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LATE CRETACEOUS AND TERTIARY STRATIGRAPHY OF THE RATON BASIN OF NEW MEXICO AND COLORADO *

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ABSTRACT

A thick sequence of late Upper Cretaceous and Tertiary sedimentary rocks is preserved in the Raton basin. These strata include the Pierre shale, Trinidad sandstone, and Vermejo formation of Late Cretaceous age; the Raton formation of Late Cretaceous and Paleocene age; the Poison Canyon formation of Paleocene age; the Cuchara and Huerfano formations of Eocene age; the Farisita conglomerate of probable Oligocene age; and the Devil's Hole formation of probable Miocene age. Some of the events of Laramide deformation are recorded in the rocks of these formations.

Locally Laramide deformation began with epeirogenic movements west of the Raton basin in late Montana time. The epeirogenic movements were followed by at least seven orogenic episodes, as shown by angular unconformities and lithologic changes in the sedimentary rocks.

Sills, dikes, plugs, stocks, sole injections, and laccoliths were intruded into the sedimentary rocks of the basin during the Eocene epoch.

INTRODUCTION

The Raton basin is an Upper Cretaceous and Tertiary sedimentary and structural basin that lies in northeastern New Mexico and southeastern Colorado (fig. 1) in the westernmost part of the Great Plains province. The basin is bounded on the west by the foothills of the Sangre de Cristo Mountains and on the east by the Sierra Grande-Las Animas arch. It merges with faults and folds in front of the Cimarron Mountains to the south. The northern part of the Raton basin is divided by a southward plunging anticlinal extension of the Wet Mountains. The axis of the western or main part of the basin is in Huerfano Park and Wet Mountain Valley. The axis of the eastern or secondary basin trends northeastward between the Wet Mountains and the Las Animas arch and terminates to the north against the Apishapa arch. The principal axis of the Raton basin in New Mexico trends slightly east of north, but in Colorado it has a northwest trend.

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The Raton basin is asymmetric; the eastern limb dips gently westward, whereas the western limb dips steeply eastward. Locally this western limb is vertical or overturned along the basin margin. Late Upper Cretaceous and lower and middle Tertiary rocks occupy the deepest part of the basin in the Raton Mesa region and Huerfano Park (fig. 1). The deepest part of the trough is generally parallel to but not coincident with the structural axis of the basin.

In 1948 the Geological Survey began a regional investigation of the geology and an evaluation of the fuel resources of the Raton Mesa region and Huerfano Park in Colorado. This investigation is still in progress, and reports covering most of the region have been released. Reports published to date by the Geological Survey on the Raton Mesa region are given in the list of references that concludes this paper. Investigation of the geology and fuel resources of the New Mexico part of the Raton Mesa region was begun in the summer of 1955, and most conclusions derived from work in that area are tentative.

The Raton Mesa region and Huerfano Park contain the most complete stratigraphic succession of late Upper Cretaceous and Tertiary rocks that is exposed on the eastern side of the Southern Rocky Mountains. This stratigraphic succession includes the following formations: the Pierre shale, the Trinidad sandstone, and the Vermejo formation of Late Cretaceous age; the Raton formation of Late Cretaceous and Paleocene age (Brown, 1943, p. 82–83); the Poison Canyon formation of Paleocene age; the Cuchara and Huerfano formations of Eocene age; the Farisita conglomerate of probable Oligocene age; and the Devil's Hole formation of probable Miocene age. Only the Pierre shale, the Trinidad sandstone, and the Vermejo, Raton, and Poison Canyon formations are known to occur in the New Mexico part of the Raton Mesa region. Preserved in the stratigraphic succession are the records of several pronounced episodes of the Laramide Revolution (fig. 2).

GENERAL STRATIGRAPHY

Cretaceous rocks

The Pierre shale (Meek and Hayden, 1862, p. 419, 424) is about 1,600 feet thick in the southern part of the Raton Mesa region in New Mexico, but reaches a thickness of about 2,300 feet southeast of Huerfano Park in Colorado. The lower 1,300 to 2,000 feet of the Pierre shale is chiefly dark gray to nearly black noncalcareous shale with several thin zones of calcareous and iron carbonate concretions. The upper 200 to 300 feet of the Pierre consists of

