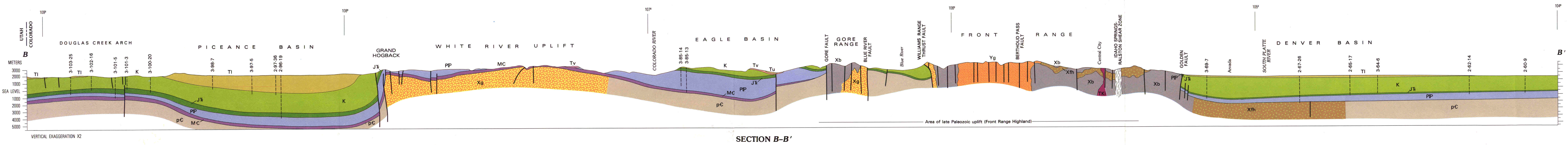
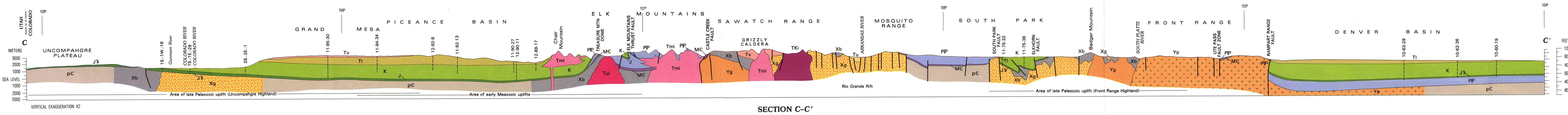
SECTION A–A′
Latitude 40°38′25″
Near line between secs. 24 and 25, T. 8 N., 6th Principal Meridian



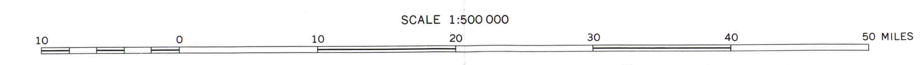
SECTION B–B′
Latitude 39°47′50″
Near line between secs. 12 and 13, T. 3 S., 6th Principal Meridian



SECTION C–C′
Latitude 39°03′00″
Near line between Tps. 11 and 12 S., 6th Principal Meridian and near line between secs. 24 and 25, T. 1 S., Ute Principal Meridian

SECTION D–D′
Latitude 38°15′30″
In northern part of T. 46 N. New Mexico Principal Meridian and near line between T. 20 and 21 S., 6th Principal Meridian

SECTION E–E′
Latitude 37°30′40″
Near line between Tps. 37 and 38 N., New Mexico Principal Meridian, and near center of T. 29 S., 6th Principal Meridian



EXPLANATION

PHANEROZOIC ROCKS

- Tu — UPPER TERTIARY SEDIMENTARY ROCKS. Pliocene to Oligocene in age
- Tv — VOLCANIC ROCKS. Miocene and Oligocene in age
- Tl — LOWER TERTIARY SEDIMENTARY ROCKS. Eocene and Paleocene in age
- Tui — UPPER TERTIARY INTRUSIVE ROCKS. Age < 20 m.y.
- Tmi — MIDDLE TERTIARY INTRUSIVE ROCKS. Age 20-40 m.y.
- TKi — LOWER TERTIARY AND UPPER CRETACEOUS INTRUSIVE ROCKS. Age 40-70 m.y.
- K — CRETACEOUS SEDIMENTARY ROCKS
- J♄, J — JURASSIC AND TRIASSIC SEDIMENTARY ROCKS. J where Triassic rocks absent
- PIP, P — PERMIAN AND PENNSYLVANIAN SEDIMENTARY ROCKS. P where Pennsylvanian rocks absent
- IPs — SALT FACIES OF PENNSYLVANIAN ROCKS. Largely diapiric
- M€ — MISSISSIPPIAN, DEVONIAN, ORDOVICIAN AND CAMBRIAN ROCKS, IN VARIOUS COMBINATIONS
- €i — CAMBRIAN INTRUSIVE ROCKS

PRECAMBRIAN ROCKS

- Yu — SEDIMENTARY ROCKS OF UINTA MOUNTAIN GROUP. Age 925–1100 m.y.
- Yp — GRANITIC ROCKS OF PIKES PEAK BATHOLITH. Age ~1000 m.y.
- Ys — SEDIMENTARY AND VOLCANIC ROCKS. Inferred age > 1200 and < 1400
- Yg — GRANITIC ROCKS OF 1400-m.y. AGE GROUP. Age 1400–1450 m.y.
- YXu — SEDIMENTARY ROCKS OF UNCOMPAHGRE FORMATION. Moderately metamorphosed; age > 1440 m.y. and <1695 m.y.
- Xg — GRANITIC ROCKS OF 1700-m.y. AGE GROUP. Age 1665–1700 m.y.
- Xb — BIOTITIC GNEISS AND SCHIST. Predominantly metasedimentary; age 1750–1800 m.y.
- Xfh — FELSIC AND HORNBLENDIC GNEISSES. Predominantly metavolcanic; age 1750–1800 m.y.
- Xq — QUARTZITE. Age 1750–1800 m.y.
- p€ — PRECAMBRIAN ROCKS. Character and age unknown

