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XLI C-4

GSA Bull. v. 65 p. 1380

SANGRE DE CRISTO MTS

STRUCTURE OF HAYDEN PASS-ORIENT AREA, SANGRE DE CRISTO MOUNTAINS, COLORADO

Linus R. Litsey
University of Colorado, Boulder, Colo.

GSA
Bldr. Colo.
5/54

[redacted]

XLI C-4

GSA Spec. Pap 82, 1964, p. 26

Gravitational Evidence for a Batholithic Mass of Low Density along a Segment of the Colorado Mineral Belt

CASE, J. E., *U. S. Geological Survey, Denver, Colo.*

[redacted]

XLIC-4 Colorado

GSA Spec Pap. 82, 1964, p 74

Tertiary Deformation and Batholithic Intrusion in the Sangre de Cristo Mountains, Colorado

[redacted]

XLI C-4

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CONTRIBUTION TO THE GEOLOGY OF THE SANGRE DE CRISTO MOUNTAINS OF COLORADO

J. HARLAN JOHNSON, M. S.[1]

INTRODUCTION

[redacted]

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A-

GEOLOGY AND MINING DISTRICTS

of the

SANGRE DE CRISTO MOUNTAIN RANGE

James R. Dunn
Mining 111A
January, 1949

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INTRODUCTION

The Sangre de Cristo Mountains are a part of the Rocky Mountain system in Colorado and New Mexico. The range starts at Salida at the north and trends south-southeast to the Gray back area ~~Spanish Peaks region, just east of the Sangre de Cristos.~~ Here the range jags eastward about fifteen miles and then trends southward into New Mexico. For this paper the southern termination of the Sangre de Cristo Mountains will be considered to be at Santa Fe, New Mexico. Actually the range, while continuous, has been artificially divided into different geographical units. Between the Spanish Peaks area and the New Mexican border it has been called the Culebra Range. In New Mexico it is called the Taos Range north of Ferdinand Creek Pass, the Mora Range from there to a point about 15 miles east of the Santa Fe Range from about Ferdinand Pass due south to Santa Fe.

The Sangre de Cristo range is very imposing because of its height and narrowness. Its highest peaks are the 13,390 feet Mt. Blanca, just north of Gunnison Pass; and North Truchas Peaks, 13,306 feet, near Santa Fe. Throughout most of its length the range is not more than fifteen or twenty miles wide, but at its southern end, in New Mexico, the Sangre de Cristos widen to over thirty miles.

The range rises steeply from the surrounding plateau country, which is about 6,000 feet in elevation. The relative height, the glaciated peaks, the spruce and pine forests in the lower portions of the range, and the snow fields make the Sangre de Cristos a beautiful range.

Economically, however, the range, for the most part, is valueless. The rainfall in the range is too small to make it a good storage area for water, and the mineral resources are very meager, with only one district, the Elizabethtown district, in New Mexico, having produced any notable mineral wealth. Because of this lack of rainfall and minerals the Sangre de Cristos have received only a small

amount of geological study. The information about the range is scattered and often too general to be of value. Several areas have received some attention from geologists, and these will be discussed and from these bits of information something of the history and ore deposits will be deduced. The areas which have been studied in some detail are: between Crestone and Orient at the northwestern part of the range; the eastern portion of the range adjacent to Huerfano Park; the Grayback mining district; a small area adjacent to the Spanish Peaks region; and the ore deposits in the New Mexican part of the range.

FORMATIONS IN THE SANGRE DE CRISTO RANGE

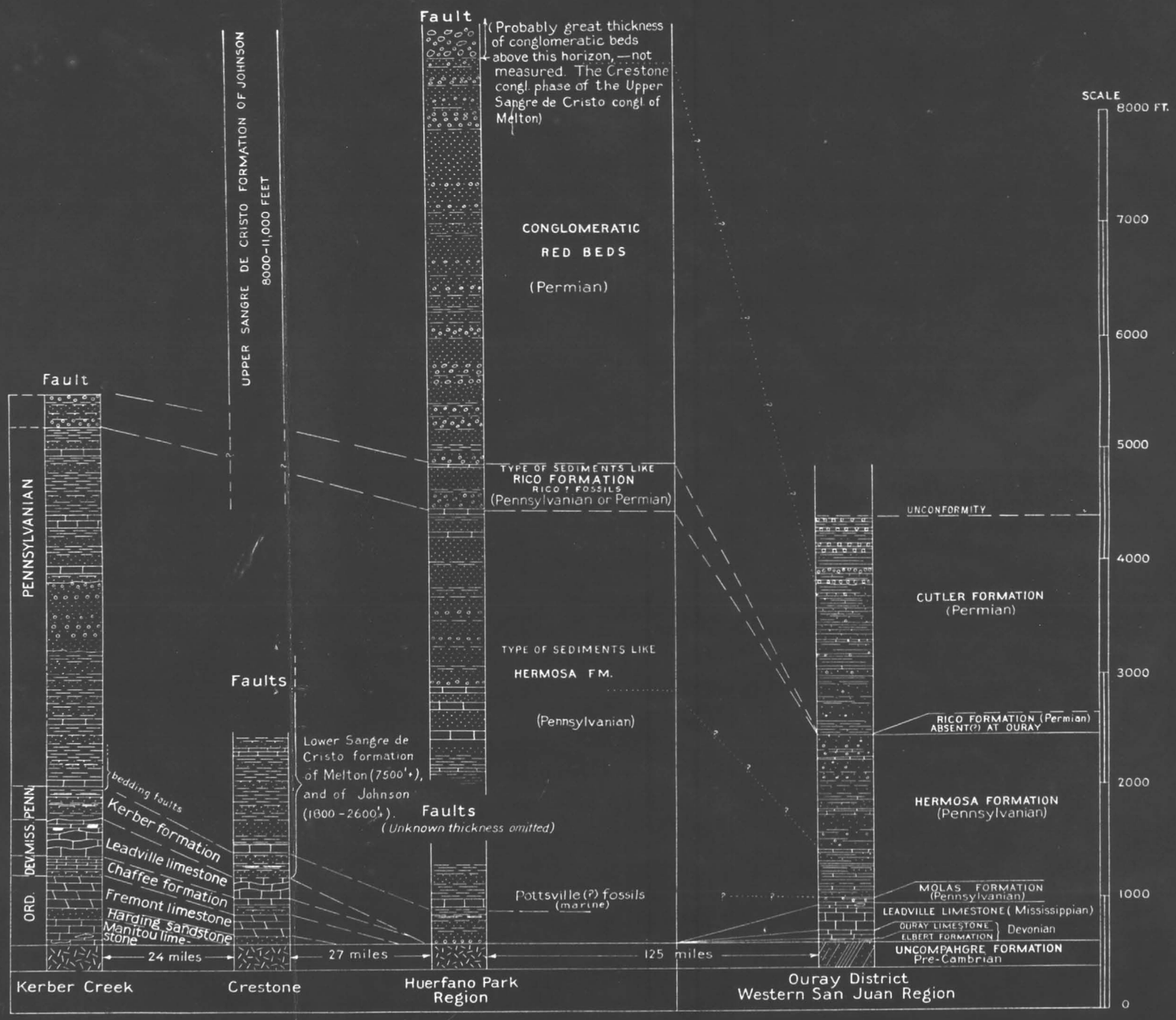
The following is a generalized section taken from J. H. Johnson (6) giving the character, age, and approximate thickness of the formations in the Sangre de Cristo range, Colorado.

