Second-day road log, from Truth or Consequences to Fra Cristobal Range via Elephant Butte dam, northern Caballo Mountains, Cutler Sag, and Jornada del Muerto

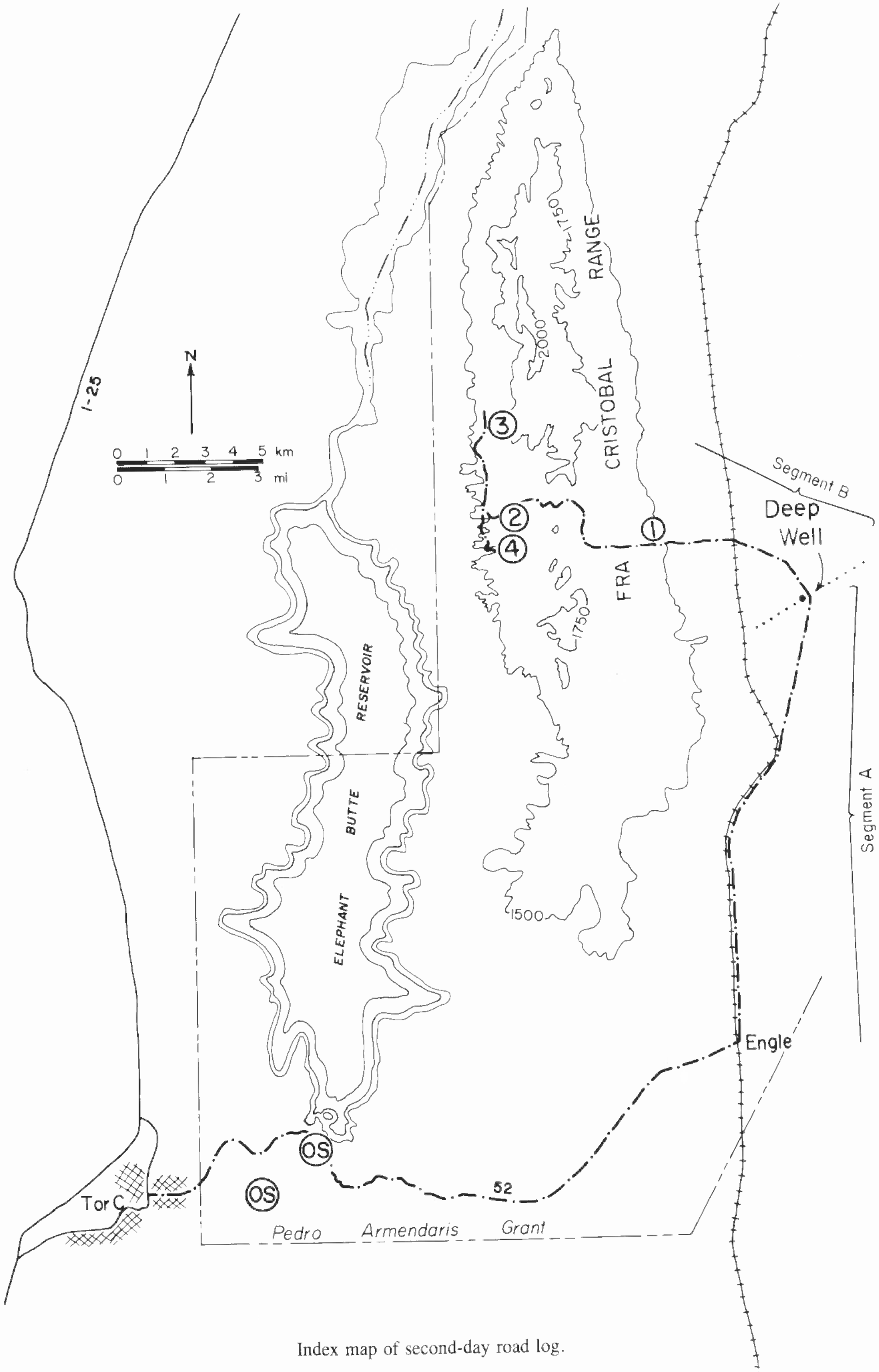
Richard P. Lozinsky, Glenn R. Osburn, and Richard W. Harrison

1986, pp. 21-28. https://doi.org/10.56577/FFC-37.21

in:

Truth or Consequences Region, Clemons, R. E.; King, W. E.; Mack, G. H.; Zidek, J.; [eds.], New Mexico Geological Society 37th Annual Fall Field Conference Guidebook, 317 p. https://doi.org/10.56577/FFC-37

This page is intentionally left blank to maintain order of facing pages.



Index map of second-day road log.

SECOND-DAY ROAD LOG, FROM TRUTH OR CONSEQUENCES TO FRA CRISTOBAL RANGE VIA ELEPHANT BUTTE DAM, NORTHERN CABALLO MOUNTAINS, CUTTER SAG, AND JORNADA DEL MUERTO

Assembly point: Deep Well Ranch (mile 26.6, Segment A)
Departure time: 8:00 from Deep Well
Distance: 79.6 mi roundtrip from T or C
Segment A: 27.4 mi
Segment B: 24.8 mi
Retrace A: 27.4 mi
Stops: 6 (2 optional)

SUMMARY

The second day's tour is divided into two segments, A and B. Segment A covers the region from Truth or Consequences to the Jornada del Muerto (Deep Well Ranch) and Segment B takes us on a tour of the Fra Cristobal Range. Segment A describes the Tertiary and Quaternary Palomas Fm., Quaternary terrace deposits, Cretaceous and early Tertiary stratigraphy, and Pliocene basalts. Laramide deformation and the McRae Fm. are emphasized at optional stops. Segment B emphasizes (1) Paleozoic stratigraphy (units from the Cambrian–Ordovician Bliss Ss. to the Permian San Andres Fm.), and (2) Laramide structures.