SYMBOLS

CONTACT
FAULT
SHEAR ZONE
38-14-18 — Location by township, range, and section of borehole projected to plane of section

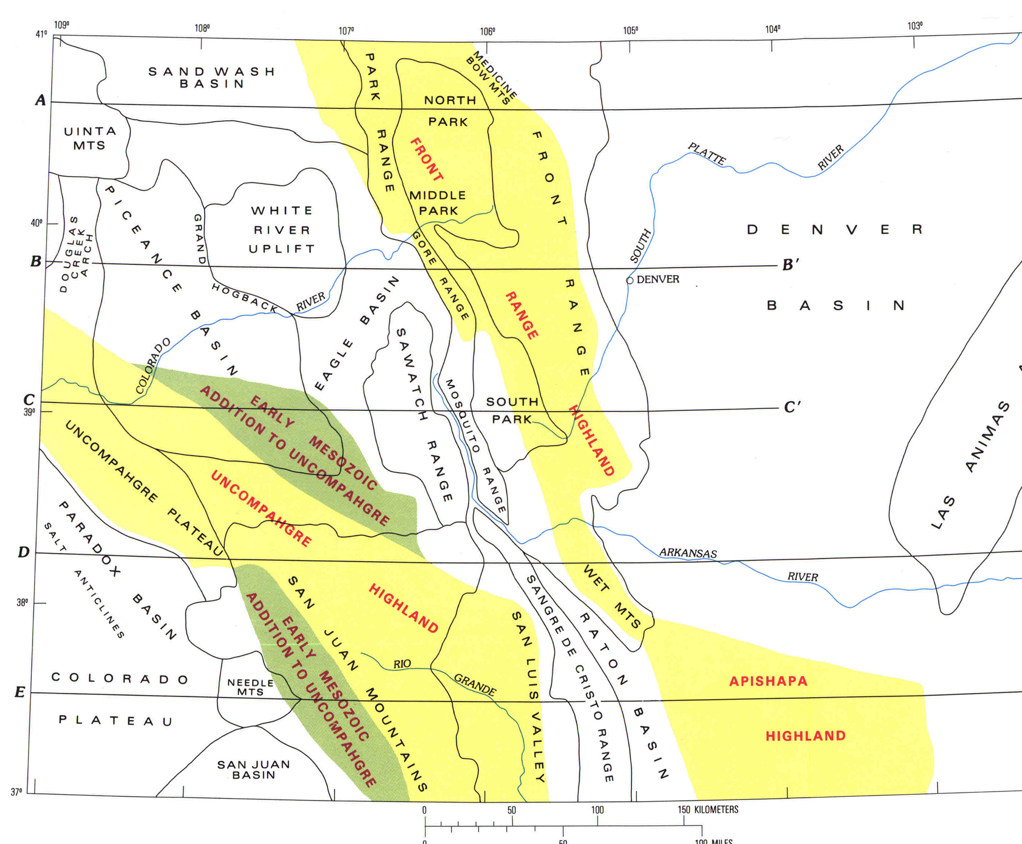


Figure 1—SHOWS LINES OF SECTION AND LOCATIONS OF ANCIENT HIGHLANDS WITH RESPECT TO EXISTING TECTONIC FEATURES IN COLORADO. YELLOW, AREAS OF LATE PALEOZOIC UPLIFTS; GREEN, AREAS OF ADDITIONAL UPLIFT IN EARLY MESOZOIC.

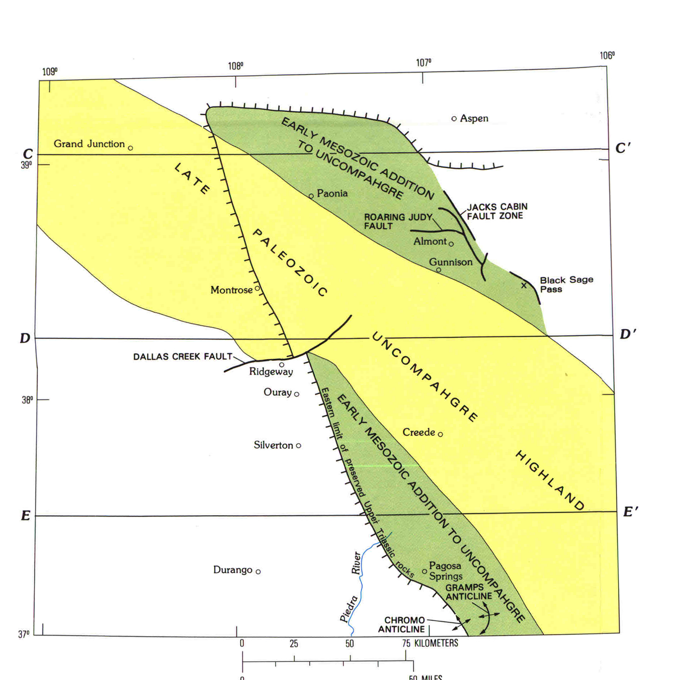


Figure 2—LOCATIONS OF SOME PALEOTECTONIC FEATURES IN SOUTHWESTERN COLORADO.

