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**RESULTS OF TRENCHING INVESTIGATIONS ALONG THE
NEW CASTLE RAILROAD SURVEY-1 SEISMIC LINE, NEW
CASTLE, DELAWARE**

By

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ABSTRACT

Five trenches were excavated to a depth of 5 to 8 ft along the path of an abandoned railroad grade near the city of New Castle to investigate potential near-surface faults that may be related to earthquake activity in northern Delaware. Seismic reflection profiles along this line suggested the existence of significant faulting in the area, which lies along a postulated fault trend in eastern New Castle County. Subsequent drilling, however, failed to substantiate displacement interpreted for faults in the sedimentary section. Detailed examination of exposures in the trenches also failed to reveal the existence of near surface faults. Together these findings suggest that there has been minimal or no modern near-surface fault activity in this area of New Castle County.

INTRODUCTION

The purpose of this study is to document the results of a trenching investigation of potential near-surface faults in the New Castle, Delaware, area that may be related to earthquake activity in northern New Castle County. This study is part of a multidisciplinary investigation conducted by the Delaware Geological Survey (DGS) on behalf of the Delaware Emergency Management Agency (DEMA) to assess earthquake hazards in northern Delaware.

The DEMA Earthquake Project was initiated to investigate areas with a potential for faulting related to the minor earthquake activity that occurs in northern New Castle County. As part of its responsibility for emergency management in the state, DEMA has an interest in understanding the nature of earthquake risk. Historically, the area has been affected primarily by minor earthquakes. Of the 56 documented earthquakes in the DGS Catalog of Earthquakes in Delaware (Baxter, 2000), most are less than magnitude 3.0. Six stronger earthquakes have been documented, the strongest being an estimated magnitude 4.1 earthquake in Wilmington in 1871. These records extend back only to the 19th century; the magnitude of earthquake activity before these historical records, and hence potential for future hazards, can only be assessed through geological investigations. Earthquake activity in northern New Castle County indicates that active faults are present. However, faults with surface expression are rare (Jordan et al., 1972; Woodruff, 1984). The DEMA Earthquake Project was designed to investigate the presence of active near-surface faults in the area.

New Castle was chosen as the site for the study (Fig. 1) because of its location along what has been interpreted as a basement fault trend in northern Delaware (Spoljaric, 1973). The faults are were

identified based on structure maps of the crystalline basement (Spoljaric, 1973) and may extend into the overlying Cretaceous and Quaternary Coastal Plain

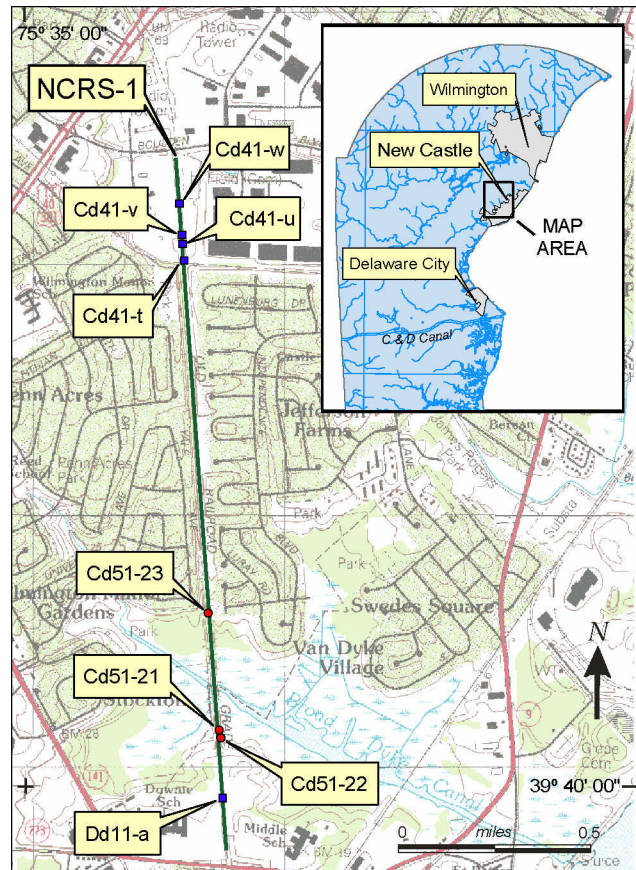


Figure 1. Location of sites discussed in this report. Seismic line NCRS-1 was run on a north-south abandoned rail line in the middle of the map.

sedimentary units (Fig. 2). An abandoned railway path that runs north from the town (Fig. 1) provides a logistically advantageous location for conducting seismic and drilling operations to investigate faulting in the basement rocks and overlying sedimentary units.

The project was coordinated by Stefanie J. Baxter and Thomas E. McKenna, with contributions by a number of DGS staff, and was undertaken in three stages. The first stage involved collection of a 40 Hz seismic reflection and refraction profile by the U.S. Geological Survey (USGS) Western Earthquake Hazards Team along the path of the abandoned railway in June 1998. This is referred to as the New Castle Railroad Survey-1 (NCRS-1) seismic line. This seismic project was designed to resolve geological features to a depth of approximately 1500 ft. The rail line is oriented approximately north-south at a high angle to the trend of the hypothesized fault zone, making the seismic line ideally situated to reveal any related shallow faults. The USGS team processed the line and provided time and depth sections to the DGS (Catchings et al., 2000). Gravity and magnetic survey data were also obtained along these lines. The seismic sections appeared to show the existence of significant faulting along the NCRS-1 line (Fig. 3).

The second stage of the project was a drilling program designed to test the results of the seismic survey. Three boreholes were drilled to basement along the trend of the NCRS-1 seismic line at locations where it was thought the wells could document the existence of faulting (Fig. 1). The first borehole, Cd51-21, was continuously cored to 555 ft depth by the USGS Eastern Region Earth Surface Processes Team's drilling crew in May 1999. The location of the hole was designed to cross a significant fault interpreted from the seismic data. The second borehole, Cd51-22, was drilled by a contractor's mud rotary rig to a depth of 351 ft on February 28 and March 1, 2000. This hole was located approximately 197 ft (60 m) south of Cd51-21 for the purpose of obtaining a nearby geophysical log to assess the potential vertical displacement on a fault interpreted on the seismic

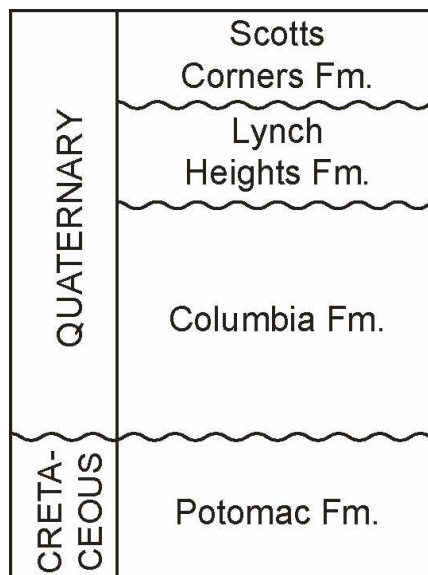
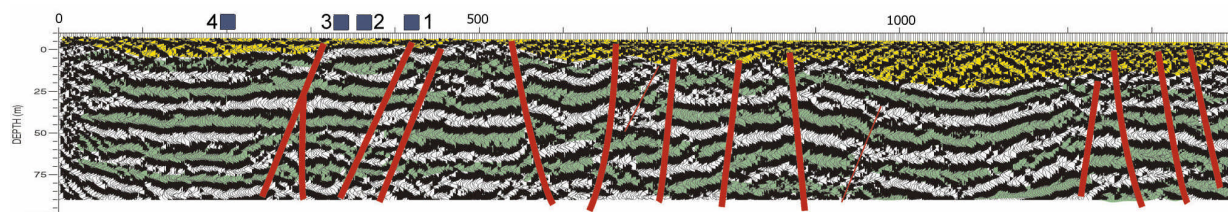


Figure 2. Stratigraphic column for the Coastal Plain section of the New Castle area.

section (Fig. 4). The third borehole, Cd51-23, was continuously cored to 508 ft depth by the USGS drilling crew in March and April 2000. This third location was chosen to penetrate an interpreted fault and to investigate the potential existence of a graben-like feature interpreted on the seismic section at the same location as a large negative gravity anomaly. The results of the drilling have failed to confirm any of the shallow (500 ft and shallower) faulting identified in the sedimentary section on the seismic line. In the case of the fault interpreted between the Cd51-21 and Cd51-22 boreholes, geophysical log correlations do not support the degree of offset indicated (Fig. 4).

