



FIGURE 1—Typical conglomerate of Upper Sangre de Cristo Series—
Crestone Canyon N. E. of Crestone.



FIGURE 2—Intraformational unconformity within Sangre de Cristo For-
mation—East of Mosca Pass.

siderable portion of them in the Permian. The only fossils we found were poorly preserved, and belonged to the genera that were common to both the Pennsylvanian and the Permian. The foraminifera suggest Permian, rather than Pennsylvanian age, but not conclusively so. The whole series is broken by diastems and other minor unconformities. (See figure 2.) The great thickness of the sediments and the number of local unconformities in the section suggest a considerable time interval, yet the character of the sediments and the structure of the beds are such as to indicate relatively rapid deposition. Comparing these with the formations in the areas to the south and west, we would consider them as probably of Permian age, but they may be Upper Pennsylvanian.

JURASSIC

The Jurassic rocks rest unconformably upon the Sangre de Cristo formation. The term Morrison has been applied to them. They average between six and seven hundred feet in thickness all through this general area. They resemble the typical Morrison of most of the localities along the Front Range, consisting largely of shales and rather fine-grained sandstones which vary in color from white to pale green and red. At the point where we measured a section along the Cuchara road north of Cuchara Camps we found some fossils. These consisted mainly of small teeth and fish scales. There were in one or two beds a great number of very small forms, possibly bryozoa or algae. These have not been determined; but the Marland Oil Company geologists tell me that they have found the same fossils in the lower "Morrison" over a very large area during the last two years. This coupled with the fact that Professor Keyte of Colorado College has found *Pentacrinus* and other Crinoid stems and fragments of other marine fossils in limestones near the base of the Morrison at the Garden of the Gods, in Perry Park, and southwest of Colorado Springs on the road to Canyon City, would lead us to conclude that the Sundance (i. e. marine Jurassic) is present at the base of the so-called Morrison.

DAKOTA

The Dakota is rather thin in the area studied. It generally consists of white to buff sandstones, rather massively bedded and in some places displays poor cross-bedding. The middle portion is rather soft and sometimes even shaly, while the outer members are hard and massive. Beds above the Dakota were not studied. They appeared to represent the normal Cretaceous sequence.

STRUCTURE

The earlier writers all regard the structure as a steep anticlinal fold, (1, 8, and 9) though they seem to have recognized the presence of minor faults. Bagg, writing about the copper of the northern Sangre de Cristo in 1908, mentions that "This major anticline has been broken by parallel and cross faults in the vicinity of Rito Alto, which are partly concealed from view by surface weatherings of the sandstone, aided by heavy growths of spruce timber." (1). He seemed, however, to have regarded these faults as purely local phenomena of very little structural significance, though possibly having some importance in connection with possible mineralization of the area. The Van Diests mention faulting east of the San Luis-along the western side of the range near the New Mexico line. (39.)

The writer, while in the field, observed thrust faulting at La Veta Pass and in the area to the south where the Pre-Cambrian crystalline rocks have been thrust against and over the Pennsylvanian sediments. This is beautifully shown in the area north of Trinchera Peak and to the west of the Blue Lakes, where Pre-Cambrian rocks actually overlie heavy fossiliferous Pennsylvanian limestone. Closer study revealed the fact that most of the way between Trinchera Peak and the Sierra Blanca, the contact between the Pennsylvanian and Pre-Cambrian was a fault contact. This was very evident in some localities, but in others it was obscured either by talus or glacial deposits. North of the Sierra Blanca the contact was examined only at localities twenty to twenty-five miles apart, but

everywhere faulting was found at or near the contact. The faulting was always of the thrust type. The trend of the faults was approximately parallel to the strike of the sediments. In a number of localities minor cross-faults were also observed. These were particularly developed in the vicinity of the major Tertiary intrusions. The only place where definite over-lapping relations between the Pennsylvanian and Pre-Cambrian were found was in the area west of Stonewall, Las Animas county, but at this place there appears to be thrust faulting east of the contact in the Pennsylvanian sediments themselves.

From these and other observations, the writer has come to the conclusion that thrusting has played an important part in the structural history of this range and helps to explain their unusual narrowness. The thrust was from the west.