SANGRE DE CRISTO MOUNTAINS, COLORADO

GENERALIZED SECTION---SANGRE DE CRISTO REGION

AGE	FORMATION	CHARACTER	THICKNESS FEET
Pleistocene	Recent	Glacial and stream deposits	0-300
Cretaceous	Dakota	White to buff sandstones	about 70
		Unconformity	
Jurassic	Morrison	Shales and sandstones, green White, and red	600-700
	Sundance (?)	Thin limestone layers and shales, mainly gray	0-30
Permo-Pennsylvanian Probably largely Permian	Upper Sangre de Cristo Formation	Coarse clastic sediments, largely red beds. Sandstones, grits and conglomerates. Upper portion all red beds. Lower down some beds are gray to buff or even brownish.	8000-11000
		Unconformity	
Pennsylvanian	Lower Sangre de Cristo	Sandstones, shales, and limestones. Some conglomerates. Some beds quite fossiliferous.	2100
		Unconformity	
Mississippian	Leadville (?)	Hard gray to white limestone. Found only at northern end of range	0-300
		Unconformity	
Ordovician	Harding formation	Thin limestones and sandy limestones, found only at northern end of range	25
Pre-Cambrian		Gneisses, Schists, and Granite.	

Photostat II



STRATIGRAPHIC COLUMNS OF PALEOZOIC FORMATIONS IN THE SANGRE DE CRISTO REGION AND AT OURAY, COLORADO

Photostats I and II give the stratigraphy as compiled by Burbank and Goddard. No comparable sections were seen in the literature for the New Mexican Sangre de Cristos.

Photostat I

BULL. GEOL. SOC. AM., VOL. 48 — BURBANK AND GODDARD, PL. 3

PERIOD	FORMATION		THICKNESS IN FEET	GENERAL CHARACTER
PLIOCENE OR PLEISTOCENE	Terrace gravels			
EOCENE	Huerfano fm.		2300-3500	Marls, clays, soft sandstones and shales, predominantly red, but in part gray, yellow green and purple.
	Cuchara fm.		300-500	White and pink sandstone with thin layers of shale; surface cavernous.
	Poison Canyon fm. Possibly including beds equivalent to Raton formation.		2000-3500	Arkosic sandstone and fine conglomerate, with thin beds of yellow clay; lower beds weather pale yellow.
UPPER CRETACEOUS	Vermejo fm.		0 - 450	Dark shale, light gray friable sandstone and coal in alternate layers.
	Trinidad ss.		160 - 225	Massive sandstone, shaly in lower part
	Pierre shale		1800-2000	Yellowish gray to dark gray shales, with zone of impure limestone concretions.
	Apishapa sh.	OF NIOBRARA AGE	450-500	Bluish gray shales at base, grading upward through papery shales to sandy shales.
	Timpas ls.	OF BENTON AGE	180 - 200	Grayish white ls. and calcareous sh.
	Carlile sh.		170 - 180	Dark gray shale, capped by yellowish ss.
	Greenhorn ls.		30 - 40	Thin-bedded dove colored limestone.
	Graneros sh.		200 - 310	Gray to black sh. with concretions near base.
	Dakota ss.		350 - 400	Dense, fine grained sandstone. Coarse, yellowish gray ss., overlain by thin bed of gray shale.
LOWER CRET.	Purgatoire fm.			
UP. JURASSIC	Morrison fm.		100 - 240	White sandstone, pink and green shales and hard fine grained limestone.

STRATIGRAPHIC COLUMN OF MESOZOIC AND TERTIARY FORMATIONS OF HUERFANO PARK AND VICINITY

GEOLOGIC HISTORY OF THE SAN GRE DE CRISTO MOUNTAINS

The oldest rocks exposed are Pre-Cambrian granite and contorted gneisses and schists. However little is known of their original character and therefore the geologic history of this area will begin with the Cambrian.

Cambrian: Most of the area in this period probably was a low lying land mass.

Ordovician: Again most of the area was a low land mass, but the sea had begun to encroach on what is now the northern part of the range. This sea may have covered some of this land during part of the Cambrian also, but this point is indefinite.

Silurian and Devonian: During these periods the land rose a little and no sediments were deposited.

Mississippian: The sea again encroached in this period this time moving some twenty miles south of its Ordovician boundary. The sea was quiet and deposited a fairly pure limestone. In the later Mississippian period a mild deformation took place. The axis of this minor deformation, which was about north-northeast, was at a slight angle to the present Sangre de Cristos. It cut the present range axis at about Alamosa.

Pennsylvanian: The Sangre de Cristo Range area was now downwarped and the Permo-Pennsylvanian geosyncline was formed. This trough, which trended north-northwest received thick sediments during this time from the rigid shelves to the east and west, with most coming from the San Luis-Uncompahgre geanticline to the west. A small area immediately to the east of this trough, from about Silver Cliff to fifty miles south, probably was an island at this time and also a source of sediments. These lands rose quite high ~~and~~ in the Pennsylvanian and Permian periods, and the debris was deposited in the geosyncline was largely coarse conglomeritic "Red Beds".

Permian: The conditions now were a continuation of the Pennsylvanian conditions, with the lands gradually wearing downward.

Mesozoic: During this age the Sangre de Cristo area was predominantly a fair-

ly stable lowland, and only a few feet of marine sediments were deposited at this time. At the end of the Jurassic there was a mild deformation which was enough to cause a slight unconformity between the thin Jurassic and Cretaceous beds.

However, the major deformation was not until the end of the Cretaceous.

The Larsmide Revolution: No more sediments were deposited in the Sangre de Cristo area proper after the end of the Cretaceous period. At this time and continuing into the late Eocene or possibly later, the Paleozoic and Mesozoic strata were strongly deformed by folding and thrust faulting. This orogeny has been studied particularly on the eastern slope where it is most apparent. There the mountain range seemed to ride eastward overturning beds before it and causing large westward dipping thrust faults. This deformation however was sporadic, or at least varied somewhat in intensity, as will be seen in the section on structure. The Wet Mountains to the east are considered to be forelands, and to be equivalent to the island arc south of the Dutch East Indies by Burbank (1).

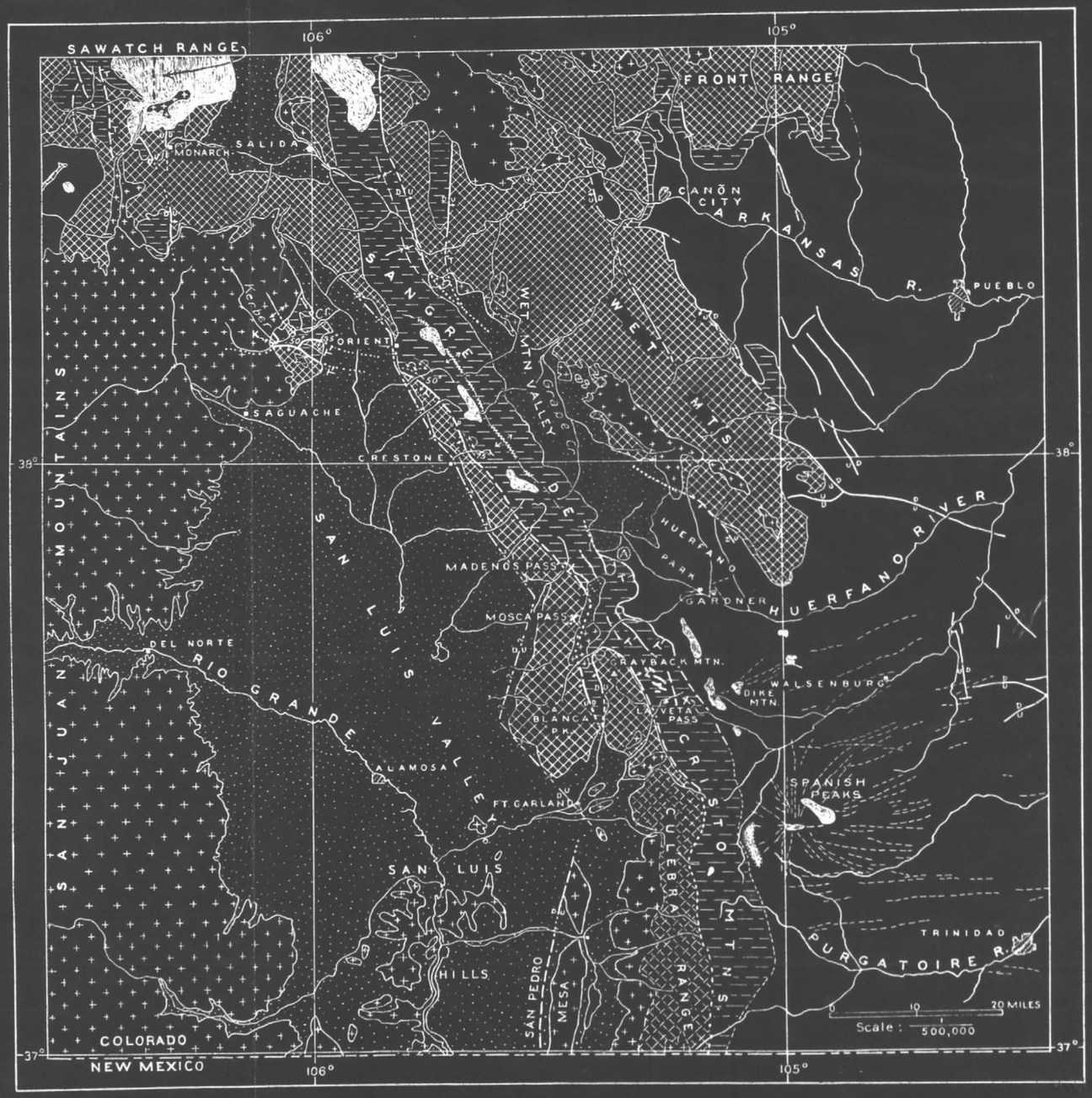
No volcanism took place during this first folding, possibly because of the thick sedimentary cover. However in the late Eocene some minor volcanism occurred along the range. The most important volcanism, although still not on a large scale, occurred in the Miocene. This was accompanied with some intrusions also, with the Spanish Peaks being formed at this time.

