A Study of the Structure and Associated Features of Sheep Mountain Anticline Big Horn County, Wyoming[1]

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Abstract. A study was made of the joint sets developed within two stratigraphic units of significantly different ages in the Sheep Mountain region, Bighorn County, Wyoming, in an attempt to determine if any pre-Laramide orogeny existed in the area. The field methods used and the relationships exhibited between joint sets are discussed. From the data presented, no significant support of the premise is concluded.

INTRODUCTION

The Problem

It is generally accepted that a study of regional tectonic elements such as folds, faults, and joints will suggest genetic connections with the standard stress-strain distribution patterns. If an area under study is not too complex, the type, relative age, and direction of diastrophic forces may be proposed.

The goals of this study were two-fold:

1) To describe the tectonic and geologic setting of the area surrounding Sheep Mountain Anticline, Bighorn County, Wy-

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oming, by geologic and structural mapping, and the gathering of data on structural features (joints and folds).

2) To interpret such a tectonic study, and suggest the possible characteristics of the applied deforming stress in the area.

The Area

Lovell S. E. quadrangle is located entirely within the Bighorn Basin of the Middle Rocky Mountain physiographic province of Wyoming (fig. 1). The basin is underlain by up to 3000 feet of Paleozoic strata, 1500 feet of Triassic and Jurassic strata, 9000 feet of Cretaceous strata, and in the central and western parts by several thousand feet of Paleocene and Eocene strata. The basin region acted as a stable shelf until Cretaceous time when considerable subsidence occurred due to the active Cordilleran area to the west.

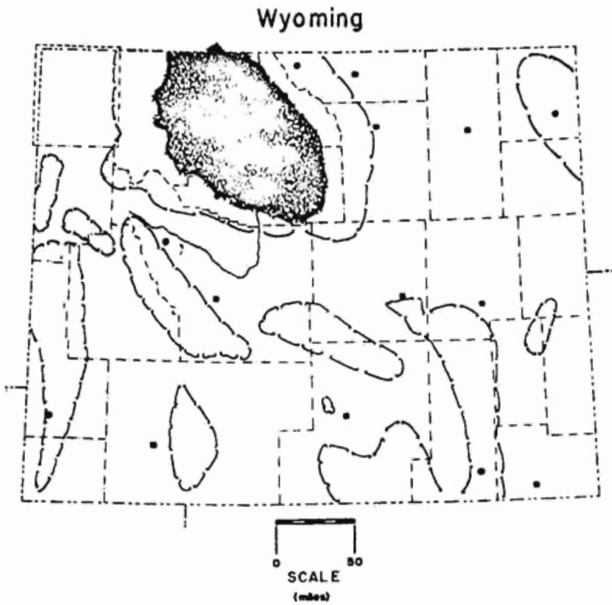

Figure 1. Index Map of Wyoming showing area of study.

Lovell S. E. quandrangle lies in the northeastern part of the basin. Sheep Mountain Anticline is the most prominent topographic feature. Sheep Mountain rises some 900 feet above the surrounding basin and is a breached, plunging, asymmetrical anticline. It is roughly 15 miles long, 3½ miles wide, and trends N45W along most of its length, plunging N28W and S14E. The dip of the western flank ranges from 30 degrees to slightly overturned, while on the western flank, the steepest dips are more than 40 degrees (fig. 2).