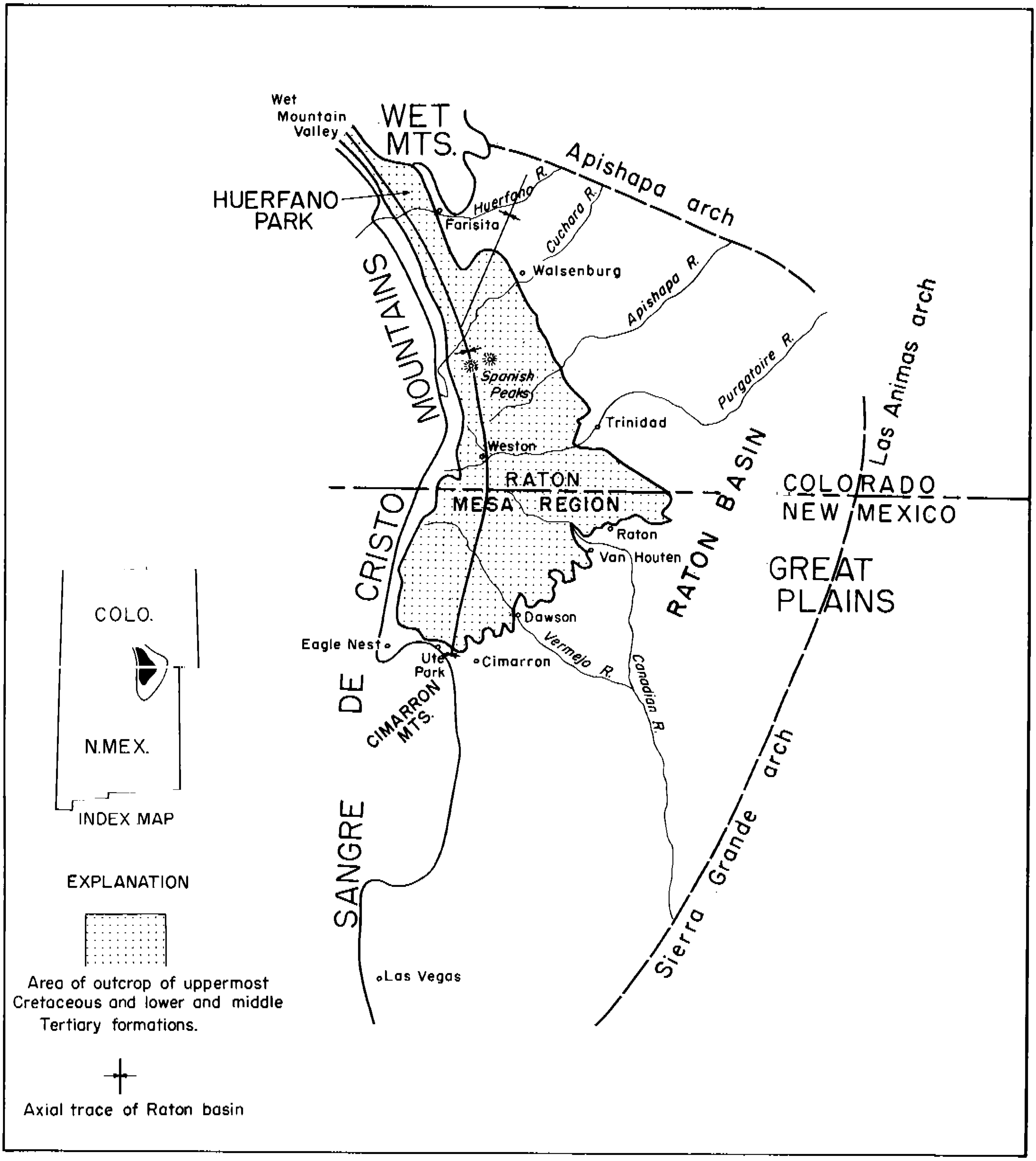

Fig. I. MAP OF THE STRUCTURAL RATON BASIN OF NEW MEXICO AND COLORADO

0 10 20 30 40 50 Miles

Scale

AGE		FORMATION	THICKNESS
QUATERNARY		Alluvium	0'–30'
			Unconformity
TERTIARY	Miocene (?)	Devil's Hole formation	25'–1,300'
			Unconformity
	Oligocene (?)	Farasita conglomerate	0'–1,200'
			Unconformity
	Eocene	Huerfano formation	0'–2,000'
			Unconformity
		Cuchara formation	0'–5,000'
			Unconformity
	Paleocene	Poison Canyon formation	0'–2,500'
			Local unconformity
		Raton formation	0'–1,700'
CRETACEOUS	Upper Cretaceous	Vermejo formation	0'–500'
		Trinidad sandstone	0'–240'
		Pierre shale	1,600'–2,300'

