STRATIGRAPHY OF PLAYAS IN THE PANTEX AREA—PLAYA 5 AND PANTEX LAKE

Milestone Report Activity 1
Annual Supplement to Scope of Work 1993–1994

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ABSTRACT

Sediments of two playas in the Pantex area, Playa 5 and Pantex Lake, were examined to (1) look for evidence of alteration that may have occurred as a result of recharge and (2) provide a context for hydrologic and hydrochemical studies of these playas. These playas are significant in that they have received large volumes of sewage and industrial and agricultural wastewater. The results of these studies, coupled with unsaturated zone hydrologic and geochemical studies, clarify our understanding of the pathways and processes used by recharging wastewater. This better understanding of recharge processes can be used to guide remediation and more quantitatively estimate the amount of contaminant remaining in the unsaturated zone.

Playa sediments beneath Playa 5 are more than 70 ft thick and contain evidence of multiple episodes of lake enlargement and reduction. The stratigraphy of the older lake clays is more complex than that of the younger clays, and evidence of postdepositional dip, complex lake shape, and migration of the center of the lake suggests that the evolution of the lake basin may have been influenced by syndepositional subsidence, perhaps related to dissolution of Permian salt. The steepest northwest shore of the lake shows strongly erosional relationships between upland and lake sediments, with little or no Blackwater Draw upland accretionary facies preserved. The sewage discharge pipe formerly sited in this area therefore discharged water into a pit scoured into the lower medium sand unit. These facies relationships may have influenced the movement of fluids and contaminants in this lake. Evidence of wastewater movement through

sediments is recorded by organic stains and abundant limonite, and possibly by patchy reduction of sediment.

Pantex Lake is in an unusually large playa basin. Transects across the lake show thick older lake sediments toward the southern edge of the present playa lake and unusually thin playa sediments in the northern half of the lake. Thin playa sediments suggest that this lake might have higher than average vertical transmissivity; however, no water quality or hydrologic data are available to document potential mounding or water-quality degeneration beneath this playa. Facies relationships suggest that the playa lake has migrated northward during its Quaternary evolution. Lake sediments were cored in the subsurface high up on the southwestern shore of the lake, indicating that some past lake stages were much larger and deeper than those of the present lake.

INTRODUCTION

During earlier phases of study of playa lake stratigraphy in the Pantex Plant area, the sediments beneath 10 lakes were examined using transects of hollow-stem auger cores, shallow trenches, and storm-water impoundment excavations (fig. 1). The results of these studies (Hovorka, in press), coupled with hydrologic and geochemical analyses of the unsaturated zone beneath playas (Scanlon, in preparation; Fryar, in preparation) provide baseline data on the natural characteristics and variability of playas. These data are necessary in order to correctly interpret the results of analyses on playas on the Pantex Plant that have received varying amounts of wastewater recharge and contaminant.

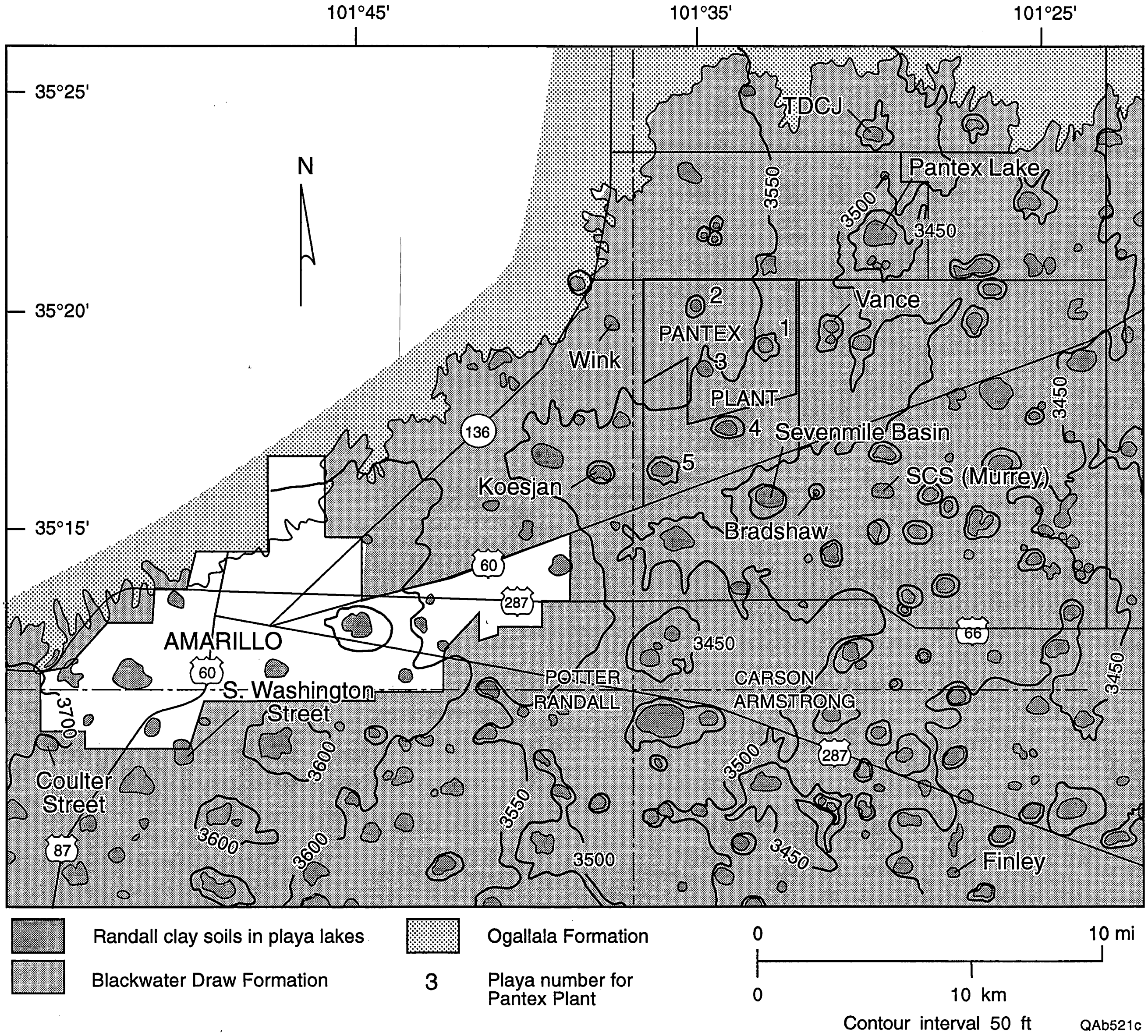

Figure 1. Pantex area playa location map. Pantex Lake and Playa 5 sediments are described in this report. Other playas are described by Hovorka (in press).