The third phase of investigation is the subject of this report. Trenching is a widely used means for identifying recent fault activity in earthquake studies (e.g., Cox et al., 2000; Fonseca et al., 2000). Faults interpreted on the seismic section were not documented

Figure 3 (continued on next page). Original interpretation for the depth-section for the NCRS-1 seismic line (Catchings et al., 2000). Trench locations are indicated by blue squares, boreholes by red circles, and interpreted faults by red lines. Horizontal scale represents meters from north end of line. Location of section shown in Figure 4 is indicated by the boxed area near 2300 m.



by the drilling program; trenching provided an important additional means to investigate faulting. The trenching operation was undertaken in October 2000 with a series of excavations made to investigate potential sites of near-surface faulting identified along the NCRS-1 seismic line. The trenching work did not reveal the existence of any near-surface faults at these sites, calling into question the degree of faulting suggested by the seismic reflection patterns on the NCRS-1 line. This report documents the methods used in the trenching investigation, presents the results obtained at each trenching site, and discusses the implications of these findings for the DEMA Earthquake Project.

GEOLOGIC SETTING

New Castle lies along a postulated basement fault trend that underlies the Coastal Plain of northern Delaware. Spoljaric (1973) reported the existence of a northeasterly (N. 25° E.) oriented graben near Delaware City. The fault plane solution (N. 28° E.) for the magnitude 3.8 earthquake that occurred near Wilmington in 1973 (Sbar et al., 1975) is consistent with this trend. In addition, Higgins et al. (1974) suggested the southwestward-flowing parts of the Potomac, Susquehanna, and Delaware rivers are controlled by a basement fault zone that trends N. 25° E. which forms part of a regional fault system extending from Virginia to Connecticut.

New Castle lies in the Atlantic Coastal Plain province of Delaware. The area is underlain by a crystalline basement of amphibolite- to granulite-grade metamorphic rocks of the Wilmington Complex (Plank et al., 2000). This unit crops out approximately 3.5 miles north in the Piedmont Province of Delaware. Non-marine Cretaceous deposits of the Potomac Formation overlie the basement (Fig. 2). The Potomac Formation in northern Delaware is composed of variegated red, white, and gray silts and clays interbedded with quartz sands (Jordan, 1962). These facies reflect deposition in an alluvial plain with extensive paleosol formation. The Potomac Formation is unconformably overlain by Pleistocene fluvial deposits of the Columbia Formation. The Columbia Formation is typically composed of yellow to dark

reddish-brown, coarse, quartz sand with common gravel (Jordan, 1962, 1964). Near the Delaware River, it is, in places, eroded and unconformably overlain by sediments of the middle to late Pleistocene Lynch Heights and Scotts Corners formations. These

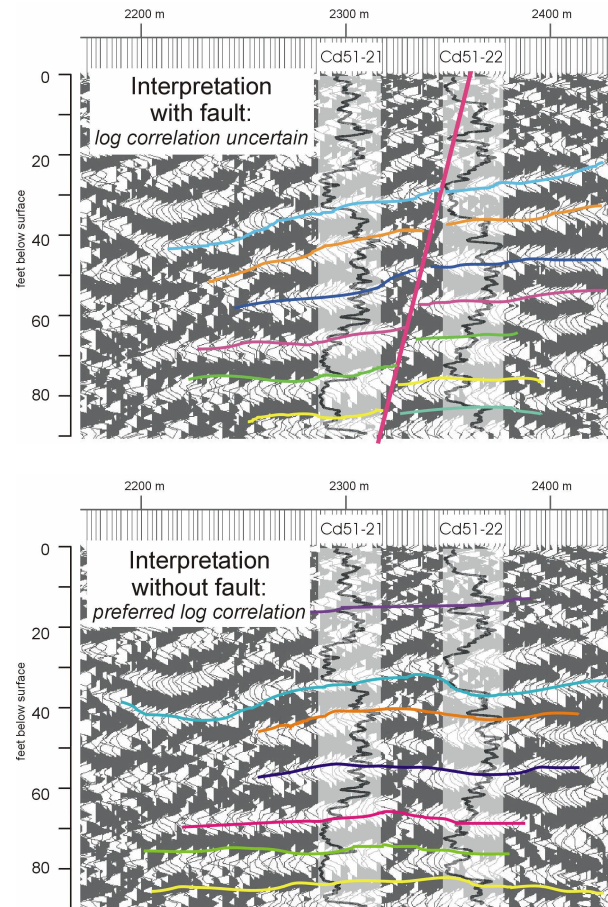


Figure 4. Alternative structural - stratigraphic interpretations for correlations between wells Cd51-21 and Cd51-22. Gamma logs are overlain on part of the depth-converted NCRS-1 seismic line. Geophysical log correlations are more reasonable with no fault between the two wells.

Figure 3 (continued from previous page).

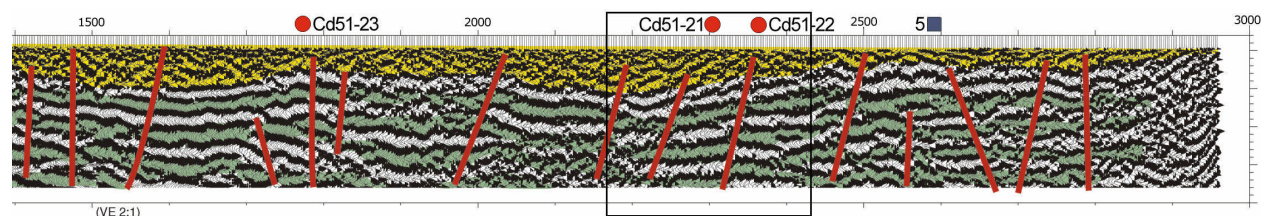


Table 1. Location data for trench geographical reference points, defined at center of each designated 32.8-ft (10-m)-long trench area (the entire length of the designated trench area was not excavated on all trenches). Distances are measured from the north end of NCRS-1 seismic line profile at Boulden Boulevard (Fig. 1).

Trench No.	Lat. (N)	Long. (W)	Excav. Date	Ground Elev. (ft)	Distance to ref. pt. (ft)	Distance to ref. pt. (m)
1	39° 41' 7.8"	75° 34' 35.4"	10/24/00	31.7	1368.1	417.0
2	39° 41' 9.6"	75° 34' 35.6"	10/25/00	32.9	1195.5	364.4
3	39° 41' 10.7"	75° 34' 35.7"	10/26/00	33.5	1090.9	332.5
4	39° 41' 14.9"	75° 34' 36.1"	10/27/00	34.5	656.2	200.0
5	39° 39' 58.1"	75° 34' 27.7"	10/30/00	15.2	8459.7	2578.5

formations were described by Ramsey (1997) as light reddish brown to gray sands with beds of gray clayey silts and brown, organic-rich, clayey silt. Each represents one or more periods of erosion and deposition associated with fluctuations of sea-level along the margins of the Delaware Estuary (Ramsey, 1977). Although originally described from Kent and Sussex counties, these units are considered by Ramsey to also be present in eastern New Castle County.