Access to the Fra Cristobal Range is available by special arrangement for this conference. The range is entirely private land, part of the Pedro Armendaris Grant. Surface rights are owned by Oppenheimer Industries Inc. and the mineral rights belong to Tenneco Minerals. **Access is granted for the conference only. Individuals and groups may not return for subsequent tours.** Please abide by these restrictions and preserve good landowner relations for those persons with research access agreements. Optional stops are provided in Segment A for future use.

The tour begins at the stoplight near the courthouse in T or C (intersection of Date Street with NM-51) and proceeds east on NM-51 toward Elephant Butte Dam across the Palomas Fm. and several levels of Quaternary terraces cut by the Rio Grande. The route crosses the Hot Springs fault, western bounding fault of the northern Caballo Mtns., onto Cretaceous strata. The northern Caballo Mtns. are the site of Optional Stop 1. This stop provides a walking tour of a large Laramide fold similar in some respects to deformation seen at Stop 3 in the Fra Cristobal Range. This fold is a large, asymmetrical, upright to overturned syncline whose vertical western limb forms Turtle Mtn. Excellent exposures of Pennsylvanian, Permian, and Cretaceous strata can also be seen here. Cretaceous Crevasse Canyon Fm. and Cretaceous–Tertiary McRae Fm. border the route for the next several miles past Elephant Butte Dam and through Cutter sag, a topographic and structural low between the Caballo Mtns. and Fra Cristobal Range. The McRae Fm. is highlighted at Optional Stop 2. The route continues east to the Jornada del Muerto. Thin alluvium covers the shallow bedrock of the Jornada in most places and Pliocene basalts locally cap the surface both north and south of the route.

The caravan will assemble at Deep Well Ranch and follow road-log Segment B. This route initially traverses the east-dipping western slope of the Jornada del Muerto. Stop 1 provides an overview of the eastern side of the Fra Cristobal Range, a gentle, east-dipping homocline broken by a few normal faults along the eastern range front. The route next traverses the range through Red Gap, mainly on Permian Abo and Yeso strata. Stop 2, on the Abo and Yeso Fms., is at the boundary between the relatively undeformed eastern, and the highly deformed western parts of the range. At this locality, the boundary is a down-to-the-west normal fault. The route continues west and then north along the western margin of the range to Stop 3, where a spectacular Laramide basement-cored anticline is exposed. This locally overturned fold is straight-limbed, has a fairly tight angular hinge, and is paired with an overturned syncline in Pennsylvanian strata to the east. The Precambrian granite core and the surrounding unconformity with the Bliss Fm. are very well exposed, as are the Cambrian and Ordovician sections on the eastern vertical limb of the anticline. Basaltic flows and agglomerates, related to a nearby Pliocene(?) vent, cap the ridge a short distance north of the stop. From Stop 3 the tour travels back south along the range front and climbs higher in the stratigraphic section to look at Laramide(?) thin-skinned structures in the Yeso Fm. (Stop 4). These structures illustrate a marked contrast in deformational response to the same(?) tectonic event that produced the large folds viewed at Stop 3. Here the tour ends for the day and returns along the entry route to T or C.

SEGMENT A, FROM TRUTH OR CONSEQUENCES TO DEEP WELL ASSEMBLY POINT

R.P. LOZINSKY, G.R. OSBURN and R.H. HARRISON
New Mexico Bureau of Mines & Mineral Resources, Socorro, NM 87801

Mileage

0.0 Starting Point: Traffic light at corner of Date (US-85) and 3rd (NM-51) Avenues in T or C. Sierra County Courthouse building on northeast corner of intersection. **Proceed east on 3rd (NM-51) toward Engle.** For next 0.5 mi traveling on Rio Grande terrace level 4 of Lozinsky (1986) that is cut into the piedmont facies of the Palomas Fm. This late Pleistocene terrace is about 18–24 m above the present Rio Grande floodplain. **0.5**

0.5 Gold Street intersection. View of northern Caballo Mtns. from 12:00 to 2:00. Red beds at 12:00 are Permian Abo and Yeso strata that overlie Pennsylvanian limestone at 2:00. **0.1**

0.6 Silver Street intersection. Ascend to Rio Grande terrace level 3 of Lozinsky (1986). This late Pleistocene terrace stands 24–30 m above present floodplain. Terrace levels 3 and 4 are remnants of a meander loop that once extended into this area. Low hill at 2:00 is Ordovician Montoya Fm. dolomite. **0.3**

0.9 Permian San Andres limestone forms highest ridge in the northern Caballo Mtns. at 1:00. Dark-colored silicified zone at base of mountain front is in the Hot Spring fault zone which bounds Caballo Mtns. on west. Silicified zone contains low-grade manganese mineralization. Pinkish-red beds on west side of fault are Palomas Fm. piedmont sediments. **0.1**

1.0 Descending from Rio Grande terrace level 3 to terrace level 4. **0.5**

1.5 Descending from terrace level 4 to Rio Grande floodplain. Roadcut sequentially exposes fine-grained sands, terrace gravels, and fanglomerates of the Palomas Fm. (for measured section see section 4, p. 32, of Lozinsky 1986). Clasts in the terrace gravels include porphyritic volcanics, basalt, Abo and Crevasse Canyon sandstone and granite, whereas the Palomas Fm. contains Paleozoic and Mesozoic clasts (Abo, Crevasse Canyon sandstone, San Andres, and Magdalena limestone). **0.2**