Fig. 2. UPPER CRETACEOUS AND TERTIARY SEDIMENTARY FORMATIONS OF THE RATON MESA REGION AND HUERFANO PARK

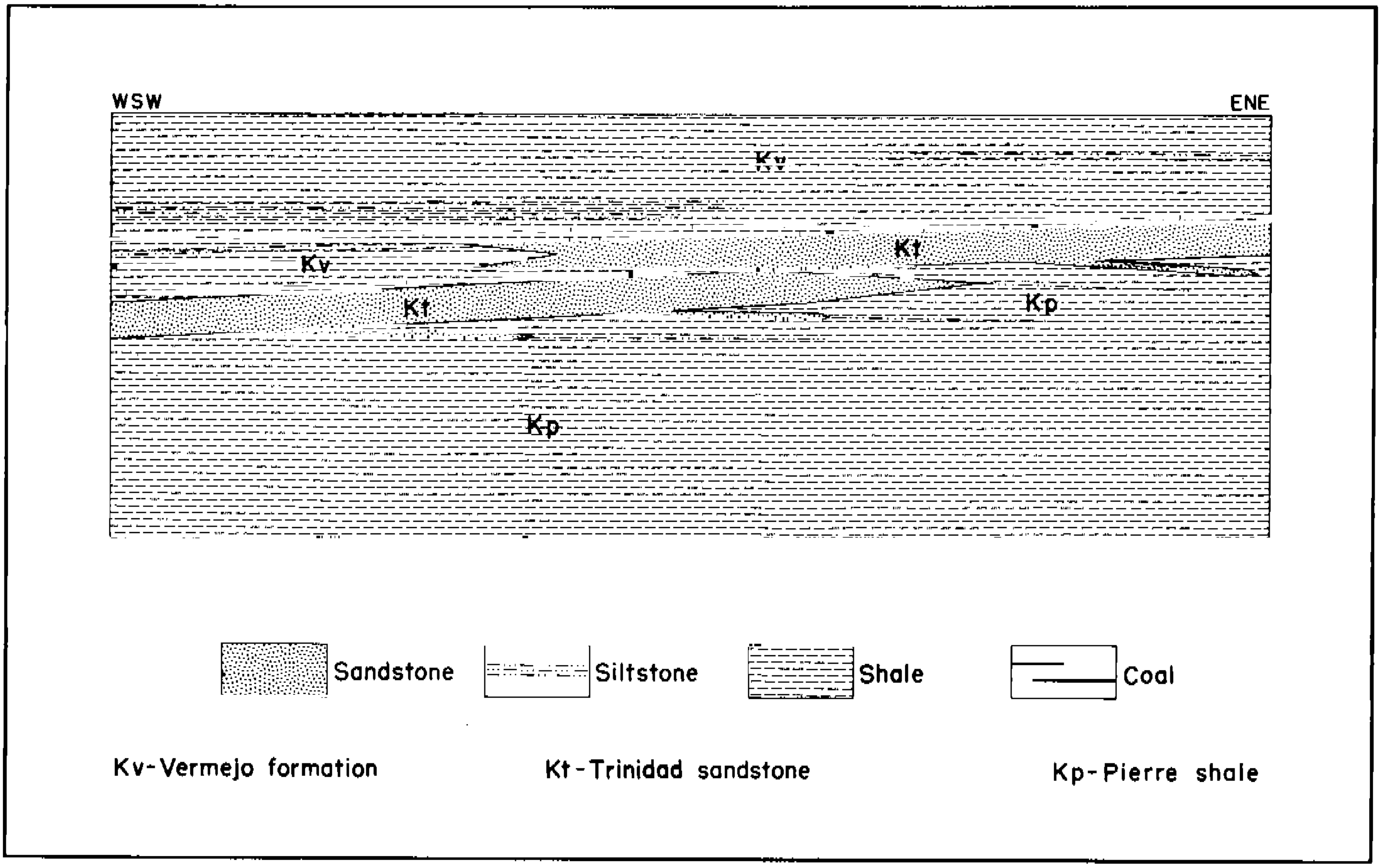

Fig.3. CONTACT RELATIONSHIPS OF VERMEJO FORMATION, TRINIDAD SANDSTONE, AND PIERRE SHALE BETWEEN CIMARRON AND DAWSON, NEW MEXICO.

buff to gray, thin-bedded, fine-grained sandstone intercalated with thin beds of gray to dark gray silty and sandy shale. These beds grade into and intertongue with the lowermost beds of the overlying Trinidad sandstone. Tongues of Pierre shale wedge out in a westerly direction, whereas tongues of the Trinidad sandstone wedge out laterally in northerly and easterly directions (fig. 3).

The Trinidad sandstone (Hills, 1899; Lee, 1917, p. 48–51) is composed of buff to gray, slightly arkosic sandstone with local thin interbeds of light tan to gray silty shale. The formation is 40 feet thick southeast of Trinidad, Colorado and from this point northwestward it increases in thickness to 240 feet on the western margin of the basin southwest of Walsenburg, Colorado (fig. 4). Sandstone beds are medium- to massive-bedded and the bedding structure is most commonly tabular, less commonly irregular, and in places lenticular. The grains are mostly quartz with subordinate amounts of weathered feldspar, mica, and ferromagnesian minerals. The grain size is chiefly fine, but ranges from very fine to medium. Casts of *Halymenites sp.* are locally abundant.

The lithologies and stratigraphic relationships between the Pierre shale and the Trinidad sandstone are similar to those reported for their homogenetic correlatives, the Pierre shale and Fox Hills sandstone (Richardson, 1915, p. 6) in areas north of the Raton basin; and the Lewis shale and Pictured Cliffs sandstone (Dane, 1948; Wood, Kelley, and MacAlpin, 1948; and Zapp, 1949) of northwestern New Mexico and southwestern Colorado.

The Pierre shale accumulated as a thick marine sequence of mud and silt with minor amounts of lime and sand during Montana time (Eldridge, 1888, p. 93) throughout much of the area now accupied by the Great Plains and the Rocky Mountains. The begining of Laramide deformation is recorded in the upper 100 to 300 feet of the Pierre shale by alternating fine sandstone and shale beds. Epeirogenic uplift forced the strand line to retreat to the northeast, and some of the fine sand eroded from the uplifted area or areas was deposited in the present Raton basin. As the strand line shifted, the Trinidad sandstone accumulated in the sea and on its margins as regressive beach and offshore deposits The regression was discontinuous, however, and the direction

