drawn with respect to the intensity of inclination of the igneous intrusion. This was done by subtracting the normal intensity of inclination of the area from the total intensity of inclination taken at each location in the traverse. Corrections were made to allow for change of sensitivity of the dipping needle, due to handling and other unforseen magnetic variations.

An index map of the Abilene Arch area in Riley County, Kansas is included to show the locations of the igneous intrusions and the pitching folds.

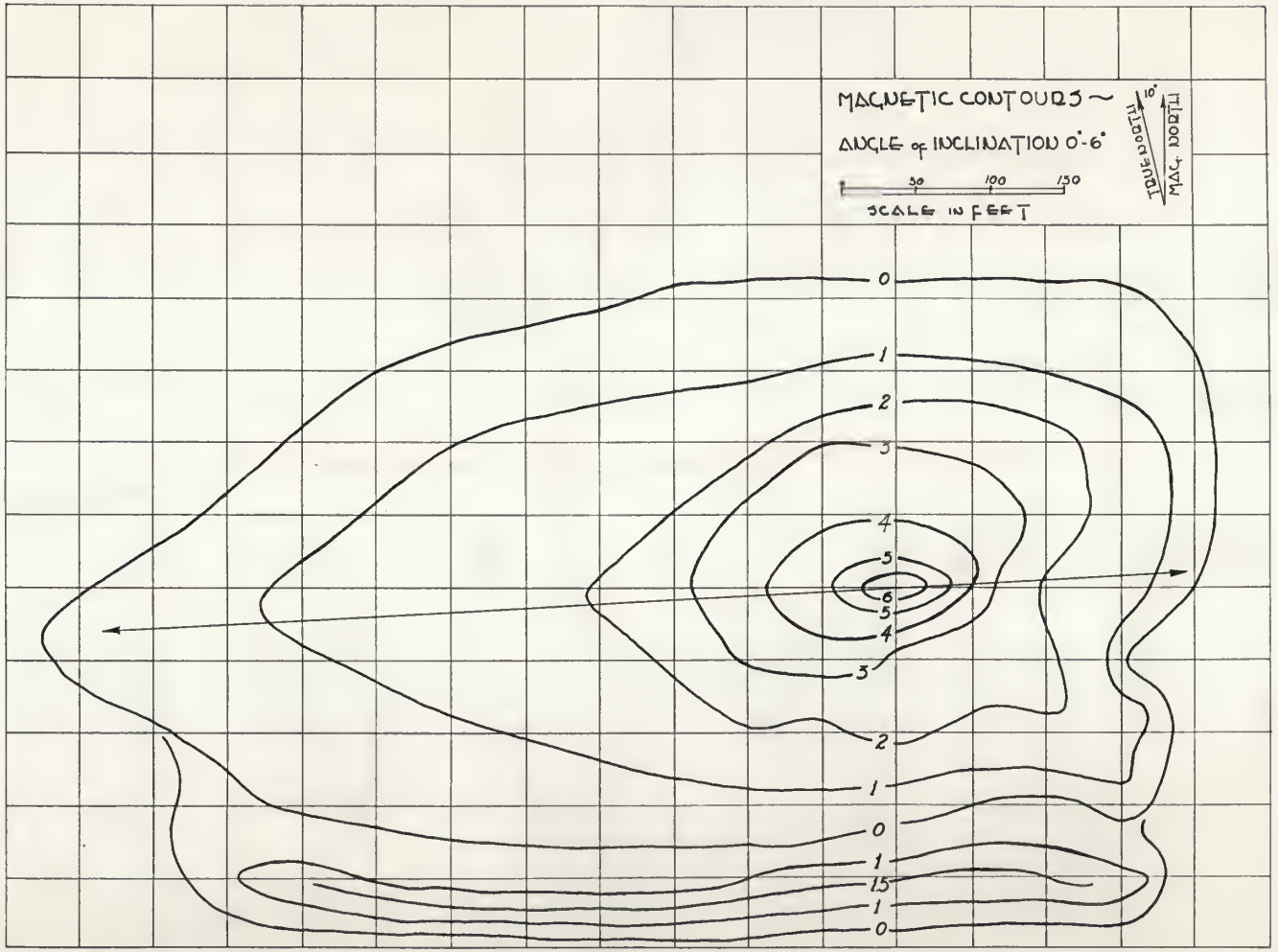

Fig. 4. Magnetic contour map of the Stockdale intrusion.