The andesites and basalts of the San Luis Valley are Quaternary or late Tertiary.

During most of the Tertiary three large basins were receiving sediments from the Laramide Highlands. These were the Uinta Basin, the San Juan Basin, and the Huerfano Basin. This latter basin, located just east of the Sangre de Cristo Mountains, was probably formed in the early Eocene, and received late Eocene sediments.

The San Luis Valley to the west of the Sangre de Cristo range also was formed at this time. The Huerfano Basin and the San Luis Valley were apparently dropped as grabens. ~~apparently.~~ The Sangre de Cristo Range should be considered to be essentially a horst, (somewhat uptilted at its westward side) ~~as the Sierra Nevada Range was~~. A

Potostat III



EXPLANATION

Late Tertiary and Quaternary formations.

Tertiary volcanic rocks.

Intrusive bodies and dikes chiefly early Tertiary.

Mesozoic and early Tertiary formations.

Paleozic formations.

Pre-Cambrian massifs. Granite, schist and gneiss.

Normal and reverse faults. Arrows give direction of dip.

Overthrust fault with amount of dip.

K Klippen at Kerber Creek.

Anticline

Anticline with metamorphosed core (partly injective or diapiric)

Overturned anticline.

Overturned syncline.

Location of detailed map of Figure 4.

GEOLOGIC MAP OF THE SANGRE DE CRISTO MOUNTAINS AND ADJACENT REGIONS, COLORADO

Based on geologic map of Colorado [with additional structural data] by the United States Geological Survey, in cooperation with the Colorado Geological Survey Board and Colorado Metal Mining Fund, 1935.

major fault of the Huerfano Basin, incidentally, runs from the Sangre de Cristo Range to the southern end of the Wet Mountains, i.e. east-west. This suggests that the Huerfano Basin dropped is a rectangular block.

Post Laramide History: After deposition of much Miocene sediments in the San Luis Valley, another uplift of the range occurred causing some folding of the Miocene sediments, but from late Pliocene to the present time there seems to have been little uplift of the range.

The last important geological event was the Pliestocene glaciation of the range peaks by Alpine glaciers.

STRUCTURE OF THE SANGRE DE CRISTO RANGE

Broadly speaking the Sangre de Cristo is a narrow high range which is arcuate toward the east. The core of the range is pre-Cambrian granites, gneisses, and schists, but very little is known of the structural details of these old rocks. The more recent rocks, which are predominantly middle and late Paleozoic age, have not been studied in detail except for the Huerfano Park area and the area between Crestone and Orient. Photostat III is a general geologic map of the Colorado Sangre de Cristos compiled by Burbank and Goddard. As is usually the case in such circumstances there is, therefore, considerable disagreement on the structure of the range.

The early workers, who did only reconnaissance mapping, considered the range to be a simple anticlinal structure caused by compression (4). Each succeeding geologist found more complexities. In 1929 J. H. Johnson (6) first saw a suggestion of thrust faulting at the eastern part of the range. The Lindgren Volume (3) in 1933 acknowledged that the Sangre de Cristos were the most complicated range in Colorado. The last paper published dealing with the structure of the Sangre de Cristos was by Burbank and Goddard (1) in 1937. Because this is the only detailed structural work done on the Sangre de Cristos most of this portion of the paper will be taken from that article. It will be necessary to extrapolate somewhat from Burbank and Goddard's paper, because

Photostat IV

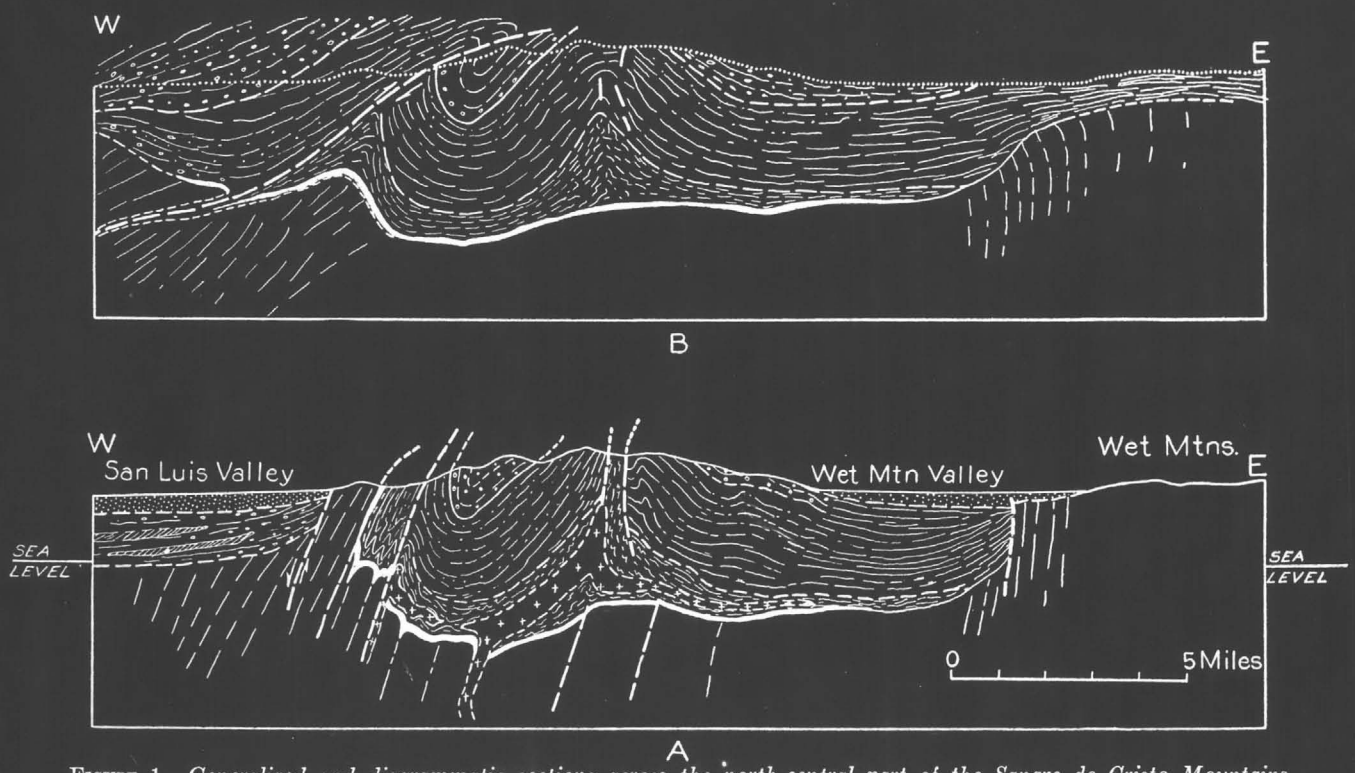


FIGURE 1.—*Generalized and diagrammatic sections across the north-central part of the Sangre de Cristo Mountains*

