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CENOZOIC STRUCTURAL GEOLOGY OF THE CENTRAL CIMARRON RANGE, NEW MEXICO

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INTRODUCTION

The Cimarron Range, in Colfax County, New Mexico (Fig. 1) is a southeastward-extending spur of the southern Sangre de Cristo Mountains. The range is bordered on the west by the down-faulted Moreno Valley, on the east by the Raton basin and on the south by the lava-covered Ocate Plateau. Elevations within the Cimarron Range vary from about 7,500 ft (2290 m) to nearly 12,500 ft (3810 m). Accessibility to the central part of the range is provided by U.S. Highway 64 which follows Cimarron Creek through its scenic canyon between Ute Park and Eagle Nest. This study is based upon a masters thesis by Goodknight (1973) under the supervision of Dr. L. A. Woodward of the University of New Mexico.

Previous work in the area was conducted by Ray and Smith (1941) and Smith and Ray (1943), who described the geology of Moreno Valley and the Cimarron Range, respectively. Wanek and Read (1956) briefly discussed the area and suggested a "diapiric plunger" origin for the Cimarron Range, and Robinson and others (1964) described and mapped all of Philmont Scout Ranch and part of the surrounding area. Baltz (1965), in a report on the stratigraphy and paleotectonics of the Raton basin, postulated the existence of a Paleozoic positive area east of Eagle Nest, which he referred to as the Cimarron arch. Simms (1965) mapped and described the stratigraphy and structure of the Rayado area, which generally includes the southern Cimarron Range. Clark (1966) mapped and described the geology and ore deposits of the Eagle Nest quadrangle, to the west of the Cimarron Range.

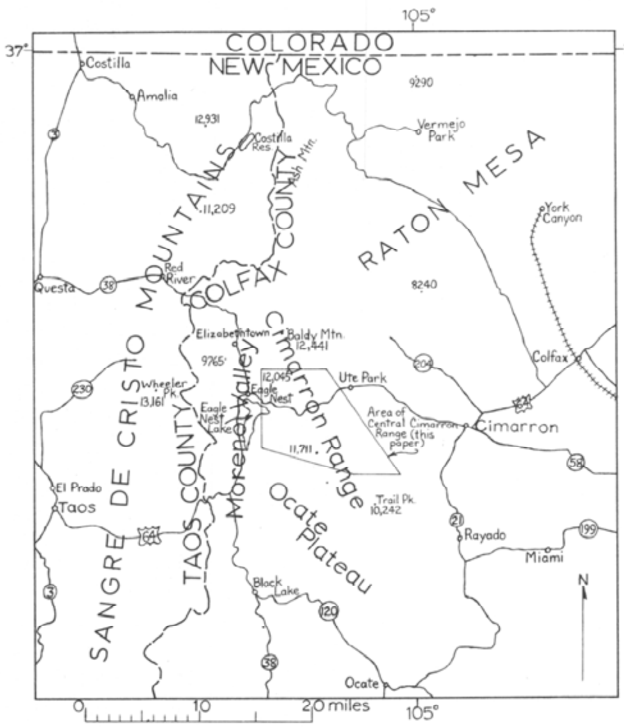

Figure 1. Index map of a part of northern New Mexico showing the area of the central Cimarron Range.

Superficially, the Cimarron Range is a north-plunging anticlinal mountain mass on which sedimentary rocks dip off a Precambrian core eastward into the Raton basin (Clark, 1966). The core of the central and southern parts of the Cimarron Range consists mainly of a vertically uplifted mass of Precambrian metamorphic rocks bounded on its eastern side by an upthrust reverse fault, which gradually steepens from moderate-angle at the surface to nearly vertical at depth. North of Cimarron Canyon the range consists mainly of a thick stack of igneous sills of mid-Tertiary age which spread apart Paleozoic and Mesozoic sedimentary rocks.

The Laramide orogeny is responsible for the major structural features of the southern Sangre de Cristo Mountains, but Laramide deformation is not apparent in the Cimarron Range north of Cimarron Canyon. South of the canyon, however, the range is well-defined on its eastern edge by the Fowler Pass fault, an upthrust of Laramide origin. The entire range was affected by late Tertiary high-angle faulting along its margins.