It is interesting to note that at about the same time the writer was engaged in his field work in this area, Messrs. Butler, Burbank and Lovering of the U. S. Geological Survey, then engaged in cooperative work in Colorado, had, from a study of the Hayden maps, arrived at the conclusion that, if those maps accurately showed the distributions of the formations, there must be thrust faulting in the Sangre de Cristo area. The first thing they asked the writer on his return to Golden was whether he had observed anything to suggest thrust faulting. A study of the Hayden map certainly does suggest this fact, and it is remarkable that it had not been noted before.

More recently Mr. Burbank (3) of the U. S. Geological Survey, working in the Bonanza area just west of the northern end of the Sangre de Cristo area, has demonstrated the presence of thrust faulting in that district. There the thrust was from the southwest.

It seems to the writer that as more detailed studies are made in the Rocky Mountain region, much more evidence of thrust faulting will be discovered, and probably it will be found that thrusting has played an important role in the formation of most of the mountain ranges.

GEOLOGIC HISTORY

The Sangre de Cristo Range itself is of relatively recent geologic origin, but it occupies an area corresponding to the border or coastal region of a former land mass of vast antiquity. In fact, if we might be forgiven for a slight digression at this point, it may be said that the main, if not all of the major structural features of Colorado, were roughly outlined or forecasted early in geologic time. Thus, we find a land mass occupying the area west of the Sangre de Cristo range, including the present San Luis Valley and the Uncompaghe plateau, in existence throughout the Paleozoic and most, if not all, of the Mesozoic eras and occupying an area which was the site of pronounced elevation in the Archeozoic or early Proterozoic time. The borders of this land were flooded at intervals by ocean waters and from time to time were elevated by diastrophic movements. Sediments were deposited around the coast line.

In the late Mississippian or early Pennsylvanian some further diastrophism and possibly local mountain building took place. Active erosion commenced, giving rise to deposition along the adjoining coasts. Intermittent diastrophism accompanied by active erosion continued, and throughout much of the Pennsylvanian we find that thick series of sediments were deposited around the shores. In the late Pennsylvanian or early Permian another and greater uplift took place, the lands were rejuvenated, and a new cycle of rapid erosion and deposition commenced, during which the great series of Permo-Pennsylvanian red beds were deposited. Gradually the lands were worn low, and apparently they remained so throughout most of the Mesozoic.

There is very little evidence to support the idea that this area was ever covered by Mesozoic sediments, though they were deposited in considerable thickness around it.

Early in the Tertiary active mountain building took place. The Sangre de Cristo Range was folded, uplifted, and somewhat faulted. The San Luis Valley to the west originated at the same time as a compensating syncline, faulted along its

eastern border. The Huerfano Basin represents a similar synclinal depression, badly faulted between the Sangre de Cristo and the southern end of the Wet Mountains. This basin contains Eocene beds which rest on deformed Cretaceous strata. Thus one would date the major uplift of the range as having occurred during the Laramide Revolution, that great time of crustal unrest so important in western North America, which brought the Mesozoic to a close and ushered in the Cenozoic.

It is interesting to note that some of these Tertiary beds (Huerfano formation) are made up in large part of material derived from eroded Sangre de Cristo conglomerate, as was noted years ago by R. C. Hills.

At a later time, after considerable deposits of Miocene sediments had accumulated in the San Luis Valley, we find evidence of another uplift of the range, which was accompanied by some deformation of the sediments in the valley and of the lavas east and southwest of the range (particularly noticeable in the mesa area around the west of Trinidad.)

There seems to have been very little movement from late Pliocene time to the present, as a fairly complete and apparently undisturbed series of deposits can be found to represent that interval of time.

During the Pleistocene the higher portions of the range were actively glaciated by Alpine glaciers. These developed during two different periods, separated from each other by a considerable interval of time.

PENNSYLVANIAN PALEO-GEOGRAPHY AND THE ORIGIN OF THE SANGRE DE CRISTO FORMATION

The great thickness and coarseness of the upper Sangre de Cristo formation has been noted and commented upon by most of the geologists who have visited this region. Various theories of origin have been expressed from time to time. Among these, a suggestion was made that they were of glacial origin, and in the last few years this statement has received considerable publicity. Thus, in the symposium on con-