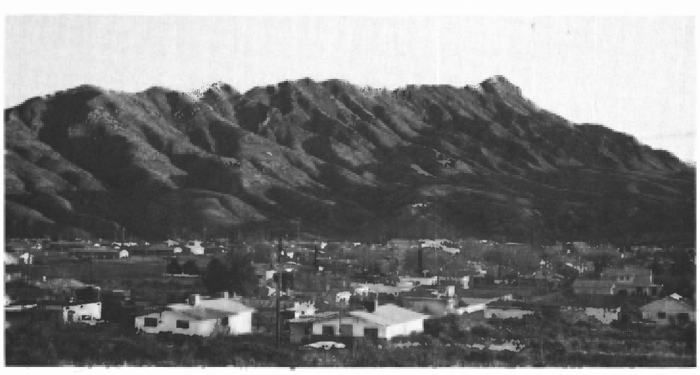


FIGURE 2A-0.5—View of northern Caballo Mtns. Crest of Turtle Mtn. consists of steeply dipping Pennsylvanian limestones. Palomas Fm. makes up gentler slopes at foot of mountain. Houses in foreground sit on Terrace level 3 (Lozinsky 1986).

1.7 Cross abandoned meander channel of Rio Grande. For next mile traveling on a former meander loop of the Rio Grande that the U.S. Bureau of Reclamation cut off in the early 1940's to establish the Rio Grande into its present course just southeast of the road. **0.3**

2.0 Note Rio Grande terrace levels 4 and 5 at 8:00. Terrace level 5 stands 6–12 m above the present river level and ranges in age from 8,000 to 25,000 yrs (late Pleistocene–early Holocene; Lozinsky 1986). **0.2**

2.2 Bridge over Cuchillo Negro Creek. Rio Grande channel from Cuchillo Negro Creek to Williamsburg was enlarged from 2,500 CSF capacity to 5,000 CSF in 1985 to accommodate larger releases from Elephant Butte Dam. Before this enlargement, releases above 2,500 CSF would have flooded large areas of T or C built on the floodplain of the Rio Grande. **0.2**

2.4 Hot Springs fault extends up arroyo at 11:00. Tilted piedmont facies of the Palomas Fm. (west) are downthrown against Late Cretaceous Mesaverde beds. The Hot Springs fault is mainly a normal fault, downthrown to the west, that dips 70–80° to the west. Some right-lateral strike–slip motion is also suggested by displaced San Andres beds at mile 2.6. Mason (1976) estimated vertical displacements between 620 and 2,740 m in the northern Caballo Mtns. a few miles to south; here vertical separation is about 1,220 m. **0.1**

2.5 Junction with NM-135. **Continue on NM-51.** Crossing concealed segments of Hot Springs fault and entering Elephant Butte Canyon. Pond on left just past intersection is part of the cutoff meander channel now called Mim's Lake, a manmade oxbow lake. Exposures to left are Late Cretaceous Tres Hermanos Fm. **0.1**

2.6 Cross another concealed splay of the Hot Springs fault. At 9:00 this fault splay can be seen where the Tres Hermanos Fm. suddenly steepens. Rio Grande terrace level 3 caps mesa here and is not offset by the fault. A fault-bounded slice of folded and broken San Andres limestone at 3:00 across river suggests about 460 m right-lateral offset on the Hot Springs fault. **0.1**

2.7 Mouth of Mescal Creek across river at 3:00. Creek has cut primarily into Mancos Sh. Excellent exposures of conformable contact between the Tres Hermanos Fm. and Mancos Sh. can be seen along east side of valley. (Optional Stop 1 up this canyon.) Roadcuts in Tres Hermanos Fm. and D-Cross Mbr. of Mancos Sh. Terrace levels 4 and 5 cap mesa at 9:00. **0.4**

