Third-day road log, from Truth or Consequences to southeastern Caballo Mountains and San Diego Mountain via I-25 and the Jornada del Muerto

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THIRD-DAY ROAD LOG, FROM TRUTH OR CONSEQUENCES TO SOUTHEASTERN CABALLO MOUNTAINS AND SAN DIEGO MOUNTAIN VIA I-25 AND THE JORNADA DEL MUERTO

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Road log begins: Williamsburg interchange on I-25 just southwest of Truth or Consequences.

Caravan assembly point: Upham interchange, 42 mi southeast of Truth or Consequences on I-25.

Departure time at Upham interchange: 8:45 a.m.

Total distance: 84.2 mi

Stops: 3 (high-clearance vehicles are required, and 4WD is recommended for access to Stop 3).

SUMMARY

The third day's tour will cover ground and geology made famous by Vincent C. Kelley and Caswell Silver in *The Geology of the Caballo Mountains*. Published in 1952, their maps, cross sections, stratigraphic descriptions, and analyses remain the most important source of information on the Caballo Mtns. area. The quality of maps and report is such that relatively few geologic investigations have been published about the area for nearly 35 years. Those that have been completed have been detailed, generally unpublished studies of small areas that confirm the accuracy of Kelley and Silver's mapping and the depth of their insight into geologic problems of south-central New Mexico. The geologic interpretations and observations offered in this road log owe much to the careful mapping, thorough descriptions, and thoughtful interpretations of Kelley and Silver. *The Geology of the Caballo Mountains* will long be respected as one of the classic studies of New Mexico geology.

One of the aspects of the geology of the Caballo Mtns. that most interested Kelley and Silver was the striking examples of Laramide deformation. This day's tour will focus on Laramide tectonics in the southern Caballo Mtns. and at the Tonuco uplift (San Diego Mtn.). The tour route is shown in Fig. 3-1 sum. and is also located on the interpreted Laramide paleogeologic map and cross section of Fig. 3-2 sum.

The southern Caballo Mtns.–Tonuco uplift area is interpreted to be part of a major Laramide basement-cored block uplift (Fig. 3-2 sum.), similar in structural style to the Wind River and Owl Creek uplifts of Wyoming (Prucha et al. 1965, Smithson et al. 1979, Gries 1983, Seager 1983). The uplift seemingly is northwest- to north–northwest-trending and prevailingly asymmetric, being bordered by a narrow zone of northeast-vergent folds and thrust faults along the northeastern margin, and featuring a broad southwesterly dipping southwestern flank. Seager & Mack (1986) applied the name Rio Grande uplift and identified complementary basins on the north and south, which they named Love Ranch Basin and Potrillo Basin, respectively. Syn- to post-orogenic fanglomerate, sandstone, shale, and other sedimentary rocks were named Love Ranch Fm. by Kottlowski et al. (1956) for exposures near Love Ranch in the southern San Andres Mtns. Various facies of the Love Ranch Fm. are thick in both basins, and younger parts of the formation overlap onto the Rio Grande uplift.

Fig. 3-2 sum. shows that the Rio Grande uplift is not a single,

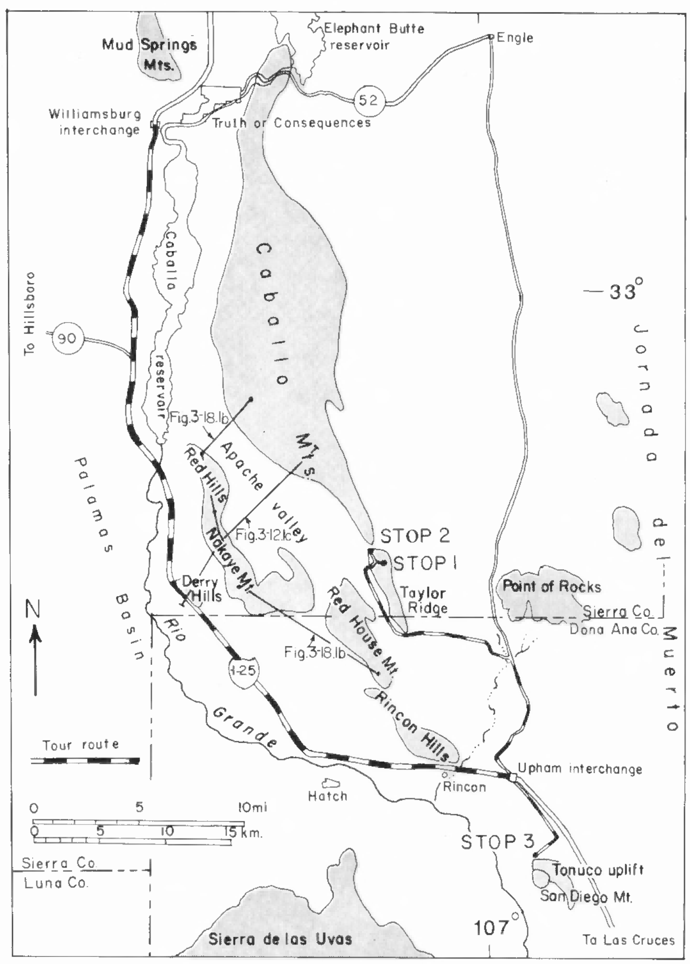


FIGURE 3-1 sum.—Location map of third-day tour route and cross sections of Figs. 3-12.1c and 3-18.1b.

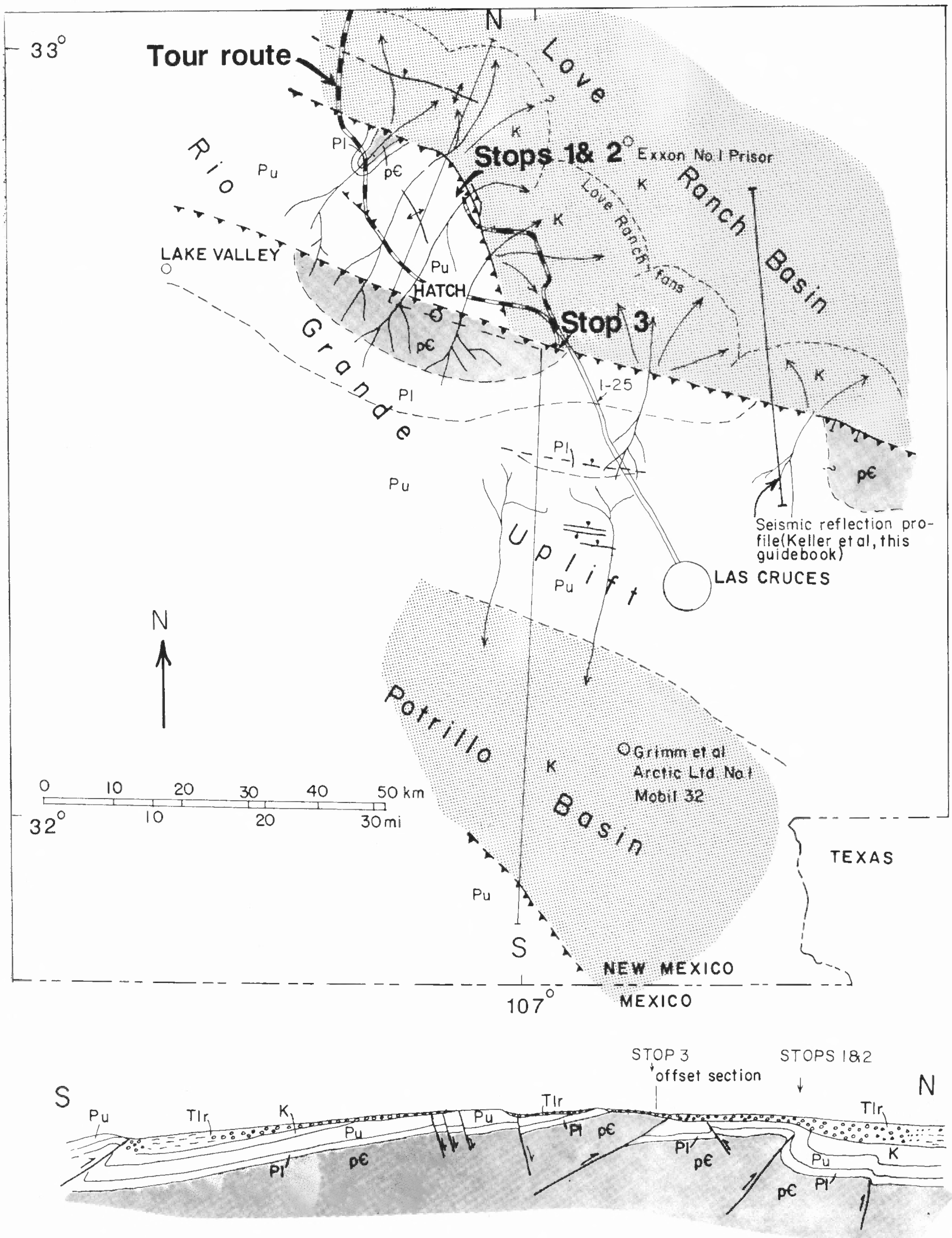


FIGURE 3-2 sum.—Paleogeologic map and cross section of Laramide Rio Grande uplift and Love Ranch and Potrillo Basins. Note tour route and stops on map. pЄ = Precambrian rocks; Pl = lower Paleozoic rocks; Pu = upper Paleozoic rocks; K = Cretaceous rocks; Tlr = Love Ranch Fm.

simple block. At least two major blocks, stair-stepped down to the northeast by fold–fault zones, are required to be consistent with structural and stratigraphic evidence. The southern block in Fig. 3-2 sum., which was structurally highest and furnished much Precambrian detritus to the southern Caballo area and Love Ranch Basin, is largely buried beneath the Rincon–Hatch and southern Palomas Valleys, but an excellent exposure of its thrust-faulted northeastern margin is the main reason for Stop 3 on today's tour. The structurally lower, more northern block is widely exposed in the southern Caballo Mtns., as is the Love Ranch fanglomerate whose clasts spread northeastward across the southern Caballos from their source in Precambrian terrane of the southern block. Stop 2 will provide an opportunity to examine this fanglomerate, but Stops 1 and 2 will center primarily on the folded and faulted northeastern margin of this structurally lower block. The paper by Seager et al. (this guidebook) provides details and a regional overview of the Rio Grande uplift that may help the reader to more fully appreciate the Laramide geology along the tour route and at the stops.

Although Laramide tectonics is the central theme of today's tour, one can hardly follow I-25 along the spectacular front of the Caballo range or view the geology at Stops 1, 2, and 3 without appreciating the Paleozoic stratigraphy, the late Tertiary fault blocks, or the uppermost Pliocene and Quaternary deposits and erosion that has shaped the present landscape. Consequently, entries in the road log highlight geologic features of various ages, not just Laramide, as they are encountered along the route. Discussions at Stops 1, 2, and 3, however, focus on Laramide tectonics.

From Williamsburg exit at Truth or Consequences, the tour route follows I-25 and the Rio Grande southward across the Palomas Basin, passing the wonderfully exposed Paleozoic section in the escarpment of the Caballo Mtns. and skirting Caballo reservoir and Caballo dam. Below the dam the route parallels or crosses such outlying fault blocks of the Caballo Mtns. as Red Hills, Derry Hills, and Nakaye Mtn., all of which provide important insights into the nature of Laramide and late Tertiary deformation in this region. Roadcuts offer a constant reminder of the shifting position of ancient alluvial fans and ancestral channels of the Rio Grande as the latter flowed southward into the giant fan-deltas of southern New Mexico, western Texas, and northern Chihuahua in latest Pliocene and Pleistocene time. Passing from the southern Palomas Basin into the Hatch–Rincon Valley, the tour sideswipes the Rincon Hills composed of faulted and uplifted "early rift" basin deposits.

At Rincon the tour leaves the Rio Grande valley and ascends to the surface of an ancestral Rio Grande fan-delta, whose desert surface is better known as the Jornada del Muerto. Turning northward at Upham interchange on I-25 and following the Jornada desert into the southeastern Caballo Mtns., the tour makes Stops 1 and 2 at the northeastern margin of the Rio Grande uplift where the marginal fold–thrust zone and Love Ranch fanglomerates are well displayed. Retracing the route back to the Upham interchange on I-25, the tour then proceeds southward on an I-25 frontage road to the Tonuco uplift. An exceptional exposure of a major basement thrust at the margin of the Rio Grande uplift highlights this third stop. This fault probably represents a deeper look at boundary fault zones of Laramide uplifts in southern New Mexico compared to the view afforded by the shallower-level fold–thrust zones of the southeastern Caballo Mtns. At the conclusion of Stop 3 the caravan will disband. **CAUTION: Four-wheel-drive vehicles are strongly urged for the trip to Tonuco uplift.**

Mileage

Between mileage 0.0 and 42.0, the road log is adapted in part from one by Hawley & Seager *in* Hawley (1978).

