Physiographic subdivisions of the San Luis valley, southern Colorado

J. E. Upson

1971, pp. 113-122. https://doi.org/10.56577/FFC-22.113

in:

San Luis Basin (Colorado), James, H. L.; [ed.], New Mexico Geological Society 22 nd Annual Fall Field Conference Guidebook, 340 p. https://doi.org/10.56577/FFC-22

This page is intentionally left blank to maintain order of facing pages.

PHYSIOGRAPHIC SUBDIVISIONS OF THE SAN LUIS VALLEY, SOUTHERN COLORADO*

by

J. E. Upson†
University of Idaho
Moscow, Idaho

EDITOR'S NOTE: The New Mexico Geological Society is grateful to the Journal of Geology for permission to reprint this classic article. After 32 years the work still remains the most quoted reference in its field on the basin. The photographs were retaken under Mr. Upson's direction and duplicate the originals as closely as possible, with the exception of Figure 5, which was taken a short distance "north" of the mouth of the Rio Costilla. Slight editorial changes in punctuation and capitalization were made on the article to conform to present day usage.

INTRODUCTION

The San Luis Valley, forming the upper end of the great valley of the Rio Grande, is one of the most impressive topographic features of southern Colorado. As originally outlined by Siebenthal,[1] it is a great lowland about 150 miles long and 50 miles in maximum width, flanked on the east by the linear Sangre de Cristo Range and on the west by the eastern portion of the more extensive San Juan Mountains. It is, in a sense, part of the chain of intermontane basins, or parks,[2] lying west of the Southern Rocky Mountain front ranges, but is unlike the others in having no southern mountain border. The meeting of the Sangre de Cristo Range and the San Juan Mountains about 135 miles north of the Colorado-New Mexico state boundary forms a natural northern limit to the valley. The southern limit is indistinct and was arbitrarily placed by Siebenthal about 15 miles south of the Colorado border (see index map, fig. 1).

During the course of geological field work conducted during the summers of 1935, 1936 and part of 1937 in the southeastern part of the San Luis Valley, it became apparent that the valley is not a unit either geographically or geologically. To the south it actually merges with the great structural depression of the Rio Grande[3] in New Mexico and within its own boundaries consists of five distinct subdivisions. Each of these smaller units, having had a somewhat different geologic history, now possesses distinctive geologic and topographic characteristics and is therefore considered as a distinct physiographic subprovince. In the following pages is presented a description of these subprovinces and a brief account of their geologic backgrounds. The subdivisions described are named and located as follows: the Alamosa Basin, the main northern part of the San Luis Valley; the San Luis Hills, forming most of the southeastern border of the basin; the Taos Plateau, extending southward from the San Luis Hills; the Costilla Plains, constituting an alluvium-mantled strip

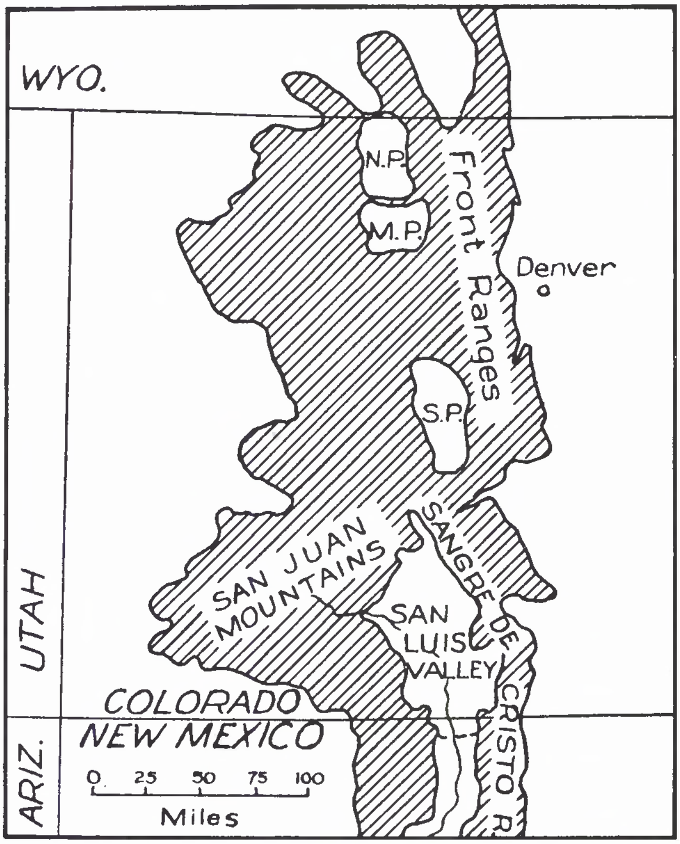

FIGURE 1.

Index map showing the position of the San Luis Valley in the Southern Rocky Mountains (shaded) and its relation to the intermontane parks: *N.P.*, North Park; *M.P.*, Middle Park; *S.P.*, South Park. Boundaries from Fenneman, slightly modified.

* Reprinted from the Journal of Geology, vol. XLVII, no. 7, 1939.
† Presently U.S. Geological Survey, Water Resources Division, Washington, D.C.