INTRODUCTION

The geologic sections presented here supplement the Geologic map of Colorado (Tweto, 1979a). As shown by the sections, the State is a tectonic mosaic of mountain uplifts and intervening or bordering structural basins. Stratigraphic relations portrayed in the sections demonstrate that the uplifts and basins are of more than one age. Most of the uplifts and basins were products of the Laramide orogeny of latest Cretaceous and early Tertiary time. Some of them, however, were created in the post-Laramide Tertiary. Others coincide in part with uplifts and basins that were created as part of the Ancestral Rockies in the late Paleozoic, or with areas of recurrent tectonism in the early Mesozoic. The record of these various tectonic events is considered briefly in the text that follows.

Locations of the main uplifts and basins, as they exist now, are shown in the sections and on figure 1, as well as the locations of the uplifts that existed in the late Paleozoic and the early Mesozoic. Geology shown at the surface in the sections is from the State map except that, owing to the small scale, surficial deposits are not shown, and in some areas, certain thin formations at the surface are necessarily included with the underlying geologic unit, as noted. The subsurface geology is based on stratigraphic and structural data from many sources, on borehole data, and in some small areas, on published seismic data. Geology of the Precambrian basement is from a map (Tweto, 1980a, fig. 1) that is an interim product of a continuing study of the composition, structure, and configuration of the basement.

LATE PALEOZOIC UPLIFTS AND BASINS

Three major uplifts, known as the Front Range, Uncompahgre, and Apishapa highlands (fig. 1), rose in Colorado in the late Paleozoic, probably beginning in the Late Mississippian or Early Pennsylvanian. The locations and general outlines of these highlands were recognized early by several authors (Melton, 1925; Lovering, 1929; Burbank, 1933; Heaton, 1933). The boundaries were better defined later, following more detailed studies and subsurface exploration (Maher and Collins, 1953; J. D. Howard, 1966; Mallory, 1972), and further refinements are made herein.

The old highlands are identified by a combination of geologic features. The pre-Pennsylvanian Paleozoic rocks wedge out by erosional truncation on the flanks of the highlands, or are cut off by faults that border the highlands. In contrast, Pennsylvanian and Lower Permian rocks wedge out against the highlands by depositional onlap. Coarse and arkosic sandstone and conglomerate characterize the Pennsylvanian and Lower Permian sedimentary sequences near the old highlands, a feature emphasized by Maher and Collins (1953) and Mallory (1972). Depositional structures in the sediments indicate proximity to a source highland (Hubert, 1960; J. D. Howard, 1966). Upper Permian rocks lie on the Precambrian rocks of the old Apishapa highland (section **E–E′**), and Upper Triassic or Middle and Upper Jurassic rocks lie on the Precambrian rocks of the Front Range and Uncompahgre highlands. However, not all localities where Jurassic or Triassic rocks lie on Precambrian rocks are parts of late Paleozoic uplifts. Renewed uplift of extensive parts of the highlands and environs occurred in the Triassic and again in the Jurassic. Consequently, the upper Paleozoic rocks were eroded back from their original depositional borders on the flanks of parts of the highlands. This erosion exposed new areas of Precambrian rocks before a cover of Triassic or Jurassic rocks was deposited.

Along much of their lengths, the Front Range and Uncompahgre highlands were tilted blocks bounded on their southwest sides by faults and apparently only gently uptilted along their northeast sides (Tweto, 1980b). An exception to this pattern may have existed in the part of the Uncompahgre highland that is now hidden beneath the late Tertiary graben of the San Luis Valley. This part was called the San Luis highland by Melton (1925). Exceptionally coarse conglomerates in the Permian and Pennsylvanian Sangre de Cristo Formation, in the Sangre de Cristo Range immediately east of the valley, suggest that the northeastern side of the highland was high and steep, as noted by Heaton (1933), and that it may have been fault-bounded.

The Apishapa highland of southeastern Colorado was bounded by faults on its east and west sides (section **E–E′**) and also on its north side (Tweto, 1980b). To the south, it extended irregularly into the Sierra Grande highland of New Mexico. Precambrian rocks of the Apishapa highland are capped by Upper Permian rocks, indicating that the highland did not persist beyond the Early Permian.