0.0 Williamsburg overpass on I-25, MP75. Drive south on interstate until mile 42 (Upham exit). **0.5**

0.5 Freeway entrance on right from Williamsburg. East-tilted mass of Caballo Mtns. at 1:00–10:00. Paleozoic and Precambrian rocks form the western escarpment of the range. In general, reddish Precambrian granitic rocks underlie lower slopes, lower Paleozoic carbonates form the lowest set of cliffs, and Pennsylvanian carbonates weather to the ledgy slopes or cliffs in the upper half to one-third of the escarpment. Permian and Cretaceous rocks crop out on the eastern dip-slope of the range or, in the southern Caballo Mtns., are exposed in down-faulted blocks below the escarpment. See Fig. 3-0.5 for Kelley & Silver's (1952) columnar section.

Intergtonguing piedmont-toe slope and alluvial-flat deposits of the upper Santa Fe Gr. (Palomas Fm., Pliocene [or older] to middle Pleistocene age) are exposed in bluffs and badlands and highway cuts for the next 16 mi. These clays, silts, sands, and gravels constitute the upper part of the fill of the Palomas Basin. They were deposited by arroyo systems draining the eastern Black Range, Animas Mtns.–Salado Hills region to the west (see Lozinsky & Hawley in this guidebook). **0.6**

1.1 MP74. Palomas Gap in Caballo Mtns. at 9:30. Except for the ridge north of Palomas Gap where dips are steep, the strata in the Caballo Mtns. generally display gentle to moderate eastward dips. Locally, however, there are spectacular monoclines or overturned folds with angular hinges. One of these is visible under good lighting conditions just south of Palomas Gap (Fig. 3-1.1), and still others can be seen a few miles farther south along the ridge crest. Most of the folds are overturned toward the east or northeast and consist of anticline–syncline pairs, locally stacked on top of one another (Kelley & Silver 1952). See entry road-log segment 2A, first optional stop, for good examples in the northern Caballo Mtns. **2.1**

3.2 Bridge across Palomas Creek. Palomas overpass just ahead. A test well near here (B. Iorio No. 1 Fee) "was drilled to 2,100 ft and plugged back to 1,550 ft for a flow of 30 gpm of water having a temperature of 90°F. In this well the Santa Fe Fm. had a thickness of 1,165 ft" (Kelley & Silver 1952: 189). The hole bottomed in the upper Oligocene–lower Miocene Thurman Fm. **1.8**

5.8 Bridge across King Arroyo. Good view of Caballo frontal scarp at 9:00. Red Precambrian granite at base, lower Paleozoic carbonates in lower cliffs, and Pennsylvanian carbonates in upper half of ridge. Low-angle illumination highlights a prominent piedmont scarp that extends

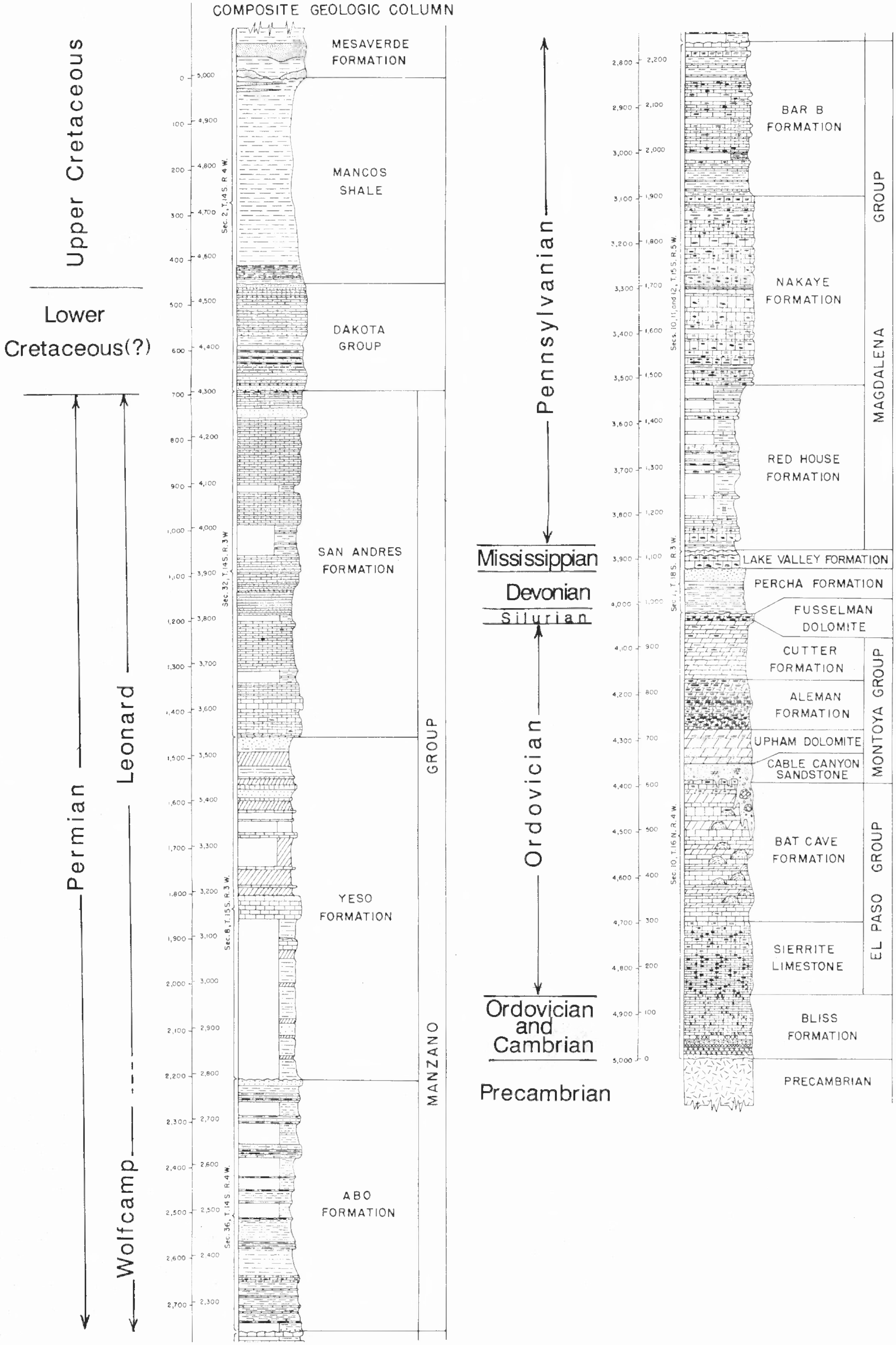


FIGURE 3-0.5—Composite columnar section of Paleozoic and Mesozoic rocks in the Caballo Mtns. (from Kelley & Silver 1952).

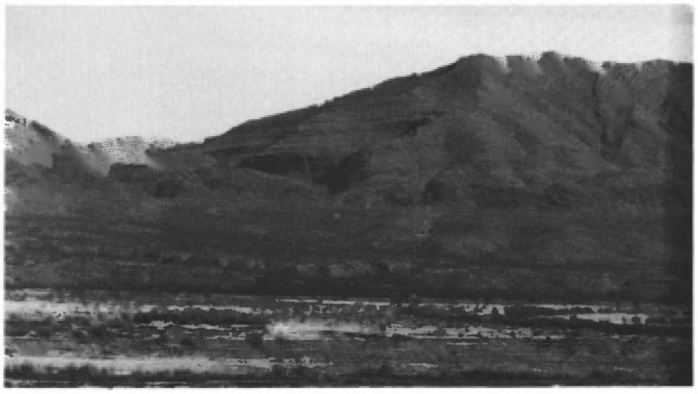


FIGURE 3-1.1—Overturned syncline just south of Palomas Gap.

along the foot of the range just below the apex of high-level fans and pediments. The fault cuts fans as young as late Pleistocene, but not Holocene fans. **2.7**

7.7 Rest area, both sides of highway. Timber Mtn. at 9:30–10:00, highest (2,317 m) ridge in the Caballo Mtns., stands approximately 1,037 m above the Rio Grande which flows near its base. Timber Mtn. and more northerly parts of the Caballo Mtns. may have been part of the Laramide Love Ranch Basin by the reconstruction of Fig. 3-2 sum. **1.1**

8.8 Arroyo Seco bridge. Upper end of Caballo reservoir at 9:00. Across lake major down-to-the-north fault zone follows Granite Wash at north end of Timber Mtn. Fault dies out into Putnam anticline to the east (Kelley & Silver 1952), and is approximately aligned with a major Laramide fault that crops out in the Salado Hills 19 km to the northwest. The Granite Wash fault too is presumed to be Laramide and a member of the series of faults that steps the Laramide Rio Grande uplift down into the Love Ranch Basin (Fig. 3-2 sum.). **1.5**

10.3 Animas Arroyo bridge. During highway construction the carapace and limb bones of a giant tortoise were recovered from Palomas deposits near the base of the deep roadcut ahead. **0.8**

11.1 Hillsboro interchange (overpass). Continue south on I-25. **1.0**

12.1 MP63. Timber Mtn. at 9:00, Apache Valley at 9:30, Red Hills at 10:00, Sierra de las Uvas dome at 11:00. Notch at summit of Sierra de las Uvas dome is apical graben (Fig. 3-12.1a).

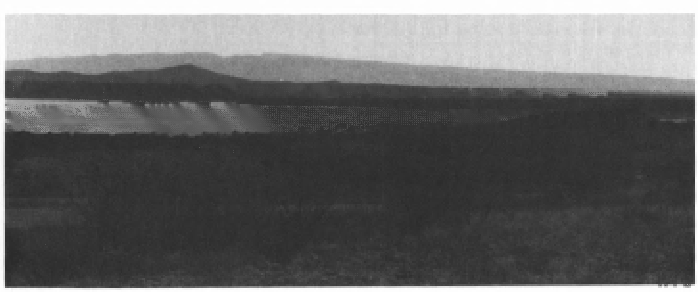


FIGURE 3-12.1a—Sierra de las Uvas dome on skyline with apical graben, the notch at the summit. Caballo reservoir in foreground and Derry Hills in middle distance.

Apache Valley is a complex graben between the main Caballo Mtn. block and the lower Red Hills block. An excellent section of Laramide syn- to post-orogenic fanglomerate, as well as middle Tertiary volcanic rocks and upper Tertiary rift deposits, are well exposed in the graben (Fig. 3-12.1b). Placer gold has been won from deformed "early rift" (Hayner Ranch and Rincon Valley) fanglomerates located just north of the Red Hills and east of Caballo reservoir.

The Apache Valley graben was completely buried by Camp Rice (correlative with Palomas Fm.) fanglomerate in middle Pleistocene time so that the basin must have appeared at that time as an undissected intermontane basin similar to those of southwestern New Mexico. There was little or no hint in middle Pleistocene time as to the structural geometry of the graben.

Because the bedrock floor of the graben is high and the cover of Camp Rice fans is thin, upper Pleistocene and Holocene erosion exposed the structure of older rocks beneath the Camp Rice. Revealed by this erosion are a series of tilted fault blocks that stair-step down toward the basin axis, which lies closer to the main Caballo block than to the Red Hills block (Fig. 3-12.1c). The faults are all normal and dip moderately (50–60°). Antithetic tilting of blocks creates a faulted, dome-like structure and raises the question of whether the faults might be listric at depth. The exposed structure of this intermontane basin may be similar to that of the undissected intermontane basins elsewhere in the Rio Grande rift or Basin and Range. Geophysical and conceptual models (e.g. Stewart 1971, Thompson & Burke 1974, Healey et al. 1978, Veldhuis & Keller 1980, Anderson et al. 1983, Okaya & Thompson 1985) often portray a similar graben structure, but rarely do outcrops such as those in Apache Valley confirm such models. **3.0**

15.1 MP60. Cross Percha Creek diversion channel to Caballo reservoir. Caballo dam at 9:30, Red Hills at 9:30–11:00; Sierra de las Uvas dome at 1:00 (Fig. 3-12.1a).

In this general area we pass from the Laramide Love Ranch Basin onto the northern margin of the Laramide Rio Grande uplift. The northeast-facing boundary between the two features is a west–northwest-trending fold–thrust belt which is exposed at the southern edge of the high Caballos (Timber Mtn.), truncated at the Caballo range-boundary fault, and presumably is downfaulted and buried beneath northern Apache Valley, Caballo reservoir, and I-25 (Fig. 3-2 sum.).