[1] C. E. Siebenthal, "Geology and Water Resources of the San Luis Valley, Colorado," *U.S. Geol. Survey Water-Supply Paper 240* (1910), p. 9.

[2] N. M. Fenneman, *Physiography of Western United States* (New York and London: McGraw-Hill Book Co., 1931), pp. 125-32.

[3] Kirk Bryan, "Outline of the Geology and Ground-Water Conditions of the Rio Grande depression in Colorado and New Mexico" (mimeographed report, Rio Grande Joint Investigation, National Resources Committee, 1936).

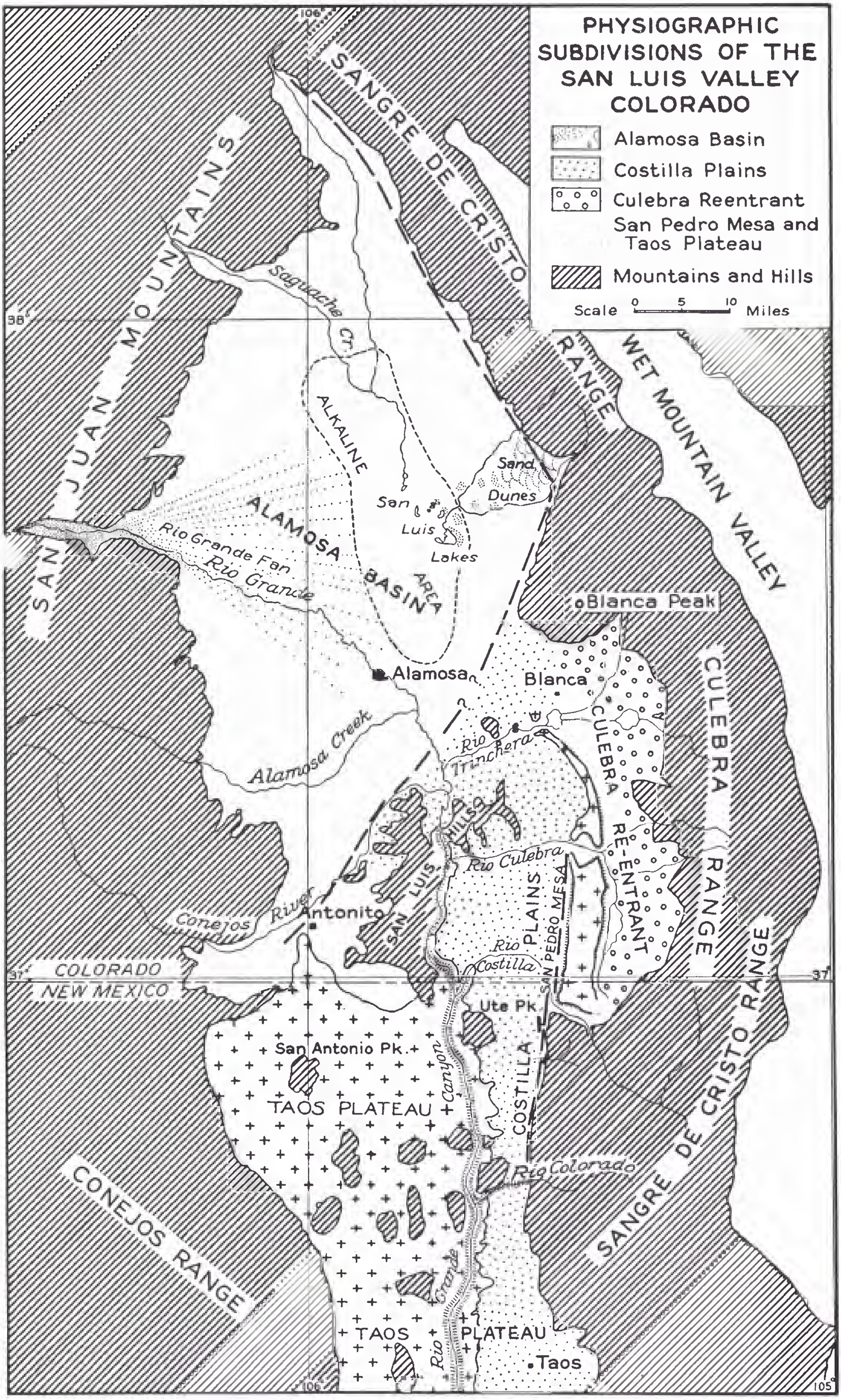

FIGURE 2.

Physiographic subdivisions. Approximate location of the principal late faults shown by heavy, dashed lines. Two recent scarplets east and southeast of Ute Peak indicated by short, heavy lines.

FIGURE 3.

Sierra Blanca from the southwest showing the glaciated valleys and the bordering alluvial fans. The level plain in the fore- and middle-ground is that in which the Alamosa Basin merges with the Costilla Plains and the Culebra reentrant.

along the east side of the Taos Plateau; and finally, the Culebra reentrant, that part of the San Luis Valley lying east of the previously named areas (fig. 2). Many of the geomorphologic interpretations herein presented are the result of fairly detailed structural and stratigraphic work. The writer intends to discuss those studies directly in later papers. They will be little more than mentioned here.