The late Paleozoic highlands were bordered through parts of their lengths by downwarps in which thick Pennsylvanian and Lower Permian sediments accumulated. The Eagle and the Paradox basins (sections **B–B′**, **D–D′**) are leading examples. The Raton basin (section **E–E′**) and the west-central part of the Denver basin (section **C–C′**) also originated as late Paleozoic structural and sedimentary basins but underwent further growth during the Laramide orogeny, when differential subsidence and attendant sedimentation recurred.

The Paradox and Eagle basins contain thick Pennsylvanian evaporite deposits. Deformation related to flowage of the evaporites began at least as early as the Early Permian and continued through the Triassic and part of the Jurassic. Flowage of the evaporites probably was triggered by movements on old faults in the Precambrian basement (Cater, 1970; Freeman, 1971). In the Paradox basin, flowage in the Permian and early Mesozoic produced a series of northwest-trending anticlines and synclines. These folds were later accentuated by renewed flowage in Laramide and later time (Cater, 1970, fig. 13). One of the anticlines—that of Paradox Valley—is shown in section **D–D′** as depicted by Cater (1970, pl. 1). In the Eagle basin, at least one large anticline was formed and was erosionally truncated before the Late Permian (Freeman, 1971). A pronounced thickening of Upper Permian and Triassic formations in a part of the basin is attributed to centripetal evaporite flowage and may not be reflected in the pre-Pennsylvanian rocks (Tweto, 1977).

EARLY MESOZOIC UPLIFTS

In the area of the Uncompahgre highland and bordering areas to the northeast and southwest (fig. 2), Triassic or Jurassic rocks lie either on Precambrian rocks or with angular discordance on erosionally truncated Paleozoic rocks. In scattered localities in the same areas, evidence is seen of faulting and folding that occurred after deposition of Lower Permian rocks and before deposition of Upper Triassic or upper Middle Jurassic rocks. These features define a large region in southwestern Colorado that underwent uplift and moderate deformation at one or more times between the Late Permian and the Middle Jurassic. The area affected by faulting extended at least to the western flank of the late Paleozoic Front Range highland. Farther east, areas of uplift or warping are indicated by unconformities below and within the Triassic and Jurassic sequence.

In the western San Juan Mountains the Lower Permian Cutler Formation and older rocks were faulted and warped before the Upper Triassic Dolores (or Chinle) Formation was deposited (Weimer, 1980). Uplift and erosion are expressed by an unconformity beveled through the Cutler and part or all of the underlying Pennsylvanian Hermosa Formation in the Ouray and Piedra River areas (fig. 2) (Luedke and Burbank, 1962; Steven and others, 1974). North of the Dallas Creek fault, near Ridgway (fig. 2), the Dolores (or Chinle) lies on Precambrian rocks, whereas south of the fault it lies on the Cutler, indicating major movement on the fault before the Dolores was deposited. Stratigraphic relations in the western San Juan Mountains date these various features or events only as Late Permian or Early or Middle Triassic. On the basis of stratigraphic relations elsewhere in the region, the features are interpreted to be principally Triassic rather than Permian. In the Aspen area (fig. 2) and northward, where Upper Permian and Lower Triassic rocks are preserved, the Chinle is in angular unconformity with those rocks also, and it postdates fault displacements within those rocks (Bryant, 1979, p. 80). The pre-Chinle (or pre-Dolores) tectonic disturbance thus probably occurred principally in the Middle Triassic.

Evidence of folding and of the removal of upper Paleozoic rocks from a large area before deposition of the Dolores is indicated from well records in the area of the Chromo and Gramps anticlines near the New Mexico border (fig. 2). In most places on both anticlines, the Entrada lies on Precambrian rocks (Ryder, 1977, figs. 22, 24), but in at least one well on the Chromo anticline the Entrada is separated from the Precambrian by a few feet (2 m) of rock of the Dolores Formation (Wood and others, 1948). By contrast, in the syncline between the two anticlines, a well (Butler 1 Crowley) bottomed in Middle or Lower Pennsylvanian rocks as indicated by a fusulinid fauna (Osterhoudt, 1978; W. J. Osterhoudt, written commun., July 1980). Preservation of Pennsylvanian rocks in the syncline, and of a remnant of the Dolores Formation resting on Precambrian rocks on the Chromo anticline, indicates folding and erosion prior to deposition of the Dolores. The fact that only a remnant of the Dolores is preserved in the area indicates tilting or renewed folding and erosion prior to deposition of the Entrada.

The outlier of Pennsylvanian rocks in the syncline is at least a few miles east of the main body of Pennsylvanian rocks known from drilling in the San Juan basin but is some distance west of the inferred edge of the late Paleozoic Uncompahgre highland (fig. 2). Another remnant of Pennsylvanian rocks is preserved beneath the Chinle at a locality in New Mexico 23 mi (37 km) southeast of the Chromo-Gramps area (Muehlberger, 1967). The remnants in the Colorado and New Mexico localities indicate that Pennsylvanian rocks, as well as overlying Permian (Cutler) rocks, were removed from a substantial area during deformation and erosion prior to deposition of the Chinle and Dolores Formations.

