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REGIONAL TECTONICS OF SOUTH-CENTRAL NEW MEXICO

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INTRODUCTION

The area directly involved in this paper is that included within the geologic map in the pocket. This geologic map lies between latitudes 32° 46' and 33° 30' north and longitudes 106° 29' and 107° 44' west and embraces approximately the eastern three-fourths of Sierra County. It is an area of about 3,200 square miles. The geology of the area is dominated by three northerly trending uplifts which are from west to east the Cuchillo Negro, Caballo-Fra Cristobal, and San Andres. Intervening with or adjoining the uplifts are four depressions which are from west to east the Hillsboro-Winston graben, Rio Grande depresion, Jornada del Muerto basin, and Tularosa basin (Fig. 1). The above structural elements are a typical part of Fenneman's Mexican Highland section of the Basin and Range physiographic province (1930). From another point of view they are of the Eastern Rocky Mountains structural province (Eardley, 1951, p. 285).

The region is assigned to the Basin and Range province because the mountains are in part fault blocks, and because the drainage of many of the valleys is interior. Assignment of the region to the Eastern Rockies is justified partly on the observation that there is continuity of the belt of deformation from the typical Rockies of Colorado southward through New Mexico into the Oriental belt of deform-

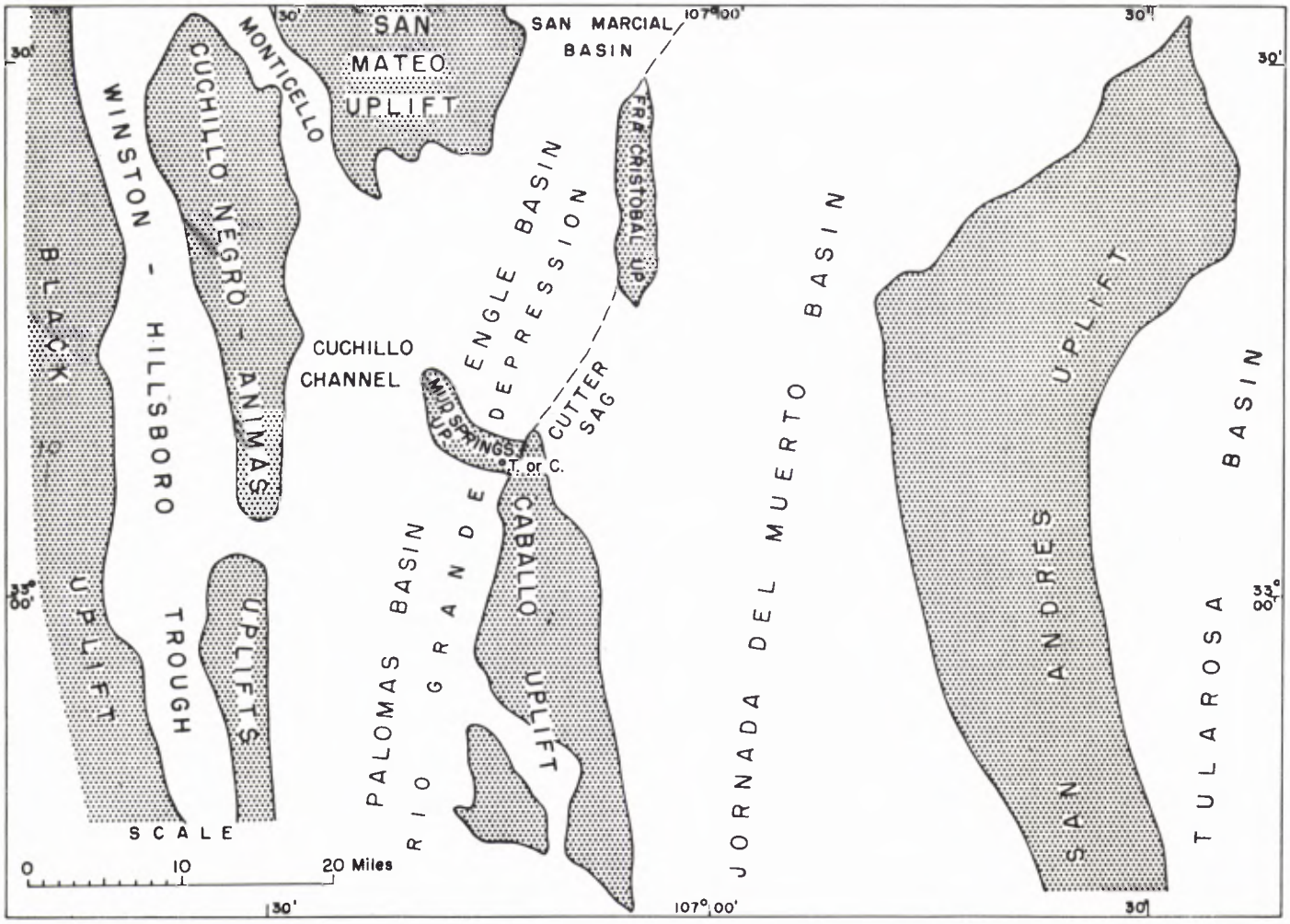

Figure 1. Outline map of the principal tectonic features of the Sierra County region.

ation in Mexico. Involved here also, in a tectonic sense, is the fact that the Rockies belt extending from central Wyoming into northern New Mexico has long been considered Laramide (late Cretaceous-early Tertiary), and there is, therefore, the implication, and the conclusion by some, that the deformation through central New Mexico has underlying or basic Laramide elements. That this may be the case can not be rigorously proved in central and southern New Mexico because of the dominance and masking effects of late Tertiary faulting and because of the absence of the necessary Tertiary sedimentary sequences in close relationship with the structures.