Section A constructed chiefly from a traverse across the range near Crestone. Symbols are generalized: solid black pattern (base) represents lower Paleozoic sandstones and limestones; overlying crinkled line pattern, lower Pennsylvanian beds involved in zones of shearing and plastic deformation; lighter line and conglomerate pattern, higher Pennsylvanian and Permian formations; the filling of the San Luis Valley depression is late Tertiary and Recent alluvium, and older lavas and gravels; intrusive bodies are entirely hypothetical but are at positions corresponding to similar bodies exposed in other parts of the range. Section B is a diagrammatic representation of the same section, based upon the hypothesis of an earlier phase of lower-angle overthrusts (pre-Bridger), which are presumed to be responsible for the greater part of the shallower tangential deformation in the marginal belt.

Photostat VIII

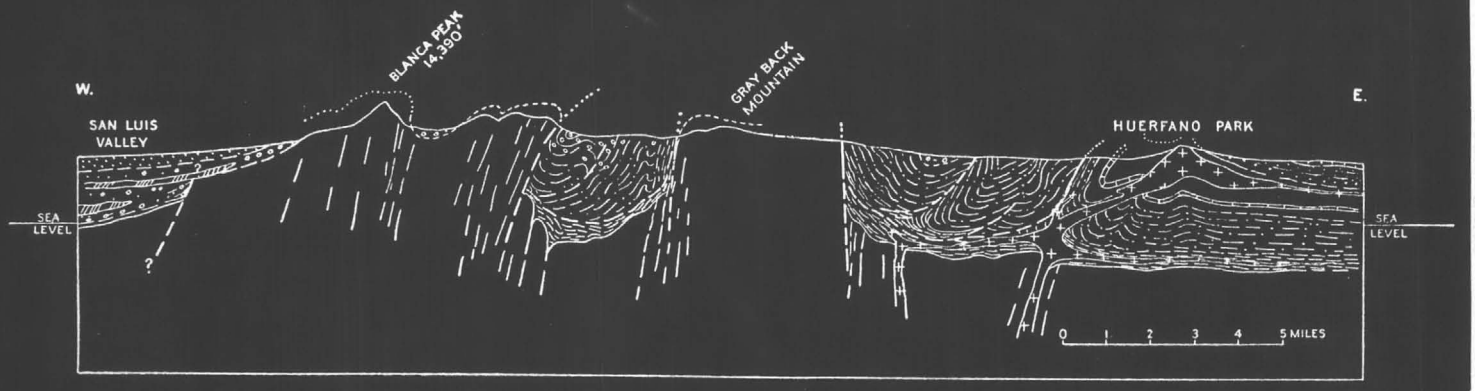


FIGURE 4.—*Geologic section across Sierra Blanca and Culebra massifs to the edge of Huerfano Park*

Section (along line A-A′ of Plate 4) illustrates diagrammatically the probable late origin of the upthrust massifs, following a phase of thrusting and folding of the sedimentary blanket. Deformation in the sedimentary blanket must be largely accounted for by thrust plates of granite, such as those shown in Figure 1-B.

they studied only small areas around Huerfano Park and between Crestone and Orient. Due to the great complexity of the geology that was all these men could study in detail.

The cause of the complex structure of the Sangre de Cristos is probably related directly to the great thickness of sediments. This thickness probably was a contributing cause not only to the intense folding of much of the Paleozoic formations, but also to the great thrusting on the flanks of the range which probably took place in conjunction with uplift and folding.

In their study of the "marginal deformation" east of the pre-Cambrian massifs between Orient and an area midway between Crestone and Huerfano Park Burbank and Goddard found that complex folds and overthrusts dominated the structure. The folds, which trend N 35 W E, are major features, and locally recumbent, while the thrusts, which were westward dipping, were imbricated and sometimes steeply inclined. Here the massif seemed to be thrust upward toward the top of the range. The Paleozoic sediments eastward toward the peaks of the range were found to be steeply dipping or overturned, and in places showed yielding by plastic flow. Eastward, past the top of the range, however, the sediments show a normal eastward dip gradually becoming shallower in dip toward the Wet Mountain Valley. East of the crest, therefore, the beds assume the simple anticlinal attitude seen by earlier writers. See ~~Plate~~ Photostat IV.

The thrusts themselves were folded and later apparently rebroken particularly in the major anticlinal structure near the peaks. The thrusts are considered to be possibly a surface rebreaking of a major fault in depth.

The pre-Cambrian rocks show two stages of deformation, one in pre-Huerfano times (pre-late Eocene) in which thrust plates of granite overrode the border zone of the Sierra Blanca massif (Photostat VIII) and the other stage, post-Huerfano, which is also upthrusting. The latter formed the thrust boundary at the eastern edge of the massif (photostat VIII). The maximum vertical uplift of the massifs are about 3 miles in the Blanca Peak area and 2.5 miles at Grayback Mountain. (Photostat VIII).

Burbank and Goddard concluded that the very complicated structure seen in the Carboniferous rocks in the Sangre de Cristos all could have been formed above the basement pre-Cambrian. This suggests the possibility of uplift and flow down the sides of uplifted structures forming overturned folds and thrusts.

MINERAL DEPOSITS OF THE SANGRE DE CRISTOS IN NEW MEXICO

Thw Sangre de Cristo Mountains are in parts of Taos, Colfax, Mora, San Miguel, and Santa Fe counties in New Mexico. In the range in this area there are numerous, minor ore deposits. Their most important metals are copper, gold, and silver, and their age varies from reputedly Pre-Cambrian to Pliocene.

PRE-CAMBRIAN ORE DEPOSITS: In San Miguel County at the Hamilton Mine and in the Rociada district the ore deposits are thought to antedate the Paleozoic sediments. Three types of Pre-Cambrian deposits were noted; they are: quartz-filled fissures (usually lenticular), shear zones filled with quartz veinlets, and sulfide disseminations in amphibolitic schists. These deposits are generally associated with secondary heavy silicates (so-called high temperature silicates) and have been subjected to stresses of dynamometamorphism, showing the effects of pressure by following the corrugation of the schists.

The principle pre-Cambrian deposits in the Sangre de Cristos are the Arroyo Hondo and Picuris districts in Taos County and the Rociada and Pecos districts in San Miguel County.

Picuris or Copper Hill District: This district is in southern Taos County just east of the Rio Grande. The veins are glassy quartz containing chalcocite, cuprite, malachite, and chrysocolla in addition to some possible argentite and tetrahedrite. The presence of limonite suggest that pyrite was once present, and locally high silver and gold values were encountered.

The veins are predominantly in pre-Cambrian schists, slates and quartzites which have a schistosity which runs slightly "north of west" and dips steeply to the south. The veins apparently cut this schistosity, because they strike north-south and dip moderately to the west.