In this phase of the study, we examined two playas near the Pantex Plant that have received wastewater in the past. Playa 5, on the Texas Tech Research Farm and in the buffer zone of the Pantex Plant (fig. 1), received varying amounts of industrial and agricultural wastewater, including untreated sewage, between 1974 and 1992 (Fryar and others, in press). Pantex Lake, on Department of Defense property managed by the Pantex Plant, received treated wastewater from 1942 to 1954 and from 1952 to 1968 (Fryar and others, in press).

METHODS

Hollow stem auger cores were drilled along several transects across each playa. In Playa 5, 13 cores along 2 transects (northwest–southeast and north–southwest) were examined as part of the stratigraphic studies (fig. 2). Borehole sites were selected to complement the geochemical and unsaturated zone hydrologic studies, with borehole 8 sited near the outfall of the old sewer pipe, borehole 7 near the playa neutron access tube, and boreholes 15 and 28 near the neutron access tubes and other instrumentation in a fairly undisturbed playa basin slope (interplaya) site. Boreholes 11, 12, and 13 were located to examine undisturbed shoreline in a deltaic and adjacent setting. Boreholes 3 and 4 sampled the typical, complex stratigraphy on the southern lake shore.

In Pantex Lake, 14 cores along 3 transects (north to south, northwest to lake center, and southwest lake center to southeast) were included in stratigraphic studies (fig. 3). Borehole 1 was located in a grassland setting well above the lake. Borehole 3 was located to sample the large delta in the southwestern part of the lake. Boreholes 14, 15, 16, and 17 were located to sample the northwestern shoreline, an area that has been underrepresented

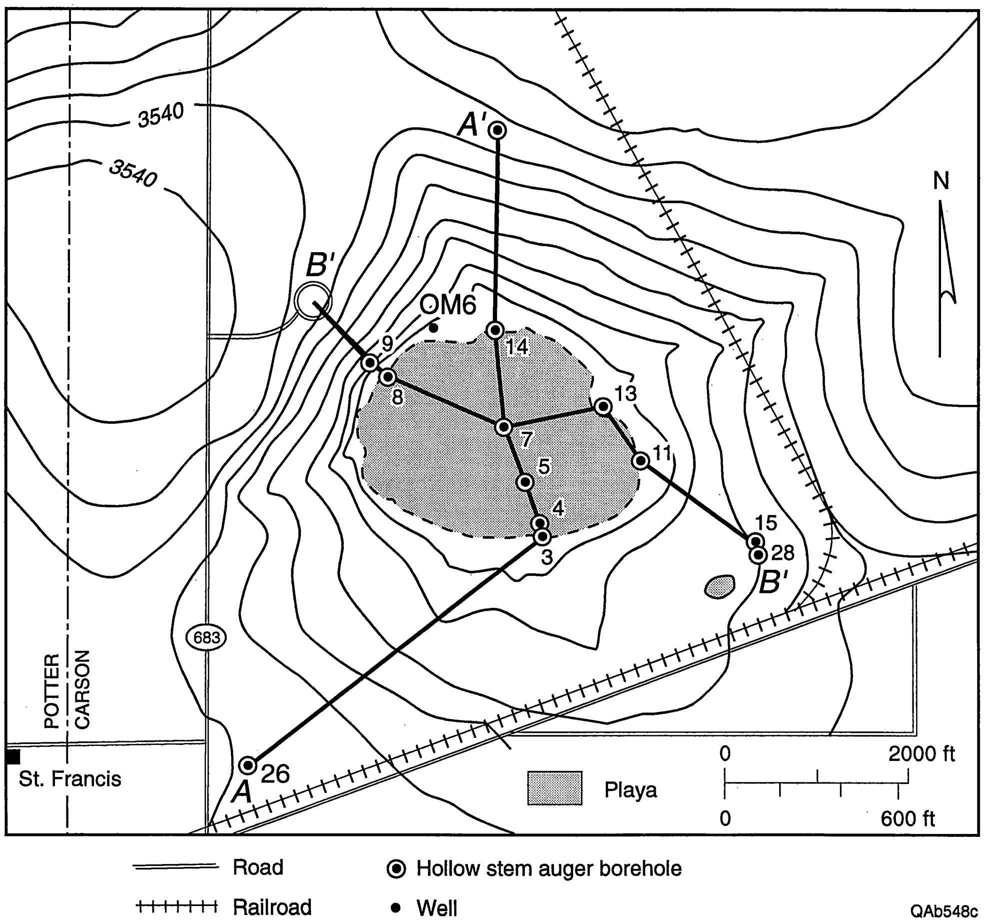

Figure 2. Playa 5 detail map. Cross sections shown in figures 3 and 4.