PALEOTECTONICS

The Cimarron arch, a low, northwestward extension of the Sierra Grande uplift, occupied the approximate site of the central Cimarron Range in late Paleozoic time. The presence of the Cimarron arch, formed on Precambrian rocks, influenced the position and deposition of sedimentary rocks from Mississippian through Early Jurassic time. The Cimarron arch was probably bounded by faults; however, no evidence of these structures presently exists. The location of later Cenozoic tectonism in the Cimarron Range may have been partially controlled by bordering faults associated with the late Paleozoic Cimarron arch.

The structurally highest part of the Cimarron arch in the central Cimarron Range appears to strike in a northwesterly direction from the Tolby Park area toward McElvoy Hill (Fig. 2). Remnants of this part of the arch appear as gentle surfaces of low relief upon which sediments of the Dockum Group of Late Triassic age were deposited. The top of McElvoy Hill and the gently dipping uplands above Tolby Creek canyon are examples of this surface.

Other hypotheses have been proposed to explain the contact relations of Precambrian metamorphic rocks with rocks ranging in age from Pennsylvanian to Cretaceous in the western part of the Cimarron Range. Wanek and Read (1956) proposed a fault contact in which the Cimarron Range was a "plunger" of Precambrian rocks having a flat underthrust contact with sediments on its western side, and a high-angle overthrust contact with sediments on the east. This diapiric structure is similar to that reported by Burbank and Goddard (1937) in Huerfano Park, in the northern Sangre de Cristo

