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R. L. Graham

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ENGINEERING GEOLOGY AT TWO CANADIAN RIVER DAM SITES

R. L. GRAHAM
Placitas, New Mexico 87043

INTRODUCTION

The Canadian River and its tributaries flow southward and eastward from the Sangre de Cristo Mountains in north-central New Mexico towards the Texas Panhandle. At Conchas Dam and Reservoir in San Miguel County, the Canadian River makes a sharp bend eastward. Here the river contains an inner and an outer canyon, wider at locations where softer shale units form its banks. Below Ute Dam, in Quay County, the river channel is highly sinuous, and its meanders are braided over a very wide floodplain. This paper discusses the engineering geology of Conchas and Ute Dams located on the canyon segment of the Canadian River in east-central New Mexico (Fig. 1). The purpose of the discussion is to acquaint field-trip participants with the effects of Tertiary geology and Canadian River geomorphology on dams constructed for water storage and supply in the Santa Rosa–Tucumcari area.

CONCHAS DAM

Conchas Dam, located 50 km northwest of Tucumcari, is a flood-control and reclamation project that was one of the earliest Corps of Engineers dams constructed west of the Mississippi River. Construction of the 70.5-m-high dam began in 1935 and was completed in 1939. The concrete gravity structure has a crest length of 375 m and is currently only filled to two-thirds of its storage capacity due to silting of its reservoir. Construction was carried out under contract to Bent Bros. Inc. and Griffith Co. (Mermel, 1958). There are no power-generating capabilities at the dam, which controls flooding of the Canadian River in downstream Texas, Oklahoma and eastern New Mexico and provides irrigation water for the Arch Hurley conservation district. The reservoir became Conchas Lake State Park in 1955 (NMBMMR, 1985).

As Conchas Dam is a concrete gravity structure, it behaves as a rigid body in engineering analysis and design. The weight of the dam is directed downward when the reservoir is empty, and the force vector is downstream when the reservoir is full, due to both hydrostatic pressure on the upstream face and the weight of the dam (Wahlstrom, 1974). The straight concrete structure is in a canyon 37.5 m deep and has earth-fill wing dams at either end. North of the main dam is an emergency spillway, which has never been overflowed by the reservoir (NMBMMR, 1985).

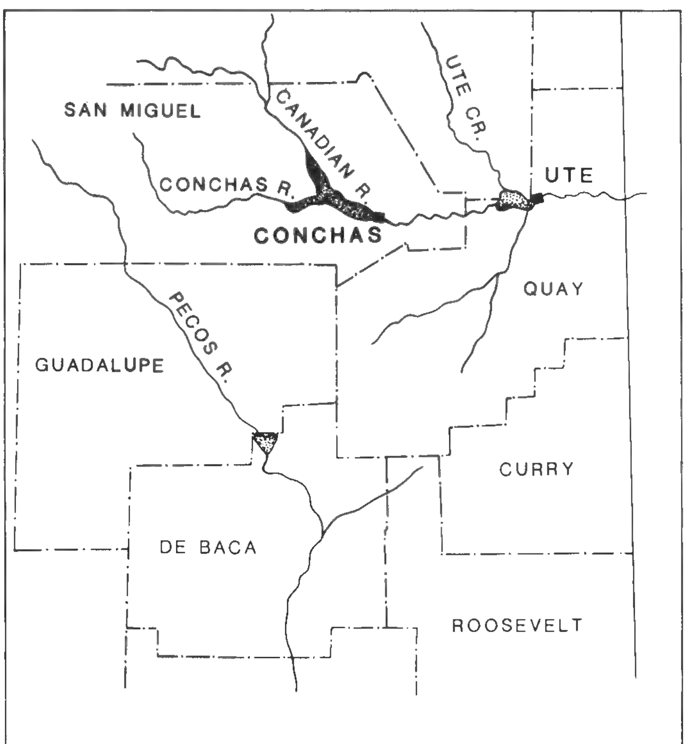

FIGURE 1. Location map: Canadian River drainage in Santa Rosa–Tucumcari country with locations of Conchas Lake and Dam and Ute Lake and Dam.

UTE DAM

Ute Dam, located on the Canadian River just upstream of the town of Logan, is a water-storage facility that was designed and constructed under the supervision of Bechtel Corporation. Completed in 1963, it is owned and operated by the New Mexico Interstate Stream Commission. The structure is a zoned embankment (earth-fill) dam with a concrete spillway located north of the main dam (U.S. Dept. of Interior, 1984). Embankment dams require less bearing strength of the foundation than do concrete structures. Zoned embankment dams use materials of distinctly different properties in various portions of the dam (Wahlstrom, 1974).

Ute Dam was completed with soil-cement protection on its slopes, and was one of the first dams successfully constructed using this technique. Soil-cement was prepared at an on-site central plant that maintained high quality of cement. This method resulted in significant savings over riprap protection of the upstream slope (Wilder and Koller, 1967).