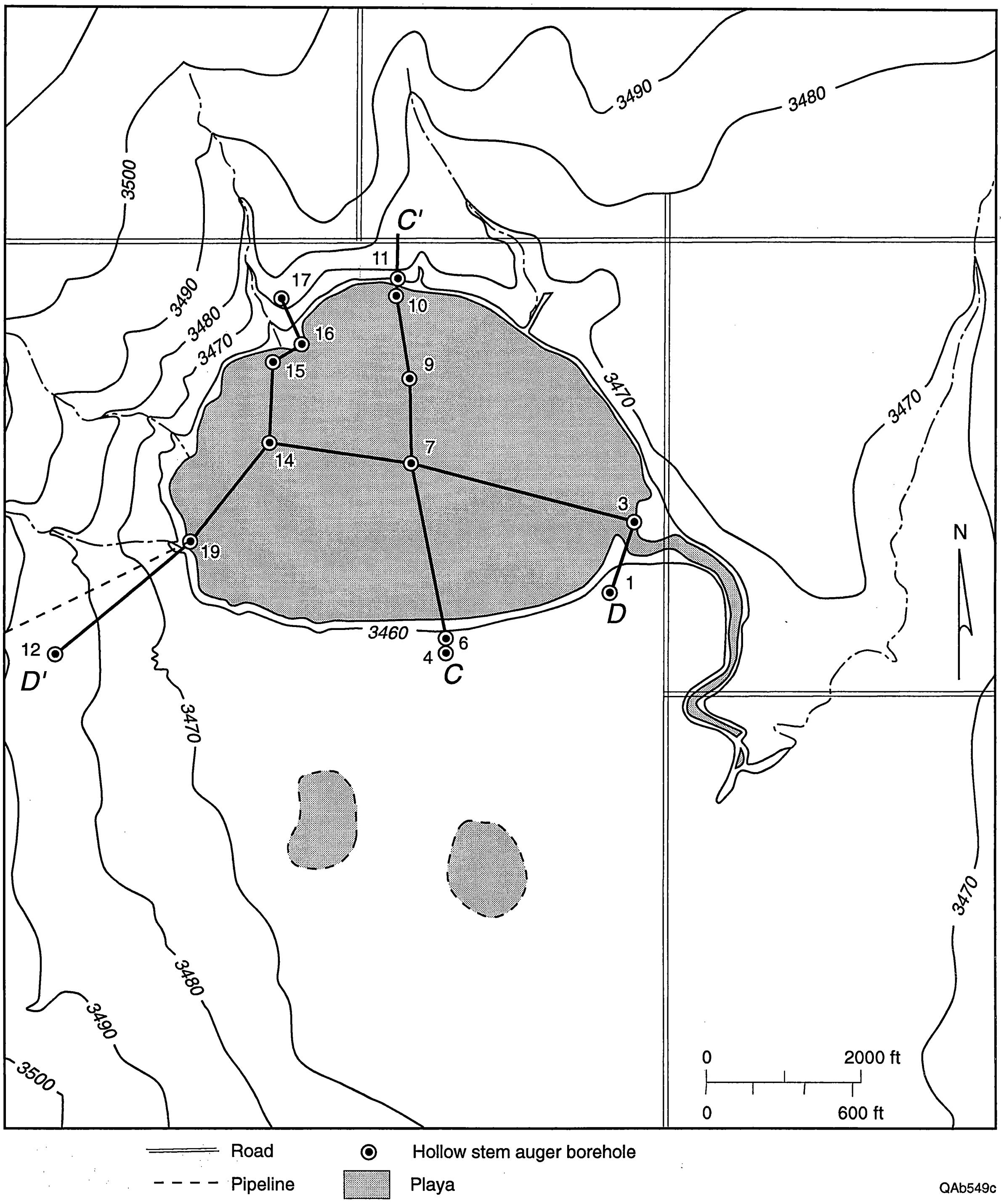

Figure 3. Pantex Lake detail map. Cross sections shown in figures 6 and 7.

in transects across other playa basins. Borehole 19 was located near the former treated sewage discharge point.

PLAYA SEDIMENTS BENEATH PLAYA 5

The facies beneath Playa 5 are similar in most respects to those previously examined in the baseline playas in the Pantex area (Hovorka, in press). Major facies beneath the lake include fine-grained lacustrine gray to tan mud and clay, fine-grained oxidized lacustrine red and brown clay and mud, well-sorted fine lacustrine/eolian sand, lacustrine clay with sand and silt interbeds, and local lacustrine deltas. Upland and slope facies include pedogenically modified silty clay loam of the Blackwater Draw Formation upland accretionary facies, Bk soil horizons, channels, and Pullman and slope soils. The lower medium sand facies is found beneath both lake and upland areas. The typical composition and character of these facies are described in detail by Hovorka (in press).

The spatial facies distribution in Playa 5 (figs. 4 and 5) is also similar in many respects to that observed in other playas (Hovorka, in press). Six cyclic couplets composed of thin intervals of lacustrine/eolian sand or lacustrine clay with sand and silt interbeds overlain by thicker intervals of fine-grained lacustrine facies produce the uninterrupted lake sediment sequence, which is a maximum of 44 ft thick (fig. 4). The uninterrupted lake sediment sequence underlies the modern lake, with some lake units extending an unknown distance beneath the slope and upland (figs. 4 and 5). Stratigraphy is more complex in the annulus than in the playa center because of more numerous and thicker sand interbeds. In the Playa 5 transects, only one tongue of upland accretionary facies is recognized extending beneath the southern shore of the modern playa (fig. 4). Both the uninterrupted lake sediment sequence and the