Forming part of the uplifted hanging wall of the fold–thrust zone, the Red Hills reveal important evidence for the Rio Grande uplift. Exposed there is an impressive, northeasterly trending Laramide paleocanyon floored by Precambrian granite, walled in by lower and upper Paleozoic carbonates, and filled with more than 300 m of Love Ranch fanglomerate (Fig. 3-15.1). This deep erosion indicates substantial uplift of the Red Hills area relative to the high Caballo range in Laramide time. In fact, Cretaceous and upper Paleozoic rocks were almost completely eroded from all parts of the southern Caballo

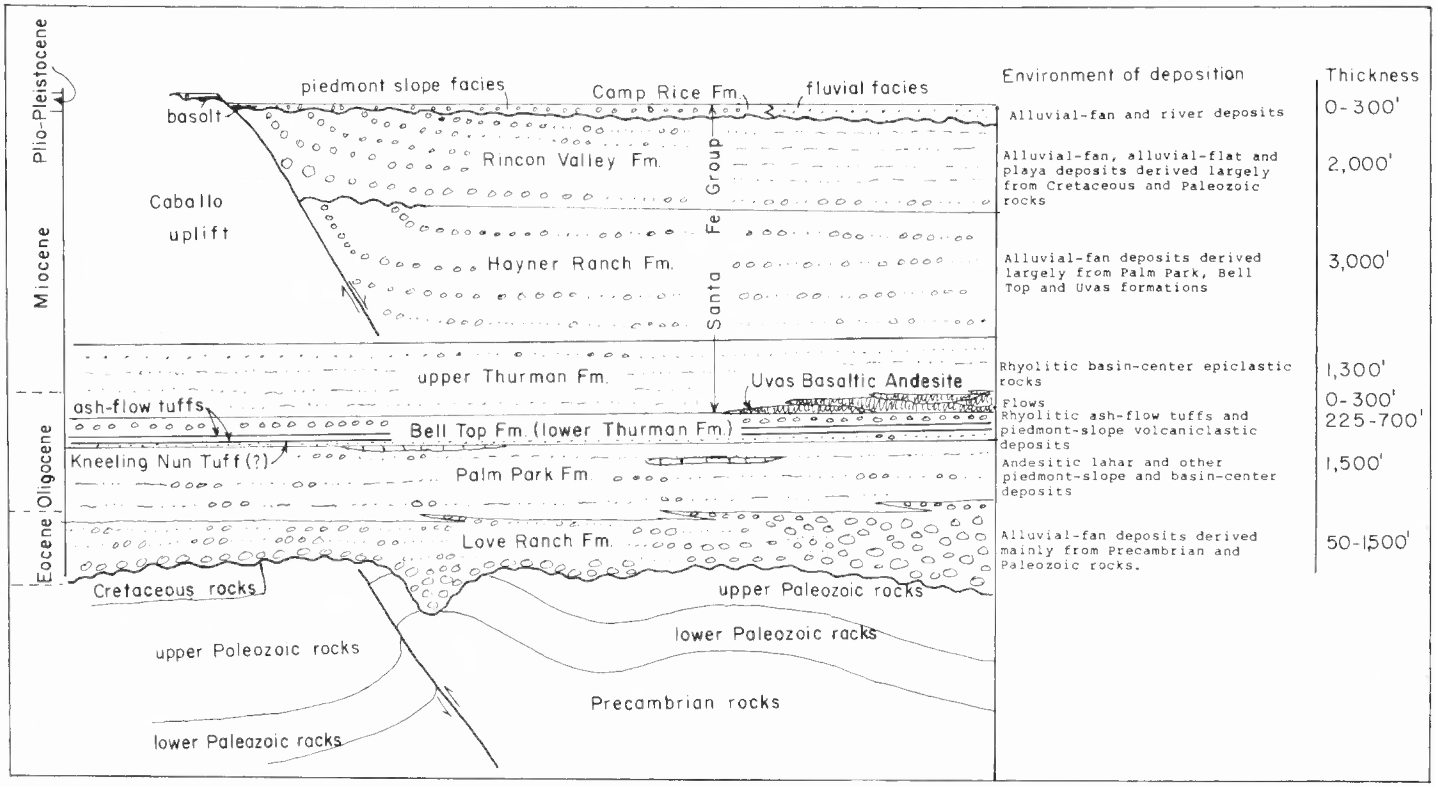


FIGURE 3-12.1b—Diagram illustrating Cenozoic rocks exposed in Apache Valley and their relationship to Laramide and late Tertiary deformation.

region south of the fold–thrust belt before Love Ranch time. This widespread stripping of strata also constitutes important evidence for the Rio Grande uplift. In contrast, the high Caballos still retain a complete section of Paleozoic and Cretaceous rocks, as well as thick lower Tertiary Love Ranch fanglomerate, all spared from erosion by subsidence of the Love Ranch Basin.

Imbricated cobbles show that the Love Ranch fanglomerate that backfilled the Red Hills paleovalley and buried Paleozoic strata on the Rio Grande uplift was derived from source terrane located southwest of the Red Hills, terrane now buried beneath the southern Palomas and Rincon Valleys (Seager et al. in this guidebook). Furthermore, clast composition and size indicate the source was a block of substantial relief consisting largely of Precambrian granite and lower Paleozoic carbonates (Fig. 3-2 sum.). **0.3**

15.4 Caballo dam exit and old US-85 overpass. **0.7**

16.1 MP59. Bluffs ahead on left are tilted basal Camp Rice fanglomerate overlain by light-gray fluvial sandstone and gravel, deposits of the ancestral Rio Grande, which are also part of the Camp Rice Fm. (Fig. 3-16.1). From approximately Caballo dam (latitude 33°N) southward, Camp Rice Fm. rather than Palomas is used to designate upper Santa Fe Gr. fluvial and piedmont-slope deposits (see Lozinsky & Hawley in this guidebook). **0.7**

16.8 Cross Rio Grande (Fig. 3-16.8). Roadcuts ahead in Holocene fan alluvium. **1.3**

18.1 MP57. Ridges at north and south ends of Red Hills (8:30 and 9:30) are capped by lower Paleozoic Bliss Ss. and

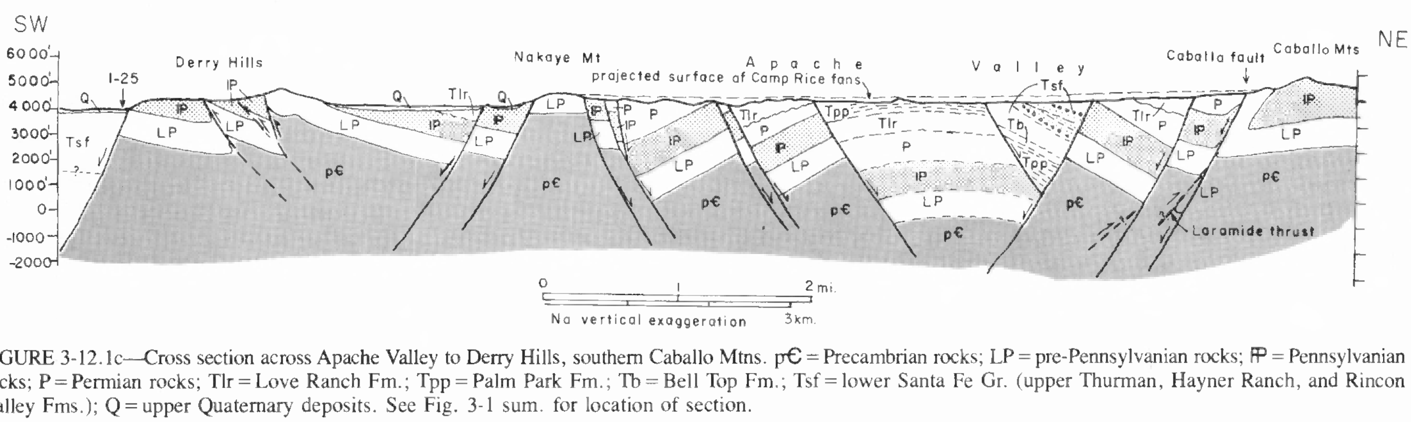


FIGURE 3-12.1c—Cross section across Apache Valley to Derry Hills, southern Caballo Mtns. p€ = Precambrian rocks; LP = pre-Pennsylvanian rocks; IP = Pennsylvanian rocks; P = Permian rocks; Tlr = Love Ranch Fm.; Tpp = Palm Park Fm.; Tb = Bell Top Fm.; Tsf = lower Santa Fe Gr. (upper Thurman, Hayner Ranch, and Rincon Valley Fms.); Q = upper Quaternary deposits. See Fig. 3-1 sum. for location of section.

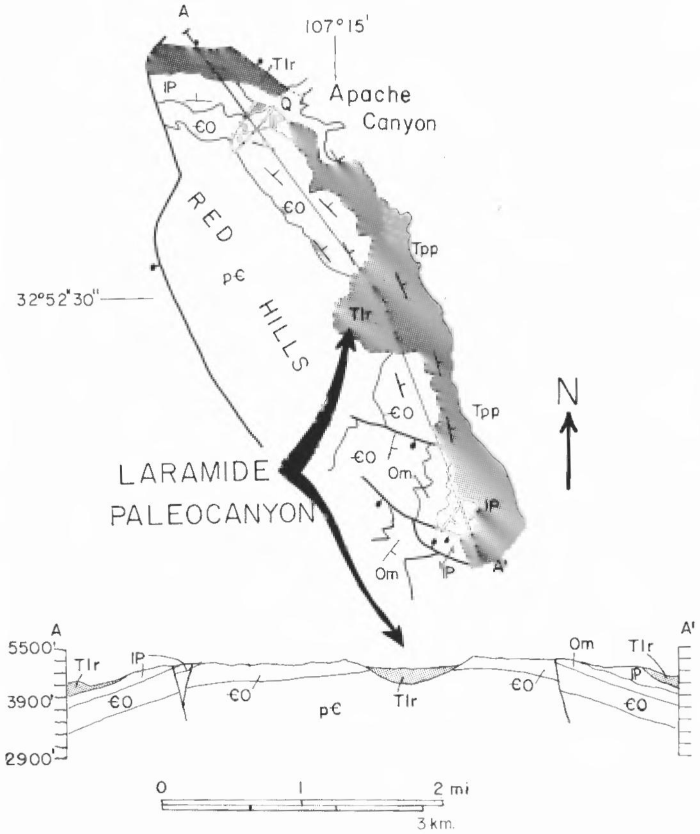


FIGURE 3-15.1—Geologic map and section of the Red Hills, southern Caballo Mtns., illustrating major Laramide paleocanyon. p€ = Precambrian rocks; € O = Bliss and El Paso Fms.; Om = Montoya Dolomite; IP = Pennsylvanian rocks; Tlr = Love Ranch Fm.; Tpp = Palm Park Fm.

El Paso Fm. (Fig. 3-18.1a). Low saddle between the two ridges is axis of Laramide paleovalley (discussed at mile 15.1) floored by red Precambrian granite and filled with 300 m or more of Love Ranch fanglomerate.

The Red Hills also offer evidence for uplift of the southern Caballo Mtns. area in middle Paleozoic time. On the dip-slope of the northern ridge in the Red Hills, Pennsylvanian strata unconformably overlie El Paso

FIGURE 3-16.1—Western escarpment of Timber Mtn. in background exposing Precambrian rocks (lower slopes), Bliss Ss. (dark band at base of stratified sequence), Ordovician and Silurian carbonates (lower cliffs), and Pennsylvanian strata (upper ledgy slopes). Camp Rice fanglomerate in foreground cliffs.

FIGURE 3-16.8—Rio Grande flowing beneath bluffs of Camp Rice fanglomerate. Timber Mtn. in background.

limestone, the intervening section of Ordovician, Silurian, Devonian, and Mississippian strata having been removed by erosion in latest Mississippian or earliest Pennsylvanian time. Beyond the Red Hills the basal Pennsylvanian unconformity truncates older rocks in such a way that a broad dome-like late Mississippian or earliest Pennsylvanian uplift can be reconstructed (Fig. 3-18.1b). The highest part of this uplift coincides with the summit of the Laramide Rio Grande uplift in the Red Hills, suggesting the Laramide uplift may be a reactivated older structure. **1.0**

19.1 MP56. Roadcuts for next 2.2 mi are in Camp Rice fluvial and piedmont facies locally capped by upper Quaternary deposits. **2.2**

21.3 Red beds on left are outcrops of Abo Fm. at northern end of the Derry Hills fault block. Road follows approximate contact of Abo and uppermost Pennsylvanian strata for next 0.9 mi. Nakaye Mtn. on skyline at 9:00 is a narrow horst exposing the Precambrian through Pennsylvanian section; it is a southward continuation of the Red Hills. **0.9**

22.2 Green Canyon bridge. Green Canyon dam upstream at 9:00. Derry Hills area is a gently east-tilted late Tertiary fault block with Laramide thrust faults and overturned

FIGURE 3-18.1a—Red Hills in shadows in foreground. Broad, low saddle near center of Red Hills is exhumed Laramide paleocanyon. Timber Mtn. on skyline in background.