Much of the high-angle faulting in the Rockies of Colorado also may be late Tertiary or Basin and Range in type and age. Therefore, it is not possible to make a clear separation or dividing line at the southern ends of the Nacimiento and Sangre de Cristo Ranges between Basin and Range and Eastern Rockies structures in the way that the physiographer has separated the Basin and Range province and Rocky Mountains. The belt of deformation is continuous from Wyoming to Mexico, and it is more meaningful and logical to consider the belt of deformation that extends northward through New Mexico as part of the Eastern Rockies tectonic belt. It probably has Laramide elements of thrusting and overturning as well as late Tertiary rifts and other high-angle Basin and Range type of faulting. However, the trends, position, connections, and structural relief set it apart from the Basin and Range structural province of Arizona. Furthermore, it is so far removed from the typical Basin and Range of Nevada as to make it pointless to attempt a tectonic connection with that province.

TECTONIC ELEMENTS

The principal tectonic elements of the Sierra County region are shown in Figure 1 and are briefly described below.

Tularosa Basin

The Tularosa basin is the largest of the basins in the Rockies belt of southern New Mexico, being about 120 miles long and 30 miles wide. It lies between the San Andres and Sacramento uplifts and probably is bounded structurally in most places by faults. Late Tertiary and Quaternary sediments of variable thicknesses appear to cover an irregular bedrock floor of Permian, Pennsylvanian, and Cretaceous rocks. The areas of bedrock exposed in the valley bottom make it appear that the basin fill is not uniform and that it may be localized in greater thicknesses in certain areas or sub-basins.

Inasmuch as the uplifts on either side are tilted away from the basin it has been supposed that the basin may be the result of collapse of a broad arch that formerly extended across the basin. Although this interpretation is possible there are details of structure within and immediately adjoining the basin which make it appear that the origin of the basin is more involved. Also in the early stages of deformation it may have been a broad syncline between two opposing asymmetrical anticlines.

San Andres Uplift

The San Andres Range is about 80 miles in length and is one of the longest and most prominent in New Mexico. It is a relatively simple, westward-tilted fault-block. The bold eastern escarpment consists of Precambrian rocks that are capped by Paleozoic rocks essentially along the entire crest. The westward dips are generally less than 10 degrees. The structure is broadly arcuate to the west and is structurally relatively simple along the long, straight middle part and more complicated at its extremities. The northern and southern ends consist of plunging anticlines that are much modified by faults. At the northern end the fault complications are most pronounced in the part north of Sly Gap, where it may be seen from the geologic map in the pocket that the range consists of several small tilted blocks as at Fairview Mountain. Elsewhere the structure of the northern part of the uplift is marked by numerous diagonal, northwesterly trending faults of both right- and left-lateral separations.

A line of interrupted fan scarps occurs along the eastern base of the uplift attesting to some recent rise of the range. These may mark the coarse of the principal bounding fault zone along which the range has risen.

Jornada Del Muerto Basin

The Jornada basin lies between the San Andres-Oscura and the Caballo-Fra Cristobal uplifts. It is about 110 miles long and 15-20 miles wide. It is slightly arcuate to the west along its over-all length, and in this respect conforms to the trend of the San Andres uplift. The altitude along the axis of the depression is about 4,700 feet, which is about 700 feet higher than the bottom of the Tularosa basin to the east.

In the latitude of the Caballo uplift no faults appear to bound the Jornada basin, and it has been most commonly considered to be a broad simple syncline between the eastward tilted Caballo uplift and the westward tilted San Andres uplift. The general position of the structural trough may be noted from the disposition of the volcanic beds in the Poague Hills (geologic map in pocket). East of the Caballo uplift, low-dipping Cretaceous beds floor the basin

in wide areas out to the center of the basin. Although there is a general eastward dip in this wide pediment-ed area, locally there is much faulting and folding in the late Cretaceous rocks.

Along the eastern half of the basin, however, the bedrock is covered by valley fill and whether a westward dip, corresponding to that in the San Andres uplift, exists in the bedrocks can only be surmised in the absence of subsurface data. The eastern margin of the basin against the San Andres uplift is erosional. Although the erosional face is in most places one of near dip slopes on the San Andres formation, there are places where the San Andres beds dip more gently than the erosional escarpment and there is the possibility that the Jornada depression is downthrown with respect to the San Andres uplift along a fault zone beneath the valley alluvium. This possibility is suggested because of the absence of bedrock outcrops in the eastern half of the basin as compared to the western half.