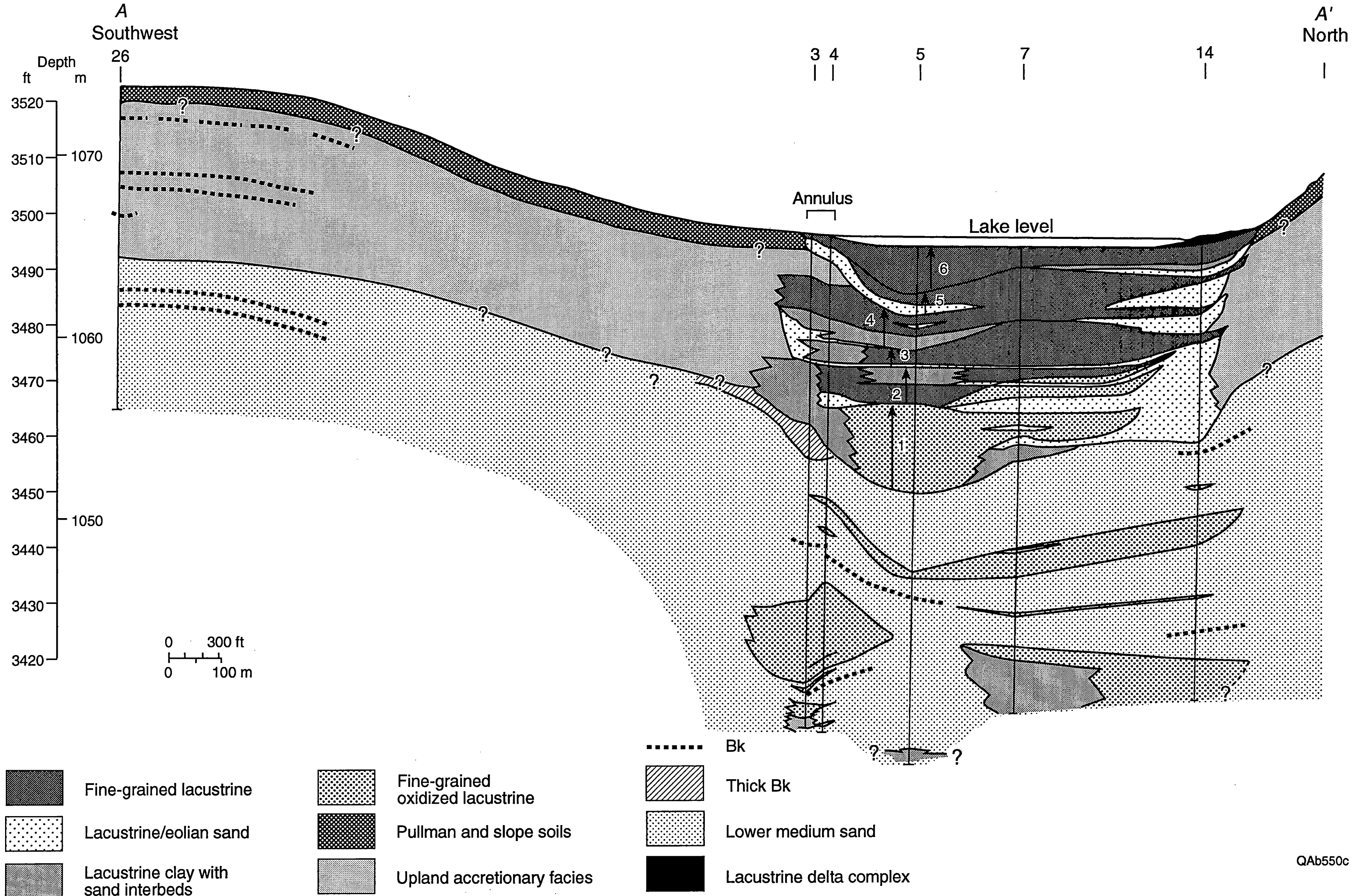

Figure 4. Playa 5 southwest-to-north cross section A-A'. Cross section location shown in figure 2. Depositional units 1 through 6 are discussed in the text.

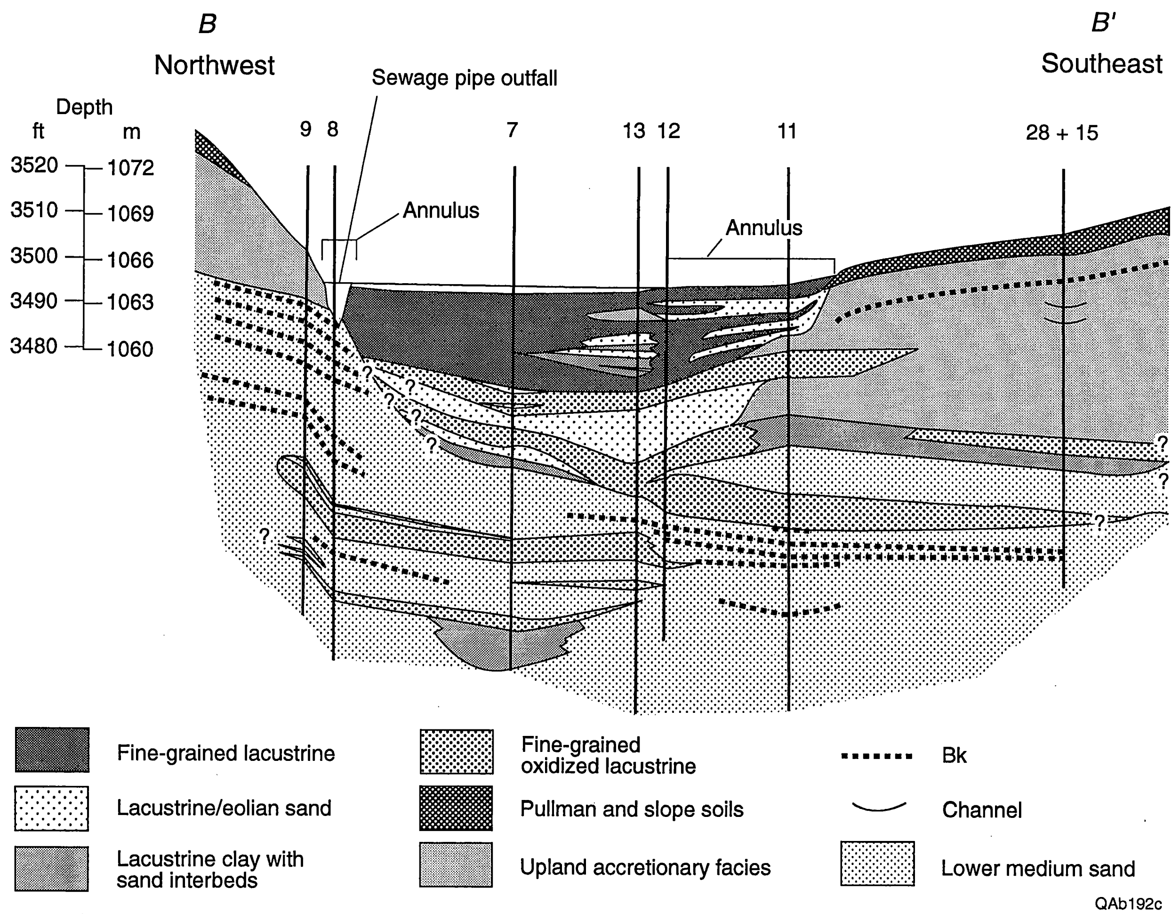

Figure 5. Playa 5 northwest–southeast cross section B-B'. Cross section location shown in figure 2.

upland accretionary facies of the Blackwater Draw Formation are underlain by the regional medium sand unit, which contains soil carbonate (Bk) horizons beneath the upland and locally beneath the playa. A thick soil carbonate unit was cored at the contact between the medium sand upland accretionary facies on the southern shore of the playa in borehole 3, but this horizon does not seem to be prominent elsewhere in the playa. No conclusions are drawn about its equivalence to the Caprock caliche, the most prominent soil carbonate elsewhere on the Southern High Plains.

In detail, the stratigraphy of Playa 5 is unique. Significant features observed for the first time in this playa are highly complex, dipping, and extensive older lake deposits interbedded with the lower sand. The geometry of these older lake units shows that the location and extent of the lake varied during its earlier depositional history. The complexity of the lake basin evolution shown by the facies relationships might be related to the complex subsidence history suggested by seismic data from the Ogallala and Permian–Triassic bedrock beneath this playa (J. Paine, personal communication, 1995). Older lake deposits with some dip have been observed at Wink and Sevenmile Basin playas (Hovorka, in press) but do not show as much lateral migration and as complex a shape as those beneath playa 5.