Dominating the San Luis Valley region is the high and rugged Sangre de Cristo Range along the east side. The range consists of two parts: the northern part extending in a general southeasterly direction for 50 miles and the southern part pursuing a southerly or slightly southwesterly course for an additional 18 miles. From north to south the range crest gradually increases in elevation, culminating east of Alamosa in a mass of rugged peaks separated from each other by cirques and glaciated valleys. Highest of these is Blanca Peak, 14,390 feet above sea-level (Appendix, note 1). The entire group of peaks may be designated by the Spanish term, "Sierra Blanca" (fig. 3).

From Sierra Blanca northward to Poncha Pass, at the junction of the Sangre de Cristo Range with the San Juans, the range possesses a bold, linear west front undoubtedly indicative of relatively recent uplift along normal faults. Not even the accumulation of considerable debris in the form of alluvial fans can modify the sharp topographic break between the abrupt mountain slope and the relatively flat valley floor (Appendix, note 2). South of Sierra Blanca, however, the main part of the range is sharply offset to the east about 15 miles, and the steep and abrupt character of the mountain front is conspicuously absent. The front here is subdued and highly irregular, consisting of long mountain spurs which merge westward with an extensive belt of foothills.

The offset portion of the range is about 40 miles long and extends in a southerly direction to a little beyond the Colorado-New Mexico border. Near that boundary the Sangre de Cristo Range is offset westward and exhibits the abrupt, straight, and steep western front like that of the range farther north and similarly indicative of considerable displacement on one or more faults. Thus immediately west of the eastwardly offset part of the range is a sort of indentation, or reentrant. The offset part of the range bears the local name, "Culebra Range," and the reentrant is herein named the "Culebra reentrant." It is geologically the most significant of the physiographic subdivisions to be subsequently described, as in it may be seen rock bodies and structural relationships which do not seem to be visible elsewhere in the area. The subdivisions of the valley will be defined and described in the order in which they were previously listed.

ALAMOSA BASIN

Siebenthal's work in the San Luis Valley was largely restricted to the main northern part of the area lying north of the San Luis Hills. He appears to have considered the other portion of the valley peripheral and of little importance. From the standpoint of water supply this view is justified, but in a physiographic consideration of the San Luis Valley as a whole, the area emphasized by Siebenthal plays a more subordinate role. It is therefore proposed to make that area a physiographic subdivision of the valley as herein defined and to name it the "Alamosa Basin" after the principal town, Alamosa.

The Alamosa Basin is a roughly triangular-shaped area bordered on the west by the San Juan Mountains and on the northeast by the Sangre de Cristo Range. The southeast side is incompletely marked, partly by the Sangre de Cristo Range and partly by the San Luis Hills. Between these hills and the southwest end of the Sangre de Cristo Range is a low, nearly flat area (fig. 3) across which the Alamosa Basin merges imperceptibly with two of the other physiographic subdivisions of the area—the Costilla Plains and the Culebra reentrant.

The principal characteristics of the Alamosa Basin are its nearly featureless floor, the recency of the deposits in the basin and the remarkable course of the Rio Grande directly across the area from the west to the southeast sides. Actually, most of the valley floor slopes inward on all sides toward the lowest portion near the eastern margin. On the east side are numerous alluvial fans whose heads lie at the mouths of short, precipitous canyons in the Sangre de Cristo Range. Streams entering the basin from the west are much longer, have more extensive drainage basins in the San Juan Mountains and have developed much broader and more gently sloping alluvial fans. At a few miles north of Alamosa an observer appears to be surrounded by a level plain. This seeming plain is actually the surface of the Rio Grande fan; the slope so gentle as to be perceptible only on a topographic map. Thus, underlain directly by modern alluvial fan deposits, the Alamosa Basin is essentially an area of deposition. Only at the north where San Luis Creek flows out of Poncha Pass and at the south where the Rio Grande leaves the area through the San Luis Hills is there any dissection of the alluvial surface.

The visible deposits in the Alamosa Basin constitute the upper layers of the Alamosa Formation which was originally named by Siebenthal[4] and held by him to be of Pleistocene age. Beds of the formation are known only from well-logs and from a few scanty exposures near the south end of the basin where the Rio Grande has cut a shallow trench. The sediments appear to be nearly flat-lying but possess sufficient centripetal inclination to make a good artesian basin, from which most of the water supply of the northern part of the San Luis Valley is derived (Appendix, note 3). As indicated by well-logs, the deposits are at least 4,000 feet thick below the lowest part of the basin (Appendix, note 4). Deposition was apparently accompanied by downward tilting of the valley block along great faults bordering the Sangre de Cristo Range and the northwest side of the San Luis Hills (fig. 2). Evidence for the faulting is mainly topographic and was recognized by Siebenthal,[5] Atwood and Mather,[6] Cross and Larsen,[7] and others.