METHODS

The NCRS-1 seismic line and shot-hole records were evaluated to determine the most promising sites for fault trenching. Trenching methods were based on procedures used by Ray Lambert (oral and written communications, 2000). The locations of the sites were determined based on three requirements: (1) seismic data indicated the potential for shallow faulting near the ground surface; (2) the water table was likely at least five feet beneath the surface, below targeted trench depths; and, (3) the bulk of the vertical exposure was likely in geological materials rather than fill or railroad ballast.

Five trenches were dug with a backhoe to a depth of approximately 7 ft and shaped to create at least two perpendicular walls with clear exposures of geological features. Trenching was conducted by Walton Drilling Corporation personnel following Occupational Health and Safety Agency (OSHA) guidelines for trench dimensions and protective equipment (OSHA Excavation Standard Handbook, 1997). The two walls chosen for description were further cleaned with small shovels to create flat, even faces for the descriptive work. Geographical reference point locations reported for each trench are from the targeted center point of a 32.8-ft (10-m)-long by approximately 13.2-ft (4-m)-wide area designated for trenching, centered on the middle of the old rail line. Precise locations for the reference points were obtained by measuring from survey markers established for the seismic line (Table 1). For Trenches 1 through 4, the

excavation was started at the southern end of the designated trench area, 16.4 ft (5 m) south of its reference point. For Trench 5, the excavation was started at the northern end of the designated trench area, 16.4 ft (5 m) north of its reference point.

The trench dimensions were measured and marker flags were laid out at 1-ft intervals (3-ft intervals in Trench 1) along the edges of the faces to be described in order to provide horizontal coordinates for observations. A horizontal datum was marked with a length of string positioned approximately 1 ft below the ground surface of each face to be described. Significant lithologic boundaries identified in each trench face were marked by colored flags, with a flag placed at every horizontal coordinate where possible. Each boundary was assigned a horizon name based on the color flag used; for example, the "Yellow horizon" is a level marked with yellow flags (no correlation between trenches was implied by use of the same color marker flags). Vertical coordinates were recorded for the horizons at each 1-ft horizontal coordinate. The horizontal and vertical coordinates for these points were recorded in the field on a sheet of mylar laid over graph paper at a scale of 1 in to 1 ft, creating a diagrammatic representation of each face while on site. Detailed notes were made for each lithologic unit identified, and sketches and digital photographs were made to record the exposed faces and features of interest. On several days, soil scientists Dianne Shields, Phillip King, and Richard Hall from the U.S. Department of Agriculture's Natural Resource Conservation Service (NRCS) participated in the description of the excavations, providing valuable information on soil forming features and processes.

RESULTS

Four trenches were excavated on the north end of the NCRS-1 seismic line and one on the south end (Fig. 1). The observations for each of the five trenches are described in detail and illustrated below.

Trench 1 (Cd41-t)

Trench 1 was the southernmost excavation of those on the north end of NCRS-1, with a geographical reference point 1368.1 ft (417.0 m) south of Boulden Boulevard (Table 1). Descriptions were made by Thomas E. McKenna, measurements by Scott A. Strohmeier, and plotting of data points by Stefanie J. Baxter. Four samples were taken in this excavation (Appendix). Five lithologic units were described in this excavation, overlain by units of railroad bed ballast and fill (Figs. 5 and 6).

1. The lowest unit was exposed in the south wall of the trench under the Yellow horizon. The sediments consist of silty to clayey, very fine grained sand interlaminated with approximately 0.1-ft-thick light gray clay.
2. Overlying the Yellow horizon and under the Green horizon is an interval of silty to clayey, very fine grained white sand interlaminated with 0.1-in-thick clay laminae and lenses. The sand is predominantly subrounded quartz grains and contains abundant opaque heavy minerals, and some mica, with orange iron-staining in places and ripple marks throughout.
3. Within the sand unit described above is an approximately 0.5-ft-thick, heavily iron-stained zone. Its top and bottom are delineated by the upper Pink horizon and the lower Pink horizon.
4. Overlying the Green horizon and under the Blue horizon is an interval of fine-grained quartz sand, heavily stained to a brownish orange color throughout by iron-oxide. The sand is predominantly subrounded quartz grains, silty, with no lithics observed. Tabular cross-beds are evident, forming cross-bed sets up to 0.2 ft thick. In the bottom 0.1 to 0.4 ft of this interval is a quartz gravel interval, containing gray rip-up clasts of the underlying unit.
5. The Blue horizon is a sharp boundary, marked by a 0.2-in-thick black interval with iron and/or manganese stain. Overlying this black contact, and under the railroad ballast, is a unit of very fine to fine-grained, light gray to brownish-orange sand. Tabular cross-beds are evident, forming cross-bed sets up to 0.2 ft thick, and faint ripples occur.

Stratigraphically, the sediments exposed in this excavation are interpreted as Quaternary deposits of the Columbia Formation. No faults of significant displacement were observed in the excavation. However, an interesting feature was noted below the Blue horizon near the lower contact with the Green horizon in the lower part of the east wall of the trench. Subvertical, discrete, iron-stained bands exhibit apparent displacement of 0.05 to 0.15 ft along what appears to be an east-west striking, 10° south-dipping fault. Sedimentary bedding is not evident in this



Figure 5. Photograph of south wall of Trench 1. Iron-stained cross-bedded sands above the Green horizon overlie ripple-marked white to light gray sand. The exposed strata are placed in the Columbia Formation.

interval. This was the only location in the trench with subvertical iron-stained banding. The apparent fault may be the product of channel-bank slumping in a fluvial setting (or possibly soil- or frost-related processes) and is likely not related to tectonic activity.

Trench 2 (Cd41-u)

Trench 2 was excavated north of Trench 1, with a geographical reference point 1195.5 ft (364.4 m) south of Boulden Boulevard on NCRS-1 (Table 1). Descriptions were made by Kelvin W. Ramsey, measurements by Scott A. Strohmeier, and plotting of data points by Stefanie J. Baxter. Nine samples were taken from this excavation (Appendix).

The main stratigraphic surfaces dip gently northward (<10°), with six lithologic units described under the railroad bed ballast and fill (Figs. 7 and 8).

1. The lowest unit was exposed at the bottom of the trench walls under the Pink and Yellow horizons. It is composed of homogenous, silty, stiff clay. The color is overall purple and dark red, with a gray zone with purple mottling the upper 1 ft of this interval, and an area of yellowish brown with dark red mottles on the northern third of the west wall. Iron-cemented concretions are common and associated with the deep-purple mottling.
2. On the south wall and the south end of the west wall, a zone of silt was exposed between the Pink and Yellow horizons. This interval is characterized by gray to light pink sandy (very fine) silt in the lower part, passing upward to light purple-pink to

Figure 6 (next page). Trench 1 geological sketch, showing the predominantly sandy Columbia Formation deposits exposed on both walls of the excavation.