Another, possibly related aspect of the stratigraphy at Playa 5 is the highly erosional character of the northwestern shoreline, seen in cross section B-B' (fig. 5). Surficial soils and some of the Blackwater Draw Formation on the steep northwestern slope of the playa basin appear to have been stripped off, thinning the upland accretionary facies to 10 ft in borehole 9, less than a third of its typical thickness. This suggests that the playa lake has moved northwestward in its basin, steepening and eroding this slope. Rather than mimicking the present-day topography as is typical (Hovorka, in press), the depression in the top of the lower medium sand is offset from the modern topographic basin. The lower medium sand therefore occurs at unusually shallow depths on the northwest edge of the basin. This geometry is significant because the outfall from the sewage discharge pipe was over this area of near-surface sand (fig. 5). Examination of core from borehole 8, close to the sewage pipe outfall suggests that the upper 9 ft of sediment are modern deposits related to scour and infill of the scour pit during the active period of discharge. The sediments are finely laminated, unusually dark waxy-appearing clays and dark, well-sorted silt interbeds (fig. 6 a). A few roots were cored, but other than that there is no evidence of pedogenesis. Below the scour-pit fill, lower medium sand beds with moderately well developed Type II soil carbonate horizons were cored. To depths of 18 ft, sands have unusual orange colors (7.5 YR 5/4 to 5/6) and abundant limonite stain. Local unusual dark-brown (10 YR3/2) stains are present to depths of 15 ft (fig. 6 b). The soil carbonate in this interval is damp and crumbly.

A coincidence of pattern is apparent between the extractable NO_3^- profile in borehole 8 (Fryar and others, in press, 1995) and the stratigraphy. The highest NO_3^- at the top of the core is hosted by the modern dark-clay-and-silt fill in the scour pit. The underlying near-surface lower medium sand at 9 to 23 ft also has detectable NO_3^-; this interval approximately corresponds to the interval with limonite and brown stains. Beneath this interval, NO_3^- is below detection limits, and the sand is mostly homogeneous and the only evidence of post-pedogenic alteration is sparse areas of reduction of iron oxide coats on sand grains, producing lighter colored bleached patches. The lower interval of detectable NO_3^- begins at 50 ft, coincident with the older lake clays interbedded with the lower medium sand. The older lake clays are moist but oxidized and fractured, their hydrologic behavior in the unsaturated zone is