3.1 Entering Elephant Butte State Park, cross bridge over

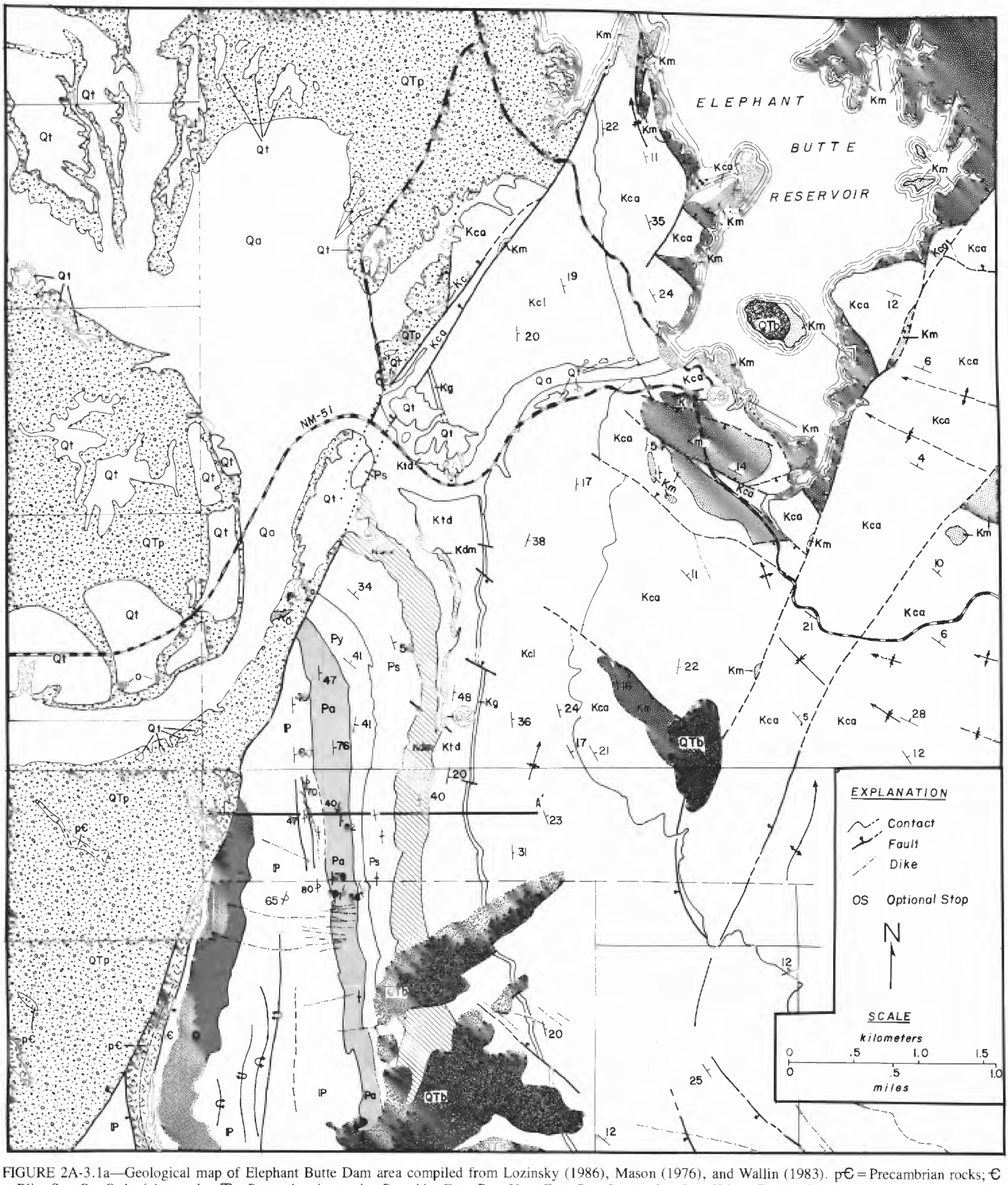


FIGURE 2A-3.1a—Geological map of Elephant Butte Dam area compiled from Lozinsky (1986), Mason (1976), and Wallin (1983). p€ = Precambrian rocks; € = Bliss Ss.; O = Ordovician rocks; IP = Pennsylvanian rocks; Pa = Abo Fm.; Py = Yeso Fm.; Ps = San Andres Ls.; Kdm = Dakota Ss. and Mancos Sh.; Ktd = Tres Hermanos Fm. and D-Cross Tongue of Mancos Sh.; Kg = Gallup Ss.; Kcl = lowr mbr. of Crevasse Canyon Fm.; Kca = Ash Canyon Mbr. of Crevasse Canyon Fm.; Km = McRae Fm.; QTp = Palomas Fm.; QTb = basalt flows; Qt = terrace deposits; Qa = undivided alluvium.

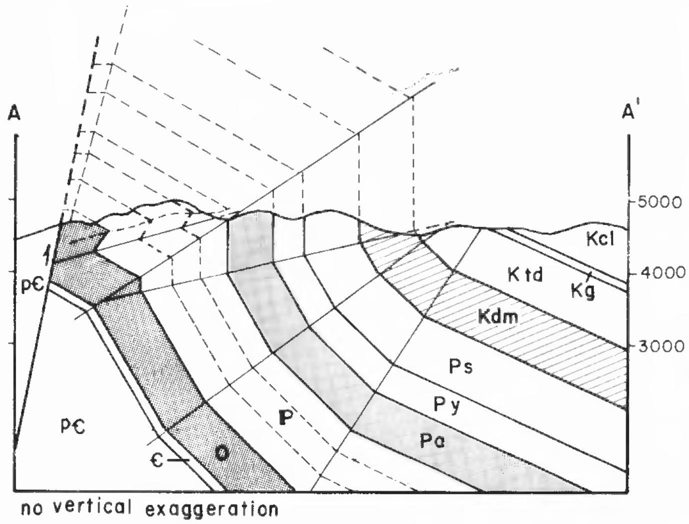


FIGURE 2A-3.1b—Geologic cross section through northern Caballo Mtns. illustrating nature of structural deformation.

FIGURE 2A-3.1c—View north along vertical San Andres Ls. beds; western limb of syncline near Optional Stop 1.

FIGURE 2A-3.1d—View of southern wall of Palomas Gap illustrating sharp nature of fold. Fold hinge and bedding accentuated locally by lines. (Photo C.H. Maxwell).

FIGURE 2A-3.1e—Tight fold on north flank of Turtle Mtn. Lower limb, in foreground, is overturned and dips 40–50° west. Upper limb dips about 20° east and is upright. Hinge-plane trace is nearly horizontal and extends across hill through obvious fold nose.

Rio Grande. **Continue ahead for assembly.** For next 1.5 mi traveling through progressively younger, east-dipping beds of the Mesaverde Gr. In this area, Wallin (1983) divided the Mesaverde Gr. into the Gallup Ss. and Crevasse Canyon Fm. The 22 m thick Gallup Ss. crops out in canyon at 3:00. Dirt road on right just after bridge leads to Mescal Canyon and west side of northern Caballo Mtns. and to Optional Stop 1. **0.1**

OPTIONAL STOP 1. Follow optional-stop log for 2.6 mi south up Mescal Canyon from mile 3.1 in main second-day log.