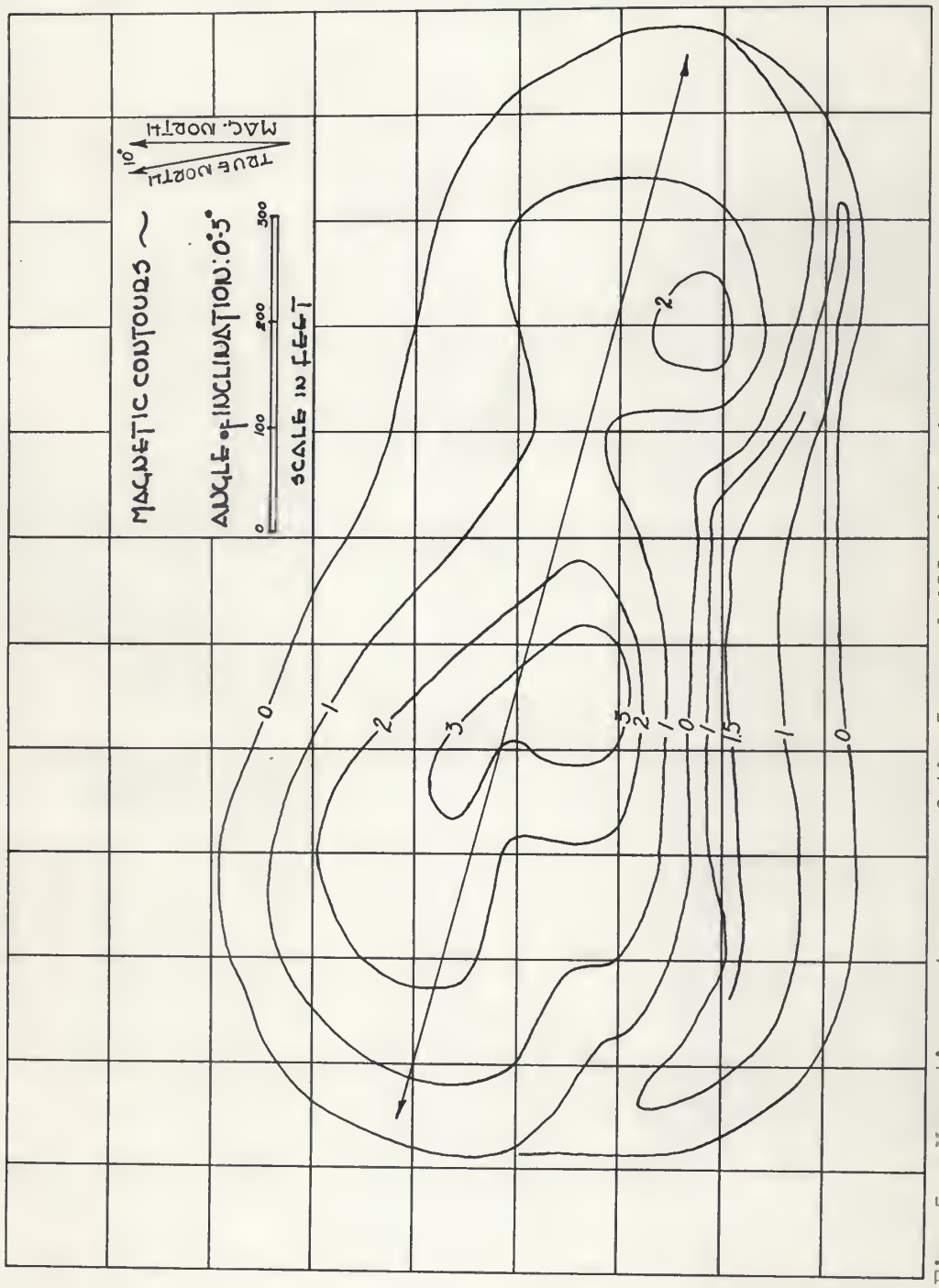

Fig. 5. Magnetic contour map of the Leonardville intrusion.