Figure 6

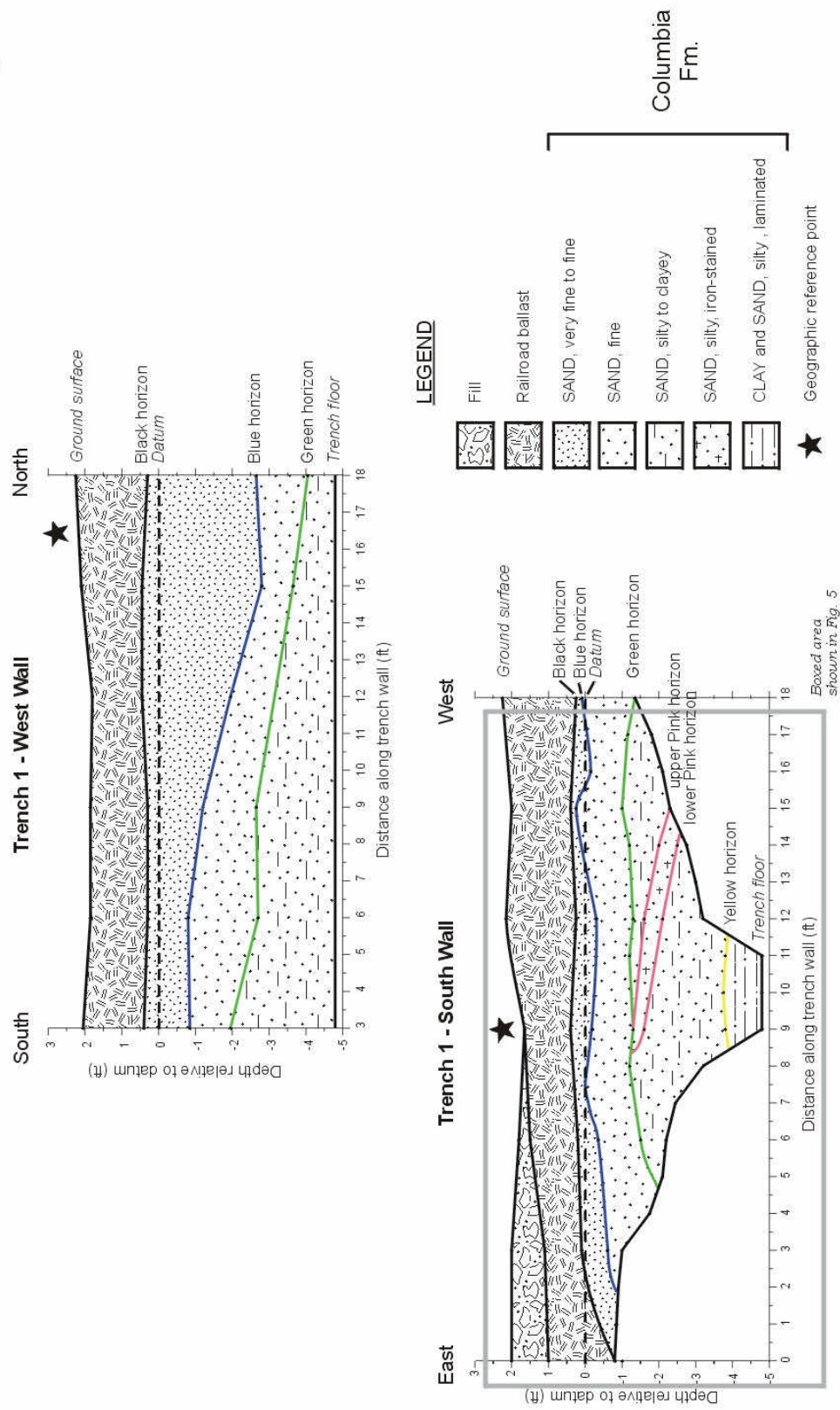


Figure 7

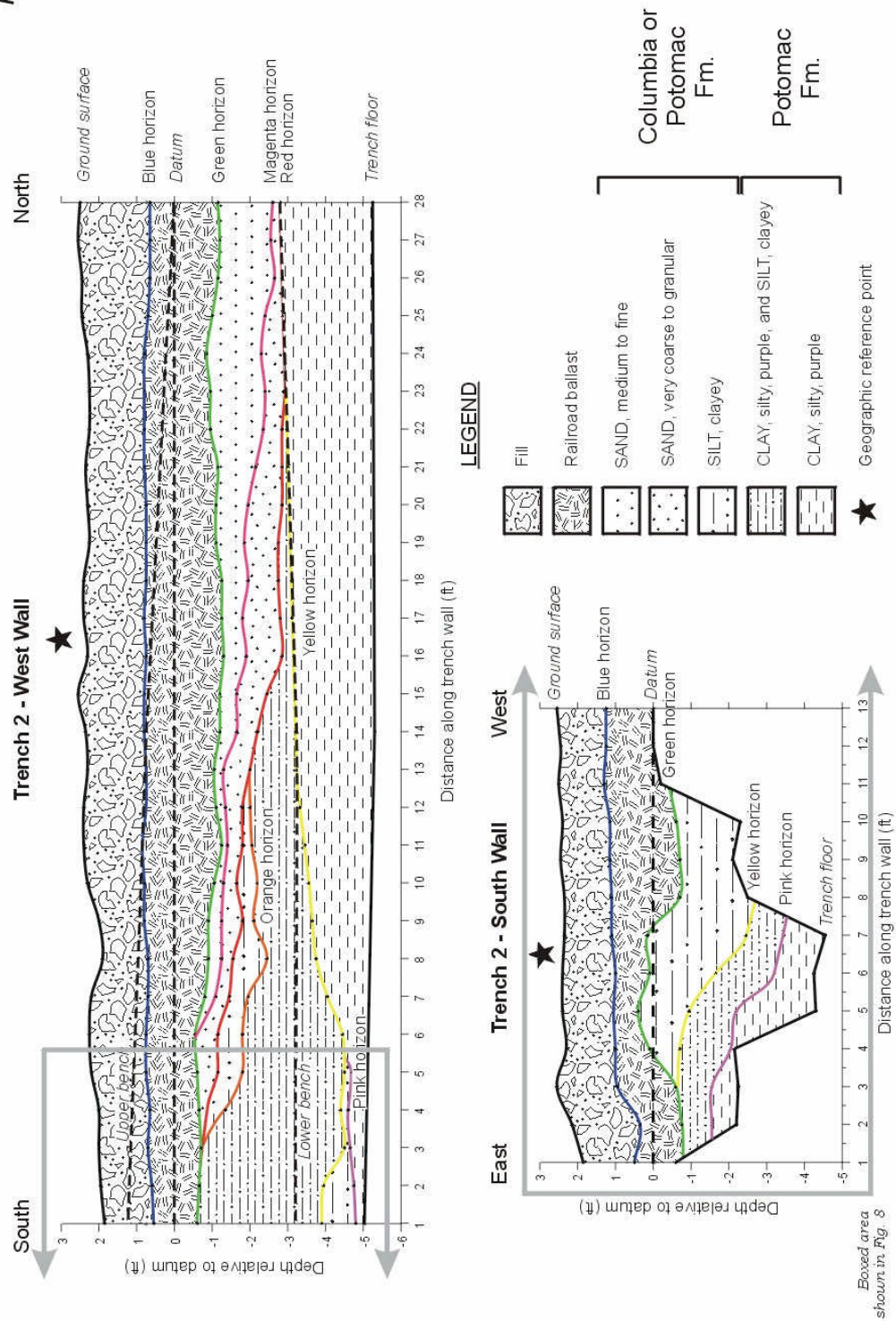


Figure 7 (previous page). Trench 2 geological sketch, with mottled oxidized interfluvial and fluvial facies of the Potomac Formation below the Orange horizon and sands of the Potomac or Columbia formations above the Orange horizon.

reddish gray clayey silt with small gray mottles in the upper part. It includes two dark red zones which are slightly cemented in places, with dark-red iron-cemented clasts and layers near the base of the upper zone.