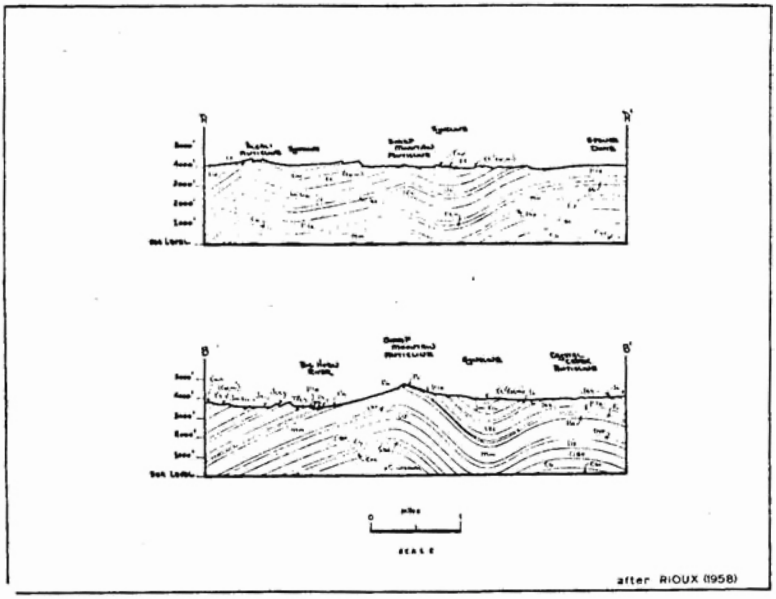

Figure 2. Cross sections at selected points on Sheep Mountain (see Figure 3).

The Bighorn River is superimposed upon the structure and cuts the anticlinal axis at one-third the distance from the northern end. Several other flexures, some quite sharp, are closely associated with the major anticline (fig.3). Its axial trend and those of the other structures roughly parallel the NW-SE trends of the typical fold structures of the Wyoming Rockies. (fig. 5A)

The formations exposed on, and in the vicinity of Sheep Mountain range from the Madison Limestone of Mississippian age to the Fort Union Formation of Paleocene age. These are mostly marine sediments. (fig. 4).

Principles Involved and Procedures Used

Joints and Faults

To better understand joints and faults, let us consider a sheet of rock being folded by compressive forces. Generally, two types of joints will be formed; shear-joints making an acute angle with the deformative stress and tension-joints parallel to this stress. Following this, a secondary stress condition could form as a result of the elastic bending of the sheet. In this stage a set of shear-joints may form which have their acute angle bisected by the fold axis. Also, a set of tension-joints may form parrallel to the fold axis. In addition, friction shear-joints may develop parallel to the fold axis. This latter system is formed due to op-