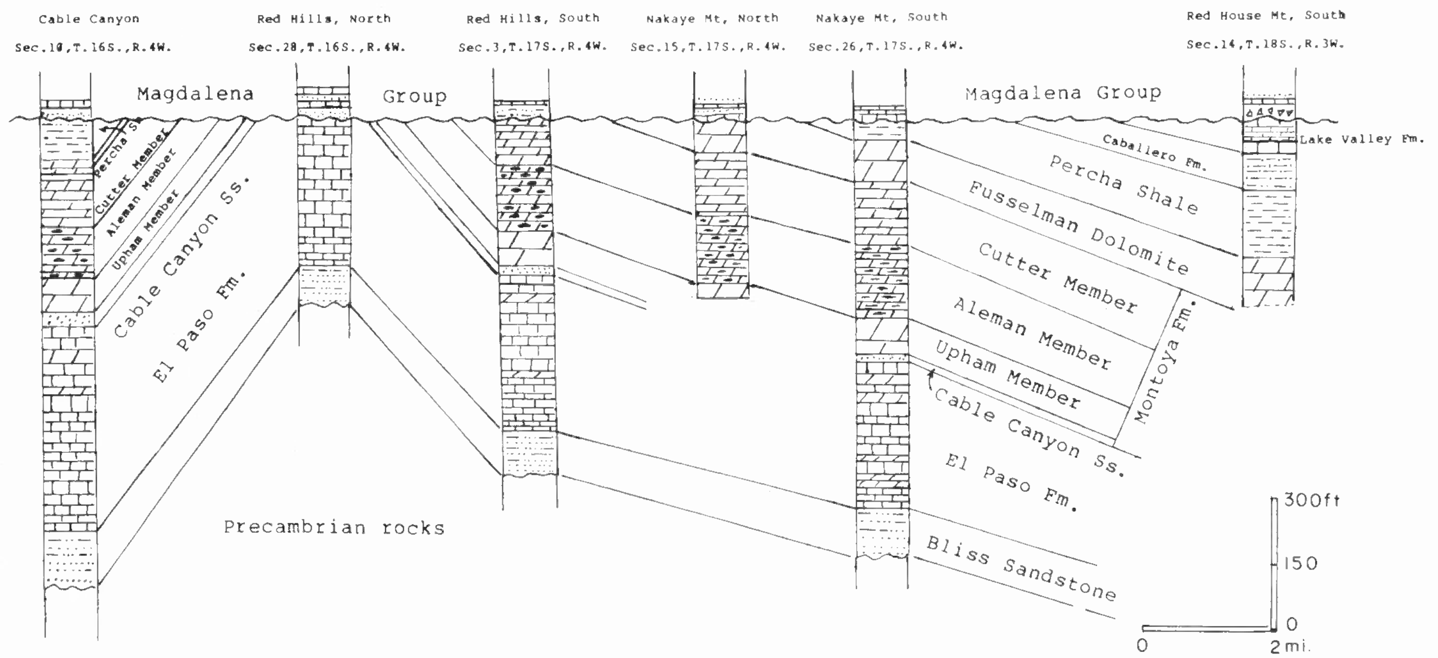


FIGURE 3-18.1b—Columnar sections of Paleozoic rocks from the southern Caballo Mtns. that illustrate erosional truncation of pre-Pennsylvanian strata. The pattern of truncation can be inferred to indicate a broad, domal uplift in latest Mississippian or earliest Pennsylvanian time centered near the Red Hills. See Fig. 3-1 sum. for location of section.

folds exposed south of Green Canyon dam (western part of Fig. 3-12.1c). Vergence of fold and thrusts here is southwestward in contrast to northeastward vergence of Laramide compressional structures elsewhere in the Caballos. Thrust and reverse faults in the Derry Hills bring rocks as old as El Paso Fm. in contact with overturned Abo and Pennsylvanian beds. **0.3**

22.5 Road bends left and follows late Tertiary frontal fault zone of Derry Hills for next 0.8 mi. Abo red beds on left are fault sliver. Escarpment ahead on left is basal Pennsylvanian limestone overlying Percha Sh. Basal Pennsylvanian limestone here is the type section of the Derryan Series studied by King (1973). **0.3**

22.8 Percha Sh. at base of roadcuts. Route crosses western end of cross section, Fig. 3-12.1c. **0.9**

23.7 Garfield exit and underpass. **1.0**

24.7 Hatch, Las Cruces, El Paso mileage signpost. South end of Nakaye Mtn. at 9:00 consists of lower Paleozoic carbonates. Below the mountain front grayer, well-bedded Pennsylvanian limestone and red Abo clastic rocks are downdropped in stair-step fashion toward the highway by high-angle normal faults (Fig. 3-24.7). Camp Rice fanglomerate and fluvial sand and gravel are exposed in gully bottoms and roadcuts for next 3.4 mi. **0.4**

25.1 MP50. Flat Top Mtn. (a faulted anticline) and Red House Mtn. (east-tilted fault block) form skyline at 8:30 and 9:00, respectively. Stop 1 of this trip will be on east side of Red House Mtn. **3.0**

28.1 MP47. Begin descent into Hatch and Rincon Valley segment of the Rio Grande valley. Panoramic view of south-central New Mexico region. Red House Mtn. from 9:00 to 10:00. High spires on skyline at 11:30 are the northern Organ Mtns. east of Las Cruces. Low, flat-top mountain in the Rio Grande valley that is in line with the Organs is San Diego Mtn., overlooking Stop 3. The Robledo Mtns. on the skyline at 12:00 are south of San Diego Mtn. Sierra de las Uvas in middle distance from 12:15 to 1:30 has a broadly domal structure with an apical graben (Fig. 3-28.1). This uplift is capped by upper Oligocene–lower Miocene Uvas Basaltic Andesite over rhyolitic ash-flow tuff and sedimentary rocks of the Bell Top Fm., which constitute the fill of the Goodsight–Cedar Hills depression (Seager 1973, Clemons 1976). The Good Sight Mtns., from 1:30 to 3:30, form the western limb of the synclinal trough that flanks the Uvas dome (Clemons 1979). The Good Sights also are capped by Uvas Basaltic Andesite overlying a sequence of Oligocene rhyolitic rocks that wedges out westward over

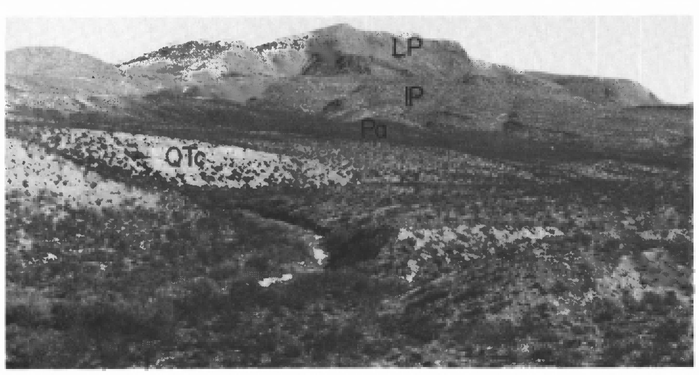


FIGURE 3-24.7—South end of Nakaye Mtn. exposing late Tertiary fault blocks downdropped in stair-step fashion toward the viewer. LP = lower Paleozoic carbonates; IP = Pennsylvanian strata; Pa = Abo Fm.; QTc = Camp Rice fanglomerate.

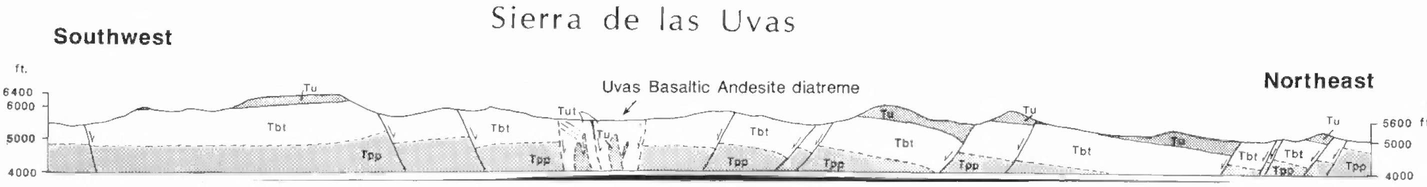


FIGURE 3-28.1—Cross section through Sierra de las Uvas dome. Tpp = Palm Park Fm., mostly andesitic volcaniclastic rocks; Tbt = Bell Top Fm., mostly rhyolitic ash-flow tuffs and tuffaceous clastic rocks; Tu = Uvas Basaltic Andesite, mostly flows; Tut = basaltic lapilli tuff in diatreme. From Clemons & Seager (1973).

andesitic to latitic volcanics of the Rubio Peak Fm. (Palm Park equivalent). Nutt Mtn. (Sunday Cone) at 3:15 is an Oligocene rhyolite intrusive body in the northern Good Sight Mtns. Cooke's Peak on the western skyline beyond Nutt Mtn. is at the southern end of the Black Range, site of the Emory cauldron (Elston et al. 1975, Abitz et al. in this guidebook).

The high mesa from 1:00 to 3:00 on the far side of the valley is underlain by about 90 m of Camp Rice fluvial deposits containing Blancan vertebrate remains. Reddish beds unconformably beneath the fluvial deposits are "early rift" basin deposits of the lower Santa Fe Gr. (Rincon Valley Fm.).

From here southward for the next 7.5 mi the highway traverses mostly upper Pleistocene and Holocene fan and river deposits that are inset below and against Camp Rice strata. **5.4**

33.5 Hatch exit and underpass. Route ahead crosses a broad zone of upwarped, tilted, and faulted "early rift" basin-fill deposits of the lower Santa Fe Gr. (Rincon Valley and Hayner Ranch Fms.). Reddish outcrops in gully bottoms and roadcuts for the next few miles are deformed Rincon Valley strata overlain by upper Pleistocene piedmont and fluvial sand and gravel. **2.6**

36.1 MP39. Rincon Hills at 11:00 are "early rift" basin deposits of Hayner Ranch (lower to middle Miocene) and Rincon Valley Fms. (middle to upper Miocene) that were arched and broken into horsts and grabens during later stages of rifting (last 10 my or so). San Andres Mtns. from 11:30 to 12:30; Organ Mtns. at 1:00 are behind the Tonuco uplift and San Diego Mtn. Robledo Mtns. are at 1:30–2:00 and Sierra de las Uvas lies across the valley from 3:00 to 4:00. **1.5**

37.6 Gray hills in middle distance at 9:00 are Oligocene ash-flow tuffs of Bell Top Fm. Dark-red Rincon Hills with microwave tower from 10:00 to 11:00 are horst of Hayner Ranch Fm., mostly fanglomerate (Fig. 3-37.6). Pinker, softer strata downfaulted along south side of Rincon Hills are playa and alluvial-flat deposits of Rincon Valley Fm. (Seager & Hawley 1973). Buff to light-gray, fluvial Camp Rice strata unconformably overlie Rincon Valley beds in several places. **0.4**

38.0 MP37. Good roadcuts in gypsiferous Rincon Valley Fm. for next 0.5 mi. Note faults and channeling in roadcuts on left. **1.0**

39.0 Rincon exit. Roadcut on left exposes Camp Rice fluvial facies with reverse drag into major down-to-the-west normal fault that crosses the highway 0.4 mi ahead. The fault can be traced southward into the Tonuco uplift. **0.7**

39.7 Cross Rincon Arroyo and begin ascent through Camp Rice fluvial and overbank deposits approximately 90 m thick. **1.2**

40.9 Signpost "Upham exit 1 mi." **Prepare to leave interstate highway at Upham exit. 0.6**

41.5 Ascend to La Mesa surface, the constructional top of Camp Rice fluvial deposits. From Truth or Consequences southward to the Derry Hills, the ancestral Rio Grande meandered across a belt no more than ca 8 km wide, which hugged the western base of the Caballo Mtns. South of the Derry Hills (mile 22.7), however, the river began to construct a huge fluvial fan-delta system which eventually covered several of the basins of south-central New Mexico and extended into western Texas and northern Chihuahua (Fig. 3-41.5). The La Mesa surface in south-central New Mexico represents remnants of the constructional top of that fan-delta system (Hawley et al. 1969, Hawley 1975, Gile et al. 1981). **0.5**

42.0 Upham exit. **Exit right. 0.2**

42.2 Stop sign. **Turn left,** pass through I-25 underpass and proceed northward across cattleguard onto unpaved county road. **0.3**

42.5 **Follow flagperson's instructions to assemble caravan. 0.6**

43.1 Bullet-scarred white brick building on right. Red House Mtn. at 12:00 consists of faulted Paleozoic rocks. Faulted

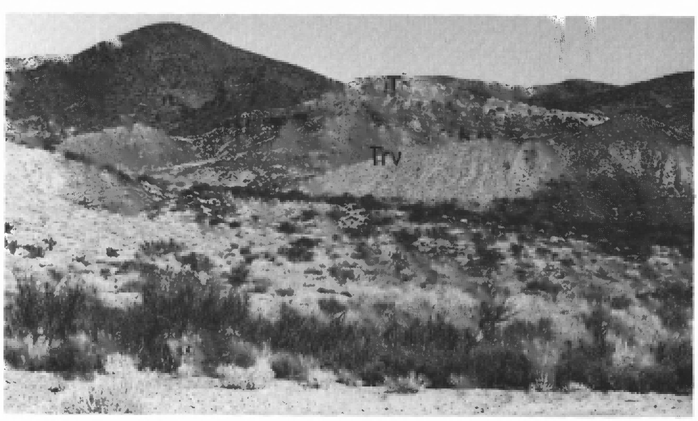


FIGURE 3-37.6—Dark Rincon Hills on skyline consist of faulted and tilted Hayner Ranch fanglomerate. Lower hills are downfaulted Rincon Valley playa deposits (Trv) capped by fluvial facies of the Camp Rice Fm. (QTc).