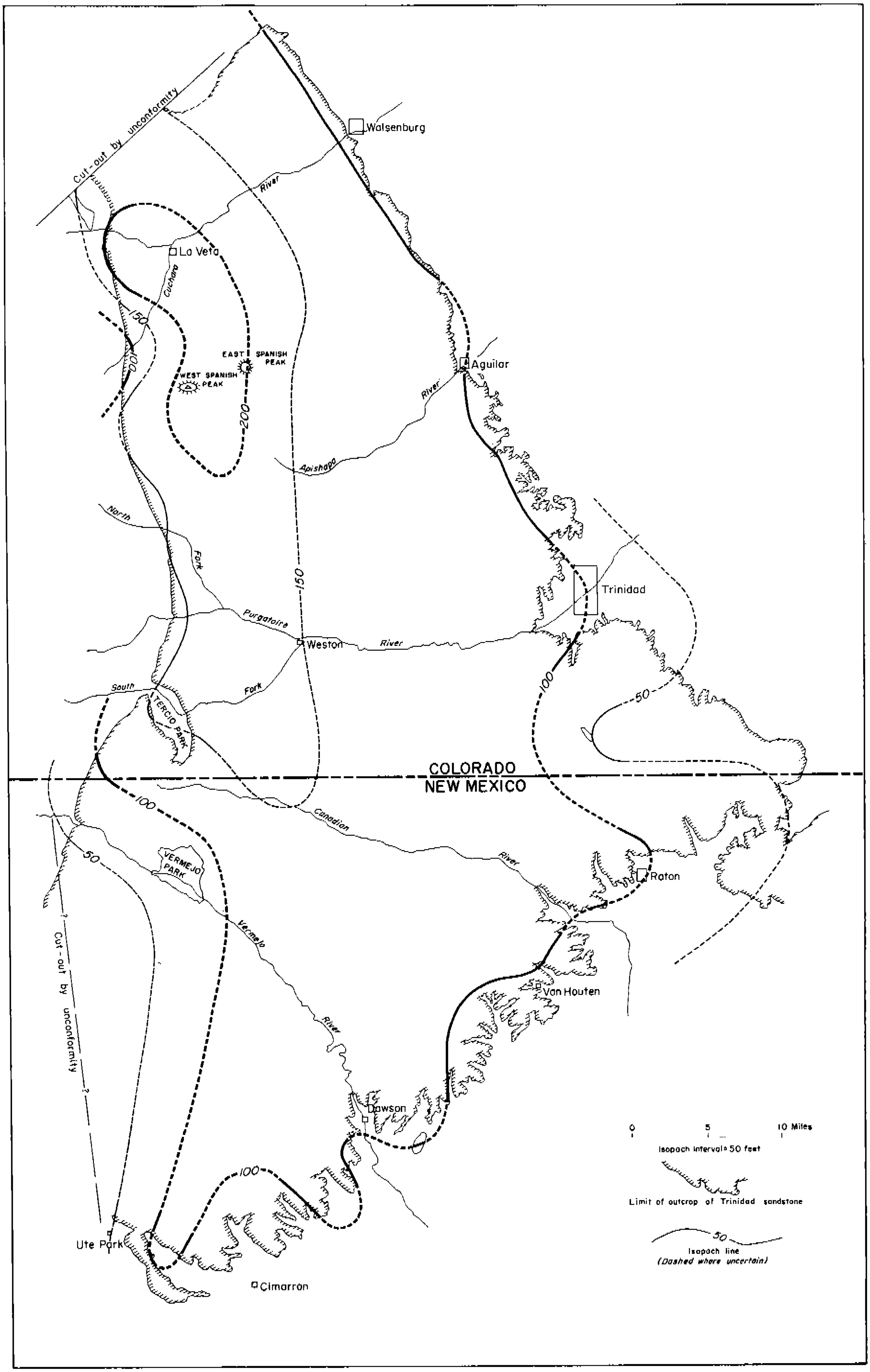

Fig.4. ISOPACH MAP OF THE TRINIDAD SANDSTONE
IN THE
RATON MESA REGION OF COLORADO AND NEW MEXICO

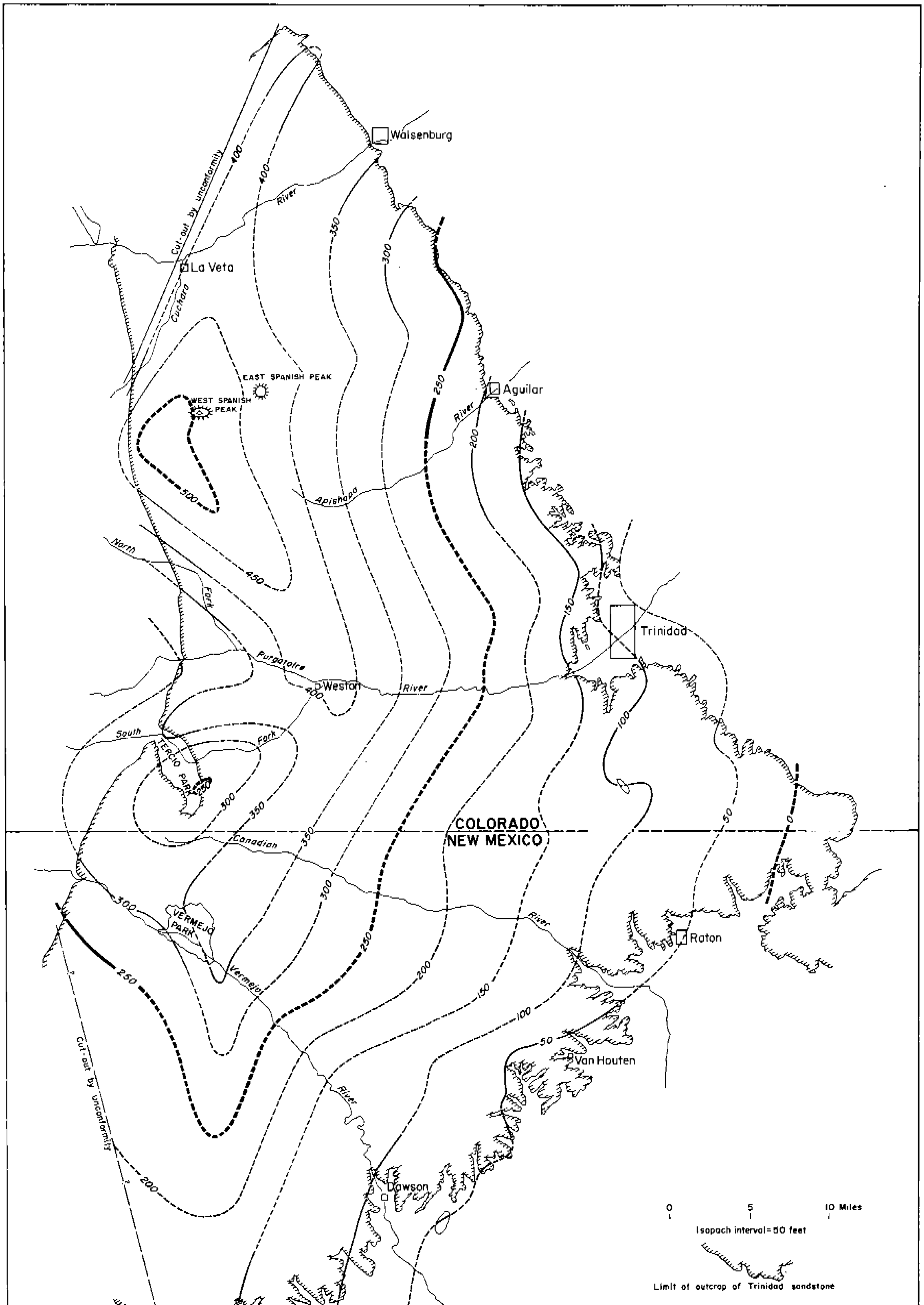

Fig. 5. ISOPACH MAP OF THE VERMEJO FORMATION
IN THE
RATON MESA REGION OF COLORADO AND NEW MEXICO

of movement of the strand line was occasionally reversed.