To the north in the latitude of the Cutter sag (west of Engle) and the Fra Cristobal uplift the concept of a simple syncline for the Jornada breaks down because the attitudes on the west side are either westward or at right angles to the basin (Fig. 3). Furthermore, it appears that the east face of the Fra Cristobal uplift is a fault scarp. About 7 miles north of Engle a southwestward dip in a small bedrock "island" is present well out in the basin (geologic map in pocket). Many of the northwesterly trending diagonal folds and faults of the Caballo uplift and the Cutter sag probably continue or are represented in kind in the Jornada basin.

In general the valley fill in the Jornada is probably nowhere very thick. Certainly it is thinner than in the Tularosa basin and greatly thinner than in the Rio Grande depression to the west. The great volume of material that has obviously been eroded from the uplifts bounding the Jornada must have been swept southward out of the basin.

Fra Cristobal Uplift

The Fra Cristobal uplift is a relatively small, north-trending fault-block which is about 16 miles long and up to 3 miles wide. It is rather sharply defined by faults and tapers structurally to rather sharp points at both ends (geologic map in pocket). In the central and northern parts the uplift is tilted eastward 4-8 degrees, but in the southern part the tilt turns to the south and southwest and dips toward the Cutter sag. The bounding fault on the west is termed Hot Springs and it continues southward without interruption into the Caballo fault which similarly bounds the Caballo uplift on the west. The length of the fault is about 55 miles and it is one of the longest, continuous late Tertiary faults in New Mexico. Along the crest of the uplift there are three northwesterly to northerly trending overturned fold belts. These are in echelon and overturned to the east in conformance with those in the Caballo uplift. Further details of the geology are discussed by Sam Thompson elsewhere in the guidebook.

Cutter Sag

The Caballo-Fra Cristobal line of uplifts is interrupted by the complex, northwesterly trending Cutter sag. It is physiographically low and is in a sense an embayment or branch from the Jornada basin. It is about 10 miles wide and along its trough is filled by 2-3 thousand feet of the late Cretaceous-early Tertiary McRae formation. The broad trough trends roughly along McRae Canyon in T. 13 S. It may be said to extend from about Elephant Butte on the south to the short northwest-trending fault which bounds the Fra Cristobal uplift near the northern part of T. 12 S. Numerous faults of northeasterly trend complicate the broad sag, and several Quaternary (?) basaltic cones and numerous late Tertiary (?) dikes lie within the area. Something of a continuation of the Cutter sag may be said to exist across the Hot Springs fault in the southern part of the Engle basin.

Further details concerning the Cutter sag may be found in the paper by Sam Thompson on the Fra Cristobal Mountains and in the third road log. Bushnell (1953, p. 59) named the Cutter sag and has mapped and described the geology.

Caballo Uplift

The Caballo range is a north-northwesterly trending, eastward-tilted uplift that is about 28 miles long and as much as 10 miles wide. The range is principally uplifted on the Caballo fault which is prominent along the western base. In the high, central part opposite the southern end of Caballo Reservoir the general eastward tilt is 10-20 degrees. However, the general structural simplicity which is apparent along the bold western escarpment has two kinds of complexity elsewhere. First, the broad southern part of the uplift and the relatively narrow northern end are complicated by numerous high-angle faults which essentially produce a mosaic of small fault blocks. Secondly, the over-all, late Tertiary, east-tilted uplift is crossed by several north-to-northwesterly trending overturned fold belts that may be Laramide in age.

Other aspects of the geology are treated elsewhere in this guidebook by Caswell Silver and the geology has recently been mapped and described by

Kelley and Silver (1952).

RIO GRANDE DEPRESSION

This depression lies along the Rio Grande and is the principal intermontane trough in the Eastern Rockies orogenic belt of New Mexico. The part in Sierra County consists of the Engle and Palomas sub-basins. These and other sub-basins to the north comprising the Rio Grande depression are a part of a grand series of intermontane troughs which extend northward through the "Parks" of Colorado to the Laramie basin of Wyoming. In effect they divide the Eastern Rockies into irregular parallel chains (Fig. 2). In Sierra County the Caballo-Fra Cristobal uplifts are the principal part of the eastern chain and the Black Range may be considered the principal part of the western chain. This situation is essentially self evident owing to the fact that the Rio Grande depression is the most pronounced of the troughs or basins across Sierra County.

The Rio Grande depression is divided into two parts by the northwest-trending Mud Springs fault block (geologic map in pocket). The northern part is termed Engle basin and it lies irregularly among the Fra Cristobal, San Mateo, Cuchillo Negro, and Mud Springs uplifts. It appears to link with the San Marcial basin to the north through a narrow constriction between the Fra Cristobal and San Mateo uplifts (Kelley, 1952, p. 92). In a similar manner it may link with the Palomas basin to the south, west of Mud Springs uplift, through what has been termed the Cuchillo channel. The Monticello graben or trough is a branch to the north from the Engle basin.