0.0 Junction at east end of bridge over Rio Grande. **Turn right** (south) on gravel road paralleling river. Several smaller roads lead to picnic areas along river to right over next 0.4 mi; continue on main road. **0.4**

0.4 Junction on right. **Keep left.** Highly fractured hill of Permian San Andres limestone ahead at 12:00. This block lies between two strands of the Hot Springs fault and is juxtaposed against Santa Fe deposits to the west and Cretaceous Mancos Sh. to the east. This San Andres block cannot be reasonably faulted to this position with normal displacement; therefore, about 0.5 km of right-lateral strike–slip displacement is postulated (Lozinsky 1986). **0.2**

0.6 Mescal Creek ahead. Several dirt tracks to left. Gravel road ahead provides access to west side of Caballo Mtns. **Turn left up road in main channel of Mescal Canyon.** Canyon is cut in Mancos Sh. as it wraps around nose of a plunging anticline. **1.1**

1.7 Junction. **Keep right** following canyon floor. Better road to left dead ends at Mescal Spring. Foot access east past Mescal Spring provides good exposures of the Crevasse Canyon Fm. **0.9**

2.6 Park at a convenient spot and begin walking tour of the northern Caballo Mtns. (see Fig. 2A-3.1a). From this point a wide variety of stratigraphic units can be viewed on relatively short walks. To the east the gently dipping

Cretaceous strata are well exposed. These units have been subdivided by Wallin (1983) into the divisions of Molenaar (1983). In more steeply dipping beds to the west, up the right fork of the canyon, Permian San Andres, Yeso, and Abo Fms. are well exposed. Pennsylvanian and lower Paleozoic strata are accessible by more strenuous walking routes over Turtle Mtn. or by following gravel road south at mile 0.6 for 1.5–2.0 mi along the west side of the Caballo Mtns.

Interesting structures are also visible in this area (Kelley & Silver 1952, Mason 1976). Fig. 2A-3.1a is a generalized geologic map of this area and Fig. 2A-3.1b a structure cross section. The major structure of the northern Caballos is a north-trending asymmetrical syncline and paired anticline which resemble hanging-wall structures above thrust faults (Suppe 1985). The hinge surface trace of this syncline is near the parking area and extends for several miles south at least to Palomas Gap (Fig. 2A-3.1d). The paired anticline is largely eroded and/or cut off by later faulting along the west side of the Caballo Mtns. The steep western limb of the syncline is further complicated by smaller, but still impressive, kink folds with gently dipping hinge planes (see Figs. 2A-0.5, 2A-3.1e, or Mason 1976). The major fold is similar to the major anticline–syncline pair seen in the Fra Cristobals. Differences are: (1) the folds deform younger units here, including those involved in thin-skinned deformation in the Fra Cristobals and (2) the anticline is not well exposed here. **Return to main route at mile 3.1.**

3.2 Paseo del Rio State Recreation area. Originally a fish hatchery, this area is now a campground and picnic area. From here to the dam, traveling through more than 700 m of Crevasse Canyon Fm. **0.3**

3.5 Rio Grande terrace level 4 deposits on left. **0.3**

3.8 Elephant Butte Dam and spillway at 12:00 with top of Elephant Butte visible. Paved road to left leads to U.S. Bureau of Reclamation Headquarters at base of dam. Large petrified logs displayed in front of headquarters. **0.3**

4.1 Roadcuts expose channel, crevasse-splay, and overbank deposits in Crevasse Canyon Fm. **0.2**

4.3 60 cm thick basaltic dike containing lherzolite inclusions in roadcut to right. **0.1**

4.4 Unconformable contact between Crevasse Canyon Fm. and overlying basal Jose Creek Mbr. of the McRae Fm. which is well exposed along road for next 0.4 mi. **0.1**

4.5 **OPTIONAL STOP 2. Park at convenient spot off road** to observe excellent exposures of conglomeratic Jose Creek Mbr. of the McRae Fm. Exposures in this area consist of pebble to boulder conglomerates, sandstone, and mudstone interbeds in varying proportions. Individual clasts are usually moderately to well rounded and most conglomerate beds are poorly sorted. Bedding attitudes are quite variable due to complex structural deformation and no effort was made (by us) to integrate these exposures into a composite stratigraphic section.