The Vermejo formation (Lee, 1913, p. 531) of Montana and Laramie age rests conformably on the Trinidad sandstone over most of the Raton Mesa region. Tongues of Vermejo strata wedge out in easterly and northeasterly directions, and tongues of Trinidad sandstone wedge out to the west and southwest. Vermejo rocks consist of buff, gray, and dark gray siltstone; buff, gray and gray-green slightly arkosic sandstone; nearly black carbonaceous, coaly, and silty shale; and numerous coal beds. Sandstone beds vary from thin- to massive-bedded. The thin sandstone beds are chiefly parallel-stratified, but the thick beds of sandstone are commonly irregular and lenticular. Sand grains are principally quartz, but weathered feldspar, mica, and ferromagnesian minerals occur. The grain size varies from very fine to medium, and the cementing materials are clay and calcium carbonate. Coal beds are intercalated in shale and siltstone units which vary in thickness throughout the Raton Mesa region.

The Vermejo formation is apparently absent a few miles east of Raton, New Mexico, and several miles southeast of Trinidad, Colorado (fig. 5), and is only a few feet thick at the mouth of Crow Creek Canyon near Koehler, New Mexico. From near these points the formation increases irregularly in thickness northwestward to 500 feet southwest of Walsenburg, Colorado.

Lee (1917, p. 64) believed that the rocks of the Vermejo formation in the western part of the Raton Mesa region were removed by widespread post-Cretaceous erosion. However, during recent investigations no evidence has been found of a regional unconformity between the rocks of the Vermejo formation and the rocks of the overlying Raton formation. Reconnaissance examination of the area east of Raton, New Mexico, and Trinidad, Colorado, indicates that the eastward thinning of the Vermejo formation is more likely due to nondeposition than to pre-Raton erosion.

Following the deposition of the offshore and beach sands that comprise the Trinidad sandstone, the sea continued to retreat, and mud, silt, sand, and carbonaceous material of the Vermejo formation were deposited on deltas, flood plains, and in swamps.

Cretaceous and Tertiary rocks

The Raton formation (Lee, 1913, p. 531) crops out over most of the Raton Mesa region, and is as much as 1,700 feet thick southeast of the Spanish Peaks. It consists of a thin basal sequence of gray to dark purple-gray siliceous granule to pebble conglomerate or buff to gray siliceous conglomeratic sandstone. Above this thin basal sequence the Raton formation is made up of buff, gray, and olive-gray very fine- to course-grained arkose, graywacke, and quartzose sandstone beds; gray to dark gray siltstone and silty shale beds, and numerous coal beds. The feldspar grains in the arkose and sandstone beds are usually weathered, and are generally white or light gray.

In the central part of the Raton Mesa region the uppermost beds of the Raton formation regionally intertongue with and locally grade vertically and laterally into the lowermost beds of the Poison Canyon formation (Hills, 1888, p. 148-164). At most places the contact between the two formations is difficult to place because of the gradual lithologic change between them. Usually the contact may be located by the appearence of unweathered grains of pink feldspar in the sandstone beds of the Poison Canyon. The sandstone beds of the Poison Canyon formation are usually coarser grained than those of the Raton formation. In addition, the shale beds in the Poison Canyon formation contain lesser quantities of carbonaceous material, and coal is present at only a few places near the base. Fifty to 100 feet above the contact between the Poison Canyon formation and the Raton formation, the Poison Canyon is characterized by massive buff to red arkosic sandstone and conglomerate beds and thin yellow shale beds. The Poison Canyon formation ranges from a thin edge in Huerfano Park to about 2,500 feet in thickness south of the Spanish Peaks.

The upper beds of the Raton formation intertongue and grade into the lower beds of the Poison Canyon formation in southerly and westerly directions (fig. 6). On the western margin of the Raton Mesa region near the New Mexico-Colorado boundary, beds of the Poison Canyon are several hundred feet below the stratigraphic position they occupy in the central part of the Raton Mesa region. Farther to the south a few miles northwest of Cimarron, New Mexico, the rocks described by Lee (1917, p. 72-74) as being in the Raton formation have lithologies characteristic of the Poison Canyon formation. It is believed by the writers that in this locality the Poison Canyon facies is dominant over the Raton facies. In the vicinity of Ute Park, New Mexico, rocks with lithologic characteristics of the Poison Canyon rest unconformably upon rocks of the Vermejo formation, the Trinidad sandstone, and the Pierre shale. This suggests that the coarser facies characteristic of the Poison Canyon formation has completely replaced the finer facies of the Raton formation, and that in the extreme southwestern part of the Raton Mesa region the lowermost beds of the Poison Canyon formation are probably the age equivalents of the basal conglomerate of the Raton formation to the north and east.