No power-generating capabilities exist at this dam. In 1969, an outlet works-control structure was added. The dam height was raised 3.3 m during a 1983 construction phase to the existing height of 39.3 m. The center line of the raised dam was moved about 13 m upstream due to the changed geometry of the higher embankment. The Canadian River canyon in the vicinity of the dam site is 21 to 39 m deep and the stream width is about 105 m at the dam. No positive cutoff to bedrock exists in the stream portion of the channel beneath the embankment (U.S. Dept. of Interior, 1984).

GEOLOGIC HISTORY OF THE CANADIAN RIVER

The depth to the Permian evaporite sequence below the Canadian River increases upstream from Ute to Conchas Dams (Fig. 2). Rocks of this age do not crop out at either dam site, nor were they encountered in any of the exploration borings. Triassic rocks are the oldest rocks encountered at the dam sites. The Chinle Formation, which consists of alternating units of shale and sandstone, is the bedrock foundation at Ute Dam. The Santa Rosa Sandstone is the oldest rock unit found in the bottoms of borings drilled at Conchas Dam (Crosby, 1937). The inner valley of the Canadian River contains mesas and terraces of Triassic sandstone, silstone and shale units of the Chinle Formation and the underlying Santa Rosa Sandstone, referred to as the Dockum Group

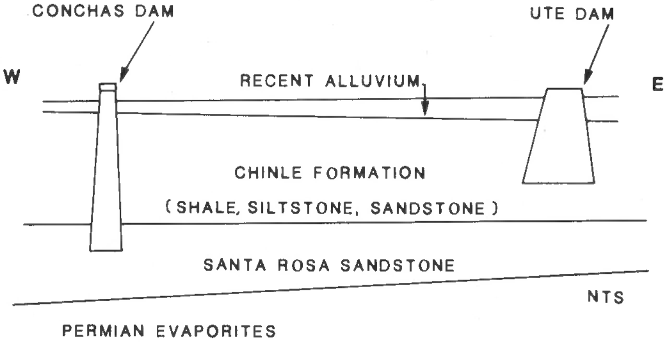

FIGURE 2. Generalized geologic cross section of the inner canyon of the Canadian River between Conchas and Ute Dams showing units excavated for dam construction.

in construction reports. The outer valley is eroded in late Tertiary (Mio-Pliocene) Ogallala sediments and alluvial channel fill.

The Canadian River is a relatively new geomorphic feature, flowing on a post-Ogallala erosional floor (NMBMMR, 1985). The downcutting of the present canyon began in late Pleistocene time, after the end of the Wisconsinan glaciation. Normal faulting which created Basin-and-Range structure in central New Mexico created the source for deposition of thick alluvial sediments in the headwaters of the Canadian River. Aggradation occurred in several stages. Uplift and renewed degradation followed, exposing rocks as old as Lower Triassic (Spiegel, 1972a). After making its sharp eastward turn at Conchas Dam, the Canadian River exhibits a series of right-angle turns which are thought to be controlled by joints in the massive sandstone units (U.S. Dept. of Interior, 1984). Finally, close alignment of the Pecos and Canadian Rivers in New Mexico suggests that the Canadian River may have pirated upper reaches of the Pecos in late Pleistocene time (Kessler, 1972).

Seismicity and structural geology

Seismicity does not pose a major hazard at the two dam sites, which are located in Seismic Risk Zone I (U.S. Dept. of Interior, 1984). Earthquake shocks of local Richter magnitude 2.4 to about 3.6 have been recorded on seismographs in New Mexico in the immediate area of the dams. Instrumentation to measure magnitudes of earthquake shocks has been available since about 1960 (Northrop and Sanford, 1972). No evidence for active faulting has been found at either Conchas or Ute Dams (Crosby, 1973; U.S. Dept. of Interior, 1984).

The Triassic rock units are mostly flat-lying, with shallow (less than 10°) dips. At Conchas Dam a southeast-plunging anticline is present through the main dam site, and the area of the emergency spillway is in a syncline. Joint patterns are vertical (Crosby, 1937). Ute Dam is typified by minor anticlinal features, with the dam situated on the northwest limb of a gentle anticlinal feature. Some of the flexures may be dissolution-caused rather than structural (U.S. Dept. of Interior, 1984).

Ground water

Unconfined ground water of marginal to good quality occurs in Triassic rocks and terrace deposits of the Canadian River. Highly mineralized ground water is found within the underlying Permian rocks and is confined under artesian pressure. Local contamination of ground water in Triassic rocks from saline artesian sources occurs downstream of the dams. However, major upward leakage of ground water from Permian rocks will most likely occur east of Ute Dam (Spiegel, 1972b).