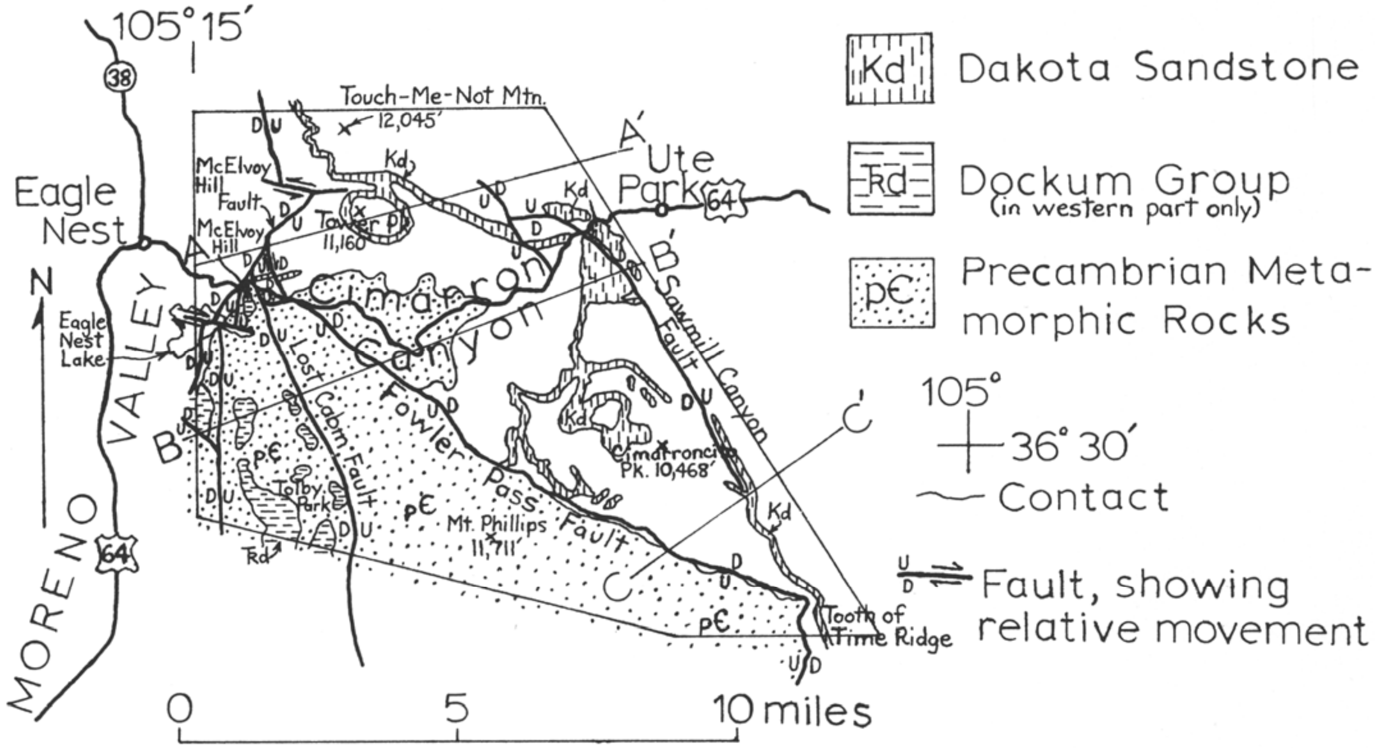

Figure 2. Generalized structure and partial geologic map of the central Cimarron Range, Colfax County, New Mexico.

Mountains. Robinson and others (1964) considered an explanation involving high-angle reverse faults. Simms (1965) found no evidence of flattening of the Fowler Pass fault at depth in Rayado Canyon which is necessitated by the plunger hypothesis. No evidence was found by Goodknight (1973) to support a fault contact between the Precambrian and sediments of the Dockum Group. Several exposures of the Dockum Group and younger strata strike into rocks of Precambrian age, particularly around McElvoy Hill, but this is mainly due to their later displacement by high-angle faults.

CENOZOIC TECTONISM

Laramide Structure

The Fowler Pass fault is the only structure in the central Cimarron Range whose origin can be attributed to the Laramide orogeny. This reverse (upthrust) fault generally trends toward the northwest (Fig. 2) and brings Precambrian metamorphic rocks into contact with Paleozoic and Mesozoic strata which are separated by sills of mid-Tertiary age. Paleozoic and Mesozoic strata dip steeply eastward adjacent to the fault in the southern part of the range; however, the strata dip gently in various directions farther to the north where the fault appears in the southern part of Cimarron Canyon.

The fault is expressed or inferred in the field by: (1) the absence of various Paleozoic and Mesozoic formations, (2) the presence of granodiorite porphyry, which was probably intruded along a fault plane between various Paleozoic and Mesozoic formations and Precambrian rocks, (3) occasional exposure of a narrow, non-resistant zone of fractured and sheared rocks, which is sometimes mineralized, between the Precambrian and Mesozoic strata in the southern part of the range and (4) changes in topography, as indicated by drainage control, the formation of saddles on ridges, and abrupt changes in slope due to juxtaposition of Precambrian metamorphic rocks with other, usually less resistant, rock types (Goodknight, 1973).

The Fowler Pass fault dips steeply to the west and southwest. The fault is well-exposed around Bear Creek, near the southern edge of the mapped area in Fig. 2, where the fault plane dips to the west at about 60°. Elsewhere, the fault zone is poorly exposed and probably dips more steeply to the southwest, as suggested by a relatively straight trace. No evidence of flattening of the fault dip at depth has been found. The fault appears to gradually die out toward the northwest. The Fowler Pass fault is obscured along much of its length by younger intrusions of granodiorite porphyry. The fault probably served as a conduit for stocks underlying the Cimarron Range. Displacement along the fault can only be roughly estimated because of the absence of marker beds. Its throw varies from several thousand feet in the southern part of the area to only several hundred feet in the northwest part of Cimarron Canyon. The fault cannot be traced with certainty north of Cimarron Canyon.

Post-Laramide Structure

Deformation Due to Igneous Bodies

All Paleozoic and Mesozoic sedimentary formations in the central Cimarron Range have been intruded, altered, and deformed by laccolithic bodies of granodiorite porphyry. These intrusives are located north and east of Fowler Pass fault in a belt 2 to 6 miles (3.2 to 9.7 km) wide. The laccoliths are composed of an interconnected stack of sills which have spread and domed the sedimentary section. These bodies have been aptly described by Robinson and others (1964) as Christmas-tree laccoliths. The thicknesses of these laccoliths are difficult to determine, because their floors and roofs are usually not both exposed.