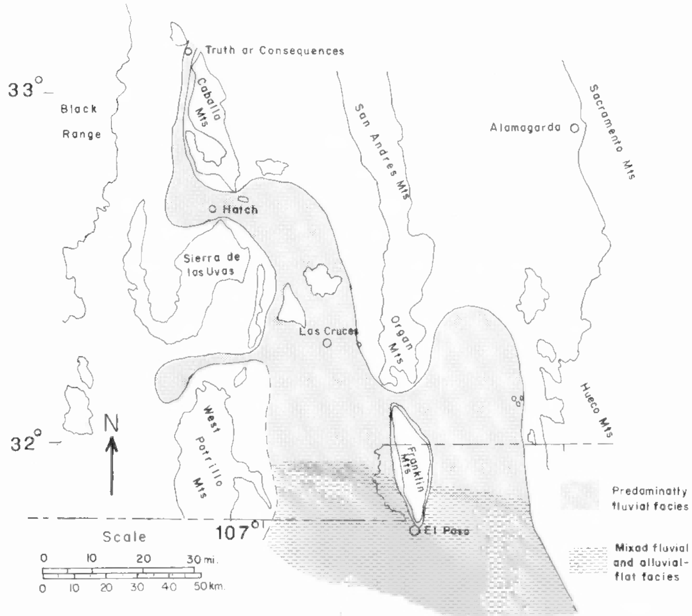


FIGURE 3-41.5—Map showing distribution of Camp Rice fluvial deposits in fan-delta system of the ancestral Rio Grande in south-central New Mexico, far-west Texas, and northern Chihuahua.

lower Santa Fe Gr., Uvas Basaltic Andesite, and Bell Top ash-flow tuffs are exposed in Rincon Hills at 11:00. **0.2**

43.3 Road junction. **Bear right. 0.2**

43.5 Road junction. **Continue straight** ahead on County Road 72. Good view of fluvial Camp Rice deposits in badlands of Rincon Arroyo at left. **2.1**

45.6 Cattleguard. Red House Mtn. at 9:00; Timber Mtn. at 10:00; San Mateo Mtns. on skyline at 11:00; Point of Rocks from 11:30 to 12:00; San Andres Mtns., a long west-tilted block of Precambrian, Paleozoic, and (locally) Cretaceous rocks, from 12:00 to 4:00. **2.1**

47.7 Cinder-block building. **Bear left** across cattleguard and continue straight ahead (north). For the last four miles, we have been crossing part of the infamous Jornada del Muerto, which stretches from the Rincon Hills and Caballo Mtns. east to the San Andres Mtns. **0.7**

48.4 Begin descent into tributary of Rincon Arroyo. Point of Rocks, from 12:00 to 2:00, consists mostly of faulted Uvas Basaltic Andesite flows and pyroclastic deposits. Thin Bell Top ash-flow tuffs and a few meters of Palm Park Fm. crop out around the western and northern margins of the hills. All of these Tertiary volcanic rocks crop out along the trough of the Jornada del Muerto syncline, the structural basin created by the westward tilt of the San Andres Mtns. and eastward tilt of the Caballo Mtns. (Fig. 3-48.4). This tilting is a product of late Tertiary rifting, so the syncline is probably also a late Tertiary feature. Geometry of the Jornada del Muerto syncline is fairly well constrained by drill-hole data (Fig. 3-48.4).

Judging from the thickness of Cretaceous rocks and thickness and facies of lower Tertiary rocks (Love Ranch Fm.) preserved in the Jornada del Muerto syncline, the synclinal basin is superimposed on a Laramide basin—the Love Ranch Basin (Fig. 3-2 sum.). **0.6**

49.0 **Take sharp left toward windmill and corral. Continue to bear left** toward gate at south side of corral. **0.1**

49.1 Gate. Proceed through gate and around south side of corral. **Stay on main road. 0.2**

49.3 Road dips into and crosses Rincon Arroyo on west side of corral. **0.6**

49.9 County Road E94 to left. **Continue straight ahead. 0.4**

50.3 Crossing alluvial flat. Bad when wet! **0.6**

50.9 Pass through gate, cross railroad tracks, and pass through second gate, heading west. **0.8**

51.7 Ascend to surface of Camp Rice alluvial fan. **1.3**

53.0 Side road to right. **Continue straight ahead.** Eastern flank of Red House Mtn. at 12:00 is dome-shaped as told by opposing dips of Pennsylvanian strata at north and south ends (Fig. 3-53.0). Rocks on the west side of the mountain (not visible from here) are truncated by a major late Tertiary normal fault, and Red House Mtn. block is relatively uplifted and tilted eastward.

The low ridge in the foreground is Taylor Ridge (Kelley & Silver 1952), a major northeast-facing, overturned Laramide anticline that forms the common boundary of the Love Ranch Basin and Rio Grande uplift in this area. The ridge summit is approximately at the fold hinge, and the eastern flank of the ridge, visible from here, is formed mostly by overturned Pennsylvanian strata dipping 30–70° west. Farther north along the base of the ridge, Abo, Yeso, San Andres, and Dakota beds are well exposed; they too are part of the overturned limb of the fold. The fold is the main feature of interest at Stops 1 and 2. **1.6**

54.6 Good view of Taylor Ridge from 1:00 to 2:00, with overturned, west-dipping strata on eastern slope of ridge (Fig. 3-54.6). **0.3**

54.9 Skirt south end of Taylor Ridge and cross from Love Ranch Basin onto Rio Grande uplift. Pennsylvanian limestone dipping 35–40° west is in overturned limb of Taylor Ridge anticline. Enter area of geologic map, Fig. 3-54.9. **0.2**

55.1 Stock tank on right and side road to left. **Continue straight ahead.** Low ridge on right at approximately 2:00 is Pennsylvanian limestone in right-side-up, western limb of Taylor Ridge anticline.

Red House Mtn. on skyline ahead. Lower ridge in foreground exposes faulted Fusselman Dolomite, Percha Sh., Lake Valley Ls., and Pennsylvanian strata. Fluorspar–barite prospects are located generally in upper part of Fusselman Dolomite. **0.4**

55.5 Road high point on ridge of Pennsylvanian limestone. Eastern overturned limb of Taylor Ridge anticline forms Taylor Ridge at 3:00, whereas western right-side-up limb is exposed in lower hills at 1:00 **0.3**

55.8 Bluffs of faulted Lake Valley Fm. (Alamogordo Mbr.) on ridge sideslope at 3:00. **0.2**

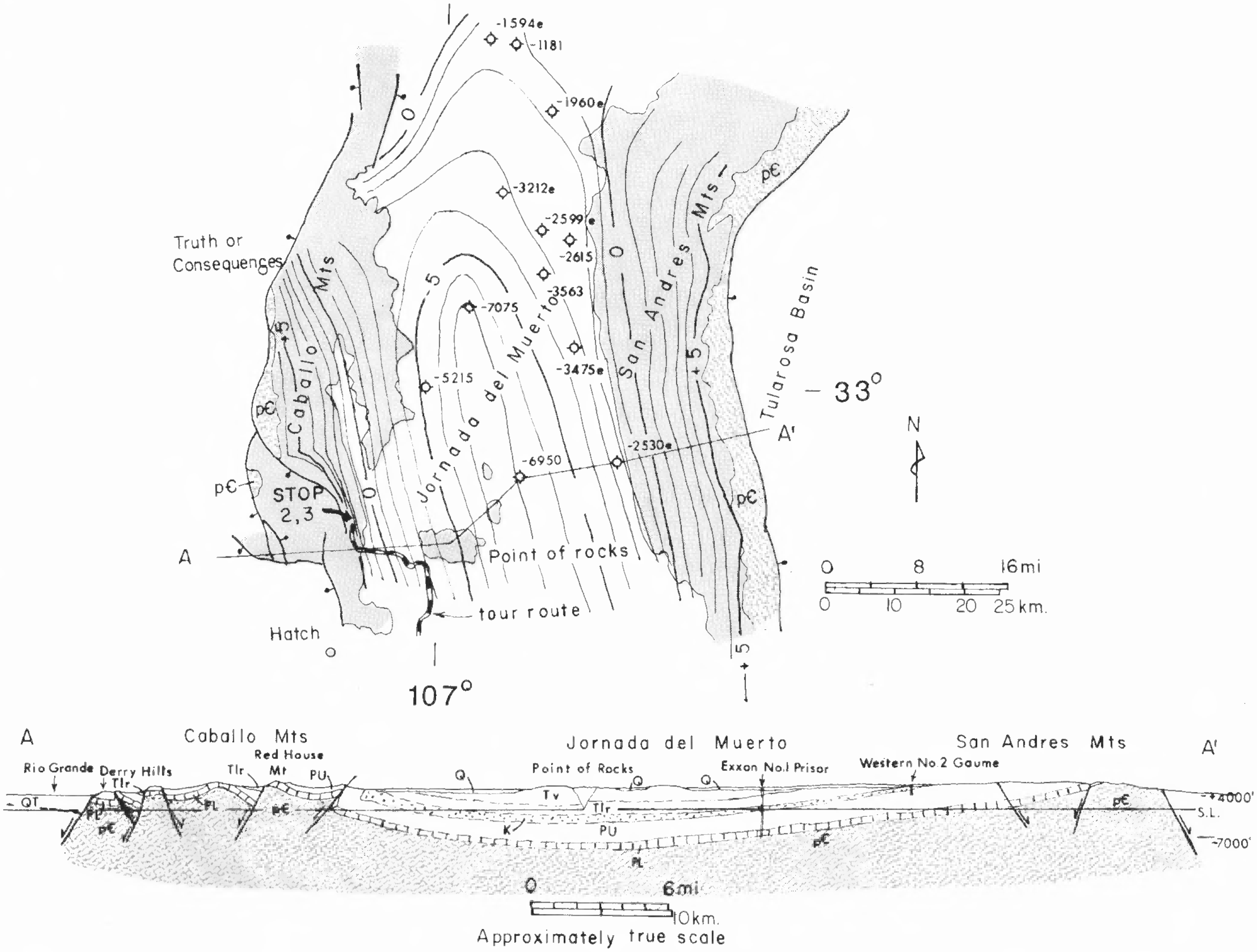


FIGURE 3-48.4—Structure contour map (drawn on top of Precambrian rocks) and cross section of central Jornada del Muerto area. p€ = Precambrian rocks; PL = lower Paleozoic rocks; Pu = upper Paleozoic rocks; K = Cretaceous rocks; Tlr = Love Ranch Fm.; Tv = middle Tertiary volcanic rocks; Q = Quaternary rocks and sediment.

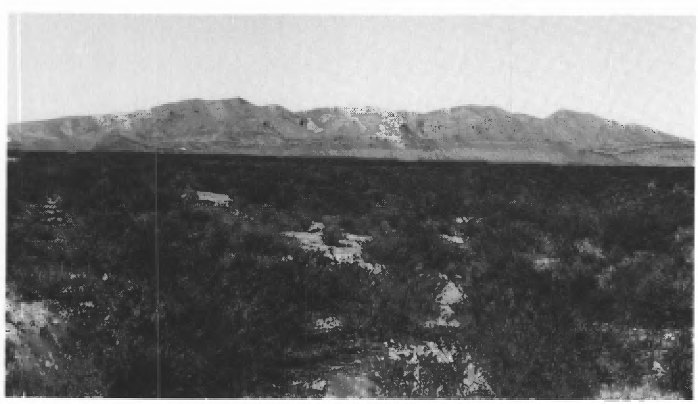


FIGURE 3-53.0—Red House Mtn. on skyline is an eastward-tilted domal uplift of Paleozoic strata. Lower ridge in front of Red House Mtn. is Taylor Ridge, an eastward-overturned anticline which marks the boundary between the Laramide Love Ranch Basin and Rio Grande uplift. Stops 1 and 2 at the northern end of the ridge provide excellent views of the structure.