Just as the upper Paleozoic rocks were stripped from most of the Chromo-Gramps area, the Triassic rocks were stripped from a large part of southwestern Colorado during the Jurassic. The eastern limit of preserved Upper Triassic rocks (Chinle and Dolores) is shown on figure 2 as modified slightly from Stewart and others (1972, pl. 5). Triassic rocks are truncated by the Jurassic along this boundary, indicating that the original or depositional edge of the Chinle and Dolores lay somewhere to the east, in or near the area of the late Paleozoic Uncompahgre highland. This highland has been cited as a source of Upper Triassic sediments (Stewart and others, 1972), but the main source may have been in the Mesozoic additions to the late Paleozoic highland shown on figure 2. Before erosion these additions contained Paleozoic rocks that probably were a principal source for the fine-grained Upper Triassic sediments (Bryant, 1979).

A second early Mesozoic tectonic disturbance occurred after deposition of the Chinle Formation and before deposition of the upper Middle Jurassic Entrada Sandstone. This disturbance is expressed by an angular unconformity beneath the Entrada and by faults and warps in the rocks beneath the unconformity. Angular unconformity is well illustrated at Treasure Mountain dome (section **C–C′**), where the Entrada bevels almost the entire Paleozoic stratigraphic section. Beveling also occurs southward along the west side of the Sawatch Range. Near Aspen, the Entrada lies on remnants of the Chinle Formation or on the Lower Triassic and Upper Permian State Bridge Formation (Bryant, 1979). To the south, it lies first on the Permian and Pennsylvanian Maroon Formation and then on the Middle Pennsylvanian Minturn Formation. South of the Roaring Judy fault near Almont (fig. 2), the Entrada is absent and a younger Jurassic unit, the Junction Creek Sandstone, lies on Precambrian rocks. Still farther southeast, near Black Sage Pass (fig. 2), the Junction Creek wedges out and the Morrison Formation lies on Precambrian rocks. These relations indicate a center of pre-Entrada uplift in the area east or southeast of Gunnison, and that uplift there may have continued into the late Late Jurassic.

The uplifted area was bounded on the northeast side by the complex Jacks Cabin fault zone (fig. 2), not all of which has yet been mapped. On the southwest side of this fault zone, Jurassic rocks lie on the Precambrian basement, whereas on the northeast side, lower Paleozoic rocks lie on the Precambrian. These relations are seen east of Almont and near Black Sage Pass (fig. 2).

LARAMIDE UPLIFTS AND BASINS

Laramide orogeny in the very late Cretaceous and early Tertiary produced uplifts and basins that together occupy almost the entire State. Some of the uplifts were rejuvenations of the late Paleozoic and early Mesozoic uplifts, but some were at sites that had no previous history of differential uplift, and some straddled the borders of earlier uplifts. Thus, though several of the uplifts had an earlier expression, Laramide uplift was more widespread than and substantially independent of earlier uplifts.

Among the Laramide uplifts on the sites of earlier uplifts are the Front, Park, and Gore Ranges and the Wet Mountains. These uplifts collectively occupy the site of the late Paleozoic Front Range highland, though the northern part of the Laramide Front Range extended beyond the old highland (fig. 1). An erosionally truncated low-amplitude Laramide uplift on the Great Plains corresponds with the late Paleozoic Apishapa highland (section **E–E′**) and clearly reflects rejuvenation of the old, fault-bounded highland. Similarly, the modern Uncompahgre Plateau (sections **C–C′**, **D–D′**) constitutes part of the late Paleozoic Uncompahgre highland that was elevated again in Laramide and later times. The Needle Mountains (section **E–E′**) and the Elk Mountains (section **C–C′**) are Laramide uplifts outside the area of the late Paleozoic Uncompahgre highland but on the borders of early Mesozoic uplifts. The Sangre de Cristo and Sawatch Ranges, the White River uplift, and the Uinta Mountains, located between the old Front Range and Uncompahgre highlands, show no convincing evidence of pre-Laramide existence. Among these uplifts, the Sangre de Cristo, in particular, was extensively modified by block faulting in the late Tertiary.

Like the Laramide uplifts, the Laramide basins are more widespread than earlier basins and seem to be distributed independently of older tectonic features. Some of them, such as the Raton basin and the west-central part of the Denver basin, subsided first in the late Paleozoic and again in the Laramide, as noted previously. Some, such as the Sand Wash basin (section **A–A′**) and the deep northwestern part of the Piceance basin (section **B–B′**) were in the area between late Paleozoic uplifts but outside the area of pronounced late Paleozoic subsidence and sedimentation. Still other basins, such as that of North Park (section **A–A′**) and the southeastern part of the Piceance basin (section **C–C′**), formed by Laramide subsidence in areas of late Paleozoic or early Mesozoic uplift.