3. Overlying the Yellow horizon is an interval characterized by light purple-pink to reddish gray clayey silt with small gray mottles passing upward into stiff purple and gray mottled silty clay. The purple-colored interval includes abundant small dark-red to purple concretions
4. On the west wall was exposed a small lenticular unit of clayey, brownish-yellow silt overlying the Orange horizon and underlying the Red horizon. This unit appears to fill a channel, with a sharper contact on its northern side and a gradual contact overlain by clayier facies to the south.
5. The base of the overlying very coarse to granule-sand is marked by a sharp contact that defined the Red horizon. This unit was noted on the west wall and fines slightly upward; no sedimentary structures were noted otherwise. The color is dark red to light reddish brown with few to common iron-cemented zones up to 1 ft thick. Water was seeping from this layer.
6. The highest sedimentary unit was described between the Magenta horizon and the base of the

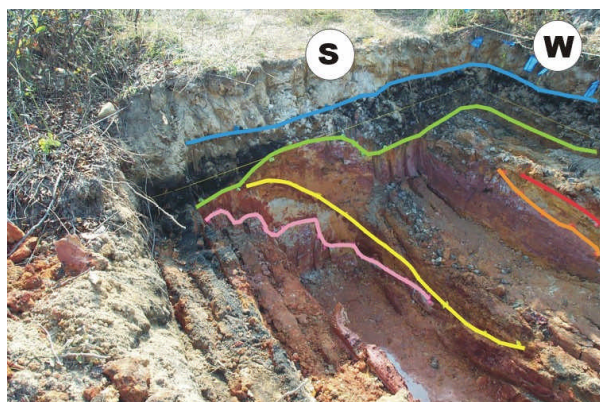


Figure 8. Photograph of junction of south (S) and west (W) walls of Trench 2, showing erosional relief in clays and silts of the Potomac Formation. Sands of the Potomac or Columbia formations lie above an erosional contact at the Orange horizon.

railroad ballast on the west wall. It is composed of whitish gray to light reddish-brown to light yellowish-brown, slightly micaceous, medium- to fine-grained, well-sorted sand. Low-angle cross-bedding occurs in common to abundant heavy mineral-rich laminae, dipping approximately 10° to the west.

All of the sediments exposed below the Orange horizon are interpreted as non-marine deposits of the Potomac Formation based on their mottled oxidized character. The silty clays at the base of the excavation appear to be highly weathered fluvial overbank deposits.

The overlying mottled silts (above the Pink horizon) are interpreted as slump materials from the collapse of a fluvial channel bank with a weathered red zone at the top representing a paleosol. This is overlain (above the Yellow horizon) by more silts and clays that may represent more overbank deposition, with the mottled gray and purple material representing alternating reduction and oxidation from weathering in alternating wet and dry conditions.

The Orange horizon is considered to represent a significant erosional surface, with the units above it possibly assignable to either the Potomac Formation or the Columbia Formation. The silts and very fine sands deposited immediately on that surface (between the Orange and Red horizons) were deposited away from any main fluvial channels in the area. These are in turn cut by an erosional surface represented by the Red horizon, which was covered by very coarse-grained sands and granules that likely represent the basal deposits in a channel. Above the Magenta horizon, at the top of the sedimentary section, are cross-bedded, fine-grained sands that may represent low-relief fluvial sand bars or sand sheets on the margins of a channel. Pollen analyses may shed light on the age of these units.

Trench 3 (Cd41-v)

Trench 3 was excavated north of Trench 2, with a geographic reference point 1090.9 ft (332.5 m) south of Boulden Boulevard along NCRS-1 (Table 1). Descriptions were made by Kelvin W. Ramsey, measurements by Scott A. Strohmeier, and plotting of data points by Stefanie J. Baxter. Seven samples were taken from this excavation (Appendix).

The main stratigraphic surfaces dip northward (Figs. 9 and 10). Four lithologic units were described in the excavation, overlain by units of railroad bed ballast and fill.

Figure 9 (next page). Trench 3 geological sketch, with possible Potomac Formation deposits below the Red horizon overlain by sandy strata of the Columbia Formation.

Figure 9

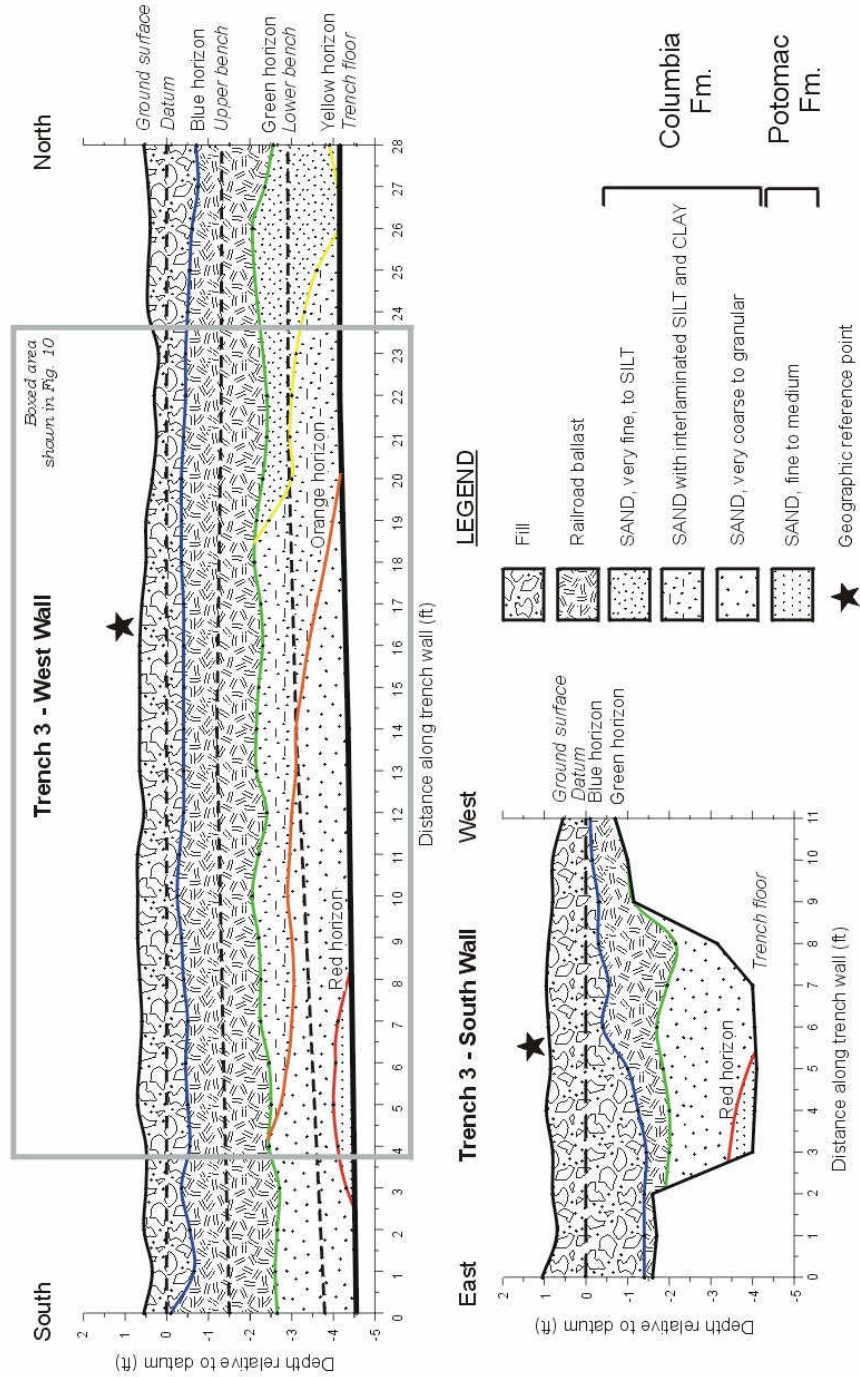




Figure 10. Photograph of west wall of Trench 3, showing northward dipping Orange and Yellow horizons in the Columbia Formation (Red horizon obscured by debris).