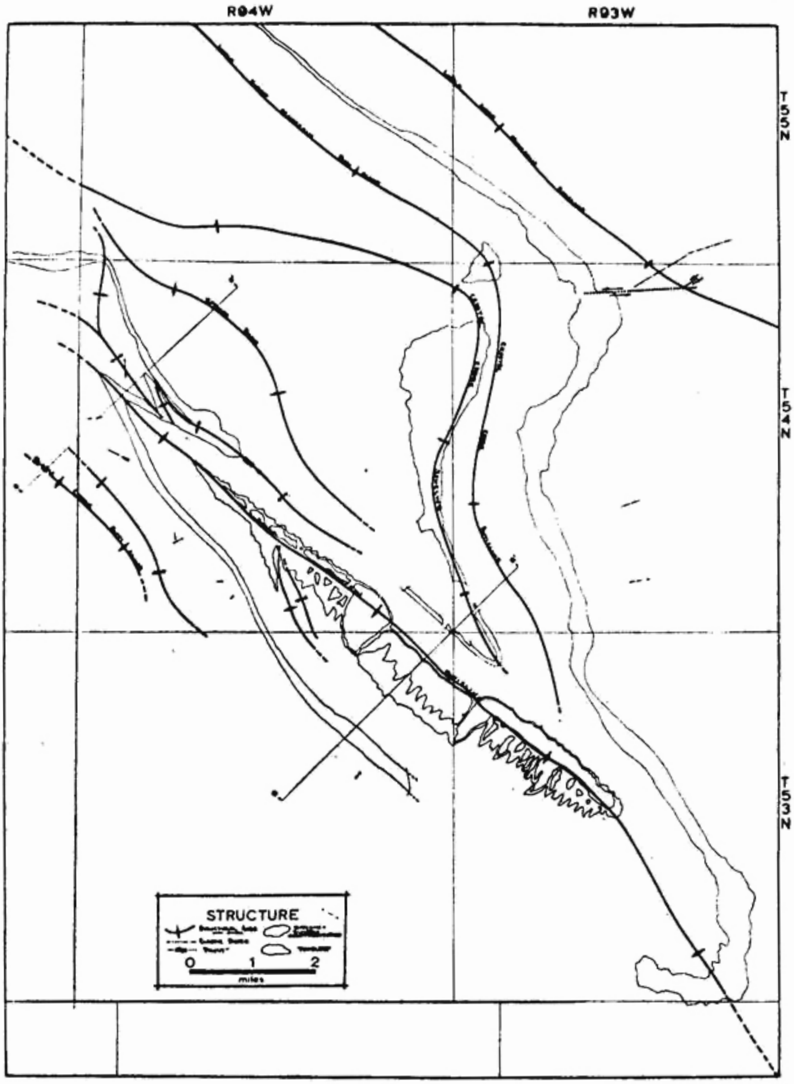

Figure 3. Structural map of study area.

posing stresses directed on the upper and lower surfaces of the rock sheet. Finally, release tension-joints might form after the stress has dissipated. They will be either parallel or perpendicular to the fold axis, depending upon whether they release the main or secondary stresses (deSitter, 1956).

It is unlikely that all of the above sets of fractures and joints will be present in any one folded rock unit. Whichever sets are

GEOLOGIC AGE	FORMATION	SYMBOL	THICKNESS (RIOUX)
EOCENE	Tatman	Tt	
	Willwood	Tw	
PALEOCENE	Fort Union	Tfu	3500+
UPPER CRETACEOUS	Lance	Kl	600±
	Meeteetse	Kme	900±
	Mesa Verde	Kmv	1250±
	Cody	Kc	2230
	Frontier	Kf	600
LOWER CRETACEOUS	Mowry	Km	330
	Thermopolis	Kt	500
	Cloverly	Kcl	620
JURASSIC	Morrison	Jm	
	Sundance	Js	370
	Gypsum Spring	Jgs	200
TRIASSIC	Chugwater	TRc	600
PERMO-TRIASSIC	Embar	P-TRe	270
PENNSYLVANIAN	Tensleep	Pt	105
	Amsden	Pa	170
MISSISSIPPIAN	Madison	Mm	780
DEVONIAN	Jefferson	Dj	180
ORDOVICIAN	Bighorn	Ob	410
CAMBRIAN	Gallatin	Cg	530
	Gros Ventre	Cgv	510
	Flat Head	Cfh	120
PRE-CAMBRIAN---	Mainly granites, pegmatites, schists, and a variety of dark colored dike rocks.		

Figure 4 Generalized stratigraphic chart of area surrounding Sheep Mountain (after Rioux).

dominant are probably determined by lithology, as well as the position on the structure (the stress field) under consideration.

Field Procedures

The major concern of this study was to determine whether or not indentifiable joint patterns had been produced both by pre-Laramide and Laramide tectonic activity. It was assumed that, if two widely separated periods of orogeny took place, a system of fractures would occur in the older rock unit which would not appear in the younger beds. Since both units would have been subjected to the compressive forces of the Laramide orogeny, any significant difference in fracture patterns would suggest the possibility of some pre-Laramide deformation.

Two competent units were selected for this study, uppermost sandstone member of the Tensleep Formation and the Greybull sandstone member of the Cloverly Formation, because of their mutual age relationships to two separate periods of crustal movement. The Tensleep is Pennsylvanian in age and the Cloverly is lower Cretaceous. The presence of a regional angular unconformity between the Tensleep and "Embar" Formations suggested the possibility of a post-Tensleep orogeny which might be evidenced in a fracture orientation. The Laramide orogeny, during which the major folding in the area took place, is post-Cretaceous in age.