Partly because of the location of the faults, and partly because of the huge size of the western alluvial fans, the lowest part of the basin is near the eastern margin. Here are shallow lakes which have become somewhat alkaline through evaporation (fig. 2). In fact the central part of the basin is known as the "Alkaline Area" because of the alkalinity of the water. Wind-blown sand has accumulated around the lakes and, in times of relative aridity, seems to be subject to deflation by the prevailing southwesterly winds. As a result, considerable sand has been piled up at the mountain front near by. This body of sand has recently been set aside by the government as the Great Sand Dunes National Monument (fig. 4). The writer, jointly with Professor H. T. U. Smith of the University of Kansas, has begun a more detailed study of these dunes (Appendix, note 5).

SAN LUIS HILLS

The Alamosa Basin is nearly completely separated from the rest of the San Luis Valley to the south by the San Luis Hills. They constitute a fairly rugged mass of hills and tilted mesas 500 to 1,000 feet high, extending from near the town of Antonito, Colorado, across the Rio Grande to near the town of Blanca, Colorado. Beginning at a broad pass near Antonito they rise to their full height above the surrounding plain. Toward the northeast they gradually decrease in altitude to pass beneath alluvium a few miles south of Blanca. The continuity of the hills as a single mass is broken only by the canyon of the Rio Grande, beginning a few miles south of Alamosa.

The San Luis Hills were apparently carved out of dominantly andesitic volcanic rocks correlated with portions of the mid-Tertiary volcanic series of the San Juan Mountains after the development of the San Juan peneplain of Atwood and Mather. The dissection of the hills resulted from post-peneplain uplifts on normal faults situated along their northwest flank.[8] The present writer believes that the faults are probably the southward continuation of those bordering the west flank of the Sangre de Cristo Range.

[4] *Op. cit.*, p. 40.

[5] *Ibid.*, pp. 38-39 and 51.

[6] W. W. Atwood and K. F. Mather, "Physiography and Quaternary Geology of the San Juan Mountains, Colorado," *U.S. Geol. Surv. Prof. Paper 166* (1932), pp. 23, 25, and 99.

[7] Whitman Cross and E. S. Larsen, Jr., "A Brief Review of the Geology of the San Juan Region of Southwestern Colorado," *U.S. Geol. Surv. Bull. 843* (1935), p. 113.

[8] Atwood and Mather, *op. cit.*, p. 23.