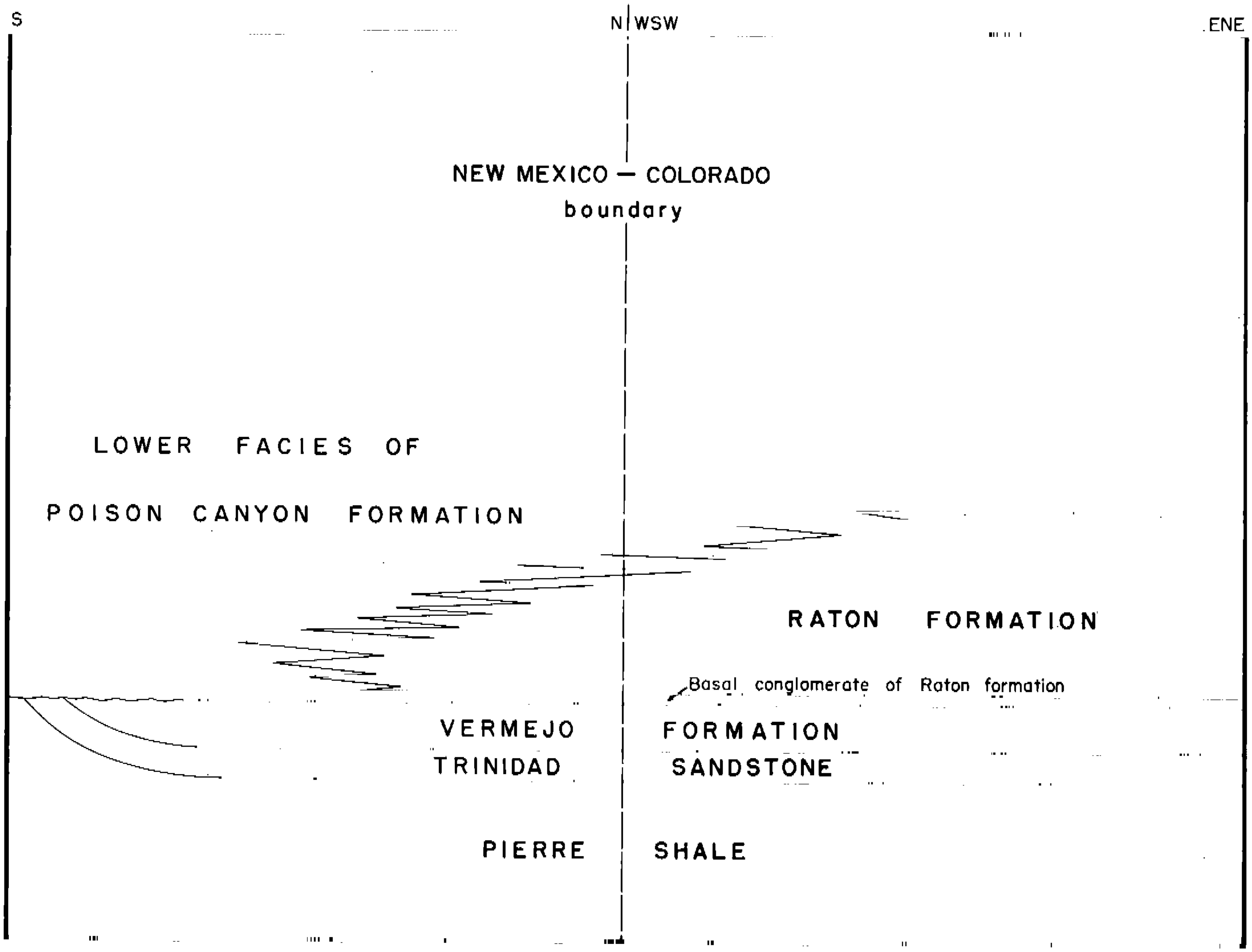

Fig. 6. DIAGRAM SHOWING INFERRED INTERTONGUING RELATIONSHIPS OF POISON CANYON FORMATION AND RATON FORMATION BETWEEN WESTON, COLORADO AND UTE PARK, NEW MEXICO.

The upper beds of the Poison Canyon formation in the central part of the Raton Mesa region are mostly metamorphic and igneous pebble to cobble conglomerate. These coarse conglomerate beds seem to grade downward into the lower beds of the Poison Canyon formation. Northwestward the base of the coarse conglomerate becomes progressively lower stratigraphically due to intertonguing with the lower facies. Near the latitude of the Spanish Peaks in Colorado the upper coarse conglomerate facies replaces the entire lower part of the Poison Canyon sequence, and rests with apparent conformity on the uppermost beds of the Raton formation (fig. 7). This conformable relationship apparently prevails northward for several miles on both the western and eastern margins of the Raton Mesa region. However, about half a mile north of Apishapa River on the east and Cuchara River on the west, the coarse conglomerate facies of the Poison Canyon formation overlies an erosion surface that cuts across the beveled edges of the uppermost beds of the Raton formation. Farther to the north this erosion surface cuts out the remainder of the Raton formation, the Vermejo formation, the Trinidad sandstone, the Pierre shale, and the uppermost beds of the Niobrara formation.

Field evidence indicates that the sediments comprising the Raton and Poison Canyon formations were derived from Precambrian or Paleozoic terranes southwest and northwest of the Raton Mesa region. The Poison Canyon forma-