Parts of at least three laccoliths are exposed in the central Cimarron Range. The southernmost laccolith forms the east-west trending Tooth of Time Ridge and is perpendicular to the Fowler Pass fault; this laccolith is probably about 2,000 ft (610 m) thick. Farther north, a larger laccolith, oriented roughly northeast, is centered around Cimarroncito Peak; it is at least 3,000 ft (915 m) thick and is perpendicular to the Fowler Pass fault. The roof of the Cimarroncito Peak laccolith has probably only recently been removed, as indicated by the gently sloping high country around Cimarroncito Peak. The northern most and most extensive laccolith is situated around Touch-Me-Not Mountain and Tower Peak; its exposed thickness is at least 4,000 ft (1200 m) and its relation to the Fowler Pass fault could not be ascertained.

Although the feeder(s) which supplied the grandiorite porphyry for the laccoliths cannot be positively recognized, the Fowler Pass fault is a probable conduit because it is obliterated by granodiorite porphyry dikes along much of its length.

High-angle Faults

High-angle faults control most of the present topographic features of the Cimarron Range. These faults range in age from Miocene to probably as young as late Pliocene (Clark, 1966). The McElvoy Hill fault (Fig. 2) is a high-angle fault which forms the western boundary of the central Cimarron Range. Some parts of this fault are obscured by younger quartz porphyry which probably intruded along the fault plane. The McElvoy Hill fault shows at least several thousand feet of vertical displacement.

Later transverse faults cut the McElvoy Hill fault in at least two places (Fig. 2). A transverse fault is inferred south of McElvoy Hill to explain left-lateral offset in the Precambrian metamorphic rocks on opposite sides of Eagle Nest Lake. Ray and Smith (1941) first recognized this fault zone and reasoned that Cimarron Creek followed this zone of structural weakness to tap the drainage of Moreno Valley.

The Lost Cabin fault (Fig. 2) is one of several faults in the southwestern part of the Cimarron Range which displaces rocks of mostly Precambrian age. This fault was named by Robinson and others (1964) for good exposures on Philmont Scout Ranch near Lost Cabin trail camp. The fault is occasionally the contact between sedimentary rocks of the Dockum Group and Precambrian metamorphic rocks. The fault zone usually consists of an area of crushed rock about 50 ft (15 m) wide or may be obscured by younger quartz porphyry dikes. The fault probably lies in the valley on the northeast side of McElvoy Hill and connects with the McEivoy Hill fault. The vertical displacement of the Lost Cabin fault is at least several thousand feet.

Several other high-angle faults of lesser displacements occur in the vicinity of McElvoy Hill. This small area exhibits a diversity of complex structural features associated with several ages of intrusion and faulting.

The Sawmill Canyon fault, in the east-central part of the range (Fig. 2), displaces Mesozoic sedimentary rocks. This fault is best exposed near the eastern end of Cimarron Canyon, just west of Ute Park, where it causes the massive Dakota Sandstone to be repeated. Northwest and southeast of Cimarron Canyon the exact position of the fault is difficult to determine because granodiorite porphyry laccolithic bodies have replaced marker beds. Vertical displacement on the Sawmill Canyon fault is probably no greater than several hundred feet.

STRUCTURAL ANALYSIS

The major structural features of the Cimarron Range were developed in Cenozoic time. The main episode of Cenozoic deformation, the Laramide orogeny, was mainly caused by vertical uplift of the Precambrian basement. This style of deformation appears to be consistent throughout the length of the Sangre de Cristo Mountains (Petersen, 1969). Evidence for vertical uplift lies mainly in the near-vertical nature of the Precambrian-Paleozoic contact (Fowler Pass fault) and the absence of structures indicative of horizontal displacement.