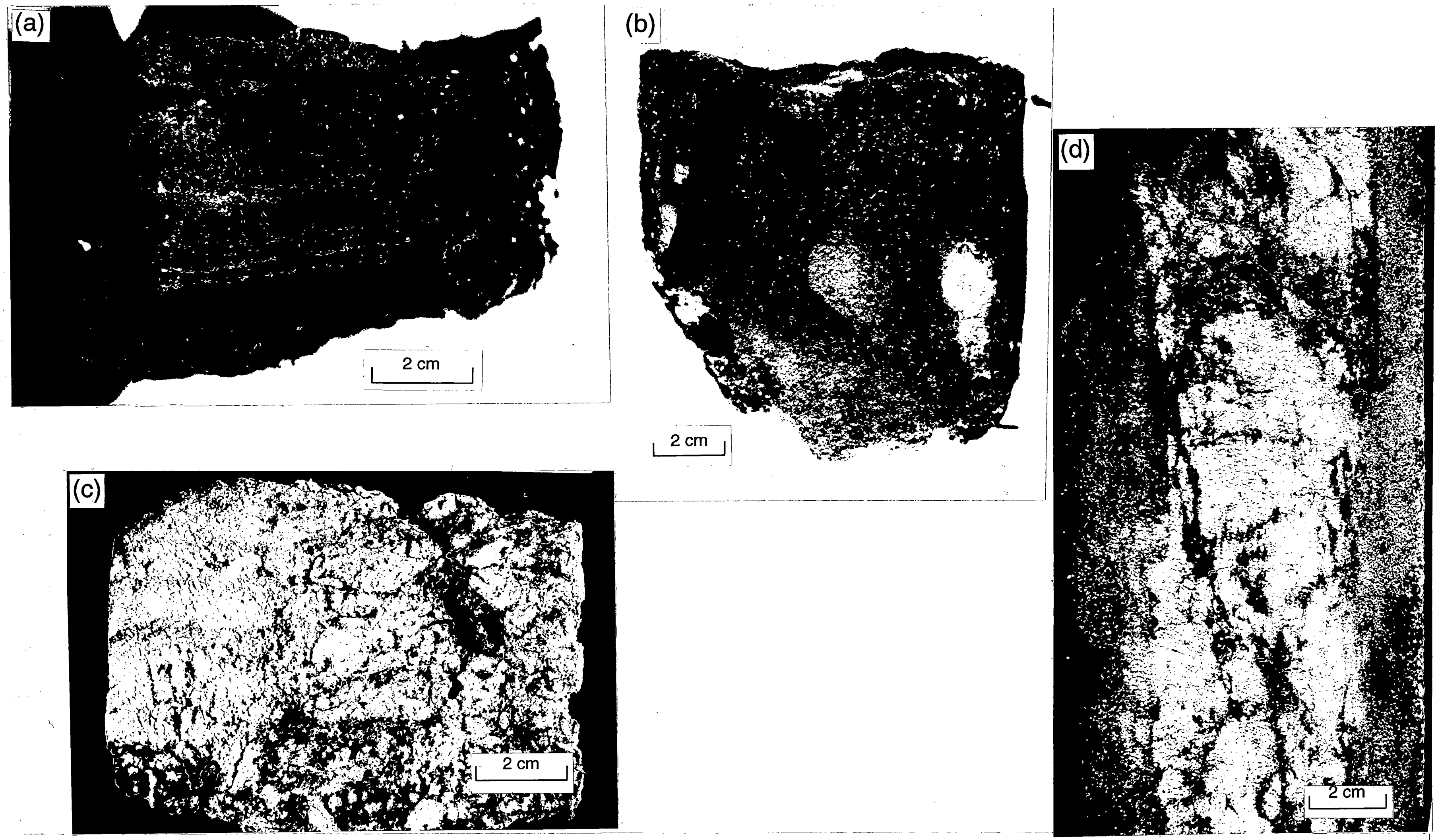

Figure 6. Unusual alteration found in sediments beneath Playa 5 and Pantex Lake. (a) Dark clay interlaminated with well-sorted silt. Playa 5, borehole 8, 7.5 ft. These sediments are interpreted as modern sediments infilling a scour pit beneath the sewage pipe outfall. (b) Dark stain in sand. Playa 5, borehole 8, 14.6 ft. This dark stain has only been observed in this borehole beneath the sewage pipe outfall and is interpreted to be staining from organic material carried by recharging fluids. (c) Limonite stain along root traces and other sedimentary structures in light-colored bleached sand. Playa 5, borehole 14, 22.5 ft. Limonite is more abundant in sediments beneath Playa 5 than in the unmodified playas examined in the preceding phase of the study. (d) Limonite and gray clay fill cracks and root traces in light-colored bleached lacustrine sand. Pantex Lake, borehole 15, 61.5 ft. Clay translocation and possibly limonite precipitation in this deep sample may reflect relict flow conditions from ancient larger, possibly more perennial lakes that have occupied this basin.

not yet clear. Additional analysis is needed to determine the extent to which the sediment texture and structure influence or are merely coincident with the NO_3^- profile.

Sediments in other Playa 5 boreholes away from the sewage pipe outfall also show some alteration that potentially might be related to artificially high water levels and chemical or biological response to wastewater discharge. Borehole 14, on the north shore of the lake, has 20 ft of interbedded lacustrine sand and clay overlying the lower medium sand (fig. 4) and underlying thin delta deposits at the surface. This interval contains local limonite concentrations on fractures, root tubules, and at grain size changes, areas of reduced colors in sand beds, and intervals with a faint sewage smell. No geochemical data were collected on this core, so the relationships between alterations and contaminated water remain conjectural. Limonite is also abundant (fig. 6 c) in the deeper section of lower medium sand and older lake interbeds (fig. 4); without additional geochemical analysis or dates it is unclear as to the extent to which this limonite abundance should be attributed to modern recharge or to older lake conditions.

Limonite is moderately abundant in other playa and annulus cores. Much of the core is appears damp, with moist sands and plastic clays to total cored depths. However, extractable NO_3^- in playa center borehole 7 was below detection limits except for the very near surface. It is unclear whether this indicates that the moisture and limonite reflect relict conditions in the geologic evolution of the basin prior to discharge of waste water, or whether the NO_3^- load was reduced in the playa center by denitrification but the flux of reducing water is shown by the alteration and moist sediments observed in core. Analysis of additional geochemical data may clarify this issue.

PLAYA SEDIMENTS BENEATH PANTEX LAKE

As has been documented in every playa examined during this study, most facies beneath Pantex Lake can be described in terms of the same eight upland and lacustrine facies (Hovorka, in press). Cores drilled through Pantex Lake sediments encountered unusually thick and abundant delta deposits (figs. 7 and 8). These deltaic sediments are dominantly laminated and ripple cross-laminated red brown (7.5 YR 5/4) silt with clay drapes and minimal pedogenic alteration, documenting relatively rapid sedimentation. In addition, deposits interpreted as alluvium or slopewash were cored. These deposits are similar in texture and color to red-brown (7.5 YR 4/4) silty clay loam of the Blackwater Draw upland accretionary facies, except that the carbonate occurs as angular, poorly sorted clasts interpreted as soil carbonate that has been eroded from older soil profiles or sediments and deposited as with minimal reworking in slope or upland settings. Root traces are present, but soil horizonation has not formed in these sediments, suggesting moderately rapid deposition in a grassy setting. Similar facies were cored on the southern side of Sevenmile Basin (Hovorka, in press).

Pantex Lake is a large playa at the northwest edge of a very large, somewhat indistinct basin. The playa has not been flooded during the study period, although much of the floor has been intermittently wet. Playa margins are defined by a wave-cut bench that can be found on both the north and south sides of the lake. This bench is locally gullied and is interpreted as a relict feature related to high water levels when the lake was deeper and more permanent during the period of its use for wastewater disposal. Core transects were sited to characterize the present-day lake; unlike the large basin at Sevenmile Basin, property ownership and agricultural use limited drilling south of the modern lake shore.