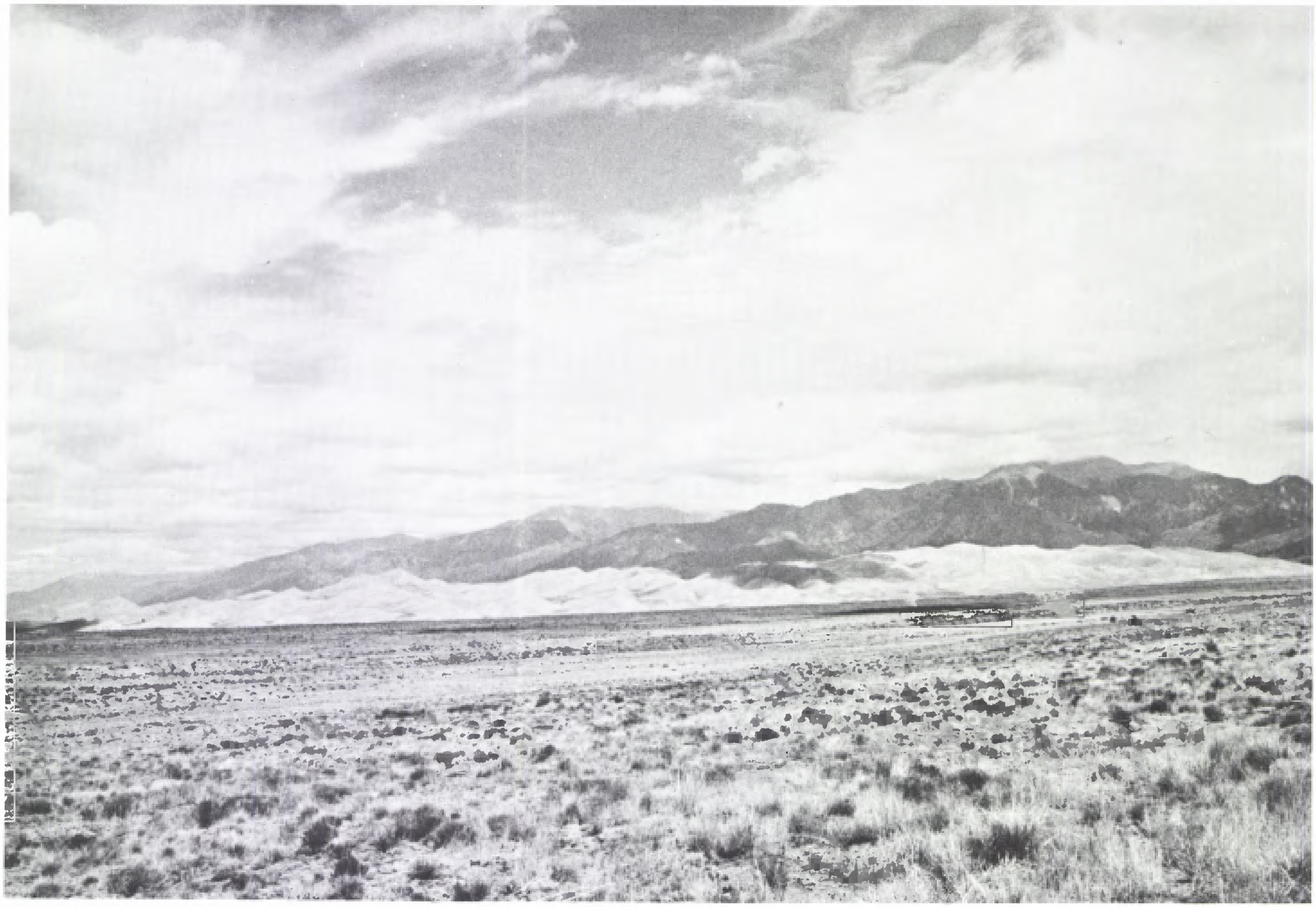

FIGURE 4.
Sand dunes of the Great Sand Dunes National Mounment.

Recurrent movements accompanied the development of the Alamosa Basin and at the same time served to maintain the hills as a prominent topographic feature.

After dissection had proceeded to the development of a mature topography, the San Luis Hills were surrounded by basalt flows belonging to the Hinsdale Series.[9] (Appendix, note 6). The basalt extended over large areas in the San Juan Mountains and for many miles down the Rio Grande Valley to the south. At one time the hills rose fairly abruptly from the surrounding flood of lava—a feature at present preserved only along their southern side. On the northwest side of the hills the lava is buried by beds of the Alamosa Formation, which rests with fault contact against the older mid-Tertiary volcanics.

Because of the island-like relationship of the San Luis Hills to the lavas, they might be considered as part of the Taos Plateau—the next subdivision to be discussed. There hills of older rocks rise above the Hinsdale flows as do the San Luis Hills, and many of them appear to be composed of volcanics of the same general series. However, the San Luis Hills are not isolated from each other as are those farther south but form a nearly continuous group both topographically and apparently also lithologically. In addition the Hinsdale has been downfaulted along the northwest side of the hills. They are therefore considered as a distinct physiographic subdivision but are not, however, distinguished from other mountains and hills in Figure 2.

TAOS PLATEAU

The Taos Plateau is an extensive plateau-like area which lies south of the San Luis Hills and extends about 60 miles southward into New Mexico. Its distinguishing features are a broadly undulating character, the presence of rounded hills rising above the general level and the deep entrenchment of the Rio Grande and other streams. The name was suggested by Kirk Bryan from the clear development of its broad, undulating character near and west of Taos, New Mexico. The plateau is largely underlain by basalt belonging to the Hinsdale Series. The hills rising above the rolling surface of the lava are composed of older Tertiary and Precambrian rocks, against which, in several

[9] Cross and Larsen, *op. cit.*, pp. 94-100; Atwood and Mather, *op. cit.*, p. 21.

FIGURE 5.

Rio Grande Canyon about ½ mile south of mouth of Rio Costilla. Canyon walls, developed in Hinsdale Basalt underlying the Taos Plateau, exhibit evidence of two stages of erosion (Appendix, note 6).

places, the basalt may be seen to rest unconformably.[10]

The Taos Plateau is trenched near its eastern side by the Rio Grande Canyon which, only about 50 feet deep at the mouth of the Rio Culebra in Colorado, becomes progressively deeper to the south. At the mouth of the Rio Costilla the river is approximately 200 feet below the surface of the lava (fig. 5). At its southern end, near Embudo, New Mexico, the canyon is about 1,000 feet deep. There the plateau-like character of the physiographic subdivision is most apparent.

On the west side of the Rio Grande Canyon the basalt essentially forms the surface of the plateau except for the projecting hills of older rocks. As the basalt is slightly deformed, so also is the plateau surface. The lava is known to be broken by normal faults near the western margin of the northern portion of the plateau;[11] and in the vicinity of Dunn's Bridge, across the Rio Grande northwest of Taos, the basalt is believed by Kirk Bryan[12] to be slightly deformed. Because of the regional eastward tilt of the lava the surface of the plateau is somewhat higher west of the Rio Grande than east of it.

East of the Rio Grande the plateau exhibits different features in that the basalt has been buried beneath a considerable accumulation of alluvium derived from the Sangre de Cristo Range. However, from the Rio Colorado southward the area is deeply trenched by large canyons made by the Rio Colorado itself, by the Rio Hondo, and by other streams issuing from the Sangre de Cristo Range. This dissection emphasizes the plateau-like character of the region sufficiently to warrant its inclusion as part of the Taos Plateau in spite of the alluvial cover on the basalt.