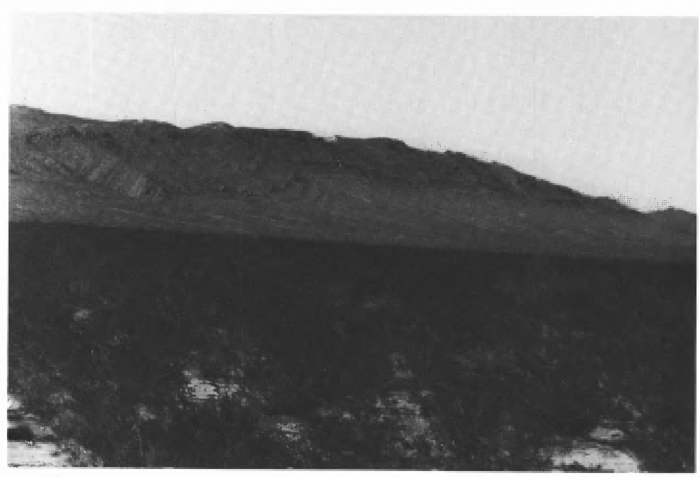


FIGURE 3-54.6—View looking northward at overturned limb of Taylor Ridge anticline. Note fold hinge exposed in canyon wall on left.

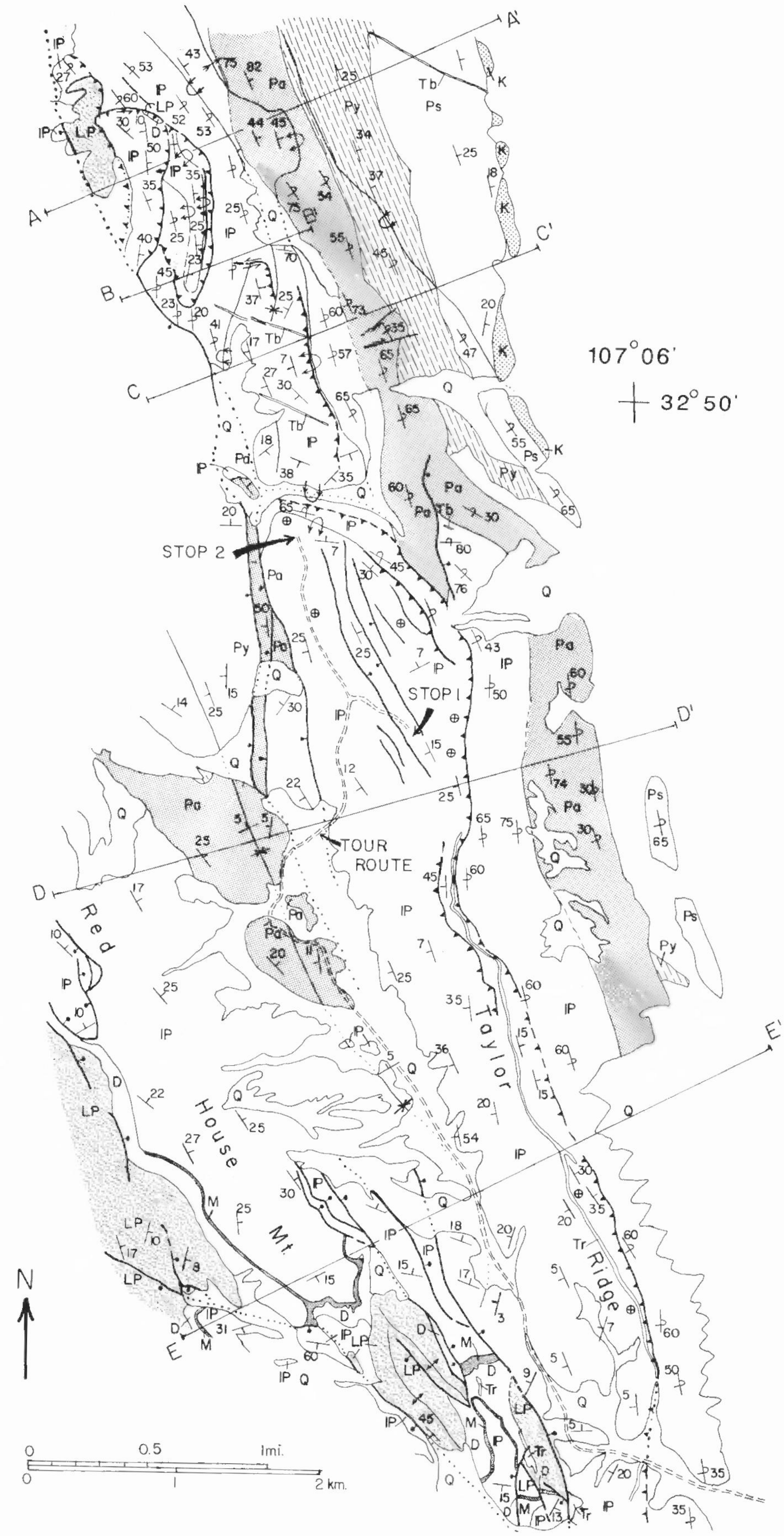


FIGURE 3-54.9—Geologic map of Red House Mtn.-Taylor Ridge area, southeastern Caballo Mtns. LP = pre-Devonian lower Paleozoic rocks; D = Percha Sh.; M = Lake Valley Fm.; IP = Pennsylvanian rocks; Pa = Abo Fm.; K = Cretaceous rocks; Tr = Tertiary rhyolite dike; Tb = Tertiary basaltic-andesite dikes; Q = Quaternary rocks and sediment. See Fig. 3-56.3 for cross sections.

56.0 Fusselman Dolomite forms ridge crest on skyline at 9:00. Downfaulted Pennsylvanian limestone forms ledges and hills in foreground in left. From here northward the road follows a synclinal valley between Red House Mtn. and the Taylor Ridge anticline. **0.3**

56.3 At this point we cross section E, Fig. 3-56.3. Good view northward along hinge of synclinal valley followed by road. Abo red beds and Yeso–San Andres Fm. crop out along hinge at 12:00, a result of the shallow northward plunge of the syncline. **1.0**

57.3 Stock tank on right. Good view of limbs of synclinal valley to the left on Red House Mtn. (Fig. 3-57.3) and right on Taylor Ridge. Abo and Yeso–San Andres strata ahead mark trough of syncline. **0.8**

58.1 Road junction. **Turn right.** Abo hills on both sides of road. **0.3**

58.4 Road junction. **Turn right again. 0.3**

58.7 Road begins ascent of Taylor Ridge in Upper Pennsylvanian limestone. Road was constructed in early 1980's in connection with extensive test drilling of Pennsylvanian limestone to determine its suitability for cement production. **0.6**

59.3 Road junction. **Bear right. 0.3**

59.6 **STOP 1.** Follow flagperson's directions. Good view of synclinal valley just traversed from 12:00 to 3:00. After climbing to the summit of Taylor Ridge for an overview of Taylor Ridge anticline, discussion will focus on local and regional Laramide tectonics.

Section D, Fig. 3-56.3 presents a northeast–southwest cross section approximately through Stop 1. The Taylor Ridge overturned anticline marks the common boundary between the Love Ranch Basin to the east and a block of the Rio Grande uplift to the southwest. In the basin, thick (915–1,220 m) Cretaceous and lower Tertiary strata are still preserved. They crop out along the eastern foothills of the Caballo Mtns. and have been penetrated by the Exxon No. 1 Prisor well located east of Point of Rocks. In contrast, on the Rio Grande uplift, which comprises most of the southern Caballo Mtns., Cretaceous rocks were almost completely eroded by early Tertiary time, so that lower Tertiary fanglomerate (Love Ranch Fm.) overlies Paleozoic or locally (Red Hills) Precambrian rocks. South of the southern Caballo Mtns., a structurally higher part of the Rio Grande uplift exposed lower Paleozoic and Precambrian rocks; this uplift was the main source of lower Tertiary fanglomerate that spread northeastward across the Rio Grande uplift "bench" of the southern Caballos into the Love Ranch Basin.

Consequently, as shown in Fig. 3-2 sum., the Rio Grande uplift consists of at least two structural blocks: a high southern block that is now largely buried beneath the Hatch–Rincon and southern Palomas Valleys, and a lower "bench" now fragmented into the fault blocks of the southern Caballo Mtns. Evidence for the first block includes clast composition and transport directions in Love Ranch fanglomerate, as well as an exposure of the uplift near San Diego Mtn. (Stop 3). Evidence for the second block is the sub-Love Ranch unconformity across the southern Caballo Mtns. as well as the uplift-boundary fold–thrust belt on which Stop 1 and Stop 2 are located.

Both blocks of the Rio Grande uplift appear to be large, southwest-tilted blocks which trend northwest and face northeast. Their folded and thrusted northeastern margins indicate tectonic transport toward the northeast. (Derry Hills folds and thrusts reveal southwesterly transport.) Southwestern dip slopes are broad and gentle, interrupted locally by normal fault-line scarps. Southerly dips on the southwestern flanks are indicated by the gradual truncation of Paleozoic and Precambrian rocks southward to Las Cruces. The southwestern flank plunges into a Wind River-type basin (Potrillo Basin) filled with as much as 1,830 m of lower Tertiary clastics penetrated by the Grimm and other oil tests in southern Doña Ana County (Thompson 1983). Two other similar Laramide block uplifts with complementary basins have been described in southwestern New Mexico by Seager (1983) and Seager & Mack (1986).

The northeastern structural boundary of the Rio Grande uplift exposed at this stop and Stop 2 can be traced along the eastern and central part of the southern Caballo Mtns. Exposed almost continuously for 24 km or more, the zone of tight, overturned folds and associated thrusts is only about 1 km wide, although locally (north of Stop 2) it widens to 2 km as the structure bifurcates. Along the southern margin of Timber Mtn. the belt turns west–northwest and is truncated by the Caballo fault, the late Tertiary frontal fault of the northern Caballo Mtns. Presumably the fold–thrust belt continues northwestward beneath the basin fill of Apache and Palomas Basins.

The most important structure in the Caballo deformed belt is an overturned, faulted anticline–syncline pair, the overturning commonly approaching recumbent geometry, as on Taylor Ridge (Fig. 3-56.3, secs. D, E). Locally, as north of Stop 2, the structure bifurcates into two fold pairs which step the section down to the northeast (Fig. 3-56.3, sec. A). Maximum structural relief across the zone is 1,830 m or more. At high structural levels, such as Taylor Ridge, minor thrust faults disrupt anticline cores or offset overturned fold limbs (Fig. 3-56.3, secs. B, D, E). At lower levels, thrust or reverse faults are more important. They display up to 300 m of stratigraphic separation and juxtapose upright lower Paleozoic rocks in the core region of anticlines against overturned limbs (Fig. 3-56.3, sec. A). At still deeper levels, a single exposure along the Caballo escarpment at the southern edge of Timber Mtn. shows that these faults transect basement at an angle of 60°. At San Diego Mtn. (Stop 3), a still deeper level of erosion reveals a major basement thrust dipping 30°. All thrust faults and axial planes of associated folds dip southwesterly.

The Rio Grande uplift and its complementary Love Ranch and Potrillo Basins appear similar to the Wind River or Owl Creek uplifts and adjacent basins of Wyoming, although the southern New Mexico structure probably exhibits less structural relief and may be smaller