1. The lowest unit was exposed at the bottom of the trench walls under the Red horizon. It is composed of fine- to medium-grained sand which is light greenish-yellow in color, well sorted, and slightly micaceous with rare light gray clasts of silty clay. Low-angle laminae accented by heavy minerals are common.
2. Overlying a sharp contact at the Red horizon is an interval of laminated to thin-bedded granule layers, coarse sands, and very coarse sands. The sands are light reddish-brown to light gray where very slightly clayey. Cross-bedding is evident with a low-angle dip to the northwest.
3. On the west wall was exposed a unit of sand with interlaminated silt and silty clay above a sharp contact at the Orange horizon. The bottom two to three inches of this unit are white to reddish brown, poorly sorted, very fine to coarse-grained sand with heavy minerals highlighting laminations. This basal unit grades upward into a very coarse grained sand to granule bed with heavy mineral laminations showing cross-bedding dipping to the northeast.
4. On the north end of the west wall was a limited exposure of the highest unit, composed of very fine to coarse-grained sand and silt lying above a sharp contact at the Yellow horizon. The sand ranges in color from light gray to light reddish and yellowish-brown and occurs in lenses as well as beds at the base and in the upper part of the interval. It includes heavy mineral laminae as well as a layer with common very small pebbles and granules in the upper part.

Limited exposure and the lack of the characteristic red clays of the Potomac Formation makes lithostratigraphic placement difficult. On the bases of textural contrast and gross mineralogy, the

lowermost, slightly micaceous unit is assigned to the Potomac Formation. The strata above the Red horizon are considered to be Columbia Formation deposits that accumulated in a channel margin setting.

Trench 4 (Cd41-w)

Trench 4 was the northernmost excavation on the north end of NCRS-1, with a geographic reference point 656.2 ft (200 m) south of Boulden Boulevard (Table 1). Descriptions were made by Peter P. McLaughlin, measurements by Scott A. Strohmeier, and plotting of data points by Stefanie J. Baxter. Four samples were taken from this excavation (Appendix).

The main stratigraphic surfaces in the excavation dip northward and three lithologic units were described under the railroad ballast (Figs. 11 and 12).

1. The lowest unit was described under the Yellow horizon in most of the west wall and under the Red horizon on the south wall. It is composed of stiff, dark gray, silty clay with minor very fine sand and silt (Fig. 12). Also exposed within this clay interval, especially on the south wall, were highly irregular and tan to bright-red, very fine grained, silty sand bodies that represent the sand-filled vertical and subvertical fractures in the clay.

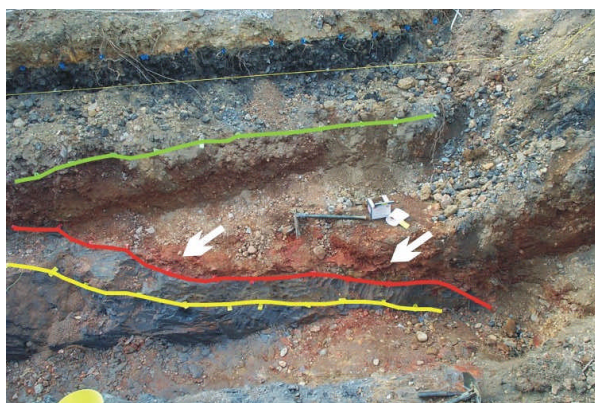


Figure 11. Photograph of west wall of Trench 4. Northward sloping erosive contact separates dark gray clays below the Red horizon and heterolithic reddish-brown conglomerate above. The upper 1 ft of clay under the Red horizon is oxidized to a tan color. A "hard pan" of plate-like fragments of ironstone creates a bright red zone just above Red horizon (at arrows).

Figure 12 (next page). Trench 4 geological sketch, with dark-gray clays overlain by poorly sorted conglomerates with well-developed soil features. Although atypical, these are interpreted as Columbia Formation.

Figure 12

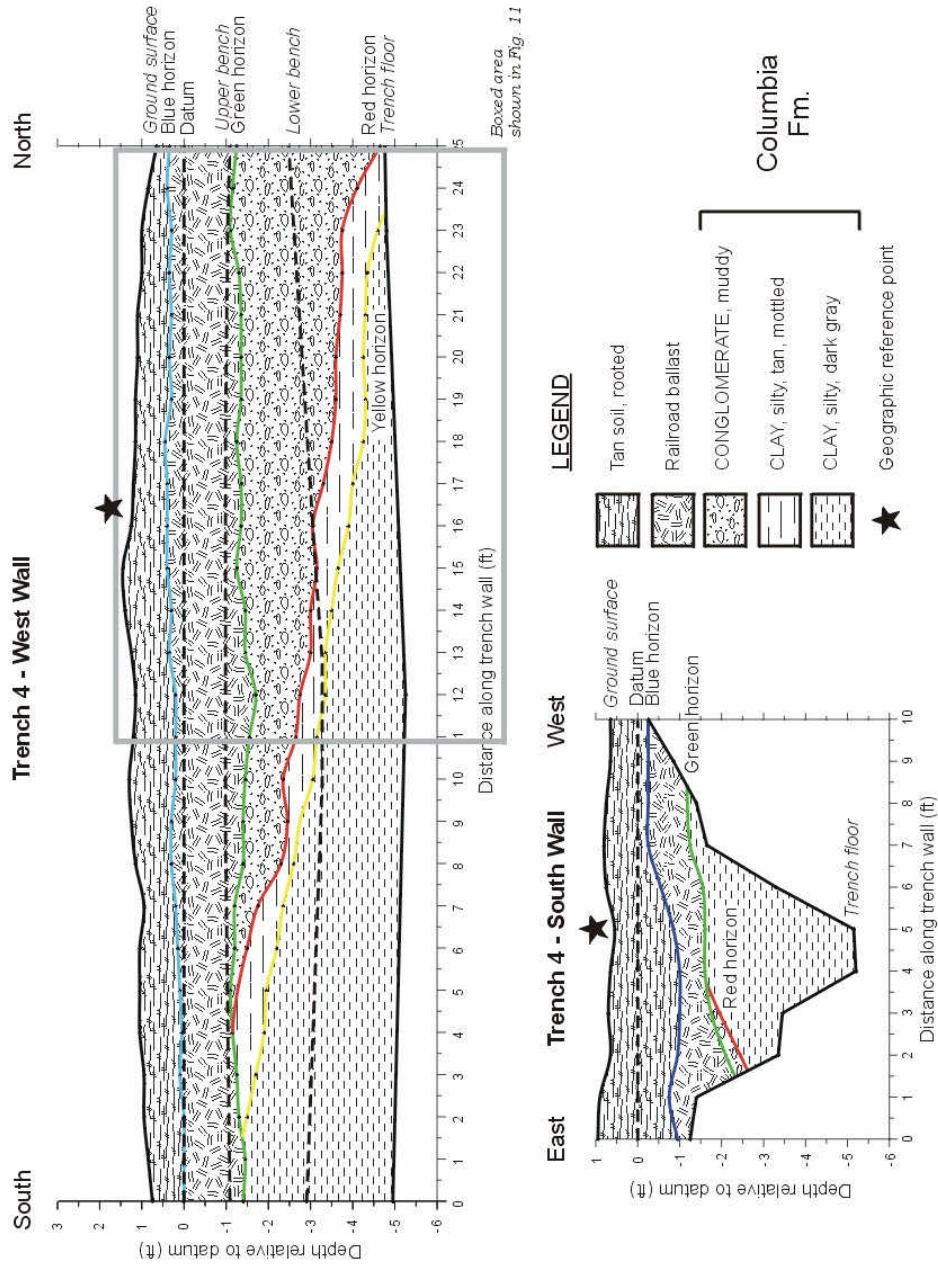


Figure 13 (previous page). Preliminary surface geology map of the New Castle area by K.W. Ramsey. The landward limit of strata assigned to the late Pleistocene “Delaware Bay deposits” of the Scotts Corners and Lynch Heights formations is drawn at a scarp approximating the 50 ft contour on the 1948 topographic sheet for the area, which was surveyed before extensive development and associated landscape modification in the area.