The sedimentary fill in the Laramide basins consists principally of lower Tertiary and Upper Cretaceous rocks (sections **A–A′**, **B–B′**). The lower Tertiary and the uppermost Cretaceous rocks are orogenic deposits derived locally from the rising uplifts. The main body of the Cretaceous rocks, by contrast, consists of a distal facies derived from a source far to the west, where orogeny occurred before the Laramide as expressed in Colorado. The orogeny to the west, once also called Laramide, has been known more recently as the Sevier orogeny (Armstrong, 1968). Upper Cretaceous sediments from the Sevier orogen were deposited in a basin that shallowed eastward across Colorado (Weimer, 1970, figs. 2, 3). Tectonic subsidence of this basin probably was supplemented locally by subsidence caused by growth of successive great deltas (Weimer, 1970). In the Laramide, the Late Cretaceous basin was disrupted by uplifts (sections **A–A′**, **B–B′**), but large surviving parts of it subsided further to become the Sand Wash, Piceance, Denver, and other basins. These basins thus are composites of two quite different manifestations of an orogeny that migrated eastward with time. In an early phase that was a distant effect of Sevier orogeny, regional subsidence and sedimentation occurred in the absence of significant tectonism in Colorado. In a late, or Laramide, phase areas of subsidence and sedimentation were interspersed among areas of uplift and deformation.

POST-LARAMIDE MOUNTAIN GROWTH AND RIFTING

In the Tertiary, after Laramide orogeny had drawn to a close in about the middle of the Eocene, the mountains that had been created in the Laramide were rejuvenated at various times and by various means, but the Laramide basins seem to have stabilized. Igneous activity in most of the mountain province during the Oligocene (Steven, 1975) added to the stature of many of the Laramide uplifts. Large-scale volcanism produced the San Juan Mountains as a superstructure on an eroded Laramide uplift on the site of part of the late Paleozoic Uncompahgre highland (sections **D–D′**, **E–E′**). Extensive igneous intrusion almost certainly caused renewed uplift of the Elk Mountains and Sawatch Range (section **C–C′**). Additionally, the widespread occurrence of intrusive bodies in the areas of highest average altitude in Colorado suggests that a deep magma body may have caused a general inflation of a large part of the mountain province in the latter half of the Tertiary.

In the Miocene and Pliocene the entire State was affected by regional uplift that accounts for the generally high altitudes, even of the Great Plains. The regional uplift was accompanied by renewed differential uplift of many of the mountain units, by block faulting, and by development of the Colorado part of the Rio Grande rift. The San Luis and Arkansas Valleys (sections **C–C′**, **D–D′**, **E–E′**) formed as grabens of the rift zone (Tweto, 1979b). The Sangre de Cristo and Gore Ranges (sections **D–D′**, **B–B′**), both consisting of elements of older uplifts, were elevated as high horsts. The southern Front Range and Wet Mountains underwent renewed uplift along the mountain-front Rampart Range and Wet Mountain faults (sections **C–C′**, **D–D′**). Volcanism related to the rifting produced superstructures of basalt on older uplifts, and igneous intrusion produced local uplifts in several places, one example of which is Treasure Mountain dome shown in section **C–C′**.

FAULTS

The faults shown in the sections originated at various times, from fairly early Precambrian to late Tertiary. Many of the older faults were reactivated during younger tectonic episodes. During successive reactivations, changes in directions of movements and reversals of displacements were common (Tweto, 1980a,b). The Ilse, South Park, Gore, and Blue River faults (sections **D–D′**, **C–C′**, **B–B′**) are elements of a major north-northwest-trending Precambrian fault system that was repeatedly reactivated in later time. The Idaho Springs-Ralston shear zone (section **B–B′**) is representative of northeast-trending shear zones that had multiple episodes of movement in the Precambrian but little later movement. The Cimarron fault (section **D–D′**) is an element of a west-northwest-trending fault system that had strike-slip movements in the Precambrian and dip-slip movements in later time.

The attitudes shown in the sections for many of the faults reflect both an interpretation of the true dip and a distortion caused by the exaggerated vertical scale of the sections. In areas of high relief, where fault dip can be observed through extensive vertical distances, most Precambrian faults are vertical or nearly so, probably reflecting their origin as strike-slip faults. Examples among the major faults are the Gore, Blue River, and Berthoud Pass faults (section **B–B′**) and the Ilse fault (section **D–D′**). Many other faults in the Precambrian terranes and in the buried Precambrian basement are assumed to be vertical.