Although the deepest part of the Engle basin on the basis of general regional relations would appear to be along the eastern edge, the irregular structural boundaries given above suggest considerable structural complications beneath the Tertiary sediments. That this is the case in part at least has been brought to light recently by the logs of two wells within the basin. These wells are the Drew-Mathews No. 1 Federal (NW-SE sec. 8, T. 12 S., R. 4 W.) and the Gartland No. 1 Garner (SW-SW sec. 11, T. 12 S., R. 5 W.). These wells are about 3½ miles apart, east-west, and the Gartland well to the west was apparently still in Tertiary sediments at its total depth of 6,524 feet whereas the Drew-Mathews well to the east went into late Cretaceous Mesaverde rocks at about 1,500 feet (Kelley and Silver, 1952, p. 221; 227-230).

The Mud Springs uplift between the Engle and Palomas basins is tilted northeastward 15-50 degrees along a fault which is probably buried by the upper part of the Santa Fe beds. Overturning appears to

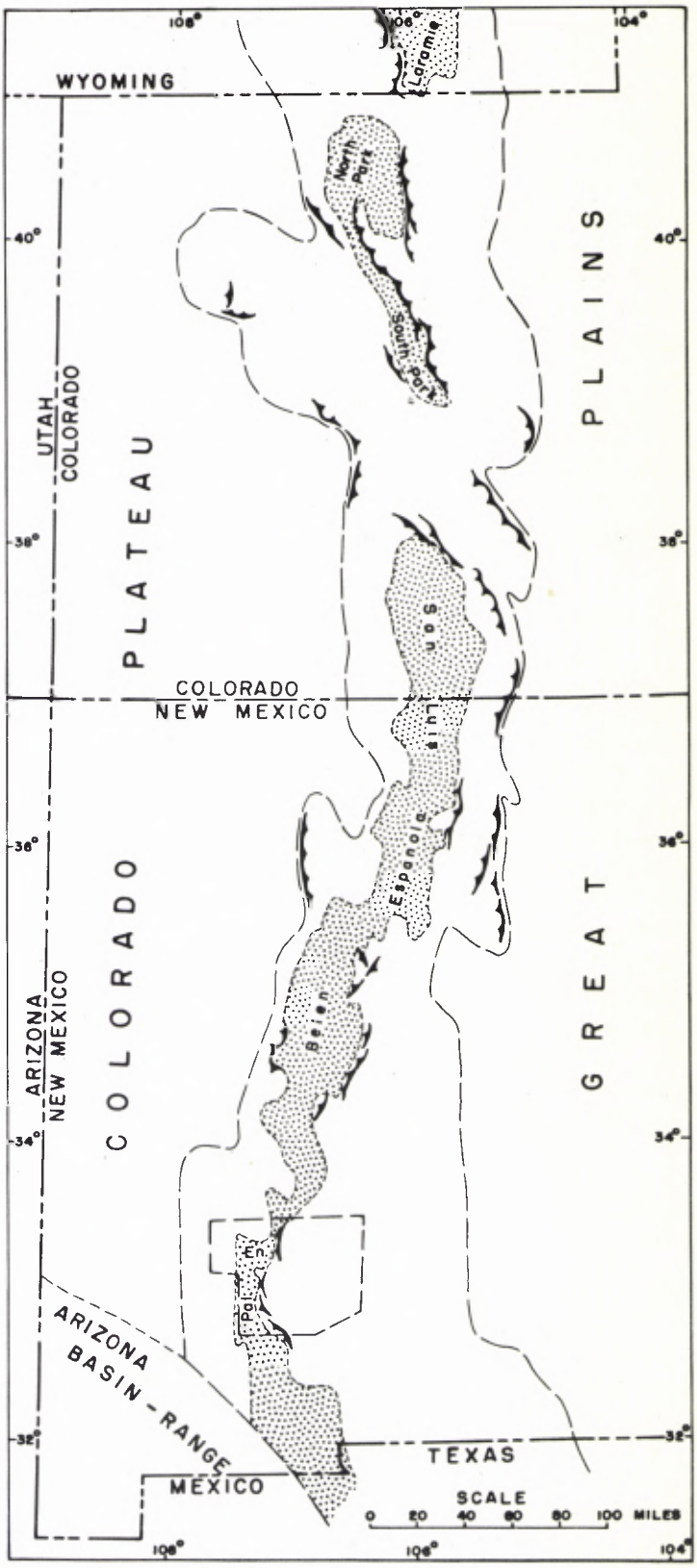

Figure 2. Eastern Rockies belt of Colorado and New Mexico showing the line of principal intermontane troughs.