DISCUSSION

Neff (6) also found the Stovall limestone to be folded and faulted. He found the faults to be, in most cases, thrust toward eroded valleys.

Neff (6) wrote:

> All of the thrust faults in the Stovall limestone of Riley County have short fault planes and a small amount of throw. They probably are due to relief by erosion of stresses resulting from differential compaction and down-dip plastic flow of the enclosing thick shales.

The writer thinks, due to the evidence pointing to tectonic movement in the Abilene Arch area, that the folding and faulting of the Stovall limestone and of the two thick shales on either side of it, is due to direct movement of the sedimentary beds in that area. The thick plastic Gage shale and the Grant shale being the controlling factor, holds the thin Stovall limestone at its mercy. Any movement in the area of these sedimentary beds would be mostly taken up by plastic flow, which would be toward eroded valleys.

Neff's (6) joint pattern of Riley County shows the active tension in the area of the igneous intrusions, to be approximately parallel to the elongation of the intrusions. This is as it should be, because joints reflect the direction of tension in the immediate area.

CONCLUSION

It is a well established fact that there is differential compaction over the buried Abilene ridge. This establishes a line of weakness along which any movement in the immediate region

would be molded.

Information obtained from wells drilled in this area indicate that there was movement along the Abilene Arch at different times in its geologic age. It is unfortunate that the wells in this area are few and far between.

The nondeposition of the non-cherty limestone zone at the top of the Schroyer limestone indicates that movement in that vicinity was taking place at that time. This indicates that the tectonic movement which formed the pitching anticline and syncline may have started in Permian times; although slight evidence shows that minor movement occurred at different times during the Paleozoic Era.

It is known that as this area was rising the Permian Seas were driven South. At the end of the Wolfcamp series, Permian system, the region was above sea level and erosion was active. It seems likely that tectonic forces would be active during this time. The writer thinks it is possible that the peak of movement in basement complex was reached before the end of the Permian system in this region.

The pitching folds found superimposed on the large anticline, which is due to differential compaction, trend parallel to the axis of the Abilene Arch. As seen by looking at Fig. 2 the dip to the west is just slightly more than the regional dip; but on the east side the dip is unusually large for this region. This would seem to indicate that the causal force came from an easterly direction; however because the line of weakness was already established, the causal force could have been revolved into compo-

mental forces which would produce the type of folding found; therefore the exact direction from which the main causal force came is not easily determined.

The tectonic force that produced the pitching anticline and syncline is probably the same force that produced the small sharp folds and the faults in the Winfield formation.

It was thought that if the igneous intrusions were mapped that they might help explain what movement took place along the Abilene Arch. Dreyer (1) magnetic survey of the Bala intrusion instigated the thinking along these lines. His finding that the intrusion was a vertical plunging dike gave birth to the idea that it was controlled by a gash fracture. With that to think about a magnetic survey of the other two igneous intrusions was made. It was found that they were elongated and in approximately the same direction.

This brings about the possibility that they also were brought about and controlled by a gash fracture. The distance between the two intrusions gives some concern but gash fractures are known to extend much farther (Mayo, Conant, and Chelikowsky, 4).

A strike slip fault would form gash fractures in competent beds. This horizontal movement would take place in the basement complex and be carried up through the crystalline dolomitic limestones until it finally would die out in the thick shales of the upper Paleozoic, through which the igneous material was intruded.

It seems logical to assume that all three intrusions are of the same age and that they resulted from the same disturbance. They are of similar composition if not identical. They are all

of the same general elevation and each cuts through nearly all the same Permian formations.

Realizing that several factors are not as complete as they might possibly be the writer put forth the idea of strike slip movement in basement complex along the established line of weakness as the explanation of what possibly could have happened along the Abilene Arch. A diagrammatic sketch of the area, Fig. 6, is included to show more clearly the over-all picture.