The reasons for calling this deposit pre-Cambrian are obscure. The glassy quartz and the presence of tourmaline in veins which are related to the ore veins suggest formation in the hypozone. The veins were almost certainly formed sometime after the metamorphism of the surrounding rocks. This metamorphism was quite intense, for such minerals as tourmaline, garnet, corundum, sillimanite, andalusite, staurolite, and perhaps cordierite were developed locally. These minerals, in addition to the presence of slates, show that the area has undergone regional metamorphism and that the rocks vary from epizone to high mesozone. Such metamorphism would deform ~~any~~ veins. The facts that the veins cut the schistosity at a considerable angle and that some are in complex fracture zones suggest that there is no relationship between the schistosity and the vein formation. All that can be stated is that the veins were formed after the formation of the metamorphics and probably by another deformation. The cover, which was probably great at the time of vein formation, has since been eroded off.

No details were given about the Arroyo Honda district in Taos County except that the veins were associated with high temperature silicates introduced along with the veins.

The Hamilton Mine, San Miguel County: The Hamilton Mine is located at the confluence of Willow Creek and the Pecos River, about 17 miles east-northeast of Santa Fe.

This deposit is in an amphibolite and forms a belt N 50° E parallel to the strike of the amphibolite. The minerals are tourmaline, hornblende, pyrite, chalcopyrite, and sphalerite. Although primarily a copper mine, gold and silver values were sometimes high enough to make the ore mineable for precious metals.

The evidence in favor of this being a pre-Cambrian deposit is much stronger than that of the Picuris district. These deposits are overlain by Carboniferous sandstone containing chloritic and serpentinous cement. Some of the sand grains look like the outcrop rock of the Hamilton Mine. However no ore minerals were found in the carboniferous rocks, nor were tourmaline pebbles or sand noted. No ore has been found in the Carboniferous rocks of the area.

The evidence points toward a possible pre-Cambrian age. However I think it not conclusive. The Carboniferous rocks may have been merely "trap rocks" guiding the solutions along the pre-Cambrian lines of weakness. No maps of this mine were included, and I think not enough work has been done to either prove or disprove a pre-Cambrian age for the Hamilton Mine ores.

The Rociada Districts, San Miguel County: This district is in the northwestern part of San Miguel County near the Mora County line.

Immediately to the west of the Rociada District is a series of eastward dipping sediments with the Dakota (?) sandstone at the top; then some "Jura-Trias" red sand stones and shales;then some carboniferous strata underlain by the pre-Cambrian core of the Las Vegas and Mora Ranges. The Rociada District itself is in an area on the eastern slope of the range where the Carboniferous rocks alternated by faulting with the pre-Cambrian. Most of the ores are referable to the pre-Cambrian, but it is interesting to me that some copper is also present in Carboniferous rocks.

The strike of the rocks at one mine, the Good Hope is N 48° W and a dip of 60° southwest.

The Sam Adams claim is on quartz stringers which are mostly parallel to the schistosity of the pre-Cambrian country rock, striking N 45° W and dipping 40° SW., but sometimes transverse to the schistosity. The minerals are: pyrite, galena, sphalerite, copper (as stains), gold and silver.

The Good Hope Mine is similar, but the ore is along limestone bedding. The bedding has about the same dip and strike as the Sam Adams stringers.

Some other quartz veins in the district are more northerly in strike and some are in sheeted zones. One vein is cut off by carboniferous dediments. If the contact between the carboniferous rocks and the pre-Cambrian were definitely sedimentary the age of pre-Carboniferous is quite definite. Again I am not satisfied with the evidence. With no maps included in the report, and no detailed work having been done, the evidence for pre-Cambrian age aannot be conclusive.

Commentary on the Pre-Cambrian Ores: On theoretical considerations the deposition of extensive ore deposits during the formation of schists seems unlikely. While schists are forming the rocks act plastically, although not really being plastic. Such "plasticity" is not conducive to the formation of channels for ore solutions. During metamorphism there is probably little addition or subtraction of substances with the possible exception of some highly volatile constituents such as boron, fluorine, or carbon dioxide. The possibility of substances of low volatility, such as metallics, being transported in quantity during metam orphism seems remote. However, theory to the contrary, the deposits discussed above, may still be of pre-Cambrian age.

OTHER ORE DEPOSITS OF THE NEW MEXICO SANGRE DE CRISTO:

The Red River District, Taos County: The Red River district is around the town of Red River in the heart of the Taos Range.

The rocks here are predominantly pre-Cambrian. A monzonite porphyry of probable pre-Tertiary age is present, and some more recent andesites, andesitic breccias, and rhyolite flows and breccias are seen. Generally these rocks are above the pre-Cambrian core. The deposits occur mostly in the monzonite porphyry but some cut the rhyolite also.

The veins trend generally within a few degrees of north-south and dip not very far from vertical, but little also has been noted about their structure. The principal gangue minerals are quartz and carbonates, with the sulfides generally disseminated through the gangue and wall rock. The metallics are: pyrite, galena, sphalerite, chalcopyrite, molybdenite, and possibly petzite. Primarily gold is mined but at places copper, silver, and lead are important.

Other Taos County Districts: In addition to the districts mentioned before there are also the Anchor, La Belle, and Glenwoody districts, but there is nothing particularly noteworthy about these districts. The geology has not been studied in detail, and the mines have hardly progressed from the prospect stage. They are mostly gold camps. The trends of the structures were not stated, nor was their age given.

The Elizabethtown District, Colfax County: This is an important mining district. It is in the western part of Colfax County in the Cimarron Range, with most of the mining being limited to Baldy Peak. The total production of the district is about $5,000,000 (1910).

The dominant rocks of the district are of Paleozoic and Cretaceous age, although some pre-Cambrian is exposed.

Broadly the structure of the range is as is shown in the diagram below.

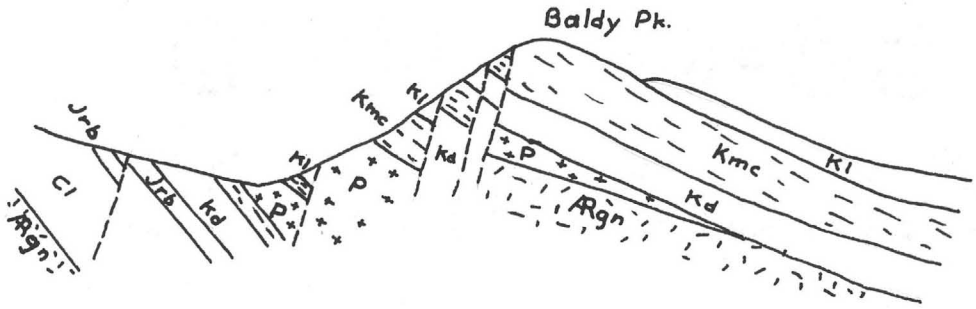


Fig. 1: Diagrammatic section through Cimarron Range at Elizabethtown. Only most important porphyry masses shown. Kl, Laramie (?) sandstone; Jrb, "Red Beds", Cl, Carboniferous limestone and grit; ARgn, pre-Cambrian granite, gneiss, and schist; p, porphyry. Dashed lines are probable lines of faulting.

The beds dip to the east and are normal-faulted as is typical in so many Rocky Mountain areas. The Cretaceous rocks are cut by numerous intrusive masses of monzonite porphyry which vary considerably in size. Contact metamorphism near these rocks is common.

The district produces gold primarily, but some copper, silver, and iron are of possible importance. The gold deposits are of two types; contact metamorphic in calcareous sediments and quartz veins striking roughly north-south.

The minerology of the veins is quite simple. The principal gangue is quartz with a little calcite. The most important metallic mineral is pyrite. Chalcopyrite, galena, magnetite and pyrrhotite may also be present.

Important mines in the district are the: Aztec Mine, Black Horse Mine, Montezuma Mine, and Rebel Chief Mine. The latter mine is interesting in that the ore occurs as irregular bodies in shale on the footwall side of porphyry dikes.