The upper layers of the alluvium, as exposed in canyon walls near the Rio Grande west of Taos, clearly overlie the basalt. Farther up the tributary streams, however, the lava is either missing or not exposed, and the precise relationships of the alluvium there are unknown. It may contain parts of more than one formation.

[10] Bryan, "Geology of the Rio Grande Canyon," in preliminary report of the New Mexico state engineer (1928-30).

[11] A. P. Butler, Jr., Doctor's thesis (Harvard University) in preparation.

[12] Personal communication.

North of the Rio Colorado the surface of the alluvium is very little dissected and the area is considered as a separate physiographic subdivision.

COSTILLA PLAINS

The area flanking the Sangre de Cristo Range north of the Rio Colorado, lying east of the Rio Grande, and extending northward to a little beyond the Rio Trinchera in Colorado, is called the Costilla Plains. The term is derived from the town of Costilla, New Mexico, situated where the Rio Costilla crosses the Colorado-New Mexico boundary near the mountain front. In this subdivision the alluvial deposits blanketing the eastward extension of the Hinsdale Basalt are practically undissected except at the very mouths of the streams tributary to the Rio Grande. But for the slight westward slope of the surface of the alluvial fans heading in the canyons of the Sangre de Cristo Range, the area is nearly featureless. North of the Colorado-New Mexico boundary it is nearly a level surface.

The Costilla Plains are only about 4 miles wide near their southern end but are considerably wider in Colorado where they reach a maximum of about 15 miles a few miles north of the New Mexico border. Their western limit is strictly the edge of the alluvium, but that is very near the Rio Grande Canyon, so that natural barrier is made the western border of the Costilla Plains in Figure 2. On the east the plains abut against the southern portion of the Sangre de Cristo Range and against the San Pedro Mesa (fig. 2). Corresponding as it does with the western front of the mountain range, the east border of the plains is nearly a straight line and probably marks or closely parallels the trace of the normal fault along the edge of the mountains. The alinement of the west side of the San Pedro Mesa with this mountain scarp to the south suggests that the concealed fault continues to or beyond the north end of the mesa.

More definite evidence of the existence of the fault is furnished by two small scarplets in the alluvium. One of these is about 70 feet high and crosses the upper portion of the alluvial fan of La Jara Creek approximately at the mountain front. La Jara Creek is the small, unnamed stream southeast of Ute Peak, shown in Figure 2. The other scarplet is somewhat longer and lower, being about 30 feet high and extending for about a mile across the lower portion of the fan of Cedros Creek—the next stream north of La Jara Creek. It is not shown in Figure 2, although the location of the scarplets is indicated. The longer scarplet approximately parallels the mountain front and can be readily seen a few hundred yards east of the road to Taos and 3 or 4 miles south of the Colorado state line (fig. 6).

Whereas most of the surface of the Costilla Plains is untrenched by streams, Rio Trinchera, Rio Culebra, and Rio Costilla in Colorado have formed floodplains about 100 feet below the general surface. That surface therefore constitutes a terrace. There are also remnants of a lower terrace about 55 feet above present stream grades. The generally fine, sandy, unconsolidated deposits visible in a few places in the sides of the terraces are tentatively correlated with the Alamosa Formation of Siebenthal in the Alamosa Basin.

Topographically the Costilla Plains are very similar to the Alamosa Basin but are believed to be different in that at least the Colorado portion of their surface is mainly erosional, whereas the surface of the Alamosa Basin is largely depositional. Additional cause for separating the Costilla Plains from the Alamosa Basin lies in the fact that they are almost entirely cut off from the basin by the San Luis Hills. However, the Costilla Plains, the Culebra reentrant, and the Alamosa Basin actually merge together in the small area west of the town of Blanca. For that reason physiographic boundaries are not drawn in that area on Figure 2.

CULEBRA REENTRANT

The Culebra reentrant differs markedly from the other physiographic subdivisions of the San Luis Valley. The topography is considerably diversified and exhibits a mature stage of dissection. In contrast to the San Luis Hills, which also possess a mature topography, the hills of the reentrant have not been surrounded or buried by basalt flows.

Although the Culebra reentrant is somewhat isolated and appears to be insignificant in comparison with the topographically conspicuous and economically important Alamosa Basin, it is geologically very important. In the reentrant are exposed formations of which only one, or at most two, crop out in any one of the other subdivisions. The formations of the other areas, however, do occur in the reentrant with the exception of the Alamosa Formation, which is represented only by local alluvium. Consequently, only in the reentrant can the structural relations of all the rock bodies of the region be satisfactorily determined.