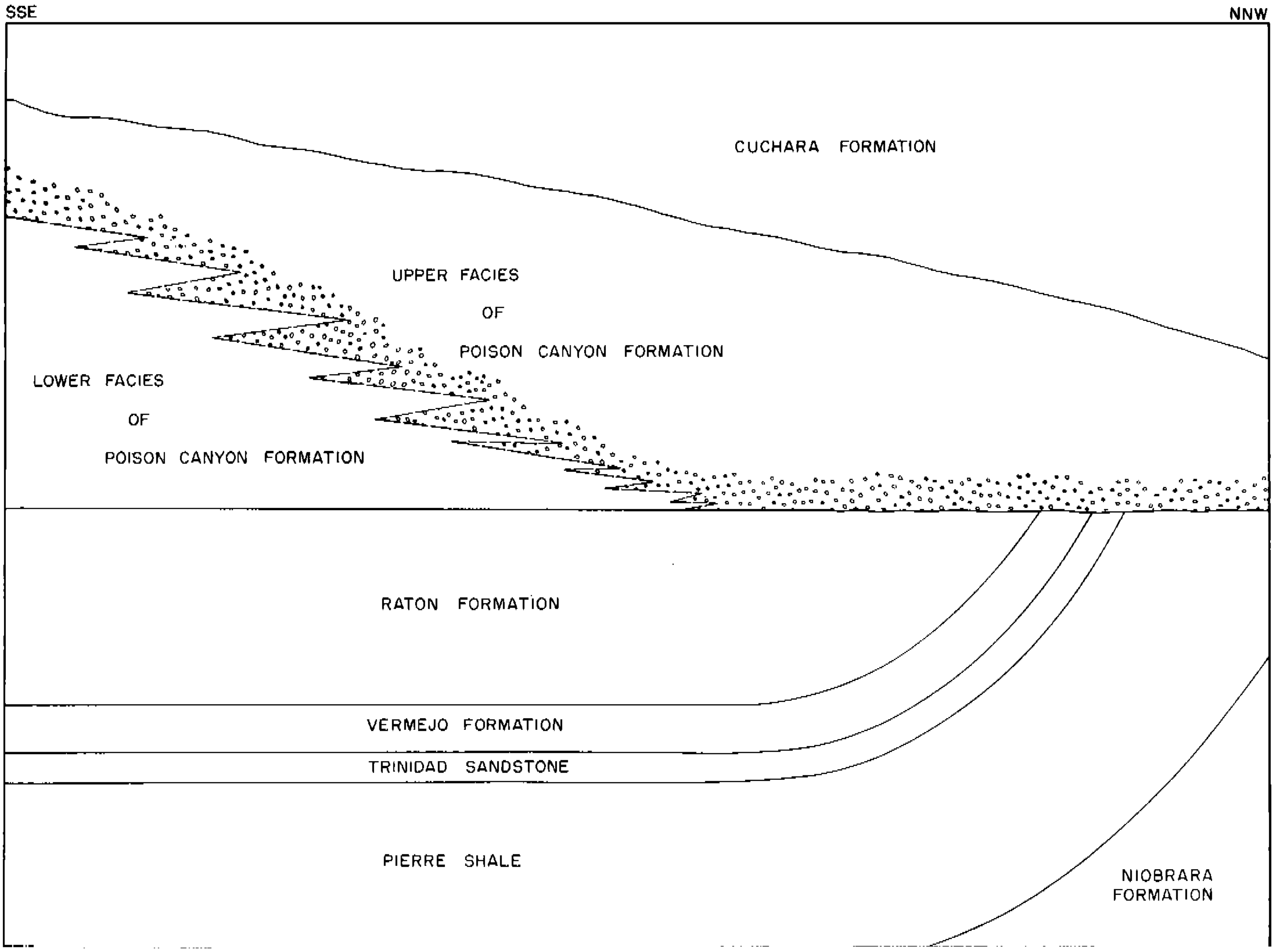

Fig.7. CONTACT RELATIONSHIPS BETWEEN POISON CANYON FORMATION AND UNDERLYING TERTIARY AND CRETACEOUS FORMATIONS FROM VICINITY OF TRINIDAD, COLORADO TO SOUTHERN PART OF HUERFANO PARK, COLORADO

tion is a piedmont facies, and the Raton formation is a swamp and flood plain facies laterally equivalent to the lower part of the Poison Canyon. The yellow shale beds in the Poison Canyon formation suggest deposition in an oxidizing environment above the water table (i.e., "piedmont"); whereas the dark carbonaceous shale and coal beds in the Raton formation suggest accumulation in a reducing environment. (i.e., "swamp and flood plain"). The presence of many conglomerate and conglomeratic sandstone beds and the relatively few thin shale beds in the Poison Canyon formation suggests that Poison Canyon sediments accumulated near their sources or on relatively steep gradients.

Near the end of Late Cretaceous time the area of epeirogenic uplift west of the Raton basin underwent its first orogenic disturbance. Mountains were formed, the extreme southwestern part of the Raton Mesa region was uplifted, and beds of the Vermejo formation, Trinidad sandstone, and Pierre shale were subjected locally to erosion. Coarse sand and gravel eroded from these mountains were deposited in a continental environment over a large part of the present Raton Mesa region. The gravel consisted largely of detritus from metamorphic and igneous rocks of Precambrian age which may have been second-cycle material derived from rocks of Paleozoic age exposed to the west. The conglomerate at the base of the Raton formation contains a part of the coarse sand and gravel eroded from the mountains, and is the principal record of this earliest orogenic phase. Deposition of continental sediments continued without interruption into Paleocene time. Minor orogenic disturbances continued intermittently in the mountains, and fine-grained sand, mud, silt, and carbonaceous material of the Raton formation accumulated far from the mountains on flood plains and swamps. At the same time the coarse detritus preserved in the lower part of the Poison Canyon formation accumulated as piedmont deposits nearer the mountains. In middle Paleocene time, while the detritus that makes up the lower beds of the Poison Canyon formation was being deposited in the part of the basin to the south, the northwestern part of the Raton basin was uplifted, and the older formations were tilted and folded and subjected to erosion. The lowermost beds of the Poison Canyon formation, the Raton formation, the Vermejo formation, the Trinidad sandstone, the Pierre shale, and the upper beds of the Niobrara formation (Meek and Hayden, 1862, pp. 419, 422) were beveled successively from southeast to northwest to a local base level. Boulders, cobbles, pebbles, and coarse sand derived from igneous and metamorphic rocks were eroded from rejuvenated mountains to the west and the rising Wet Mountains to the north. These coarse sediments were deposited on the local erosion surface, and graded into the lower facies of the Poison Canyon formation being deposited to the south in late Paleocene time. The coarse clastics have since been indurated to form the upper beds of the Poison Canyon formation. They were undoubtedly derived in large part from areas of Precambrian rocks, inasmuch as the sedimentary formations of Paleozoic and Mesozoic age do not contain boulders as large as those found locally in the upper beds of the Poison Canyon formation.

Tertiary rocks

In late Paleocene or early Eocene time, the mountains to the west and to the north were again uplifted, and the rocks in the northern part of the Raton Mesa region and Huerfano Park were irregularly tilted and folded. As a result, in this part of the basin beds of the Poison Canyon formation were unevenly eroded. Most of the sediments of the overlying Cuchara formation were probably derived from Poison Canyon rocks during this erosion cycle. The remaining sediments were derived from rocks as old as Precambrian. Cuchara sediments accumulated on piedmonts and flood plains adjacent to the uplifted areas.

The Cuchara formation (Hills, 1891, p. 7-9) of early Eocene age crops out in the trough of the Raton basin a few miles south of the Spanish Peaks. It extends into the northern part of Huerfano Park, and at the surface overlaps the Poison Canyon formation and Pierre shale with marked unconformity. The Cuchara consists of massive red, pink, and white sandstone interbedded with thin to thick beds of bright red, gray, and tan claystone. The red and pink sandstone beds are at many places conglomeratic and are generally well consolidated. The red shale beds are spotted with green shale lenses and irregular bodies. The thickness of the Cuchara formation ranges from a thin edge in Huerfano Park to at least 5,000 feet in the center of the basin on the northern slope of West Spanish Peak.