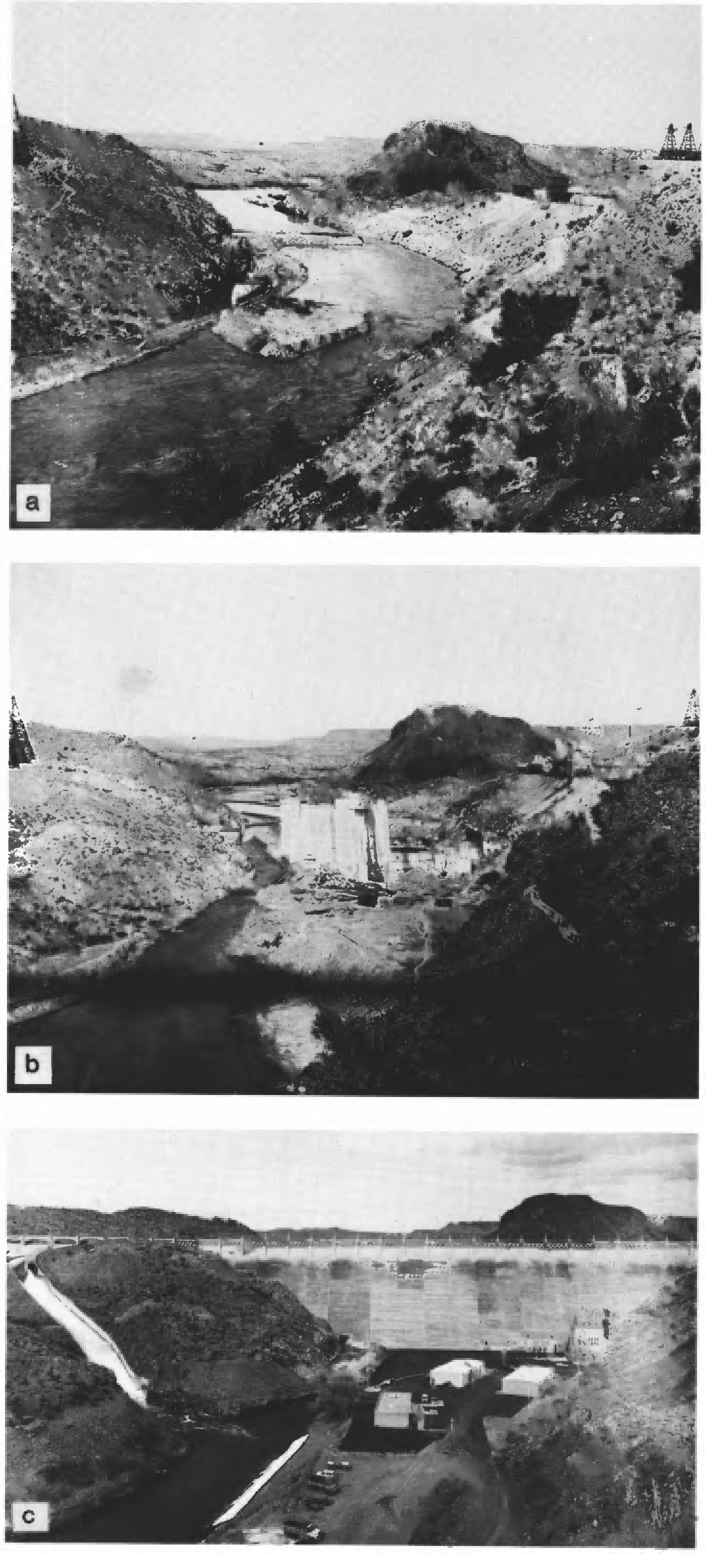


FIGURE 2A-3.8a, b, c—Sequence of photographs illustrates three phases of Elephant Butte Dam construction. **(a)** 29 May 1912 photograph shows small work area and construction of flume into which the river will be diverted during construction. Towers left and right are part of a cable-transport system that delivered construction supplies to the dam site. **(b)** Progress of dam construction by 28 October 1914. River has been diverted into flume and the dam is about half finished. At a later stage water was diverted through the powerhouse gates and the flume was blocked by an earthen dam so that the western portion of the dam could be completed. **(c)** Modern view of dam taken from nearly the same view point on 21 March 1986. Photographs (a) and (b) courtesy U.S. Bureau of Reclamation.

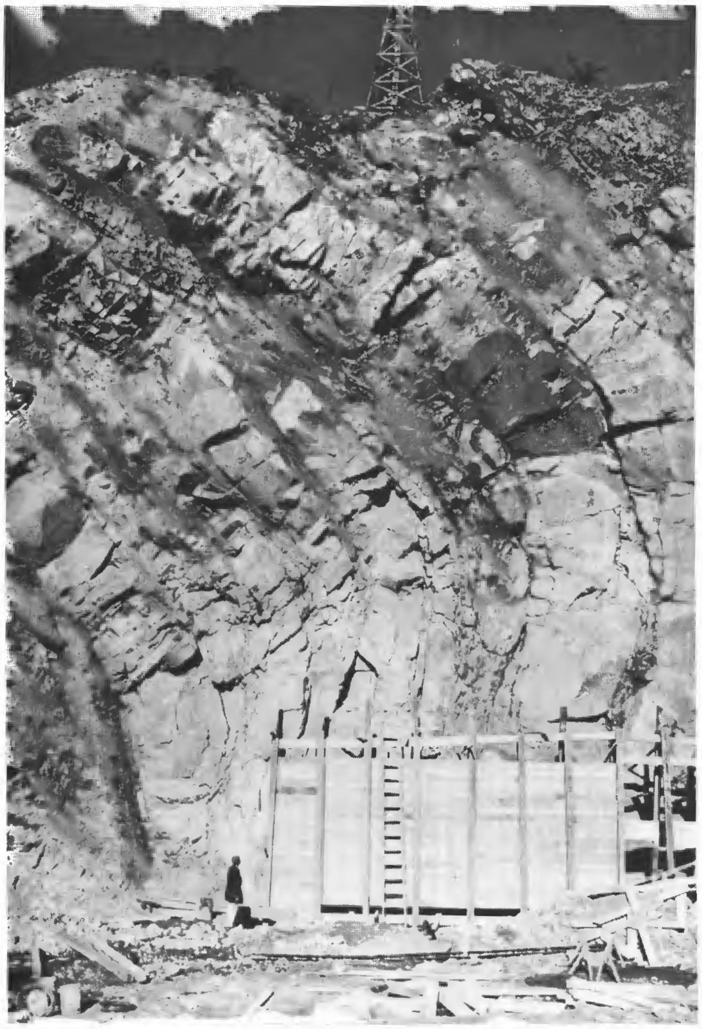


FIGURE 2A-3.8d—Looking west along dam axis at an early stage of construction. Folded and fractured Mesa Verde Gr. sandstones provided less than ideal footing for the dam. Grouting was used to strengthen the bedrock. One version of these events is given by the following quote from the papers of Eldred Harrington: ". . . After the funds had been made legal the site of the dam was changed. So happened that the new site was not a good one, geologically. And yet after all of those years of trials the people in charge wanted, desperately, to build the dam. 'This is our first chance and if we back down on this one it may take many years for us to get another chance!' . . . The management called in FAYETTE JONES as a consultant. Jones was the new President of the New Mexico School of Mines. He and JIM FRENCH, an old time civil engineer, looked over the site and cried aloud at its problems. But it had to go on. Jones borrowed a bunch of diamond drilling equipment from the Chino Copper Company just south of Silver City. He riddled the foundation site with diamond drill holes. The crew designed various kinds of pumps, some of them not unlike the familiar 'plunger' or 'plumber's friend,' and forced many tons of concrete and sand mortar into those holes. It was quite likely one of the first 'grouting' jobs in the world. The grouting job held; it is still holding up well, after more than 60 years.