2. On the plane of the west wall, these dark clays are overlain by lighter clays, representing the same lithology with some oxidation below the overlying, erosive Red horizon. This zone is approximately 1 ft thick, with the color of the dark clays and minor sands and silts altered to tan and light gray.
3. These clays are cut by a significant (5 ft relief), north-dipping erosional surface, the Red horizon, upon which lies a muddy conglomerate. This conglomerate is almost brick red in its lower part, with a significant component of soft red silty clay and clayey silt, hard red siltstone, and clay-rich pebbly sand with pebbles up to 2 in diameter. Just above the basal contact, a “hardpan”-like layer was noted where abundant, platy, <0.5-in-thick fragments of hard, iron cemented sand are abundant. Its upper part is a reddish brown, clay-rich, poorly-sorted but overall coarsening-upward conglomerate containing a mixture of cobbles (up to 4 in), pebbles, granules, and sand from very coarse to very fine grained fractions. Dianne Shields (NRCS) identified well-developed pedes with clear clay faces in this unit, indicating significant influence of soil-forming processes.

This site lies topographically above a postulated scarp that is thought to represent the landward limit of late Pleistocene “Delaware Bay deposits” of the Lynch Heights and Scotts Corners formations (Fig. 13). Therefore, the sediments exposed in this excavation are tentatively interpreted to lie within the Columbia Formation, although neither represents a typical lithology as described by Jordan (1964). The dark clays probably represent local fine-grained sedimentation. These showed some evidence of soil formation processes, including prisms and roots. The overlying muddy conglomerate may represent a channel fill, produced by channel margin failure. The clay content may be related to soil formation, as the well-developed nature of pedes and clay faces indicate that this unit was subsequently subjected to strong and long-lasting soil-forming processes.

Trench 5 (Dd11-a)

Trench 5 was excavated on the south side of the NCRS-1 seismic line at a reference point of 8459.7 ft (2578.5 m) south of Boulden Boulevard (Table 1). Descriptions were made by Peter P. McLaughlin, measurements by Scott A. Strohmeier, and plotting of data points by Stefanie J. Baxter. Two samples were taken (Appendix).

The main stratigraphic surfaces are generally flat-lying. Three lithologic units were described, overlain by units of railroad bed ballast and fill (Figs. 14 and 15).

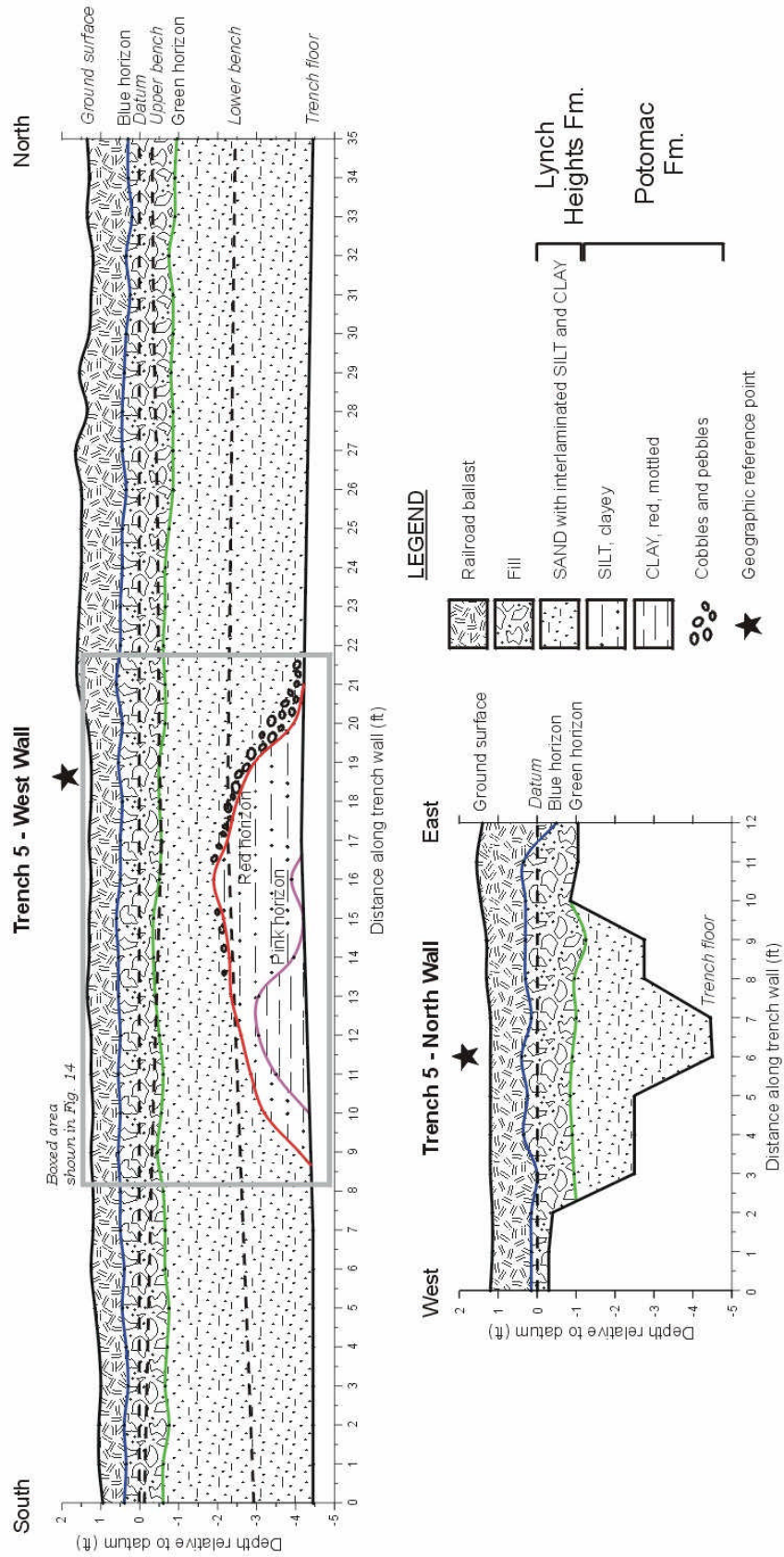
1. The lowest unit is an interval of mottled red clay exposed at the base of the west wall under the Pink horizon. It is characterized by waxy red clay mottled with vertical light gray clay zones that represent prisms beginning to form by soil processes, with reduction in zones along the prism boundaries.
2. The overlying unit was also exposed only on the west wall between the Pink and Red horizons. It is composed of waxy, light gray to tan silt and silty clay, with most of the tan areas appearing to be due to iron-staining. Cracks are evident in places with



Figure 14. Photograph of west wall of Trench 5, showing tan sandy deposits of the Lynch Heights Formation resting unconformably on an erosive remnant of red and light gray clays of the Potomac Formation. A rusty orange zone bearing pebbles and cobbles (at arrows) lies above the erosional unconformity at the Red horizon, with approximately parallel color-banding.