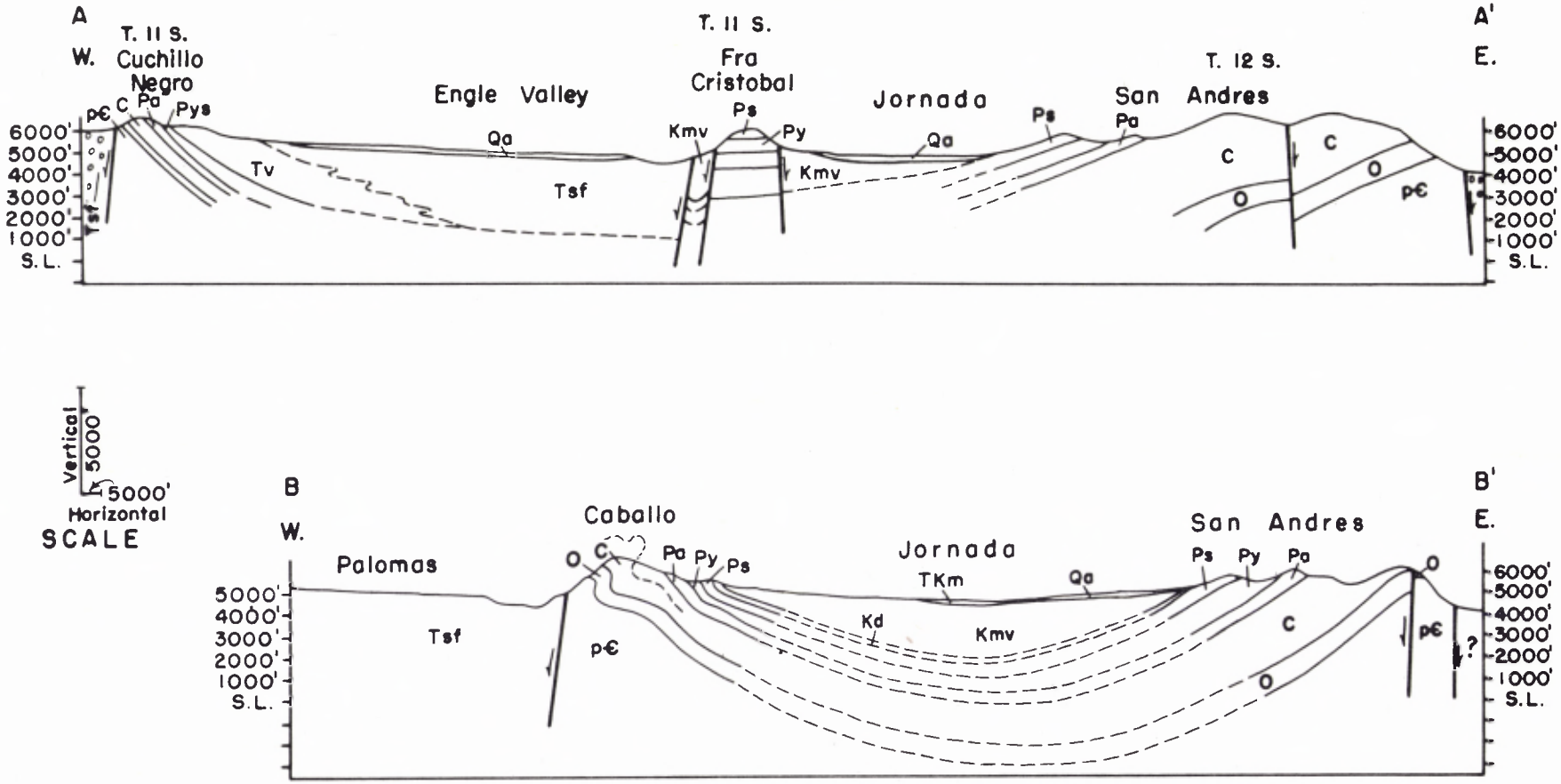

Figure 3. Structure sections. A-A' from Winston to the Tularosa basin one mile north of state road 52; B-B', along 33° 00' N. from the Rio Grande depression to the Tularosa basin.

modify the mostly buried southeastern part of the structure near Truth or Consequences (Kelley and Silver, 1952, p. 190-192).

Palomas basin is more regular than Engle basin and is principally confined between the more or less parallel north-trending Caballo and Animas-Hillsboro fault blocks. It is about 35 miles long and 12 miles wide. The southern boundary is obscured by Tertiary and Quaternary beds which blanket wide areas of the subdued older physiographic and structural areas of the Arizona-New Mexico Basin and Range province (Kelley, 1952, p. 99-100).

San Mateo Uplift

The San Mateo uplift consists largely of Tertiary volcanic rocks and details of its geology are largely unknown. Although it is probably complicated by numerous faults and more than one epoch of intrusion and extrusion, it appears in its southern part to consist generally of blocks titled gently eastward. However, small exposures of Magdalena strata are exposed beneath the volcanic rocks at both the southwestern and southeastern corners of the range. The southwestern side is bounded by a fairly straight fault scarp (geologic map in pocket), whereas the eastern boundry is more irregular apparently as the result of both erosion and overlapping burial by Tertiary and Quaternary sediments.