CONSTRUCTION PROBLEMS

Surficial units

At Ute Dam, surficial deposits of Recent alluvium are present in thicknesses of up to 22 m, and Pleistocene terrace deposits 7.5 m thick are on the uplands. At Conchas Dam, minor amounts of surficial deposits overlie a resistant sandstone caprock unit equivalent to the Trujillo Formation of western Texas. These latter deposits were removed prior to construction (Crosby, 1937). The dike extension required for the raising of Ute Dam to its present height was founded on surficial deposits on either side of the cutoff trench. Lenses and pods of sandy clay and silt occur within the alluvium layers. Caliche nodules were present at about 1 m below ground surface in clayey sand and an asphalt coating was found on gravel. Cementation of gravel and sand was more pronounced closer to the Chinle Formation bedrock (U.S. Dept. of Interior, 1984).

Triassic units

The Chinle Formation is the bedrock foundation for the dike extension cutoff trench, the labyrinth weir spillway foundation and the right abutment foundation extension at Ute Dam. Shale, siltstone and sandstone comprise the formation at the excavations. In places, the exposed formation rock slaked and deteriorated, necessitating overexcavation to fresh rock. Red shale and siltstone responded in this manner. A clayey shale unit in the Chinle became a lean clay upon wetting and was therefore wetted before compacting by wheelrolling (U.S. Dept. of Interior, 1984). Similar rock types are described by Crosby (1937) at Conchas Dam, where Chinle correlative rocks were named, from oldest to youngest, Lower Red Shale, Upper Artesian Sandstone, Pink Shaly Sandstone, Upper Red Shale and Canyon Sandstone. The Upper Red Shale behaved basically as an indurated clay and was found to disintegrate rapidly upon exposure to air. It weathered more quickly than the overlying Canyon Sandstone, and action from joint cracks caused breakage in the blocky caprock of the Canyon Sandstone.

Many of the shale, siltstone and sandstone units of the Chinle exhibit crossbedding which makes dips seem steeper than their actual 2° to 5°. Partings of clay between sediment layers, and lenses and pockets indicative of horizontal variability in deposition, are common. Clay bedding seams and shale partings behave much like units of the Chinle in which this rock type predominates. In the case of Conchas Dam, the stresses from the dam structure were particularly sensitive to these vagaries of the sediment record. Previous construction at Ute Dam required blasting, and breccias with preserved remnants of the blasting drill holes were left in the sandstone as a result of this activity. Dental concrete was required to seal these surfaces (U.S. Dept. of Interior, 1984). Jointing is common in most of the units described at Conchas Dam, except in the Red Shale where slickensides were noted (Crosby, 1937). In many cases joints were not open but filled with calcite mineralization.

Ground water

Seepage that in some cases required pumping of the excavations was noted in some excavations at Ute Dam. However, the flow of water was considered minor since joint-filling prevented the trapping of large amounts of fluid within the rock units. Artesian conditions in the underlying Santa Rosa Sandstone equivalent-rock-unit are probably the source of much seepage and also act as an uplifting force on the dam. Another effect of high ground-water pressure in the foundation unit is the restriction of flow of water from drainage holes which must be terminated in a layer without these pressures, as well as regularly cleaned (Spiegel, 1972b).

CONCLUSIONS

The Triassic Chinle Formation forms most of the bedrock and excavated portions of these two Canadian River dams. Crossbedded sandstone, siltstone and shale, often with steep foreset beds, are indicative of a cyclic depositional environment with pronounced lateral variations. Joints from the loading stress of overlying units, and some seepage from underlying artesian ground-water flow, complete the geologic impact to rock and soil properties. Conchas Dam, a rigid concrete structure, required strong foundation support. Softer shale units, and units with soft-shale partings, had to be avoided or else overexcavated to reach firmer-rock conditions. Ute Dam, a zoned embankment dam, could minimize some of the negative effects of the softer materials because the dam required less bearing strength and units could be mixed to obtain a more satisfactory foundation material. The lack of suitable riprap was mitigated by the use of soil-cement on the upstream slope.

Downstream of the easterly bend at Conchas Dam, the gradient of the Canadian River lessens and its sinuosity increases. These natural conditions permit the deposition of silt and fine sand in the channel. Conchas and Ute Dams further decrease the transport of sediment load in the river. Silting of the reservoirs is occurring today and has already lessened their water-storage capacities.

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Caprock escarpment at Ragland, New Mexico. View is N1°E, across Rincon Canyon, approximately 0.3 mi northwest of Ragland. Well-bedded Tertiary Ogallala Formation is exposed in upper part of scarp. Triassic rocks are exposed in the lower part of the scarp, and Quaternary alluvium and Triassic rocks underlie the dissected piedmont. Camera station is in SE1/4 sec. 15, T7N, R30E. W. Lambert photograph No. 85L16. 6 April 1985, 11:45 a.m., MST.