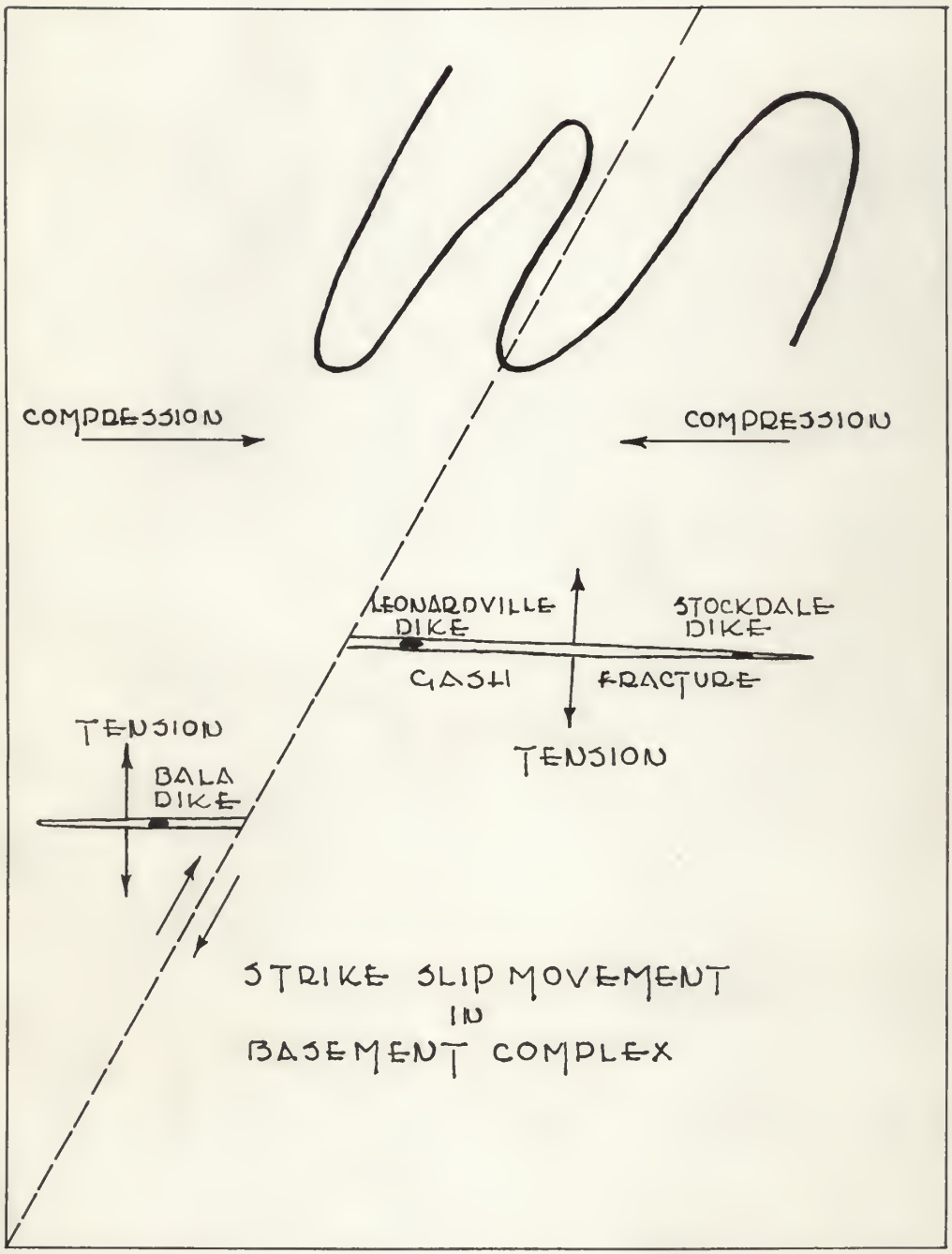

Fig. 6. Diagrammatic sketch of the Abilene Arch area in Riley County, Kansas.

ACKNOWLEDGMENT

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