Several Laramide faults along mountain fronts display thrust relations at the surface but are interpreted to be steep reverse faults that flatten upward. Examples are the fault at the west base of the Park Range (section **A–A′**), the Williams Range thrust fault and the Golden fault (section **B–B′**), the Rampart Range fault (section **C–C′**), the Wet Mountain fault (section **D–D′**), and the fault at the east base of the Sangre de Cristo Range (section **E–E′**). The Williams Range fault, though locally a striking example of a flat thrust fault, is interpreted to steepen downward (J. H. Howard, 1966; Izett and Barclay, 1973), and relations to topography in some places require that the steepening be abrupt. In an area south of section **B–B′**, the fault has a flat dip and a horizontal displacement of at least 6 mi (10 km). Wahlstrom and Hornback (1962) concluded that gravitative movements there had extended the overthrust plate far beyond the steep root of the fault.

The Golden fault has been classified by different authors as a steep reverse fault and as a moderately low-angle thrust fault. Reflection seismic investigations along the fault in the vicinity of section **B–B′** (Davis and Young, 1977) indicate that the fault is an element of a zone of closely spaced faults forming the boundary between the Front Range and the Denver basin. Faults of the zone are vertical in the Precambrian basement, but the Golden fault and a branch of it bend to a convex-upward profile in the Pierre Shale near the surface. The shale is draped into steep dips, whereas more competent rocks beneath it are merely tilted and offset (Davis and Young, 1977). Data from two boreholes at the mountain front 6 mi (10 km) south of section **B–B′** were appraised by Berg (1962), who concluded that the principal structure in the subsurface is a steeply overturned fold, and that related faulting is a subsidiary feature.

The Sparks fault, at the east end of the Uinta Mountains (section **A–A′**), is a moderately low-angle thrust fault insofar as it is known. The fault is a southeast-trending continuation of the Uinta and other faults that extend along the north flank of the Uinta Mountains in Utah. These faults have been proved by drilling to be thrust faults of low to moderate dips (Ritzma, 1971). The Sparks fault was active principally during deposition of the lower Eocene Wasatch Formation. It weakens or dies out upward in a conglomeratic facies of the Wasatch (Ritzma, 1955) and consequently is very poorly exposed.

Most faults related to the Rio Grande rift are interpreted to be listric normal faults (sections **C–C′**, **D–D′**, **E–E′**), though some are reactivated old and essentially vertical faults. Blockfaulting that accompanied development of the rift in the Neogene occurred chiefly along preexisting faults (Tweto, 1979b), many of which were vertical or subvertical Precambrian faults.