Cuchillo Negro-Animas Uplifts

To the west of the Rio Grande depression in Sierra County there is a more or less continuous line of low uplifts extending from about the northern boundary of the county to near Lake Valley. The uplifts are bounded generally on the west by a narrow irregular series of grabens that may be termed the Winston-Hillsboro trough. The Cuchillo Negro-Animas uplifts are surfaced largely by volcanic rocks, but along the western escarpment, especially in the Cuchillo Negro uplift, Precambrian, Paleozoic, and a little Cretaceous rocks are exposed (geologic map in pocket). In general the entire Cuchillo Negro uplift is tilted eastward 20-50 degrees and intruded by numerous dikes, sills, and irregular small intrusives. The uplift is considerably broken by oblique and longitudinal faults (Jahns, 1944, pl. 17).

Summary

The uplifts across the orogenic belt of south-central New Mexico are in general alternately asymmetrical east and west from the Sacramento uplift on the east to the Black Range uplift on the west. Although they all trend northerly they are otherwise rather individual and distinctive as regards their interior structures. The belt is one of diversity of deformation from east to west. The very gently eastward tilted Sacramento uplift which bounds the orogenic belt on the east is characterized by several large open folds along its western escarpment (Pray, 1949, p. 58-59). The San Andres range, the largest of the uplifts, is in general the simplest and most uniform in its deformation over large areas. Dips throughout much of its length are rarely more than 10 degrees. The exceptions to this generally are confined to the more complicated northern and southern terminations. The Caballo-Fra Cristobal line of uplifts is the most highly deformed and characterized by pronounced overturned folds and some low-angle thrusts toward both the west and the east. The small Cuchillo Negro uplift appears to be characterized by more intricate or "fine-grained" fracturing, and the great volume of intrusives may be responsible for this characteristic. The Black Range uplifts which may bound the orogenic belt on the west is a broad undulated arch which is much broken by faults especially along its steeper eastern limb (Kuellmer, 1954, pl. 1).

The reasons for the diversity of structures in the several uplifts are not entirely clear. Of course, diversity of deformation is very common in orogenic belts. Most belts are, in the over-all, asymmetrical or variable from one side to another. In part the variations in New Mexico are clearly due to differences in the tectonic history dating at least as far back as late Pennsylvanian time. Also differences in intensity and rate of deformation in the several uplifts and depth of burial of the now-exposed rocks at the time of deformation may have played a role. In part the variations may be due to the differences in the sizes of the uplifts, the small ones possibly deforming more continuously than the large ones, other factors being the same.

Pray (1954, p. 104-105) has shown that some of the folding along the Sacramento escarpment is post-Magdalena-pre-Abo in age, but some of the folds west of the Abo outcrop may be younger.

Although it can not be rigorously proved, it is possible that the overturning and thrusting in the Caballo uplift is Laramide in age. Certainly the very considerable shortening is incompatible with the gravity faults that bound the fault blocks. Thus, the Caballo Mountains may have experienced two principal periods of deformation whereas the San Andres and others may have experienced only one--late Tertiary.

The Cuchillo Negro uplift, in common with a considerable area of central New Mexico west of the Rio Grande (Kelley, 1952, p. 98), appears to have

been broadly uplifted and stripped of a considerable thickness of Cretaceous and some Permian rocks prior to burial by late Tertiary volcanic rocks. Of course similar middle or early Tertiary uplift and stripping may have occurred elsewhere but the absence of the late Tertiary volcanic rocks prevents the separation or distinction of such uplift and erosion from the late Tertiary and Quaternary ones.

The late Tertiary block faulting may have been preceded by broad warping into anticlines and synclines, but it is for the most part difficult to distinguish, under the conditions of exposure, between an anticline later broken on its steep limb from faults along which there has been large associated drag. It is difficult to propose, as some have done, large drag by gravity faults in a regional field of tension without some bending prior to the faulting.

Drag slickensides, separations, and diagonally oriented folds within the basin sediments, particularly in the Rio Grande depression, indicate considerable if not dominant, components of lateral movement on many of the late Tertiary faults (Kelley, 1952, p. 102-103).

A diversity in the structure of the several basins similar to that of the uplifts appears evident and logical, for much the same reasons as advanced for the uplifts. The basin of greatest deformation is probably the Rio Grande depression; the least may be the Jornada del Muerto.

TECTONIC HISTORY

The tectonic history of the Precambrian in south-central New Mexico is very obscure. The age of the exposed Precambrian rocks may be Proterozoic or Archeozoic. However, in view of the kind of rocks, their metamorphism, and their steep foliation it would appear that they are older than those of the Mazatzal group in Arizona. The foliation and bedding trends are locally diverse, but in the principal exposures along the Caballo and San Andres escarpments there is a dominance of east-west trends and it may therefore be assumed that this was the direction of the principal deformation. Granite and orthogneiss younger than the foliated rocks dominate the terrane and their emplacement may have profoundly changed earlier fold directions.