Another determinant in the consideration of the rock units was their relatively equal properties of thickness and competency (fig. 5B and 5C). The reason for this consideration is quite obvious; rocks possessing different physical properties would necessarily behave differently under similar conditions of applied stress.

The final factor in the consideration was the fairly uniform distribution of the units throughout the study area.

In order to obtain an unbiased and representative sample of fractures, areas of observation were decided upon prior to field inspection. These areas were located at definite intervals peripheral to the main axis of Sheep Mountain. The Tensleep formation was observed at one-mile intervals along the flanks of the mountain. An attempt was made to completely encircle the mountain with accurate observations made at these intervals. The same procedure held true for the Cloverly. In the northern part of the area mapped exposures of the Cloverly were often found more closely associated with minor structures than with Sheep Mountain anticline. These exposures, however, were considered in the analysis.

Method of Analysis

Once an exposure was found, the analysis of fractures proceeded as follows: A 15' x 15' grid was plotted on the outcrop face, and traverses were made across it at intervals of three feet. When completed, the grid appeared to be composed of 25, nine-square-foot sections. Wherever a fracture or joint was noted to cross a grid line, its strike, length, and, if possible, dip and dip direction were recorded. The regional dip and strike were also recorded. Care was taken not to make multiple readings of the same joint.

Discussion

To accomplish the first goal of the study, geologic and structural base maps were prepared of the area, from considerable field reconnaissance and aerial photo interpretation (figs. 3 and 6). The strike and frequency of the various fracture and joint sets were plotted. Several interesting relationships were revealed (fig. 7).

In most of the exposures studied, especially near the axial plunges of the main structure, there is a definite major east-

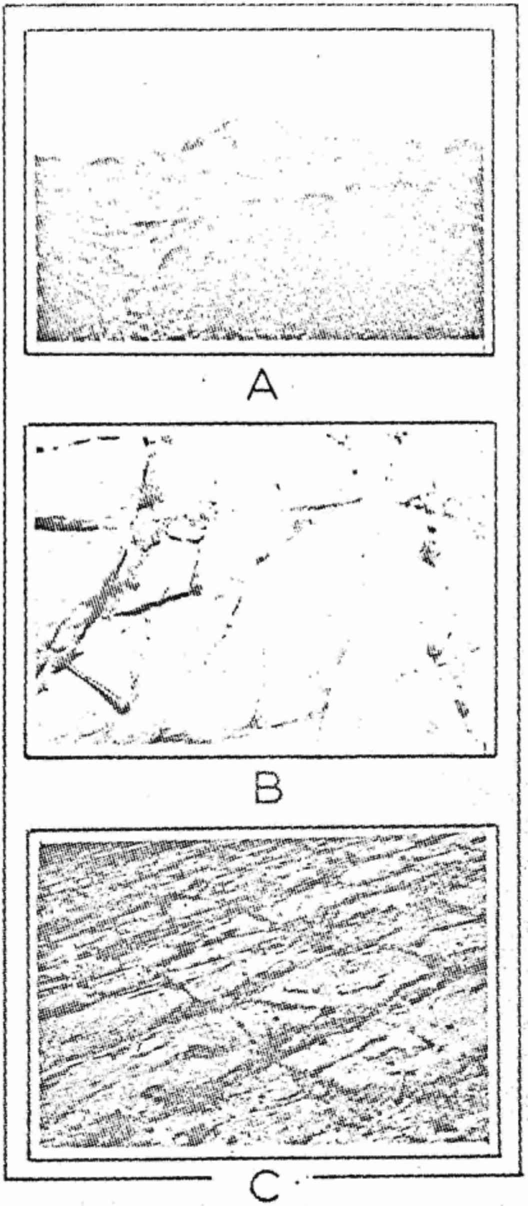

Figure 5A Looking southeast along axis of Sheep Mountain anticline from NE¼, NW¼, Sec. 18, T54N, R94W.

5B. Typical exposure of uppermost sandstone member of the Tensleep showing joint sets.