REFERENCES CITED

Armstrong, R. L., 1968, Sevier orogenic belt in Nevada and Utah: Geological Society of America Bulletin, v. 79, no. 4, p. 429-458.
Berg, R. R., 1962, Subsurface interpretation of Golden fault at Soda Lakes, Jefferson County, Colorado: American Association of Petroleum Geologists Bulletin, v. 46, no. 5, p. 704-707.
Bryant, Bruce, 1979, Geology of the Aspen 15-minute quadrangle, Pitkin and Gunnison Counties, Colorado: U.S. Geological Survey Professional Paper 1073, 146 p.
Burbank, W. S., 1933, Relation of Paleozoic and Mesozoic sedimentation to Cretaceous-Tertiary igneous activity and the development of tectonic features in Colorado, *in* Ore deposits of the Western States (Lindgren Volume): American Institute of Mining and Metallurgical Engineers, p. 277-301.
Cater, F. W., 1970, Geology of the salt anticline region in southwestern Colorado, *with a section on* Stratigraphy, by F. W. Cater and L. C. Craig: U.S. Geological Survey Professional Paper 637, 80 p.
Davis, T. L., and Young, T. K., 1977, Seismic investigation of the Colorado Front Range zone of flank deformation immediately north of Golden, Colorado, *in* Veal, H. K., ed., Exploration frontiers of the central and southern Rockies: Rocky Mountain Association of Geologists, p. 77-88.
Freeman, V. L., 1971, Permian deformation in the Eagle basin, Colorado, *in* Geological Survey Research 1971: U.S. Geological Survey Professional Paper 750-D, p. D80-D83.
Heaton, R. L., 1933, Ancestral Rockies and Mesozoic and late Paleozoic stratigraphy of Rocky Mountain region: American Association of Petroleum Geologists Bulletin, v. 17, no. 2, p. 109-168.
Howard, J. D., 1966, Patterns of sediment dispersal in the Fountain Formation of Colorado: Mountain Geologist, v. 3, no. 4, p. 147-153.
Howard, J. H., 1966, Structural development of the Williams Range thrust, Colorado: Geological Society of America Bulletin, v. 77, no. 11, p. 1247-1263.
Hubert, J. F., 1960, Petrology of the Fountain and Lyons Formations, Front Range, Colorado: Colorado School of Mines Quarterly, v. 55, no. 1, 242 p.
Izett, G. A., and Barclay, C. S. V., 1973, Geologic map of the Kremmling quadrangle, Grand County, Colorado: U.S. Geological Survey Geologic Quadrangle Map GQ-1115, scale 1:62,500.
Lovering, T. S., 1929, Geologic history of the Front Range, Colorado: Colorado Scientific Society Proceedings, v. 12, no. 4, p. 59-111.
Luedke, R. G., and Burbank, W. S., 1962, Geology of the Ouray quadrangle, Colorado: U.S. Geological Survey Geologic Quadrangle Map GQ-152, scale 1:24,000.
Maher, J. C., and Collins, J. B., 1953, Permian and Pennsylvanian rocks of southeastern Colorado and adjacent areas: U.S. Geological Survey Oil and Gas Investigations Map OM-135, scale about 1 in. = 18 mi.
Mallory, W. W., 1972, Pennsylvanian arkose and the Ancestral Rocky Mountains, *in* Mallory, W. W., ed., Geologic atlas of the Rocky Mountain region: Rocky Mountain Association of Geologists, Denver, p. 131-132.
Melton, F. A., 1925, The ancestral Rocky Mountains of Colorado and New Mexico: Journal of Geology, v. 33, no. 1, p. 84-89.
Muehlberger, W. R., 1967, Geology of Chama quadrangle, New Mexico: New Mexico Bureau of Mines and Mineral Resources Bulletin 89, 114 p.
Osterhoudt, W. J., 1978, Chromo East, *in* Fassett, J. E., ed., Oil and gas fields of the Four Corners area: Four Corners Geological Society, p. 113-115.
Ritzma, H. R., 1955, Early Cenozoic history of the Sand Wash basin, northwest Colorado, *in* Ritzma, H. R., and Oriel, S. S., eds., Guidebook to the geology of northwest Colorado: Intermountain Association of Petroleum Geologists, 6th Annual Field Conference, p. 36-40.
______1971, Faulting on the north flank of the Uinta Mountains, Utah and Colorado, *in* Symposium on Wyoming tectonics and their economic significance: Wyoming Geological Association Guidebook, no. 23, p. 145-150.
Ryder, R. T., 1977, Oil and gas potential, pt. D *of* Mineral resources of the Chama-southern San Juan Mountains wilderness study area, Mineral, Rio Grande, Archuleta, and Conejos Counties, Colorado: U.S. Geological Survey Open-File Report 77-309, p. 119-146.
Steven, T. A., 1975, Middle Tertiary volcanic field in the southern Rocky Mountains, *in* Curtis, B. F., ed., Cenozoic history of the southern Rocky Mountains: Geological Society of America Memoir 144, p. 75-94.
Steven, T. A., Lipman, P. W., Hail, W. J., Jr., Barker, Fred, and Luedke, R. G., compilers, 1974, Geologic map of the Durango (1° × 2°) quadrangle, southwestern Colorado: U.S. Geological Survey Miscellaneous Investigations Map I-764, scale 1:250,000.
Stewart, J. H., Poole, F. G., and Wilson, R. F., 1972, Stratigraphy and origin of the Chinle Formation and related Upper Triassic strata in the Colorado Plateau region: U.S. Geological Survey Professional Paper 690, 336 p.
Tweto, Ogden, 1977, Tectonic history of west-central Colorado, *in* Veal, H. K., ed., Exploration frontiers of the central and southern Rockies: Rocky Mountain Association of Geologists, p. 11-22.
Tweto, Ogden, compiler, 1979a, Geologic map of Colorado: U.S. Geological Survey, scale 1:500,000.
______1979b, The Rio Grande rift system in Colorado, *in* Riecker, R. E., ed., Rio Grande rift—Tectonics and magmatism: American Geophysical Union, Washington, p. 33-56.
______1980a, Precambrian geology of Colorado, *in* Kent, H. C., and Porter, K. W., eds., Colorado Geology: Rocky Mountain Association of Geologists, p. 37-46.
______1980b, Tectonic history of Colorado, *in* Kent, H. C., and Porter, K. W., eds., Colorado Geology: Rocky Mountain Association of Geologists, p. 5-9.
Wahlstrom, E. E., and Hornback, V. Q., 1962, Geology of the Harold D. Roberts Tunnel, Colorado—West portal to station 468 + 49: Geological Society of America Bulletin, v. 73, no. 12, p. 1477-1498.
Weimer, R. J., 1970, Rates of deltaic sedimentation and intrabasin deformation, Upper Cretaceous of Rocky Mountain region, *in* Morgan, J. P., ed., Deltaic sedimentation, modern and ancient: Society of Economic Paleontologists and Mineralogists Special Publication 15, p. 270-292.
______1980, Recurrent movement on basement faults, a tectonic style for Colorado and adjacent areas, *in* Kent, H. C., and Porter, K. W., eds., Colorado Geology: Rocky Mountain Association of Geologists, p. 23-35.
Wood, G. H., Jr., Kelley, V. C., and MacAlpin, A. J., 1948, Geology of southern part of Archuleta County, Colorado: U.S. Geological Survey Oil and Gas Investigations Map OM-81, scale 1 in. = 1 mi.

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