In any event prolonged erosion under presumably stable tectonic conditions apparently produced a wide low peneplain in the area by late Precambrian and early Paleozoic time. Slow subsidence in Cambrian time allowed the encroachment of the Sonoran seaway from the south and southwest over a broad shelf. This subsidence continued through early Ordovician time allowing the deposition of the El Paso carbonate blanket across the entire county and probably far to the north. During middle Ordovician time the area was tilted southward and gently undulated along north-south axes (Keyes, 1920, Fig. 5). Erosion widely stripped the upper part of the El Paso group throughout Sierra County and developed a karst topography before gradual subsidence allowed the northward spreading of the late Ordovician carbonate-depositing sea. Broad regional tilting to the south appears to have taken place again at the end of Ordovician time or in early Silurian time. The early or middle (Pray and Bowsher, 1952, p. 1342) Silurian seas probably spread widely across southern New Mexico and possibly far to the north of Sierra County.

The regional tectonic conditions that allowed the widespread, considerable build-up of nearly pure carbonate blankets came to an end in middle or late Silurian time and a long interval of regional tilting and stripping set in. The possible magnitude of this epeirogenic disturbance has, I believe, been greatly underestimated. There is little evidence of a shoaling facies for the Silurian strata and it therefore appears from its great thickness to have extended far beyond its present limits. The long interval from early or middle Silurian to middle or late Devonian (Percha) time was ample for the extensive stripping of early Paleozoic carbonate rocks, thus making it appear that a land area existed much nearer to the north than was probably the case. In fact there is no conclusive evidence, faunal or lithologic, to disprove the possibility that some of the Ordovician carbonate blankets may have extended as far north as Colorado. The broad epeirogenic upwarpings of middle Ordovician and late Silurian-early Devonian times may have been more important to the lower Paleozoic stratigraphy of south-central New Mexico than any original depositional thinning across the sedimentational platform.

From a broad tectonic point of view as interpreted from the sediments, there is general uniformity of erosional and depositional environments from Percha through the Magdalena and locally Hueco times in south-central New Mexico. The lithologies of the Onate, Sly Gap, Percha, Lake Valley, Kelly, Magdalena, Hueco and other formations of this time span are similar. Limestone and sandstone similar to those in the Magdalena may be found in the Devonian units and black shale units as thick or thicker than parts of Percha may be found within the Magdalena. Disturbances appear to have been more common during Mississippian time and a north-south arch through the central part of the county in late Mississippian time caused the removal of the Mississippian as well

as some earlier rocks before Pennsylvanian time (Kelley and Silver, 1952, p. 134). Valleys cut during the uplift and filled with clastic Pennsylvanian rocks are present in both the Caballo and San Andres Mountains.

During Pennsylvanian time subsidence of the area was accelerated and a deeper basin of marine deposition which persisted into early Permian time existed in the general region of the San Andres Mountains. To the west and north, however, the subsidence did not continue much into Permian time and continental deposition took over. During Wolfcamp time floodplain environment prevailed in Sierra County indicating more youthful positive source areas to the north. In Leonard time the source areas which formerly (Abo time) furnished "dirty", conglomeratic, and poorly sorted debris disappeared. Tectonic activity quieted and widespread, arid lagoonal conditions prevailed. Coarse material was no longer supplied and the sand became "clean". Great, shallow, saline lagoons and near-sealevel lakes formed, and gypsum or anhydrite and limestone were deposited. The entire area remained low enough, however, to allow recurrent influxes of marine water and fauna during both Yeso and San Andres times. In the eastern part (San Andres Mountains) during San Andres time carbonate-depositing marine environment prevailed, but farther west across the county clastics and evaporite deposition similar to the Yeso became progressively more interspersed with the carbonate beds. The source areas for the clastics must have been in extremely remote and low areas to the west and north, and wind may have carried much of the material to the lagoonal areas.

Late Permian time was one of broad, gentle uplift and stripping of previously deposited San Andres beds and overlying equivalents of Whitehorse or Bernal-type sediments. Much of the material stripped during this time probably went to the east and southeast into the Permian Basin.

In early Triassic time the south-central New Mexico area continued as a broad, low, fairly stable area which may have contributed some sediments both southward into the Mexican trough and northwestward onto the Moenkopi depositional plains.

During late Triassic and most of Jurassic time the region continued as a low source area for the continental sediments which accumulated in central and northern New Mexico. The general evidence of a southern source for many of the Triassic and Jurassic sediments in central New Mexico implies considerable stripping of an area to the south. The Upper Triassic beds may have overlapped part or all of the Sierra County area but were subsequently stripped in the process of supplying some of the Jurassic sediments. In order to supply this volume of material it appears necessary, in part at least, to assume that the Permian section above the San Andres may have been formerly much thicker in the area than is now known.

During either late Jurassic or early Cretaceous time the area across central and south-central New Mexico was more strongly upwarped than at any time previously. In early Cretaceous time it may have contributed debris, at least from its western part to the rapidly subsiding trough across southern New Mexico and Arizona. By late Cretaceous time the western part was uplifted and eroded enough to allow the Upper Cretaceous sediments to come to rest upon Abo beds in some places.