Figure 15 (next page). Trench 5 geological sketch, with an erosional remnant of waxy red clay paleosols of the Potomac Formation at the base unconformably overlain by locally pebbly sands of the Lynch Heights Formation

Figure 15



pedes forming between them, the faces coated with a thin, dark, apparently manganese-oxide stain. The top of this unit appears to be eroded, with the exposure of the bottom two units representing an erosional remnant that was eroded to the north and south (Fig. 15).

3. The highest sedimentary unit, which comprises most of the exposed section in the trench, lies between the erosive Red horizon and the base of overlying fill marked by the Green horizon. It consists of sand with interlaminated silt and clay and a thin conglomeratic zone at its base. The sand is micaceous, very silty, very fine grained to fine grained in places. Its color is mottled, ranging from yellowish brown and some yellowish-red to more commonly pale brown, with some light greenish-gray bleached zones. The thin conglomerate at the base of this unit includes clasts ranging from 0.5 in pebbles to cobbles more than 6 in diameter, most of which rest on or just above the erosive contact at the underlying Red horizon. Bands of iron staining are conspicuous, and in the lower part of this unit parallel the underlying Red horizon; in places these give a false sense of stratification. An additional observation worth noting is the presence of possible shell fragments in material brought up in a hand auger hole dug by NRCS soil scientist Richard Hall at the north end of the trench. The auger hole extended almost 3 ft below the floor of the trench, still within this unit at that position.

The two lithologic units exposed in the “erosional remnant” at the base of this excavation are part of the Potomac Formation, possessing the waxy clay and red-white mottling typical of that formation. The overlying sandy sediments are considered to be “Delaware Bay deposits” of the Lynch Heights Formation that were deposited on an erosive topography (=Red horizon) developed on the Potomac Formation, with pebble/cobble zones developed on that surface. The iron staining patterns probably reflect the response of the movement of iron-rich groundwater to relief on the top Potomac surface.

DISCUSSION

The trenching investigation was a technical success in that it provided excellent exposures of the near-surface geology at key points along the NCRS-1 seismic line. Excavations were undertaken at sites that appeared, on the seismic sections, to have the highest probability of faults extending to the ground surface. All of the trenches exposed Coastal Plain sedimentary formations under a surface cover of railroad ballast and fill. Cretaceous deposits of the Potomac Formation were encountered in the bottom of three of the excavations (Trenches 2, 3, and 5), Quaternary deposits of the Columbia Formation four of the trenches

(Trenches 1, 2, 3, and 4), and Quaternary deposits of the Lynch Heights Formation in one of the trenches (Trench 5).

The excavations were large enough and the exposures were clear enough that faulting, if present, should have been recognizable. Nevertheless, no evidence of faulting was encountered in any of the five trenches in either the Potomac Formation or the Quaternary deposits.

These findings are significant in light of apparently contradictory interpretations of the presence of shallow (500 ft and shallower) faults in the seismic and well-drilling phases of the DEMA Earthquake project. The drilling results suggested that at least one of the near-surface faults interpreted as significant on the seismic reflection profile was unsupported based on geophysical log correlation. The trenching study examined five other specific locations for which the seismic data indicated a high potential for faulting to extend to near the ground surface. The absence of faulting in any of the trenches suggests that shallow faulting is likely not present in this area. It should be noted, however, that these findings do not eliminate the possibility that some of the more significant deeper faults interpreted on the seismic lines may exist.

An added benefit of the trenching, beyond the initial objective of investigating faulting, is the opportunity to examine exposures of Coastal Plain stratigraphic units in an area where few outcrops exist. In particular, one of the trenches provided a good opportunity to examine and sample the Lynch Heights Formation in detail near the northern extent of the “Delaware Bay deposits.” The lithologic observations made in these trenches are a valuable addition to our knowledge of these sediments.

CONCLUSIONS

Detailed examination of exposures in five trenches excavated to a depth of 5 to 8 ft did not reveal the existence of near surface faults along the NCRS-1 seismic line. Seismic sections produced from data processed for this line suggested the existence of significant faulting in the area, which lies along a postulated fault trend in eastern New Castle County. However, subsequent drilling failed to substantiate displacement interpreted for shallow faults on these seismic sections. Consistent with the drilling results, no shallow faults were identified by the trenching undertaken for this project. Together these results suggest that there has been minimal or no modern fault activity in this area of New Castle County.

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APPENDIX: SAMPLE LIST

Trench 1 (Cd41-t)

1. Sample 44205 (local ID: T1-S1 Black) - from the very-fine to fine sands between the Blue and Black horizons
2. Sample 44206 (local ID: T1-S1 Blue) - from the iron-stained fine sand between the Green and Blue horizons
3. Sample 44207 (local ID: T1-S2 Green) - from the silty sand between the Green and Yellow horizons
4. Sample 44208 (local ID: T1-S3 Yellow) - from the bottom of the south wall in the interlaminated clay and sand under the yellow horizon.

Trench 2 (Cd41-u)

1. Sample 44209 (local ID: T2-S1) - Just under the Pink horizon, on the south wall of the excavation.
2. Sample 44210 (local ID: T2-S2) - In the lower part of the interval between the Pink and Yellow horizons, on the south wall of the excavation.
3. Sample 44211 (local ID: T2-S3) - In the upper part of the interval between the Pink and Yellow horizons, on the south wall of the excavation.
4. Sample 44212 (local ID: T2-S4) - In the lower part of the interval between the Yellow and Green horizons, on the south wall of the excavation.
5. Sample 44213 (local ID: T2-S5) - In the upper part of the interval between the Yellow and Green horizons, on the south wall of the excavation.
6. Sample 44214 (local ID: T2-S6) - Between the Orange and Red horizons, on the west wall of the excavation.
7. Sample 44215 (local ID: T2-S7) - Between the Red and Magenta horizons, on the west wall of the excavation.
8. Sample 44216 (local ID: T2-S8) - Between the Magenta and Green horizons, in the center of the west wall of the excavation.
9. Sample 44217 (local ID: T2-S9) - Between the Orange and Red horizons, on the north end of the west wall of the excavation.

Trench 3 (Cd41-v)

1. Sample 44218 (local ID: T3-S1) - Under the Red horizon, on the south wall of the excavation.
2. Sample 44219 (local ID: T3-S2) - Between the Red and Green horizons, on the south wall of the excavation.
3. Sample 44220 (local ID: T3-S3) - Just above the Orange horizon, on the west wall of the excavation.
4. Sample 44221 (local ID: T3-S4) - Between the Orange and Yellow horizons, on the west wall of the excavation.

5. Sample 44222 (local ID: T3-S5) - Just below the Yellow horizon, on the west wall of the excavation.
6. Sample 44223 (local ID: T3-S6) - Just above the Yellow horizon, on the west wall of the excavation.
7. Sample 44224 (local ID: T3-S7) - Above the Yellow horizon just under the base of railroad ballast, on the west wall of the excavation.

Trench 4 (Cd41-w)

1. Sample 44225 (local ID: T4-S1) - Just below the Yellow/Red horizon, on the south wall of the excavation.
2. Sample 44226 (local ID: T4-S2) - Below the Yellow/Red horizon, on the south wall of the excavation.
3. Sample 44227 (local ID: T4-S3) - Below the Yellow horizon, on the west wall of the excavation.
4. Sample 44228 (local ID: T4-S4) - Between the Red horizon and the base of the railroad ballast, on the west wall of the excavation.

Trench 5 (Dd11-a)

1. Sample 44229 (local ID: T5-S1) - approximately 3 ft below ground surface on north wall.
2. Sample 44230 (local ID: T5-S2) - From the unit between the Red and Light Green horizons, but taken from lower part of a hand auger hole that was bored approximately 3.0 ft below the bottom of the trench adjacent to the north wall. Possible shell material was reported from this hole.