The Precambrian rocks of the Culebra Range have been uplifted on a series of normal faults separating the range from the area to the west, which is underlain by deformed Tertiary volcanic rocks and fluvial deposits (Appendix, note 7). The topographic border of the mountains follows the fault boundary fairly closely, but in the southern part is very complicated. It is generalized in Figure 2. The term "Culebra reentrant" is restricted to the area lying west of the faults. In that area three formations are exposed: (1) the Early Tertiary Vallejo Formation,[13] hitherto undescribed; (2) an overlying body of flows and tuffs; and (3) a still younger, thick body of alluvial-fan sand and gravel interbedded with the basalt that elsewhere surrounds the San Luis Hills (Appendix, note 8). These rocks and their structural relationships are significant here mainly because as a body the rocks were deformed and subject to erosion considerably before the fault movements along the east side of the Alamosa Basin and the Costilla Plains had ceased. Indeed, as previously indicated, movement on these faults has been very recent, and the deformation may be thought of as continuing into the present. Because movement on the faults of the Culebra reentrant ceased relatively early, that area became one of dissection, while de-

[13] J. E. Upson, "The Vallejo Formation—New Early Tertiary Red-Beds in Southern Colorado" (in preparation).

FIGURE 6.

Slightly dissected Recent fault scarp across alluvial fan and nearly parallel to the west front of the Sangre de Cristo Range near Costilla, New Mexico. View looking northeast.

position continued in the Alamosa Basin and Costilla Plains. The comparatively great length of time since the erosion of the reentrant rocks began is the reason for the mature topography of that area in contrast to the nearly featureless Alamosa Basin and Costilla Plains and the youthfully trenched Taos Plateau. The mature topography of the San Luis Hills may be considered as a fossil topography preserved by the flood of younger basalt. When the dissection of the Taos Plateau began is not known and is an inviting field for further study.

The Culebra reentrant is herein considered as a single physiographic subdivision because it seems to have had the same geologic history in all parts. It is, however, a topographically diversified area. Differences are largely the result of the details of the Late Tertiary normal faulting acting on the volcanics and fluvial deposits. The major trend of the normal faults is north-south and movement on the faults was such as to divide the area into three parts: (1) a relatively elevated belt of foothills near the mountains; (2) a central graben, subsequently eroded so as to preserve the original topographic depression; and (3) a prominent horst—the San Pedro Mesa (Appendix, note 9).

The eastern border of the belt of foothills is not conspicuous, as those hills merge with the long spurs and ridges cut out of the Precambrian rocks of the Culebra Range proper without prominent topographic break. The latest movement on the faults separating the range from the foothills was probably not younger than Early Pleistocene, and subsequently erosion has greatly modified the fault scarps that must once have existed. As a result the western front of the Culebra Range is noticeably less abrupt and imposing than the corresponding fronts of the Sangre de Cristo Range, both north and south of the reentrant. The range crest itself, however, is in some respects more rugged than those to the north and south.

The foothills are widest in the northern part of the reentrant where their western edge is 8 to 10 miles from the mountain border on the east. In the southern part of the area their width decreases from about 6 miles near the Rio Culebra to nearly zero at the Rio Costilla. The main feature of the foothill belt is the preservation of remnants of at least four erosion surfaces cut across the deformed Tertiary rocks. In the north very few residuals rise above the highest erosion remnants, which lie at 450 to 500 feet above the present stream grades.

Remnants of apparently the same erosion surfaces are recognizable, but less extensively preserved, in the southern part of the reentrant. There numerous foothill summits, rising as much as 10,000 feet above sea-level, are residual above the highest erosion remnants.

Extensive development of comparable erosion surfaces is not known in the other subdivisions of the San Luis Valley. In a few localities, however, there are small remnants of terraces, possibly erosional, which may be the correlatives of the surfaces in the reentrant. Accurate information regarding such possible correlatives is not now at hand.

As a sort of outlier of the northern part of the foothill belt in the Culebra reentrant are two prominent basalt-capped mesas called the Garland Mesas, situated immediately southeast of the town of Fort Garland, 5 miles east of Blanca. The southern of the two mesas rises over 500 feet above the surrounding lowlands. The rocks of these mesas have been uplifted on a normal fault of considerable magnitude, first recognized by Atwood and Mather.[14]

Extending northward from the southwest corner of the reentrant is the similarly basalt-capped mesa, the San Pedro Mesa. It is 1,000 feet high at the south end and forms a prominent table-land, particularly when viewed from the west, extending northward for about 15 miles from the Rio Costilla to the Rio Culebra. Near the Rio Culebra the mesa decreases in elevation and the capping basalt assumes a gentle westerly dip. The basalt outcrop crosses the Rio Culebra and, maintaining the westerly dip, forms a narrow, cuesta-like ridge, extending for about 10 miles north of Rio Culebra and presenting a low but fairly steep escarpment toward the east. This ridge is the northward continuation of the San Pedro Mesa and is called the San Pedro Cuesta in this paper. It dies out a short distance north of the Rio Trinchera.

The San Pedro Mesa is apparently bordered by faults on both the east and west sides. As the upthrow sides of each of these faults is on the mesa side, it is structurally a horst. The fault on the east side continues north along the foot of the San Pedro Cuesta.