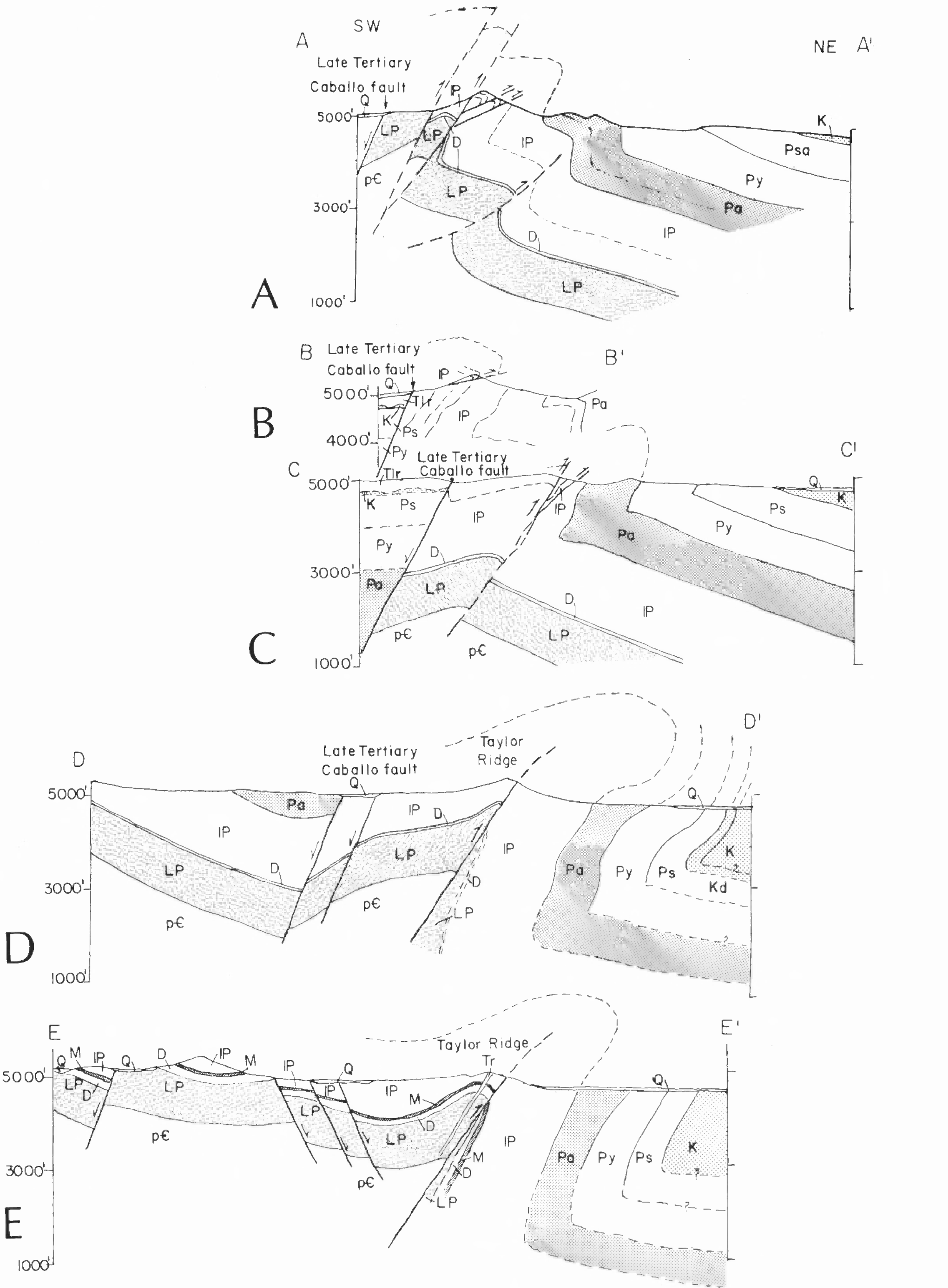


FIGURE 3-56.3—Cross sections of northeastern margin of Rio Grande uplift in southeastern Caballo Mtns. See geologic map, Fig. 3-54.9, for location of sections. p€ = Precambrian rocks; LP = pre-Devonian lowwer Paleozoic rocks; D = Percha Sh.; M = Lake Valley Fm.; IP = Pennsylvanian rocks; Pa = Abo Fm.; Py = Yeso Fm.; Ps = San Andres Fm.; Kd = Dakota Ss.; K = undifferentiated Cretaceous rocks; Tlr = Love Ranch Fm.; Tr = Tertiary rhyolite dike.

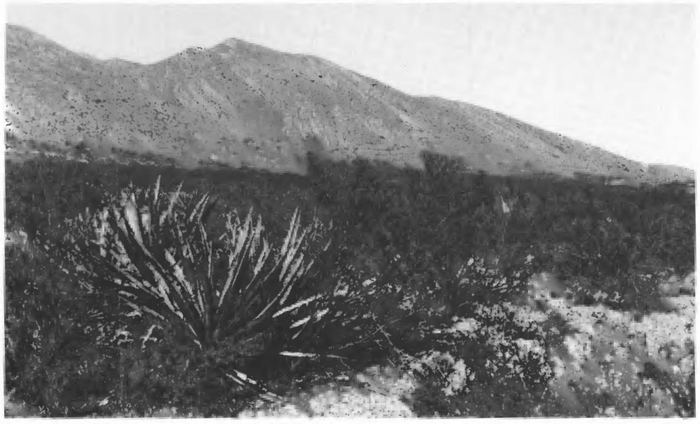


FIGURE 3-57.3—East-dipping Pennsylvanian strata on eastern dip-slope of Red House Mtn.

in areal extent. Like the Owl Creek uplift (Gries 1983), the Rio Grande uplift is a composite of at least two blocks which step the basement and cover rocks down to the adjacent basin in stair-step fashion. The relatively low dips (<60°) of boundary thrust or reverse faults and strongly overturned to nearly recumbent associated folds show that the Rio Grande uplift, like the Wind River and Owl Creek ranges, is the product of strong regional compression accompanied by substantial crustal shortening as well as vertical uplift. Retrace route to mileage 59.3. **0.3**

59.9 **Road junction. Turn right. 0.3**

60.2 Route is on Pennsylvanian limestone. Across valley at 9:00 ridge-forming Yeso siltstone, gypsum, and limestone are dropped against Pennsylvanian rocks by movement on late Tertiary Caballo fault, the frontal fault of the main Caballo Mtns. to the north. North of here the fault increases in displacement and is marked by the western escarpment of the Caballo Mtns. (Timber Mtn.) at 11:00. South of here the fault dies out in the synclinal valley followed by the tour route. Abo red beds in valley bottom at 9:00 are tectonic slices in the fault zone. **0.2**

60.4 **STOP 2.** Follow flagperson's direction for parking. This stop features a panoramic view of the northeastern margin of the Rio Grande uplift where the single fold of Taylor Ridge bifurcates into two overturned anticline–syncline pairs. Cross sections A, B, C of Fig. 3-56.3 depict the structural features of the ridges and hills just north of Stop 2. Figs. 3-60.4a, 3-60.4b, and 3-60.4c provide further details of the structure. Short (0.4 km) or moderately long (2.4 km) hikes will be taken to view: (1) hinge of major overturned anticline; (2) thrust faults in common overturned limb of major anticline and syncline (Fig. 3-60.4b); and (3) exposures of Love Ranch Fm. Return to road junction at mileage 59.1 **0.5**

60.9 Road junction. **Turn right,** retrace route back to Upham interchange on I-25. **0.8**

61.7 Road junction. **Turn left. 0.4**

62.1 Road junction. **Turn left. 3.1**

65.2 Skirt southern end of Taylor Ridge, leave Laramide Rio Grande uplift and enter Laramide Love Ranch Basin. **4.0**

69.2 Gate. Pass through, cross railroad tracks, and pass through second gate. **1.8**

71.0 Gate at southeastern corner of corral. **Bear right** after passing through gate. **0.2**

71.2 Engle–Upham road. **Turn right. 1.3**

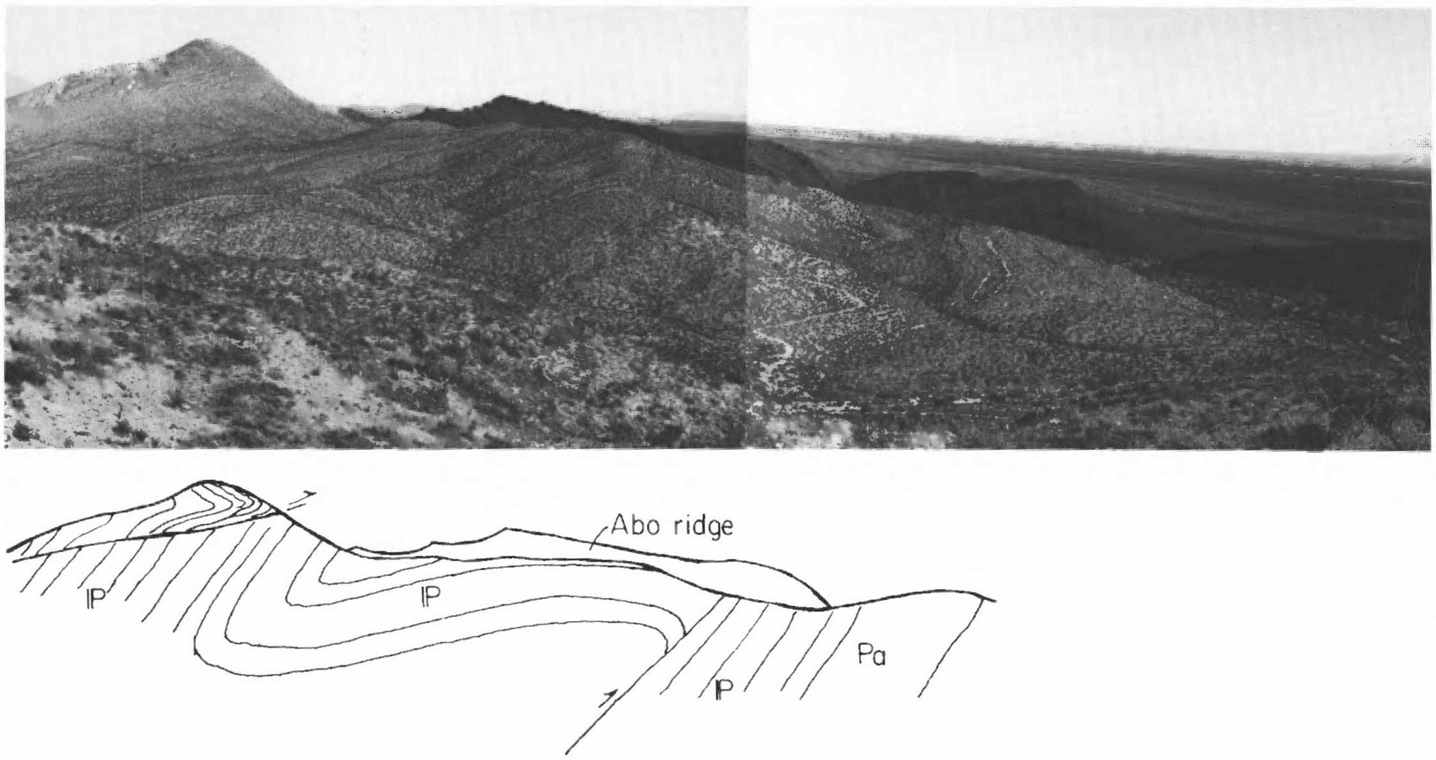
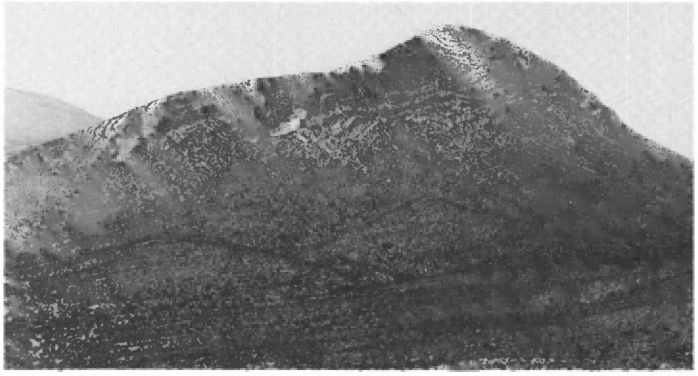


FIGURE 3-60.4a—Panoramic view northward from Stop 2. Accompanying diagrammatic sketch illustrates general structural features. IP = Pennsylvanian rocks; Pa = Abo Fm.



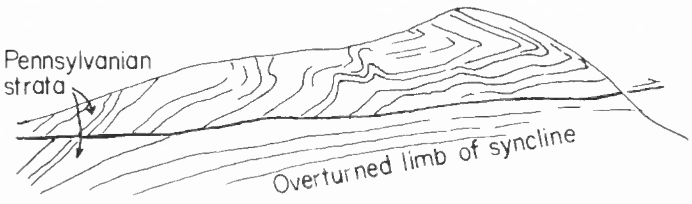


FIGURE 3-60.4b—Thrust-faulted overturned fold at Stop 2. Sketch illustrates details of structure.

72.5 Cattleguard. **Turn right** after crossing guard. **2.1**

74.6 Cattleguard. Organ Mtns. at 9:30, Doña Ana Mtns. at 10:00, Robledo Mtns. on skyline at 11:00, San Diego Mtn. closer at 11:00, and Sierra de las Uvas forms skyline from 12:00 to 1:30. **3.3**

77.9 Upham interchange. **Pass beneath I-25,** continue straight ahead, and then **bear left** across cattleguard onto unpaved frontage road heading south. **1.7**

79.6 Dirt road to right. **Continue straight ahead. 2.0**

81.6 Earthen stock tank ahead on right. **Turn right** for short loop drive and panoramic view of Tonuco uplift. **0.15**

81.75 Panoramic view of Tonuco uplift (Fig. 3-81.75). High, flat-top ridge on skyline at 2:30 is San Diego Mtn. composed of tilted, partly silicified "early rift" deposits of the Hayner Ranch Fm. Lower hills and gullied ridge to the right and left of San Diego Mtn. are part of a narrow horst of Precambrian granite. The prominent bench in the foreground with cliffs facing the viewer is formed by partly silicifed Camp Rice fluvial sandstone and conglomeratic sandstone. The Camp Rice is downfaulted against the horst of Precambrian rocks, but also overlaps onto the Precambrian. At Stop 3 we will examine this boundary fault of the Tonuco uplift as well as a window through the Precambrian which exposes the major thrust-fault boundary of the Laramide Rio Grande uplift. **0.05**

FIGURE 3-60.4c—Overturned syncline along southern edge of Timber Mtn. is northwestward continuation of Rio Grande uplift margin folds seen at Stops 1 and 2. Along western (left) side of escarpment, Precambrian rocks are thrust against overturned limb of syncline.