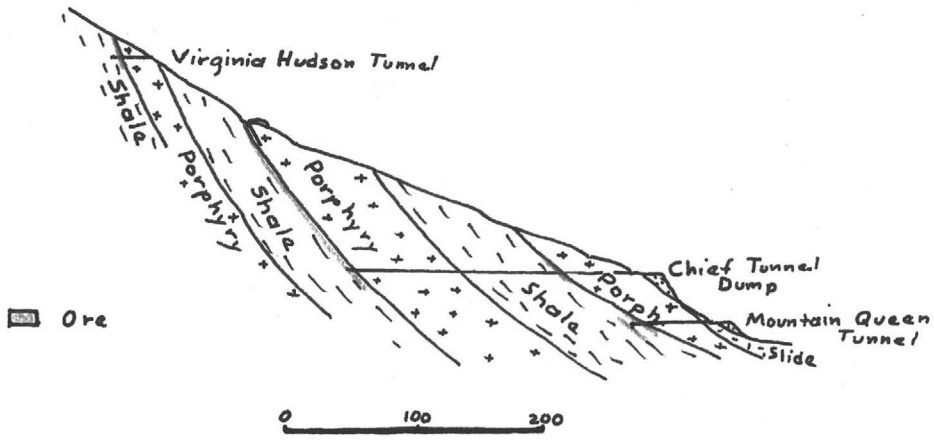


Fig. 2: Section through Rebel Chief Mine, Elizabethtown district.

At Iron Mountain the ores are deposits of epidote, garnet, magnetite, specularite, and gold, all apparently replacing limestone and limy shales.

The Cimarroncito District: This district lies about 14 miles south-southeast of Elizabethtown near the west of the Cimarron Range.

The country rock is predominantly Paleozoic and Cretaceous sediments which have been intruded by monzonite porphyry. The strata are generally gently dipping. The ores in the area are predominantly of the contact metamorphic type carrying: andradite, epidote, quartz, calcite, specularite, magnetite, pyrite, chalcopyrite, and gold. The mines are worked for gold.

Mora and San Miguel Counties: The ore deposits of these counties are minor and some have been dealt with already under the pre-Cambrian deposits. The mining districts of these counties are the Rociada district, the Tecolote district, some pre-Cambrian

deposits, and some minor copper deposits in the Santa Fe Range and the upper Pecos River.

The Tecolote district has two ore bearing horizons, both arkosic formations but of different ages, Cretaceous and Carboniferous. They are mined for copper, and although there is a large amount of copper in the county, the ore is usually subeconomic. This copper is so disseminated that it was believed to be a result of lateral secretion by some geologists, but upon examination the ore was found to parallel fissure zones which struck north-northwest, and is believed to be related genetically to these fissures.

ORE DEPOSITS OF PLOMO, SAN LUIS PARK, COLORADO:

Plomo is situated on the west slope of the Sangre de Cristo Range about forty miles north of New Mexico. The ore deposits in this area are admirably exposed by the Rito Seco Creek canyon, but the information concerning them is rather meager.

The ore occurs in the shatter zone of one of a series of steeply dipping east-west faults. The fault itself is not seen because the Rito Seco has chosen that weakened zone as its bed. However, the evidence from displacements of beds on the stream sides is unmistakeable. The beds dip gently northward and westward with the east-west faults raising the north side relative to the south.

The ore occurs in crushed, intensely folded, gneiss of granite origin. Silicification and hydrothermal alteration took place before and during the deposition of the ore minerals. These are gold and pyrite. Cutting all other features in the area, and apparently not related to the mineralization just described, are a series of true quartz veins containing galena, sphalerite, chalcopyrite, fluorite, and specularite. These veins are small and non-commercial. Where they cut the replacement ore bodies there is no enrichment of those ore-bodies.

The strike of the veins cutting the early ore deposits was not given, but ~~it is interesting that the main ore occurrences are along~~ (the presence of) east-west faults (is interesting). This suggests some downward tilting of this portion of the range to the north. The fact that the highest peak of this area is at the southern part of the range also tends to confirm this.

Copper Ores of Rito Alta: R. M. Bagg (7) mentioned some copper deposits occurring in fissures, joints, and bedding planes along the base of Rito Alto Mountain. However, he was using these deposits to prove the lateral secretion theory, and his information was, therefore, rather sketchy. The ore minerals were chalcopyrite, chrysocolla ~~chrysocolla~~, some silver, and gold. At least some of the fissures were striking roughly north-south, and dipped westward.

The Grayback Mining District: Around Grayback Mountain, just north of the jog in the Sangre de Cristos, near Spanish Peaks are a series of ore deposits. Although the mining district is minor the ores are interesting and diversified.

The ores in this district occur for the most part in carboniferous rocks which have been intruded by monzonite porphyries and a diorite stock. The rocks dip predominantly eastward and, according to the geologic map shown, the regional structure is fairly simple.

There are six main types of lode deposits in the Grayback district. They are:

(1) Contact Deposits

(a) Archean - Carboniferous contact

(b) Sedimentary - igneous contacts

(c) Archean - igneous contacts

(2) Impregnated schists

(3) Fissure veins, sheeted zones, etc.

(4) Mineralized dikes

(5) Metamorphosed bedded deposits

(6) Miscellaneous deposits

All these deposits apparently are the result of the same mineralization. Most of the values are in silver, gold and copper.

The first type of ore deposit contact ores is simply in sheeted zones and weakened areas adjacent to the contacts of dissimilar rocks, but no deposits of this type were found which were mineable.

The impregnated schists were not of any value either, although in one area a considerable amount of copper mineralization was present.

The fissure veins have been producers. Two types of fissure veins were distinguished, one steeply inclined and the other a flat-lying blanket type, with steep veins wider than the flat veins. The authors of the paper on the Grayback district assumed different ages for the two vein systems, but no intersections of the veins were seen, and their reasons for assuming different ages were obscure.

The mineralized dikes of the area contained no ore, but their alteration indicates that they were passageways for solutions.

The metamorphosed bedded deposits are replacement deposits in carboniferous limestone. The mineral contained are calcite, garnet, hematite, magnetite, a little pyrite, gold, and silver. These ores are not mineable for any of their minerals although the gold and silver were nearly economic, and under different conditions the iron may be mined.

The authors of the Grayback district paper correlated the metamorphic deposits with the intrusions of monzonite porphyries with which they are intimately associated. However they gave no details about the mineralization.

A productive deposit occurring at the Mountain View Mine does not fit into the above classification of deposits. This ore body occurs in a brecciated monzonite porphyry at the intersection of two obliquely intersecting sheeted zones, which strike N 74° W. and S 26° E, respectively and dip 79° N. and 86° S., respectively. This deposit is in a chimney form and contains sulfide of iron, siderite, limonite, and gold.

In summary the Grayback district is strictly minor as far as lode deposits go. The placers are more valuable. The paper on the Grayback district was rather sketchy and very few details of mineralization or fracture patterns were given. Apparently a northeast fissuring with a southeast dip is present. The ores are basically gold, but locally silver, copper, lead, or iron could be economic. The age of these deposits was assumed to be post-Eocene, but the dating was indefinite.

SUMMARY OF ORE DEPOSITS IN THE SANGRE DE CRISTOS:

The thickness of the post pre-Cambrian rocks in the Sangre de Cristos has not been worked out. However, I gather from the article on the New Mexican mines that the Paleozoic sediments in that area probably are less than half the thickness of those in the northern area in Colorado. It is possible that this thinner cover allowed ore solutions to penetrate the cover and enabled volcanism on a fairly large scale to take place in this southern area. It seems probable that the scarcity of volcanism and ore deposits in most of the Sangre de Cristos is due to the thick sedimentary cover. The only mineralized area of note in the Colorado Sangre de Cristos is at the Grayback district where the range jogs eastward. In this area other factors, possibly ~~because of~~ related to the jog, may have been operative.