"JIM FRENCH, the civil engineer, was a big man; about 6 feet 6 inches tall. He was very respectful of rattlesnakes which were plentiful in that area sixty years ago. Jim had very large feet and he wore high laced boots. FAYETTE JONES was about a foot shorter than French and would have weighed about 130 pounds sopping wet. He was a dressy little man with fine manners. He had a well trimmed Van Dyke beard.

"The Dam was built and in 1915 a large roadside sign was put up telling about it. The capacity of the reservoir, number of cubic yards of concrete, etc., etc., etc. But this was not enough for some desert Byron who decided to add more to this big sign. He carefully ruled off a rectangular area and wrote his poem: Here's to JIM FRENCH and his great big feet / Gathering the dope for the contour sheet / But if it hadn't been for JONES and his diamond drill rod / There'd be no dam at the Butte By God! . . ." Quote courtesy Mark Logsdon collection, photograph courtesy Black Range Museum.

FIGURE 2A-4.5a—Steeply dipping sequence of McRae Fm. volcaniclastic rocks. Sandstones and conglomerate beds interlayered. Sedimentary features include scoured surfaces and crossbedding. This sequence is typical of alluvial-fan deposits such as the piedmont facies of the Palomas Fm.

FIGURE 2A-4.5b—Closer view of conglomeratic bed within McRae Fm. illustrates coarse, unsorted, matrix-supported nature of debris-flow deposits. Note rounding of cobbles and boulders.

The Jose Creek is dated as Late Cretaceous by fossils recovered from the McRae Fm. to the north (Lozinsky et al. 1984).

Regionally, the Jose Creek Mbr. varies in thickness and extends only a few miles in any direction. Many exposures are conglomeratic, but this small exposure contains the coarsest and thickest conglomerate beds of the Jose Creek. The detritus in these exposures is primarily volcanic, although large blocks of the underlying Cretaceous rocks also occur. Most of the volcanic clasts are andesitic lava fragments containing 10–30% tabular plagioclase and 1–5% biotite and hornblende phenocrysts. These may be gray, purple, reddish, or greenish, depending on the degree of oxidation and/or propylitic alteration. Varieties with more or less phenocrysts are present in smaller amounts as are lighter-colored tan or brown, perhaps more felsic, rock types.

A thesis was recently done on the paleoenvironmental interpretations of these deposits by Hunter (1986), but the final vesion has not been available as of this writing. This site was also a stop during the 1955 NMGS conference. Bushnell et al. (1955) concluded, with some reservations, that a local vent area was probably necessary to account for the coarse nature and restricted occurrence of these conglomerates. The following quote illustrates Bushnell's et al. reasoning.

. . . East of the road intersection there is a zone of conglomerate and breccia that has been mapped as an intrusive. On first observation this zone has a sedimentary aspect, but the necessity of explaining the presence of large numbers of cobbles and boulders in the Jose Creek Member of the McRae Formation led to a search for a local source for this volcanic conglomeratic material. Several facts finally led to the tentative postulation that the source of the material was an intrusive breccia in which the fragments had been rounded as they moved up through the intrusive conduit. Some of the facts that led to that conclusion are:

(1) The Jose Creek Member of the McRae Formation has a local distribution.
(2) The conglomeratic facies of the Jose Creek Member is a local one which is confined essentially to the Elephant Butte Recreation Area and to other local zones which may also be near intrusive vents.
(3) The presence of what appears to be vertical flow lines in the postulated intrusive breccia center along with alteration rings on some of the cobbles and boulders as well as chlorite stringers are suggestive of igneous activity in this local area.
(4) There are large blocks of older Mesaverde (Ash Canyon) rocks included in what is believed to be the intrusive zone. These appear to be xenoliths.

Despite the foregoing evidence for a local igneous breccia intrusion, the rocks have many features that are suggestive of a sedimentary origin. Both sedimentary and igneous rocks appear to be intimately intermixed. This could be due to a mudflow type of deposition from the vent.

We interpret these beds to be alluvial-fan deposits. The coarse, unsorted beds are thought to be debris-flow deposits which in modern volcanic terrances travel tens of kilometers and carry very coarse detritus. We infer that such debris flows transported this detritus from a relatively distant Laramide-age andesitic volcano. One such volcano of appropriate age is exposed today near Hillsboro at Copper Flat to the southwest (see Clemons in this guidebook). Others are probably buried beneath younger cover. Future visitors are challenged to examine the outcrops and reach their own conclusions. **0.1**

4.6 Purplish-gray conglomerate beds in roadcuts. Hospital Canyon and Elephant Butte at 9:00. Elephant Butte is the landform from which the area derives its name. It is a volcanic plug consisting of alkali-olivine basalt (see boat log for more detail). **0.2**

4.8 Road to Damsite Marina on left. **Continue ahead.** Cross fault from Jose Creek Mbr. into Crevasse Canyon Fm. (Ash Canyon Mbr.). State Park maintenance yard to right. **0.2**