Anisotropic features in the Precambrian basement may have partially controlled the trend and location of the Fowler Pass fault. Another possibility is that the deformation occurred along some of the bordering faults of the late Paleozoic Cimarron arch, which was oriented roughly parallel to the Fowler Pass fault. Field evidence has been inconclusive in assigning a relation between foliation and compositional layering in the Precambrian basement with the location of the Fowler Pass fault. Late Paleozoic structures may therefore have had more influence in the location of the fault.

The Fowler Pass fault is an upthrust (Prucha and others, 1965) and is eroded to the high-angle reverse to vertical level. The fault is steeper in its northwestern part where it is in Precambrian rocks than to the southeast of Cimarron Canyon where it is exposed at structurally higher levels and forms the Precambrian-Paleozoic contact. Prucha and others (1965) note that similar upthrusts may be formed in two ways: by tilting of a crustal block with an already formed upthrust fault and by upthrusting in an area where the erosion surface has an initial slope. The origin of the Fowler Pass fault probably fits the second condition. Early Laramide uplifts to the west were probably still in evidence when vertical uplift in early to middle Eocene time formed the Fowler Pass fault on an eastward-sloping surface.

Vertical uplift of the basement initially warped the Paleozoic and Mesozoic strata into drape folds. As displacement continued, the sedimentary rocks reacted by faulting. The synclinal bend of the drape folded sedimentary rocks is still preserved to the southeast of Cimarron Canyon. At structurally higher levels, the Fowler Pass fault dips less steeply toward the southwest indicating a component of horizontal movement or northeastward compression. This yielding toward the northeast was accomplished due to lack of confinement toward the Raton basin.

The nature of Laramide faulting in the southern Sangre de Cristo Mountains is mainly confined to two schools of thought. One school, mainly supported by Wanek and Read (1956) and Clark (1966) suggests that the thrust and reverse faults are the result of primary lateral compression, flatten at depth, and have yielded eastward several miles. The lateral compression hypothesis has been questioned by Robinson and others (1964) and Simms (1965) who could find no evidence for flattening of the faults at depth. The more recent hypothesis, supported by Prucha and others (1965) and Petersen (1969), advocates a primary vertical stress system and the development of upthrusts, which may be basement controlled and steepen at depth. The postulated sequence of Laramide events and the regional geometry of the Cimarron Range are difficult to explain by compressional forces alone. A primary vertical stress system induced by magmatism, proposed by Petersen (1969), could account for Laramide uplift and later emplacement of laccolithic bodies in the Cimarron Range.

Upthrust faults have been produced in model experiments by Petersen (1969) using an expanding magma chamber to create a vertical stress system. The Fowler Pass fault could have formed in the same manner, as a tensional fracture resulting from domal uplift induced by an expanding magma chamber. The Fowler Pass fault is obscured along much of its length by intrusions of granodiorite porphyry, suggesting that the fault eventually tapped a magma chamber.

The major laccolithic bodies in the Cimarron Range were emplaced generally after Laramide deformation had ceased, in late Eocene or Oligocene time. The main feeder for the laccoliths may well have been the Fowler Pass fault; however, other Laramide faults not exposed in the immediate area may also have served as feeders.

High-angle faults of late Tertiary age developed as a tensional response to the uplift of the Cimarron Range. The two principal trends of the faults are north-northwest and west-northwest (Fig. 2). This implies that the faults are the result of a couple generally having a northeast-southwest maximum strain orientation. The high-angle faults were not as conducive to magmatism as was the Fowler Pass fault. Quartz porphyry dikes and irregular bodies intruded mainly along the faults which define the eastern margin of Moreno Valley.

Faults in the southwestern part of the central Cimarron Range define several eastward-tilted blocks of Precambrian rock. Chapin (1971) postulated that this block faulting is an eastward extension of deformation related to the Rio Grande rift. According to his model, the continental plate on the east side of the rift developed great structural relief as it was being pulled westward, due to riding up of the thicker crust onto an upward bulge of mantle material beneath the rift. This plate tectonic model explains the tilted tault blocks, and the orientation and relative displacements of the high-angle faults in the central Cimarron Range; however, more evidence is necessary to firmly establish this model.

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