Later in early Eocene time, orogenic movements occurred in the mountains to the north and west, and caused folding and tilting of the sedimentary rocks along the northwestern margins of the Raton Mesa region and in Huerfano Park. At this time sills of intermediate to silicic igneous rocks were intruded into the sedimentary rocks along the western margins of the Raton basin. During middle Eocene time the fine-grained sediments of the Huerfano formation were deposited on flood plains and bordering lowlands in the northern part of the Raton basin.

The Huerfano formation (Hills, 1888, p. 148-164) of Eocene age unconformably overlaps the Cuchara formation, the Poison Canyon formation, and the Pierre shale along the margins of Huerfano Park. The formation is as much as 2,000 feet thick, and characteristically weathers to a badlands topography. It consists mainly of maroon shale beds with gray and green zones, and red, white, and tan sandstone beds. The shale is generally not plastic, and contains considerable quantities of silt and calcareous nodules. The red and white sandstone beds are shaly and semiconsolidated; but the tan sandstone beds, which occur near the base of the formation, are conglomeratic and well consolidated. The principal area of outcrop of the Huerfano formation is in Huerfano Park; however, an erosional outlier that crops out on the upper slopes of West Spanish Peak has been tentatively correlated with the Huerfano formation. Hills (1901) also considered this outlier to be correlative with the Huerfano formation in Huerfano Park.

In late Eocene time there was extensive major thrusting, normal faulting, and folding of the rocks throughout the present mountain area of northeastern New Mexico and southeastern Colorado. In Huerfano Park the stratigraphy and structure indicate that some of the older sedimentary rocks were locally cut out by thrust faulting and covered by overturned folds. This period of major thrusting and folding culminated the episodes of Laramide deformation; the eastern part of the Sangre de Cristo Mountains, the southern Wet Mountains, and the structural Raton basin of New Mexico and Colorado were outlined in general. During this last major pulsation of Laramide deformation, sedimentary rocks of the Raton basin were intruded by various kinds of igneous rocks. The area of faulting, folding, and intrusion was then intensely eroded in latest Eocene or early Oligocene time, and a great mass of boulders, cobbles, and pebbles derived from Precambrian, Paleozoic, and Mesozoic formations was deposited. The only known record of this period of intense erosion and deposition in the area, the Farisita conglomerate, is preserved in Huerfano Park and perhaps high on the slopes of West Spanish Peak. Boulders, pebbles, and cobbles of the Farisita were deposited on an erosion surface that truncated the older sedimentary rocks to the southeast and lapped against Precambrian metamorphic rocks on the western slopes of the Wet Mountains.

Beds of buff conglomeratic sandstone of the Farisita conglomerate (Johnson and Wood, 1956, p. 718) of probable Oligocene age unconformably overlie beds of the Huerfano formation and the underlying formations of Cenozoic, Mesozoic, and Precambrian age. The Farisita conglomerate occurs entirely within Huerfano Park, and ranges in thickness from a thin edge to about 1,200 feet. The formation consists of buff conglomeratic sandstone and siltstone beds. The individual beds are lenticular and highly cross-laminated, and show limonite stains on the bedding surfaces. Conglomeratic fragments range in size from pebbles to 8-foot boulders, and are subangular to rounded and very poorly sorted. The conglomerate is made up mostly of fragments of Precambrian rocks, but locally it contains fragments of sedimentary rocks of Jurassic and Permian age. Finer grains in the matrix are angular to subangular. The rocks are generally poorly cemented, and in places form landslides on steep slopes. The formation holds up a rough terrain consisting of high hills and deeply dissected valleys.

The Farisita conglomerate and rocks of older formations were irregularly eroded in late Oligocene and perhaps in early Miocene time. Subsequently, in later early or middle Miocene time, thick layers of water-laid fragments of igneous rock and sedimentary debris comprising the Devil's Hole formation were deposited in Huerfano Park and in Wet Mountain Valley. The igneous fragments of the Devil's Hole formation may have been derived largely from volcanoes to the east in or near the Wet Mountains, and the sedimentary debris was derived from the Sangre de Cristo Mountains to the west.

The Devil's Hole formation of probable Miocene age (Johnson and Wood, 1956, p. 719) unconformably overlaps the Farisita conglomerate and older rocks of Cenozoic, Mesozoic, and Paleozoic age in the Huerfano Park area. The Devil's Hole ranges in thickness from 25 to 1,300 feet, and consists of water-laid volcanic rocks containing pebbles of Precambrian gneiss and schist. The formation occurs in the northwestern part of Huerfano Park, and extends northward for an unknown distance into Wet Mountain Valley. It consists mainly of beds of light gray conglomeratic tuff. The matrix is tuffaceous, and consists generally of angular fragments of glass, pumice, perlite, and quartz. The coarse material is a poorly sorted mixture of pebbles and cobbles of pumice, perlite, and Precambrian gneiss and schist. The beds are generally lenticular and cross-stratified, and may be thin- to massive-bedded. Local channels cut into the tuffs are filled with pebbles of Precambrian rocks. The formation intertongues westward with red conglomeratic sandstone derived from sedimentary rocks of Pennsylvanian and Permian age.

Epeirogenic upwarping of the entire region, accompanied by normal faulting, may have occurred in late Tertiary time. Erosion was followed by the deposition of sediments of the Ogallala formation over the area east of the Sangre de Cristo Mountains during Pliocene time. Volcanoes in or near the Wet Mountains continued to extrude basaltic lava over the northern part of Huerfano Park during later Tertiary or Quaternary time. During Quaternary time volcanoes in the eastern and southern parts of the Raton basin extruded basalfic lava over large areas of the basin. Erosion has continued without major interruption since the last volcanic episode, and as a result only small remnants of the younger Tertiary formations are preserved.

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