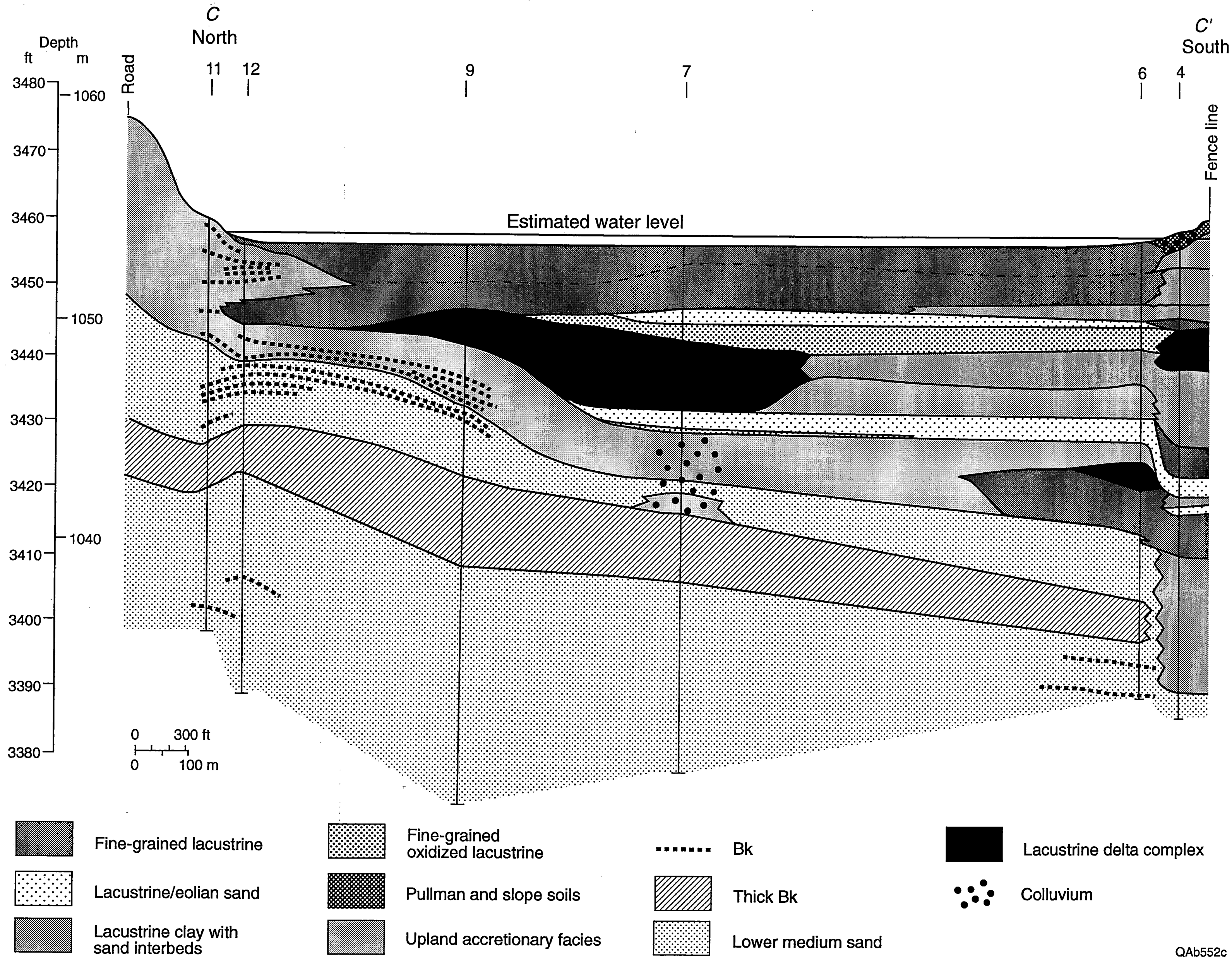

Figure 7. Pantex Lake north–south cross section C-C'. Cross section location shown in figure 3.

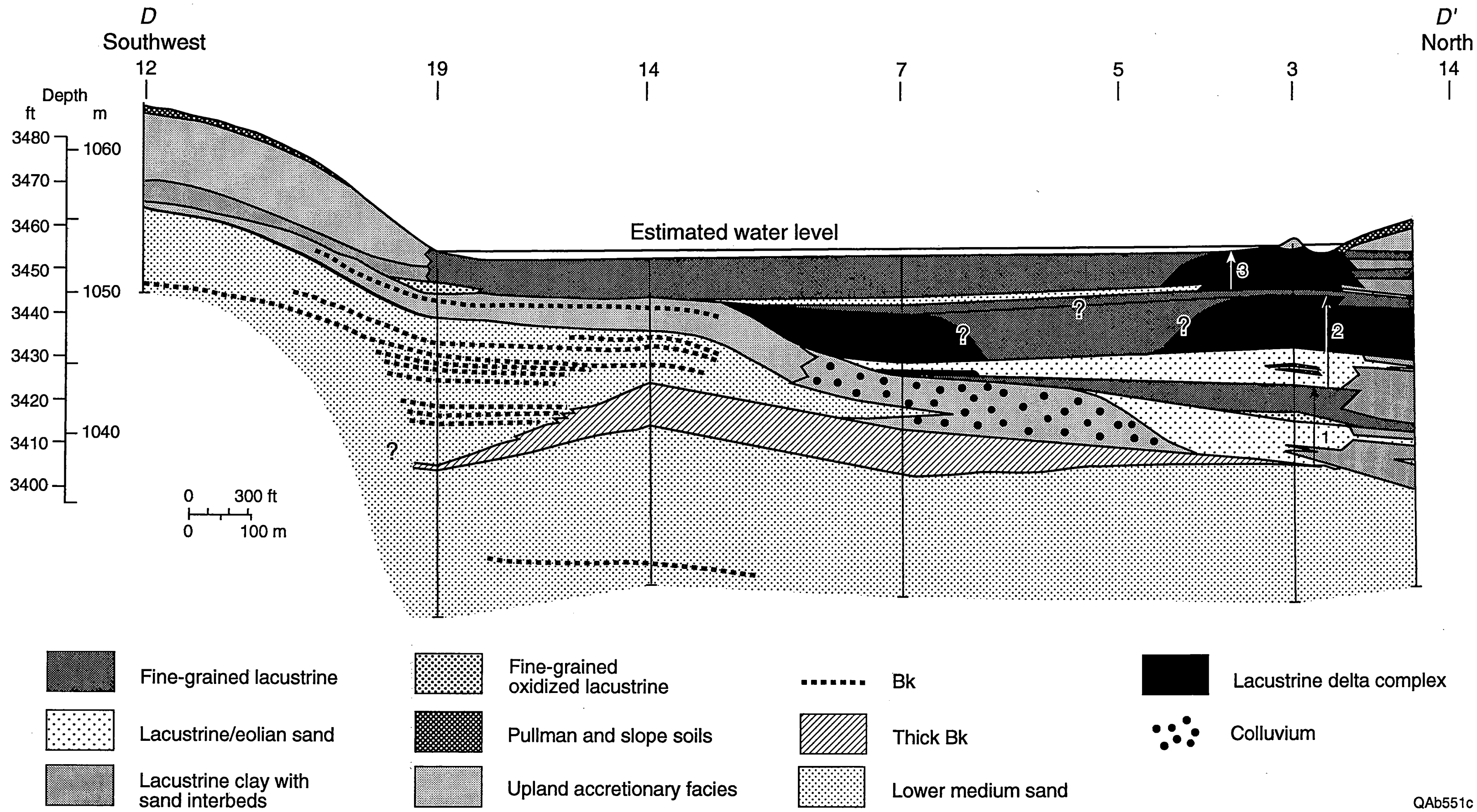

Figure 8. Pantex Lake southwest–lake center–southeast cross section D-D'. Cross section location shown in figure 3. Depositional units 1 through 3 are discussed in the text.