5C. Typical exposure of Greybull sandstone member of the Cloverly showing joints sets.

west trend noted in the joint set. These joints intersect the structural axes at acute angles ranging from 35 to 50 degrees.

Another major joint set is noted trending roughly parallel to the structural axes. These joints vary from N75W to N25W, and appear to be somewhat more prominent in the Tensleep over a larger portion of the area mapped. Occurrences of these joints within the Cloverly are relatively equally distributed over the entire area.

A minor joint set which trends roughly north-south exists in the southeast portion of the area mapped. Here the southeast axial plunge of Sheep Mountain is intersected by two closely associated fold structures from the north (Crystal Creek Anticline, etc.). In this area, joints of this set are about equally distributed in exposures of both Tensleep and Cloverly formations.

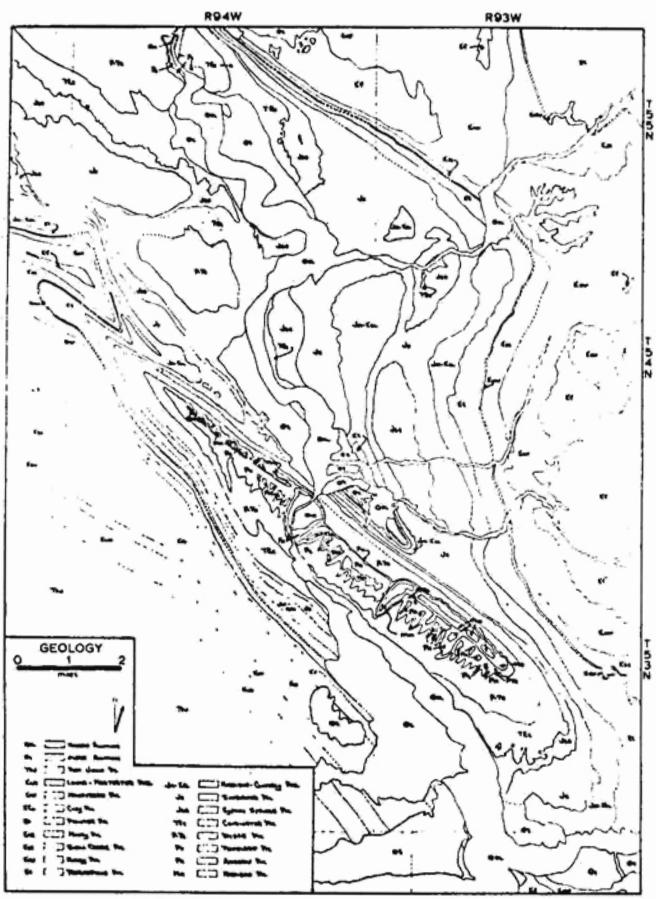

Figure 6 Geologic map of study area.