5.0 Cattleguard. Entering Ash Canyon. **0.1**

5.1 Cross fault back into badly fractured McRae (Jose Creek) beds. **0.3**

5.4 Cross fault into Ash Canyon Mbr. of Crevasse Canyon Fm. Note along north side of canyon old railroad grade and quarry at 9:00. A railroad spur line ran from Cutter (just south of Engle) to the damsite for transporting construction supplies. Large Mesaverde sandstone blocks were cut from the quarry and transported by train to the damsite. These blocks were placed in the dam and surrounded with concrete. In this area, Ash Canyon Mbr. displays amalgamated, multistory sandstone bodies. **0.4**

5.8 Cross (ford) Ash Creek and begin ascending out of Ash Canyon through relatively flat-lying beds of the Ash Canyon Mbr. **1.0**

6.8 Road to Champagne Hills on left. **0.7**

7.5 Basalt caps Jose Creek Mbr. strata on flat mesa at 9:00. A northwest-plunging syncline in the Jose Creek Mbr. of McRae Fm. is subparallel to the axis of the Jose Creek sedimentary basin as well as to the main east–west drainage from 8:00 to 10:00. Note pebble beds and lenses of the Ash Canyon Mbr. in roadcuts on right. **0.5**

8.0 Cinder cone on mesa in middle foreground at 9:00. **0.5**

8.5 Cinder cone at 3:00. Many of these cones appear to be aligned along a north–south-trending line. The basalt-capped mesas just east of the Caballos south of Mescal

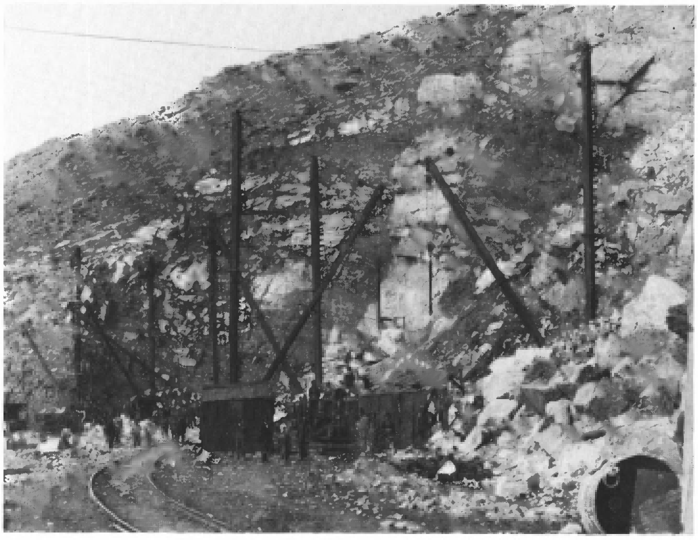


FIGURE 2A-5.4—Quarry in Ash Canyon provided sandstone blocks for Elephant Butte dam. Blocks were set in dam and surrounded by concrete. See Fig. B-9 in boat log for photograph illustrating details of dam construction.

Canyon (Maxwell 1952) are nepheline-olivine basalt with pleonaste crystals as much as 2 cm in diameter and pyroxene phenocrysts (or xenocrysts?) as much as 6 cm long. Pyroxene has 2–5 mm reaction rims. Spinel is often pitted on crystal faces and has rounded edges. Some small spinel crystals are completely rounded by resorption. **0.4**

8.9 Driving on the Cutter surface (Lozinsky 1986). This surface is cut on Mesaverde Gr. and McRae bedrock, and is capped by the Jornada alluvial deposits in the Cutter sag and locally by basalt flows and cinder cones. In this area, the Cutter surface slopes west and probably graded to the former level of the Engle Basin (Lozinsky 1986). Farther east a former drainage divide is crossed and the surface slopes eastward. This surface is thought to be early to late Pliocene (Lozinsky 1986) because it is capped by late Pliocene basalt flows. San Andres Mtns. at 12:00. **0.2**

9.1 Cattleguard. **0.5**

9.6 Cinder cone at 9:00 in foreground dated by Bachman & Mehnert (1978) at 2.1 ± 0.4 my. **0.9**

10.5 Junction with County Road A-8. **0.5**

11.0 Descending into Jornada del Muerto. Rhodes Canyon at 1:00 in the San Andres Mtns. **0.4**

11.4 Fra Cristobal Range at 10:00. Major cliff former there is limestone of San Andres Fm. Cinder cones in middle distance. **3.5**

14.9 Engle ahead at 12:00. Small playas on both sides of road. **1.2**

16.1 Entrance to vineyards. **0.6**

16.7 **Engle. Turn left (north) at stop sign** onto Sierra County Road A-26. **0.2**

16.9 Keep left at fork. **0.2**

17.1 Telephone building and tower on left. **0.1**

17.2 Cattleguard. White areas in and along road are calcic soil horizons. **0.3**

FIGURE 2A-16.7—Church at Engle, formerly a schoolhouse.

17.5 Vineyards on right. Santa Fe tracks on left. These vineyards were started in 1981 by a group of German, French, and Swiss investors. They pump irrigation water from Elephant Butte reservoir. **2.2**

19.7 Fra Cristobals in middle distance at 10–11:00, San Mateo Mtns. at 9:30 on skyline. **4.3**

24.0 Vineyard buildings on left. **1.4**

25.4 Rhyolite forms small hill at 10:00 in near distance. Mockingbird Gap between San Andres and Oscura Mtns. at 2:00, Magdalena Mtns. at 11:00. Small shield volcano on skyline at 12:45 is vent area for 0.76 my old Jornada basalt flow. Tip of Little San Pasqual Mtns. on skyline at 12:00. **1.8**

27.2 Cross cattleguard into Deep Well Ranch headquarters. **Continue ahead 0.5 mi to side road just past ranch on left for caravan assembly. 0.2**

27.4 **Assemble caravan as directed.**