The facies relationships beneath Pantex Lake are unusual in comparison to those of the other lakes examined. An unusually thick lake section (70 ft) was cored in borehole 4, 200 ft south of the present lake shore (fig. 7). Surface sediments in this core match the present-day geomorphology, with about 3 ft of transported dark topsoil and allochthonous carbonate clasts above 3 ft of red-brown (7.5 YR 3/3) slightly calcareous silty clay loam. The transported topsoil is probably slope wash deposits sourced from plowed fields just upslope. The silty clay loam is interpreted as shoreline or lower slope Blackwater Draw upland accretionary facies. Below this are various clayey and sandy lake and lakeshore sediments. To the north beneath the modern lake, the thickness of the lake sediments decreases. The lower lake marginal facies cored south of the southern shore of the modern lake could therefore be interpreted as deposited near the northern shore of the paleo-lakes. A thick (as much as 10 ft), gently southward-dipping soil carbonate horizon was cored 5 to 15 ft beneath the top of the lower medium sand unit beneath the northern part of the lake. Much of the carbonate is soft Stage III soil carbonate, but local platy horizons suggest local or incipient Stage IV development. Blackwater Draw upland accretionary facies 5 to 10 ft thick underlies the northern part of the lake, demonstrating that lake deposition did not begin well into the time of fine-grained Blackwater Draw deposition, later than is observed in other playa basins. The dip on the soil carbonate and Blackwater Draw upland accretionary facies could have been produced either by original slope toward the lake or by subsidence of the basin center. Alluvial or slopewash deposits laterally equivalent to Blackwater Draw facies document some slope at the time of their deposition.

Core transect 14–17 (fig. 3, cross section not shown), drilled across the northwest edge of the playa, shows that thin lake sediments and the underlying thick soil carbonate are flat lying, with little change between cores.

The transect across the southern part of the playa (cross section D-D', fig. 8) shows the thick lake sediments south of the modern playa lake beneath near surface Blackwater Draw upland accretionary facies and slope soils in borehole 1. Boreholes 1 and 3, near the large drainage that enters the playa on the southeastern edge (fig. 3), contain thick deltaic sequences (fig. 8). Intersection of thick lake sediments in these boreholes is similar to the relationships observed in borehole 4 on the southern edge of the playa, showing that the north edge of the paleolake was positioned beneath or just south of the south edge of the modern lake.

Cross section D-D' (fig. 8) shows that the playa has migrated northeastward. Initial lake sediments (unit 1) were found in boreholes 1 and 3 only. This lake-transgressive unit overlies the edge of the thick soil carbonate within the upper part of the lower medium sand unit. The southwest bend in the line of section at borehole 14 shows the gentle southward dip on the thick soil carbonate. Correlations suggest equivalence of lake unit 1 with colluvium in borehole 7 and with Blackwater Draw upland accretionary facies in borehole 14. Lake unit 2 shows migration of the lake northward over some upland facies, with prominent deltaic deposits in borehole 7. Lake unit 3 shows expansion of the lake to its present location. Sandy lake sediments in borehole 1 in this unit are interpreted as shoreline deposits from the southern edge of the playa lake. Red (7.5 YR 4/3) lake clay with thin sand and silt interbeds, correlative with the lower part of unit 3, were cored in borehole 12, 20 ft above the contemporaneous lake floor in borehole 14. These deposits document a time when the lake was much larger, and presumably intermittently deeper, than that at present. Similar high lake deposits were cored on the south side of Sevenmile Basin (Hovorka, in press). High deposits have not been cored in smaller basins, but lake deposits with dark colors and well-preserved lamination are found in many basins, and they also document episodes of deeper or more perennial lake conditions.

Following this episode of lake expansion, the lake abandoned most of the southern part of its large basin, and Blackwater Draw accretionary facies with well-developed modern Lofton and Church soils (Jacquot, 1959) accumulated across older lake deposits. Soils and topographic maps show several small Randall-clay-floored playas occupying the southern part of the large basin.

The unusually thin (9-ft) interval of lake clays in the northern part of Pantex Lake, coupled with the long history of use as a site of wastewater disposal, might lead to high rates of downward flux of wastewater. However, no hydrologic or geochemical analyses of either the unsaturated zone or the underlying aquifer or aquifers are available. Mineralization, localized reduction of sands and clays, and localized partial dissolution of carbonate are abundant in lake sediments. There are no data to constrain the timing of these alterations, and as is typical of most playas, many alterations are most readily interpreted as paleodiagenesis, related to former fluctuations in lake conditions. Limonite is moderately abundant through the lake sections and associated sediments (fig. 6 d), but it is not especially concentrated in the near surface or near the site of the former wastewater discharge point. Borehole 19, nearest to the former wastewater input point, encountered 9 ft of lake and lake marginal clay and 6 ft of Blackwater Draw silty clay loam above lower medium sand with abundant Bk horizons (fig. 8). No evidence of a scour or unusual alteration was found in the core. However, the general area where the wastewater was discharged is heavily vegetated, topographically complex, and perhaps modified by construction and water-level changes, so additional investigation might be required to completely characterize the area. It is possible that the treated wastewater discharged to this playa was not as organic rich or as strongly reducing as the sewage released to Playa 5 and so the sediments retain little evidence of its presence. Carbonate is generally well preserved beneath the northern part of the lake as well as near the discharge point, indicating that fluxes of recharging water during the time the lake has occupied this part of the basin have not been high enough or unfocused enough to remove all the carbonate from the basin floor. No moisture contents were measured in samples from this playa. Observation of core showed fairly dry sediments near the surface and somewhat damper sediments between 10 and 40 ft. The thick soil carbonate generally appeared to be relatively dry.

CONCLUSIONS

Pantex Lake and Playa 5 have had an unusual sedimentologic and geomorphic development. This development has influenced the way in which ponded wastewater has been recharged. Playa 5 has moved northward within its basin through geologic time; this resulted in erosion of Backwater Draw loams and occurrence of the lower medium sand at shallow depth on the north side of the lake. Discharge of sewage into a pit scoured in this area allowed recharge to completely bypass lake sediments as well as the fine-grained upland sediments. Effects of flux of reducing water can be seen in a core from this site as well as in a core from another location on the north shore of the lake. The effects include discoloration of sand by organic material, unusually abundant limonite, and possibly local reduction of iron oxide coats on sand grains.

Pantex Lake lies at the northwest edge of an unusually large playa basin. The large basin may have been created as the lake migrated northwestward during the geologic evolution of the basin, so that the present southern lake shore overlies the northern shore of former lakes, and thick lake sections are encountered in the subsurface south of the modern lake shore. One result of this migration is that lake sediments are thin (9 ft) in the northern half of the lake basin. However, there is little textural evidence of the effect of wastewater discharge to this lake. A wave-cut bench around the lake is the only observed influence of long-term ponding in this lake.

ACKNOWLEDGMENTS

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