81.8 Gate, south side of tank. Continue loop drive back to frontage road. **0.1**

81.9 Frontage road junction. **Turn right. 0.7**

82.6 Gate ahead. **Turn right just before gate. 0.2**

82.8 Descend into abandoned gravel pit in Camp Rice fluvial gravel, sand, sandstone, and conglomeratic sandstone. **Bear right through pit. 0.2**

83.0 Ascend ridge, follow road along ridge crest to power line ahead. **0.2**

83.2 Power line. **Turn right,** follow power-line road west. **Four-wheel drive recommended beyond this point.** Outcrops near road are conglomeratic sandstone and sandstone of Camp Rice Fm. **0.2**

83.4 Pink to white bluffs across arroyo at 10:00 are Camp Rice fluvial sandstone and conglomeratic sandstone faulted against and overlapping onto Precambrian granite core of Tonuco uplift. High ridge on skyline is Hayner Ranch Fm. in San Diego Mtn. Precambrian granite, near Stop 3, forms noselike ridge projecting into major arroyo at 11:30. **0.8**

84.2 **STOP 3.** Cross sandy tributary arroyo and park, following flagperson's instructions. Hike about 0.5 km south of parking area to narrow canyon in Precambrian rocks and then up canyon a hundred meters or so.

The main purpose of this stop is to view an exposure of the main boundary thrust fault of the Rio Grande uplift. Fig. 3-84.2a shows the thrust fault in relationship with the local geology of the late Tertiary Tonuco uplift, and Fig. 3-2 sum. shows the location of the thrust on the regional Laramide paleogeologic map. Hanging wall of the thrust fault is sheared Precambrian granite and the footwall is silicified Paleozoic limestone (Fig. 3-84.2b). A small patch of unsilicified limestone can be found in one place beneath the thrust. The thrust fault strikes approximately N35W and dips 30°SW. The deformation here is approximately on strike with a similar narrow zone of basement thrusts exposed in the southern San Andres Mtns. (Bear Peak fold and thrust zone; Seager 1981). The zone of thrusts is also revealed in a seismic-reflection profile across the Jornada del Muerto between here and the San Andres Mtns. (Keller et al. in this guidebook; see Fig. 3-2 sum. for location of profile). The northwestern continuation of the thrust beneath the Hatch–Rincon–southern Palomas Valley may have produced the basement uplift that supplied the large volume of Precambrian and lower Paleozoic detritus to the Love Ranch Fm. of the southern Caballo Mtns. (Fig. 3-2 sum).

A regional unconformity at the base of the Love Ranch Fm. supports the interpretation that the basement thrust exposed here in the Tonuco uplift is at the northeastern

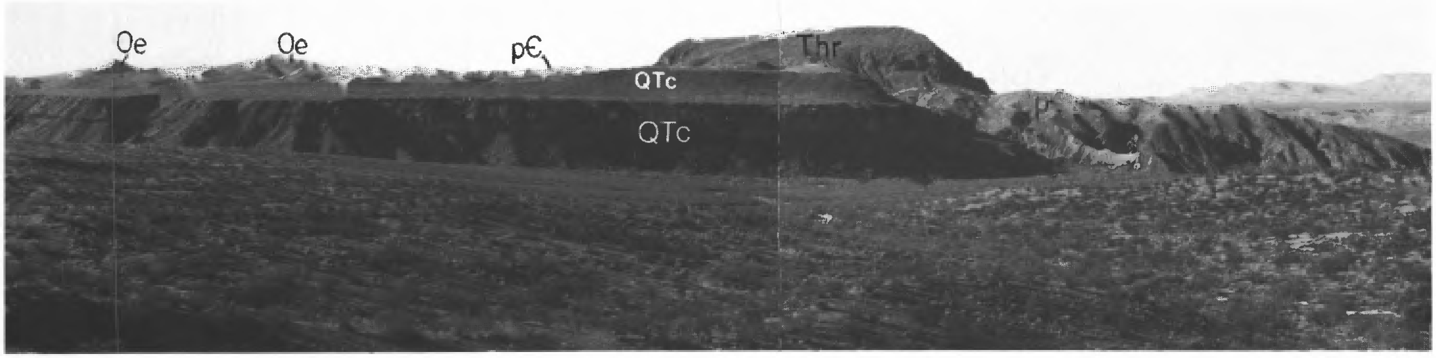


FIGURE 3-81.75—Panoramic view of Tonuco uplift. San Diego Mtn. is flat-topped mountain at center skyline. Sierra de las Uvas forms skyline on right. p€ = Precambrian granite; Oe = El Paso Fm.; Thr = Hayner Ranch Fm.; QTc = Camp Rice fluvial deposits. Note fault-line scarp in Camp Rice beds just above prominent bench in center foreground. This is the boundary fault of late Tertiary Tonuco horst.

margin of a major Laramide fault block. About 100 m above and to the west of the thrust fault about 5 m of Love Ranch conglomerate depositionally overlies Precambrian granite (Fig. 3-84.2a), indicating uplift and erosion of at least 2,134–2,440 m of Paleozoic and Mesozoic strata by late Eocene time. Movement on the exposed thrust almost certainly resulted in this uplift.

Farther south toward Las Cruces, a thin veneer of Love Ranch conglomerate overlies successively younger Paleozoic rocks, and southwest of Las Cruces Mesozoic and thick lower Tertiary basin clastics were preserved in the Potrillo Basin (Thompson 1983). These relationships are the basis for construction of the southern two-thirds of the cross section of Fig. 3-2 sum., which depicts the Rio Grande uplift as a southerly tilted, Wind River or Owl Creek-style fault block.

Exposures of the deformed Rio Grande uplift margin in the Caballo Mtns., Tonuco uplift, and San Andres Mtns. may represent different levels of erosion. Folds and minor thrusts on Taylor Ridge may be shallowest; 60° dipping reverse faults cutting basement north of Taylor Ridge and in the San Andres Mtns. are just below the Paleozoic cover and may represent intermediate levels; and the 30° dipping thrust in the Tonuco uplift may represent a somewhat deeper level. If these observations are valid, the exposures taken collectively may indicate that the marginal faults of the Rio Grande uplift dip approximately 30° southward and are planar at depth,

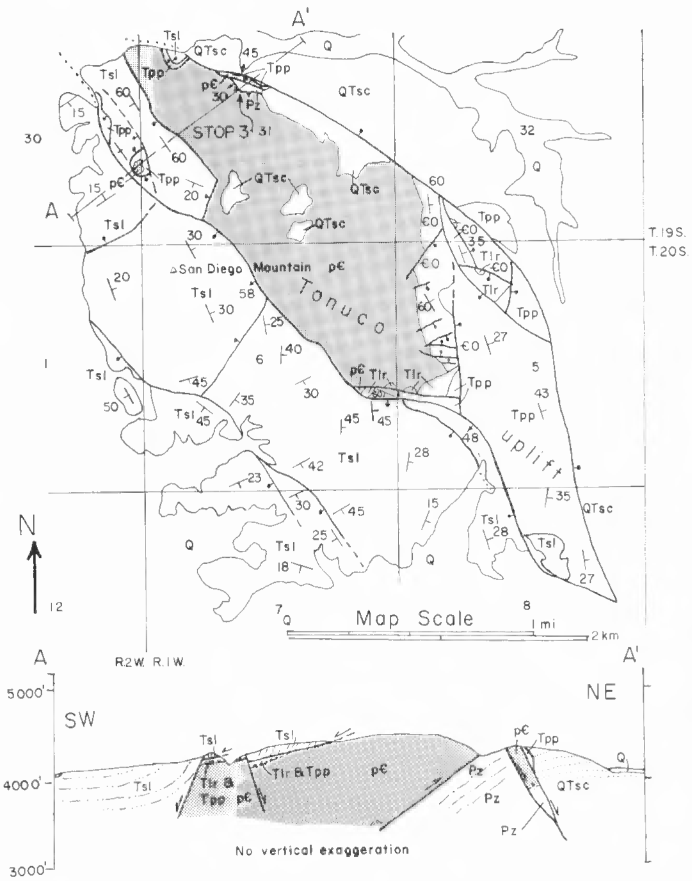


FIGURE 3-84.2a—Geologic map and section of late Tertiary Tonuco uplift. The section features the northeastern boundary thrust of the Laramide Rio Grande uplift, and also shows the location of thin Love Ranch conglomerate lying in depositional contact on Precambrian rocks. p€ = Precambrian rocks; €O = Bliss Ss. and El Paso Fm.; Pz = silicified Paleozoic rocks; Tlr = Love Ranch Fm.; Tpp = Palm Park Fm.; Tsl = lower Santa Fe Gr.; QTsc = Camp Rice Fm.; Q = upper Quaternary sediments. From Seager et al. (1971).

FIGURE 3-84.2b—Thrust fault exposed at Stop 3. Hanging wall is sheared Precambrian granite, footwall is silicified Paleozoic limestone. Fault dips 30° southwest and is interpreted to be the main boundary thrust of the Rio Grande uplift in this area.

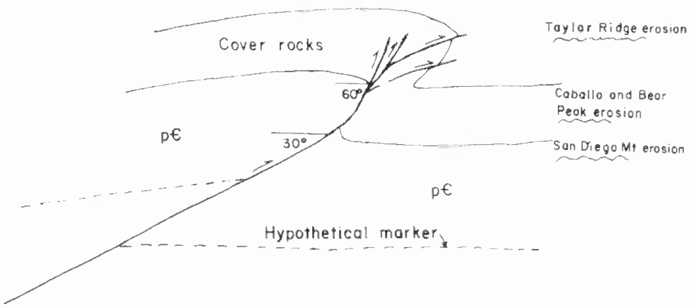


FIGURE 3-84.2c—Sketch of possible geometry of boundary thrusts of Laramide Rio Grande uplift, based on different depths of exposures in Caballo and San Andres Mtns. and in Tonuco uplift. p€ = Precambrian rocks.

steepen to 60° as they approach Paleozoic cover rocks, and then die out upward into huge overturned, locally almost recumbent folds whose cores and limbs are broken by minor thrusts (Fig. 3-84.2c). Faults of similar geometry have been interpreted from seismic-reflection profiles in Wyoming (Gries 1983).

A secondary purpose of this stop is to view the late Tertiary boundary fault of the Tonuco uplift, exposed at the mouth of the canyon that leads to the thrust-fault exposures (Fig. 3-84.2d). The fault places Camp Rice fluvial deposits against Precambrian granite, although there are local slivers of purple Palm Park volcaniclastic rocks. The fault contact along one of these slivers is exposed on the southeast side of the canyon; it strikes northwest and dips 45°NE. Whether this low angle is typical of the fault zone as a whole or is just a local dip in a branching and anastomosing system of fault slivers is not known. Camp Rice beds on the downthrown side of the fault are at least 90 m thick, whereas on the upthrown side much thinner Camp Rice beds overlap the Precambrian, Laramide thrust fault, and silicified Paleozoic rocks. Note offset of the Camp Rice beds by 30 m or more as a result of late Quaternary movement on the fault. Hot-spring deposits of late Pleistocene age occur locally along the fault and may be responsible for the discontinuous silicification of Camp Rice strata.

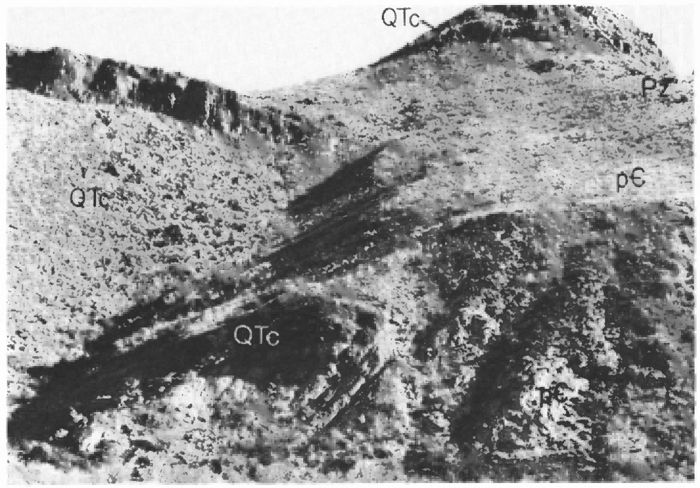


FIGURE 3-84.2d—Late Tertiary northwestern boundary fault of Tonuco uplift at Stop 3, looking southeast. Late Quaternary movement has offset upper cliffs of silicified Camp Rice fluvial sandstone. Camp Rice deposits in upper right cliff are thin and overlap onto Precambrian granite and silicified Paleozoic rocks. Cliff-forming Camp Rice strata on the downthrown side of the fault (to the left) are underlain by at least 90 m of older Camp Rice fluvial strata which are in fault contact with Precambrian rocks or slivers of Palm Park Fm. p€ = Precambrian granite; Pz = silicified Paleozoic rocks; Tpp = Palm Park Fm.; QTc = Camp Rice fluvial strata.

At the conclusion of Stop 3, the caravan will disband.

End of trip.