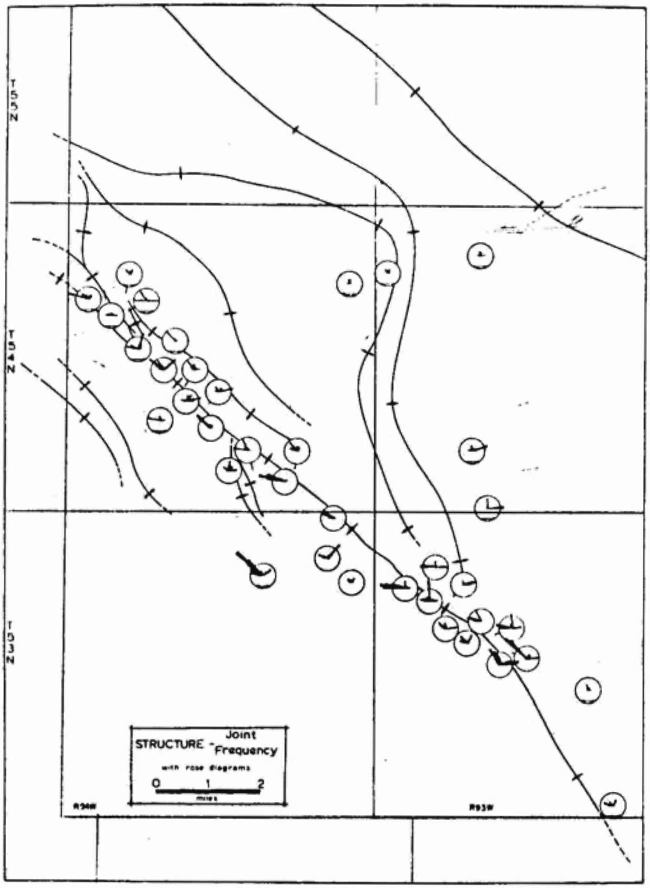

Figure 7 Map showing joint frequencies at selected points of study with relation to structural axes.

The acute angles formed by the joints with respect to the structural axes are of the same magnitude as those noted for the east-west trending joints as before mentioned. Another set of joints, also minor in importance, is noted within the area. This particular set is approximately perpendicular to the strike of the structural axes, and trends from N25E to N65E in various exposures. Over the entire area, its occurrence is rather uniform in the Cloverly, but sporadic in the Tensleep, occurring in appreciable numbers within the axial plunge areas of the major fold structure.

Other joints of varying strike were noted, but relationship to an important set seemed unlikely. These were regarded as unimportant.

In the northeast portion of the area mapped, three large very good exposures of the Greybull sandstone were studied. The trends noted here belong to only two sets; north-south and east-west. In this area, due to the orientations of the fold axes of the minor structures with which they are associated, both were considered major in importance (fig. 7). The north-south joints corresponded roughly to the parallel set and the east-west joints corresponded roughly to the perpendicular set as noted before. In one exposure a large set was noted which did intersect the fold axis of the anticline structure (Crystal Creek) at an acute angle.

Summary

In general consideration of the various joint sets associated with both the Tensleep and Cloverly Formations, little distinction can be noted. Since there is little difference between those sets associated with the Tensleep and those associated with the Cloverly, and in view of the stratigraphy between these two formations, one conclusion may be readily drawn.

As stated, there is no reason to believe that once a strain system has been set up within a rock, further strains, as a result of renewed stresses would not find their development along the previously existing strain patterns. This phenomenon could have an influence on all subsequently younger sediments and as a result, similar strain patterns or fracture systems would be set up.

The authors believe that such was the case here. If some pre-Laramide orogeny did exist in the area, as is indicated by the presence of several unconformities, it was sufficient enough to stress the older, in this case, Pennsylvanian Tensleep sediments to some characteristic strain pattern. As subsequent, and eventual Laramide stresses affected the area, their release was found along these previously existing strain patterns. Hence, we see many similarities in the orientations of the fracture systems.

Since we are dealing with an area of rather limited areal extent, it seems a bit futile to attempt to relate the joint sets exhibited in the area to regional stresses without first studying a wide variety of exposures over a much larger geographic area. It is interesting to note, however, that the deformation which came about in the area as a result of the Laramide orogeny was probably caused by compressional forces from the west thrusting the miogeosyncline of the Cordilleran onto the stable shelf in the latter phases of mountain-building.

The authors would like to consider the strain system so developed as a result of the secondary stress conditions which developed with the folding of the local structures. Therefore, one can assume from the relationships presented that the system represented suggests: 1) shear-joints developed at acute angles to the fold axis (north-south and east-west trending joints); 2) tension-joints developed parallel to the fold axis; 3) release tension-joints developed either perpendicular or parallel to the fold axis; and possibly 4) friction shear-joints on the flanks of the fold structures oriented parallel to the axis.

From the data gathered, it is not possible to support our earlier concept that a detailed mapping of fracture patterns in representative, selected strata would prove more than one period of tectonic activity. We would not conclude that the concept has no merit, but rather that the scope of our study produced inconclusive results.

Acknowledgments

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