There are also a few small normal faults along the western margin of the foothills with downthrow on the west. The region between the San Pedro Mesa and the foothills is therefore structurally a graben. The fault movements are believed to have carried the basalt of the mesas down so as to render the graben easily eroded. At present the feature is topographically fairly conspicuous and was designated by Stephenson,[15] the "Culebra Park." The writer sees no reason to change this name. The Culebra Park extends in a northerly direction from near the Rio Costilla, where it is very shallow but where its floor is about 500 feet above the level of that stream. This relationship suggests that at some previous time the upper Rio Costilla flowed northward through the Culebra Park but was diverted by the present Costilla cutting headward across the south end of the San Pedro Mesa from the west. North of Rito Seco the park is broader and deeper, assumes a northwesterly trend, and extends past the town of Blanca to merge with the surface of the Alamosa Basin in the northwest part of the reentrant.

North of the Rio Costilla the surface of the Culebra Park is about at the level of the present stream grades except in the region between Rito Seco and Rio Trinchera. There the floor of the park is 20 to 100 feet above the level of the streams, and on the flanks of the divide thus formed low terraces may once have been developed. They are at present so mantled by later alluvium as to be unrecognizable.

[14] *Op. cit.*, p. 100.

[15] J. J. Stephenson, "Report on the Geology of a Portion of Colorado Examined in 1873," *U.S. Geog. Surv. West of the 100th Meridian*, Vol. III (Supplement Geology, 1881), p. 363.

ACKNOWLEDGMENTS

Acknowledgments are due principally to Professor Kirk Bryan of Harvard University, who, long familiar with the region, first suggested the possibility of subdividing the San Luis Valley. Professor Bryan criticized the manuscript many times in its formative stages, aided much in the drafting of Figure 2, and is the originator of some of the subdivision names. Mr. Edward Schmitz also contributed to the preparation of Figure 2. The writer is indebted to many inhabitants of the Culebra reentrant for assistance and hospitality during the field work there—notably, Mr. and Mrs. S. H. Shannon and family of the Trinchera Ranch, Fort Garland. During the field work the writer was ably assisted at different times by H. G. Peacock, A. P. Butler, Jr., W. S. Brandhorst, R. W. Day, and the writer's brother, D. R. Upson.

APPENDIX

Note: To this reprinted paper, published nearly 32 years ago, there are added certain explanatory comments and references to later papers which may serve to bring the paper more nearly up to date. There is still room for further work.

J. E. Upson

1. Altitude given as 14,345 feet on Blanca Peak quadrangle, 1:24,000, 1967. Presently accepted elevation is 14,363—Ed.
2. Scarps in the alluvium at and north of Valley View Hot Springs have been mapped by Glenn R. Scott, 1970.
3. Wells drilled in 1959 indicate depth to Precambrian rocks in excess of 10,000 feet. Much of this interval may be in unconsolidated deposits, and the thickness perhaps substantially more than 4,000 feet. (Unpublished information from P. A. Emery.)
4. A gravity survey in the Alamosa Basin done at various times from 1961-64 indicates that the basement structure is more complex than a single east-tilted block; and that thickness of valley fill at the deepest place is probably at least 16,000 feet and perhaps as much as 30,000 feet depending on density contrasts assumed. See Gaca and Karig, 1965.
5. The writer and H. T. U. Smith have done little further work. An excellent study, with clear differentiation of dune types, was made by Johnson (1967) in the sixties.
6. Now considered part of the Servilleta formation of Butler, this formation is younger than the Hinsdale Basalt of older workers. See Lipman, 1969. Editor's Note: Photo taken ½ mile north of mouth of Rio Costilla.
7. More recent reconnaissance mapping by Johnson (1969) shows

the complex boundary between the Precambrian rocks and the Tertiary volcanics and other deposits, but it is interpreted with fewer faults.

8. See References, Upson.
9. San Pedro Mesa may not be faulted on the east side.

REFERENCES

Butler, A. P., Jr., 1946, Tertiary and Quaternary geology of the Tusas-Tres Piedras area, N. Mex.; Harvard Univ., Cambridge, Mass., Ph.D. dissert. 188 p.

Gaca, J. Robert, and Karig, Daniel E., 1965, Gravity Survey in the San Luis area, Colorado: U.S. Geol. Survey, open-file report, 21 p., plus gravity data, maps, and sections.

Johnson, Ross B., 1967, The Great Sand Dunes of Southern Colorado: U.S. Geol. Survey Prof. Paper 575-C, p. C177-C183.

Johnson, Ross B., 1969, Geologic map of the Trinidad quadrangle south-central Colorado: U.S. Geol. Survey, Miscellaneous Geologic Investigations, Map I-558.

Lipman, Peter W., 1969, Alkalic and tholeiitic basaltic volcanism related to the Rio Grande Depression, southern Colorado and northern New Mexico: Geol. Soc. America Bull. V. 80, p. 1347 ff.

Powell, Wm. J., 1958, Ground-water resources of the San Luis Valley, Colorado: U.S. Geol. Survey Water Supply Paper 1379, 284 p.

Scott, Glenn R., 1970, Quaternary faulting and potential earthquakes in east-central Colorado: U.S. Geol. Survey, Prof. Paper 700-C, p. C16-C17.

Upson, Joseph E., 1941, The Vallejo Formation: New Early Tertiary red-beds in Southern Colorado: Am. Jour. Sci., Vol. 239, p. 577-589.