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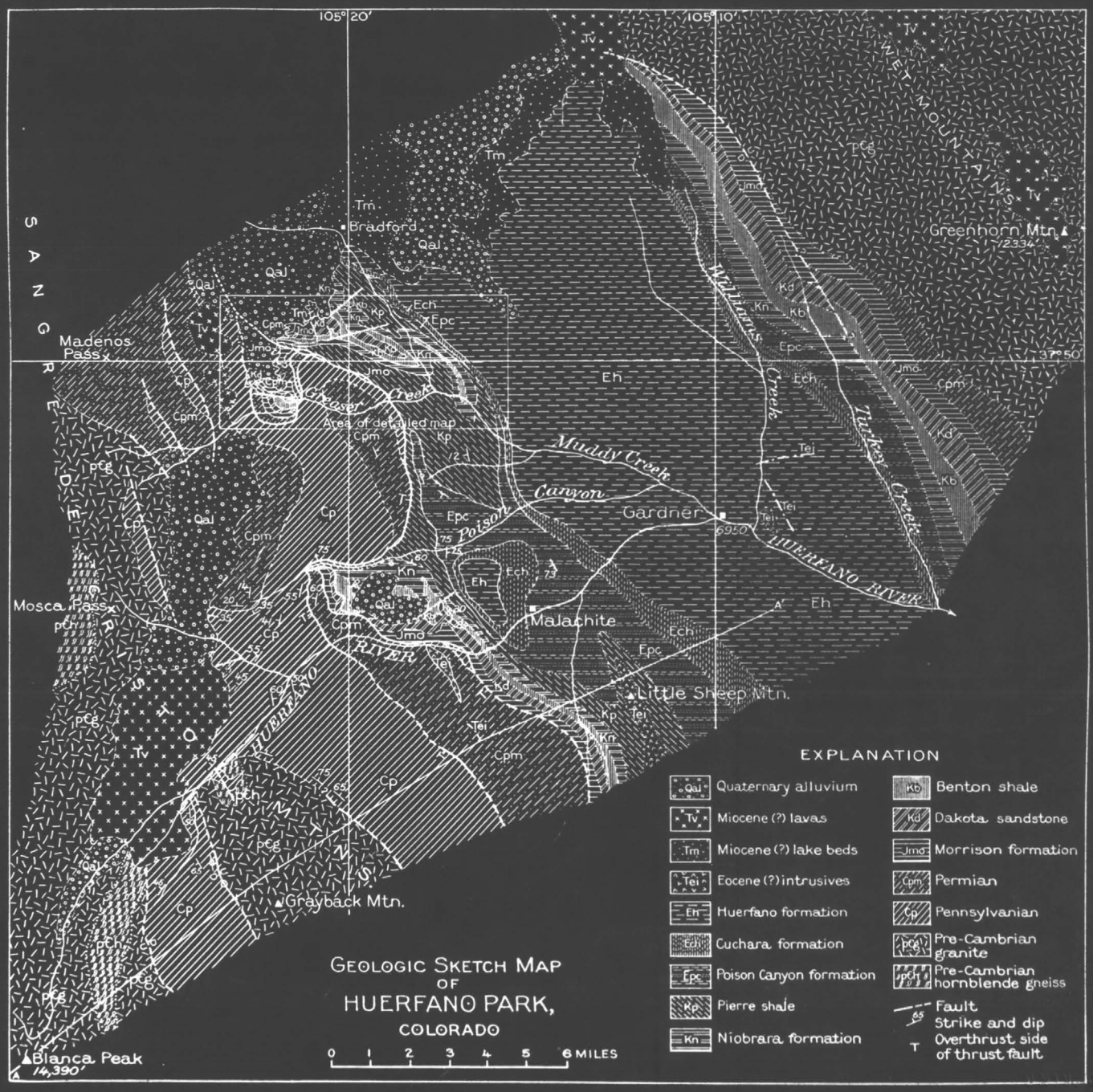
Photostats and a General Map of the Sangre de Cristo Range and Some of the Surrounding Area

Photostat V : Huerfano Park, Sketch map.

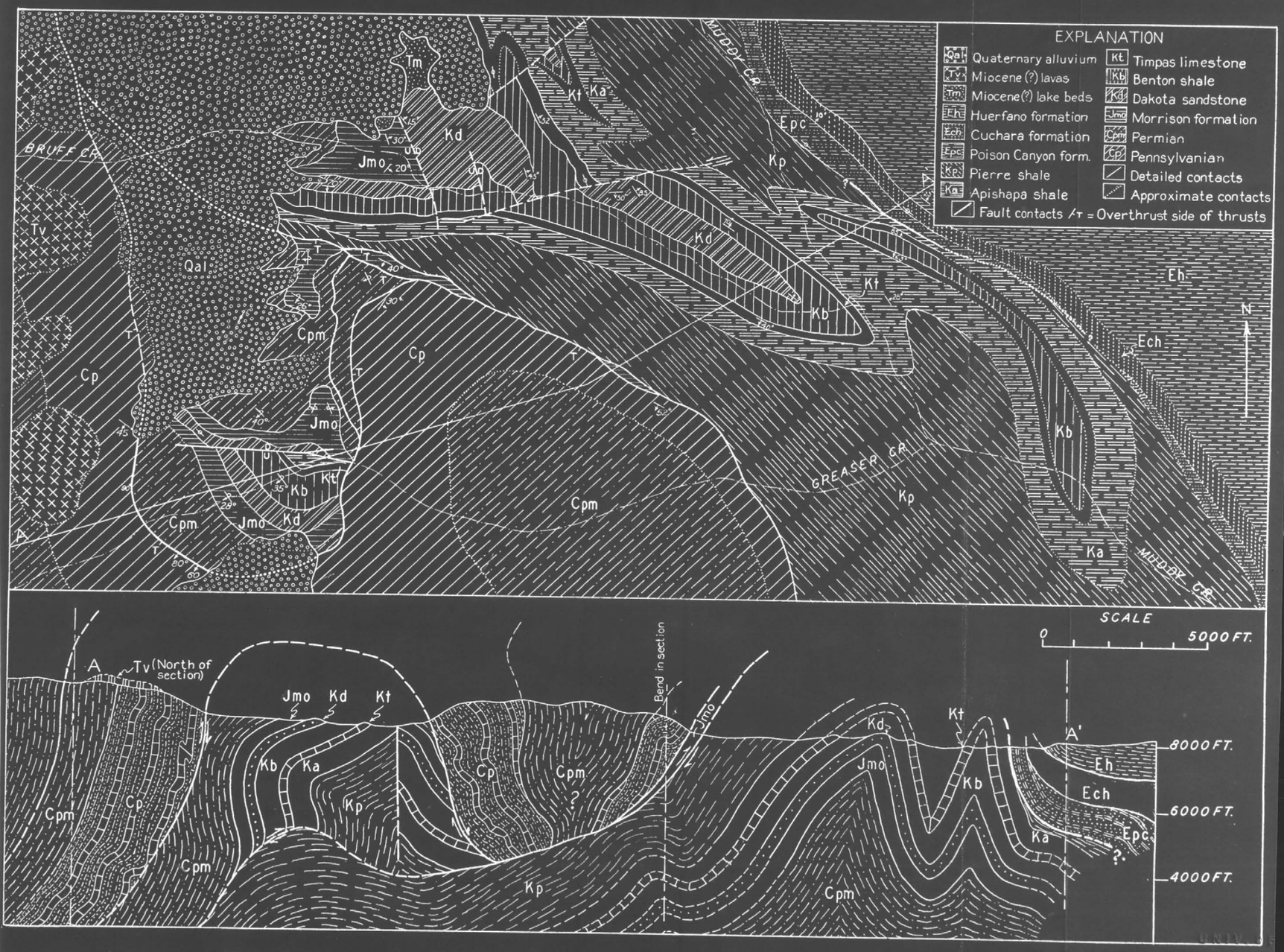
Photostat VI : Bruff Creek Area, Huerfano Park.