During late Cretaceous time the area subsided as a part of the Rocky Mountain geosyncline and was buried by several thousand feet of marine and continental beds.

The Laramide orogenic disturbances began in late Cretaceous as evidenced by the coarse, Precambrian-bearing debris found in the late Cretaceous McRae formation of the Cutter sag. It appears probable that the overturns and thrusts of the Caballo and Fra Cristobal uplifts developed in either late Cretaceous or early Tertiary time. If the deformation and uplift occurred in late Cretaceous time the McRae beds may be in part a product of the uplifts. Many of the McRae beds appear to have been derived by erosion of the Mesaverde. The McRae is nowhere in contact with the overturned folds.

Following the early compressive deformations there appears to have been at least two or three epochs of deformation characterized by block-faulting that is locally intricate. The Tertiary volcanic rocks and other sediments are very meagerly dated and correlated and hence the several deformations are of uncertain age and sequence. If some of the pre-Santa Fe beds are Oligocene or Eocene then there may be established a middle Tertiary disturbance dominated by faulting. Jahns (oral communication, July, 1955) has found that most of the volcanic rocks in the western part of the county are no older than Miocene. They commonly lie unconformably upon much eroded Cretaceous rocks or Permian rocks. Many of the volcanic units may be contemporaneous with the lower and middle parts of the Santa Fe group which so widely fills the Rio Grande depression.

The middle and late Tertiary rocks of the Sierra County region lie on rocks as young as early Tertiary to the east of the Rio Grande. To the west, on the

other hand, the late Tertiary volcanic rocks lie on much older rocks and Cretaceous, Jurassic, Triassic, and some Permian beds are generally missing. Thus, inthe Cuchillo uplift the late Tertiary volcanics lie generally on the Yeso, although locally a thin section of late Cretaceous is present. In the Black Range the unconformity is with the Abo formation. It appears that the western part of the county was more strongly uplifted and eroded in early or middle Tertiary time than the eastern part (Kelley, 1952, p. 98).

The major Basin and Range block-faulting may have begun in late Miocene time; it continued to a culmination toward the end of Pliocene time. Actually the Tertiary orogeny may have been more or less continuous or at least often repeated. The recurrences, of course, need not have been simultaneous or alike in intensity or rapidity from one place to another in the area. The numerous small fan scarps in alluvial fans and pediments at the bases of the Caballo, Fra Cristobal, San Andres, and Sacramento Mountains indicate that uplifting has continued well into the Pleistocene and Recent.

REFERENCES

Bushnell, H. P. (1953) Geology of the McRae Canyon area, Sierra County, New Mexico: Unpublished master's thesis, Univ. New Mexico, 106 p.

Darton, N. H. (1922) Geologic structure of parts of New Mexico: U. S. Geol. Survey Bull. 726-E, p. 173-275.

..... (1928) "Red beds" and associated formations in New Mexico, with an outline of the geology of the State: U. S. Geol. Survey Bull. 794, 356 p.

Eardley, A. J. (1951) Structural geology of North America: Harper, New York, 624 p.

Fenneman, N. M. (1930) Physiographic provinces of the United States (Map): U. S. Geol. Survey.

Jahns, R. H. (1944) Beryllium and tungsten deposits of the Iron Mountain district, Sierra and Socorro Counties, New Mexico: U. S. Geol. Survey Bull. 945-C, p. 45-79.

Kelley, V. C. (1952) Tectonics of the Rio Grande depression of central New Mexico, in Guidebook of the Rio Grande Country, Central New Mexico: N. M. Geol. Soc., Third Field Conference, p. 92-105.

..... and Silver, Caswell (1952) Geology of the Caballo Mountains, with special reference to regional stratigraphy and structure and to mineral resources, including oil and gas: Univ. New Mexico Pub. in Geol., No. 4, 286 p.

Keyes, C. R. (1903) Geological structure of New Mexico bolson plains: Am. Jour. Sci. 4th ser., v. 15, p. 107-210.

..... (1905) Geology and underground water conditions of the Jornada del Muerto, New Mexico: U. S. Geol. Survey Water-Supply Paper 123, 42 p.

..... (1920) Geological setting of New Mexico: Jour. Geol., vol. 28, p. 233-254.

Kuellmer. F. J. (1944) Geologic section of the Black Range at Kingston, New Mexico: New Mexico Bur. Mines and Mineral Res. Bull. 33, 100 p.

Lindgren, Waldemar, Graton, L. C., and Gordon, C. H. (1910) The ore deposits of New Mexico: U. S. Geol. Survey Prof. Paper 68, 361 p.

Pray, L. C. (1954) Road log, first day, Alamogordo to Alamo Canyon, p. 22-23; Outline of the stratigraphy and structure of the Sacramento Mountain escarpment, p. 92-106; in Guidebook of Southeastern New Mexico: N. M. Geol. Soc., Fifth Field Conference.

Pray. L. C. and Bowsher, A. L. (1952) Fusselman limestone of the Sacramento Mountains, New Mexico: Geol. Soc. America Bull. vol. 63, p. 1342.