Photostat VII : Plastic Deformation of Slate Bodies near Front of Overthrust Plates



GEOLOGIC SKETCH MAP OF HUERFANO PARK, COLORADO

Photostat VI



PLANE-TABLE MAP AND STRUCTURE SECTION OF A LOBATE SALIENT OF THE MAIN THRUST BELT

Bruff Creek area, Huerfano Park, Colorado.

Photostat VII

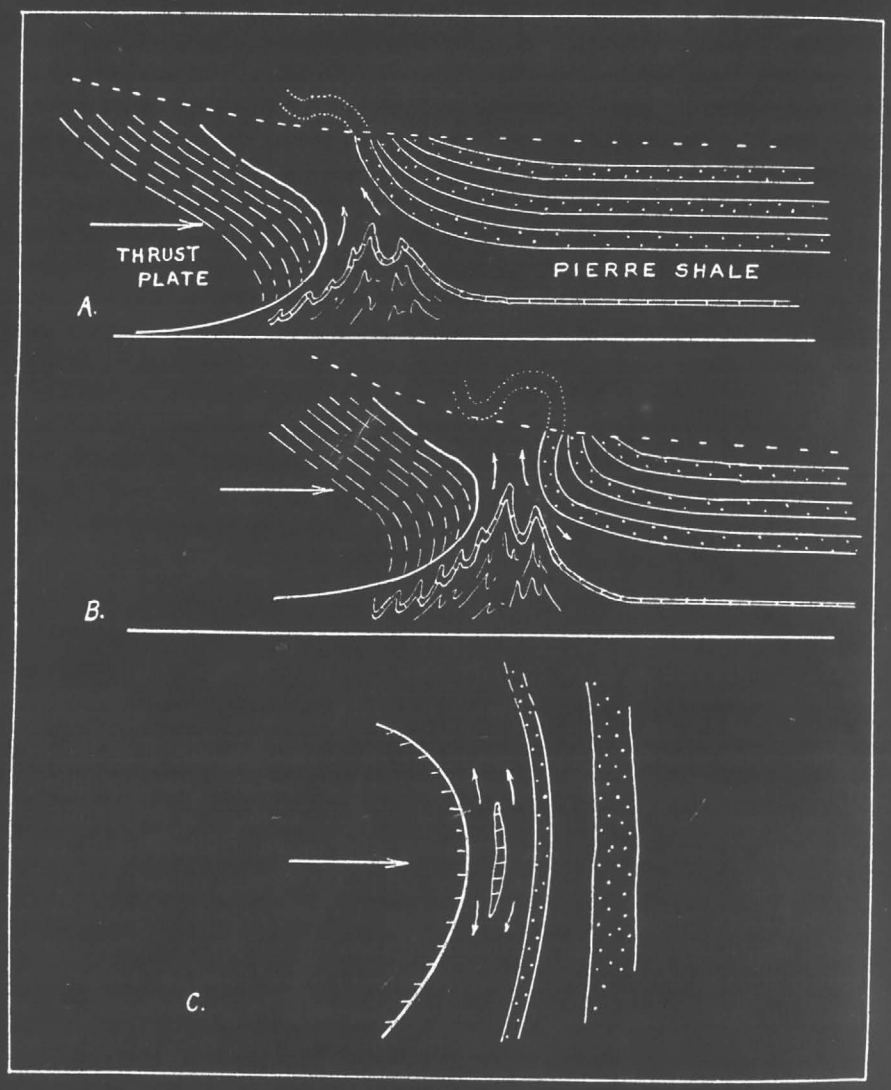
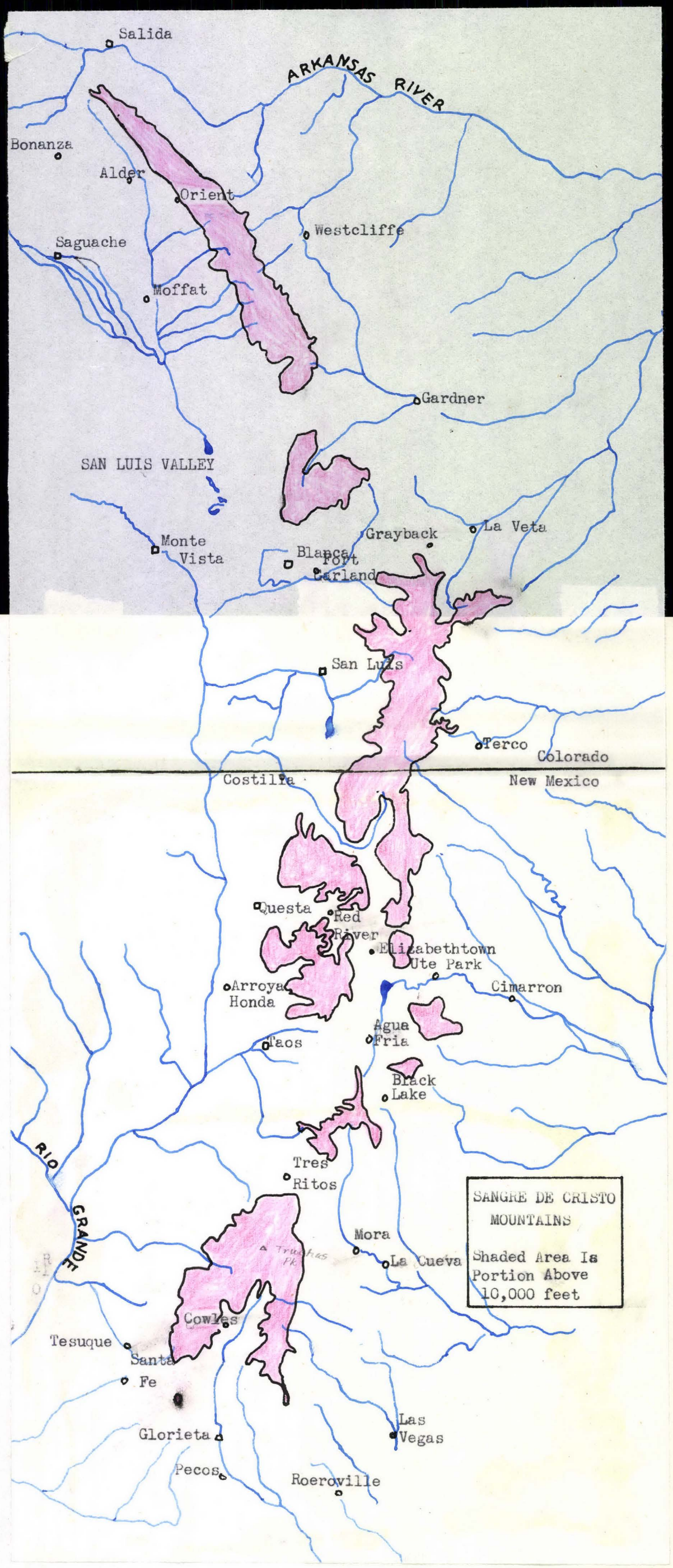


FIGURE 3.—*Diagrammatic illustration of plastic deformation in shale bodies near front of overthrust plates*

(A and B) Stages in the advance and rise of a lobate salient of a thrust plate. (C) Plan of lobate salient. Small arrows indicate probable direction of plastic flowage in Pierre shale.


Salida
ARKANSAS RIVER
Bonanza
Alder
Orient
Westcliffe
Saguache
Moffat
Gardner
SAN LUIS VALLEY
Grayback
La Veta
Monte Vista
Blanca
Fort Garland
San Luis
Terco
Colorado
Costilla
New Mexico
Questa
Red River
Elizabethtown
Ute Park
Arroyo Honda
Cimarron
Agua Fria
Taos
Black Lake
RIO GRANDE
Tres Ritos
SANGRE DE CRISTO MOUNTAINS
Shaded Area Is Portion Above 10,000 feet
Mora
La Cueva
Truchas Pk
Cowles
Tesuque
Santa Fe
Las Vegas
Glorieta
Pecos
Roeroville