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# PRELIMINARY EVIDENCE FOR HOLOCENE MOVEMENT ALONG THE BELAIR FAULT ZONE NEAR AUGUSTA, GEORGIA

BY

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## Foreword

This report describes the first documented instance of post-Tertiary fault displacement in the southeastern United States. The conclusion that movement has taken place along the Belair fault zone near Atlanta, Georgia in Holocene time could have major influence on tectonic models for eastern North America and on the siting of large engineered structures.

Because of the potential importance to the scientific and engineering communities, I believe that it is important that the provisional results described in this report be made public as rapidly as possible. It is equally important to emphasize the preliminary nature of the conclusions and make clear the scientific uncertainties involved. The major uncertainties are:

1. <u>Uncertainties as to the significance of the radiocarbon dates</u>

The principal basis for ascribing a Holocene age to the latest movement on the Belair fault zone is furnished by radiocarbon dates on carbonaceous material in sediments offset by one of the faults in the zone. As noted in Appendix A, this carbonaceous material was sparsely disseminated in a few discrete lenses in the sediments. Because of the small amount of carbon, it was necessary to mix $CO_2$ gas collected from burning samples from a number of lenses with large volumes of $CO_2$ gas of known age in order to have enough to carry out analytical procedures necessary for an age determination. The analytical uncertainties introduced by the dilution and by the counting procedures are given in the table in Appendix A.

A less measurable uncertainty is whether the age of the carbon is the actual age of the faulted sediments, or whether some of the carbon could have been introduced after deposition; if the latter has occurred, the youngest faulted sediment could be significantly older than Holocene. Every effort has been made to exclude this possibility (Appendix A) but it is difficult to prove with data at hand that no fragments of younger carbon were introduced by roots or animal burrows and that no soluble carbon was carried in by ground water.

This uncertainty could be resolved by the discovery of much more carbon-rich material such as large wood fragments or peat in the sediments cut by faults of the Belair Zone. A search will continue both in the vicinity of the trench described in this report and in other favorable locations along the Belair fault zone.

2. <u>Uncertainties regarding the rate and character of movement along the fault</u>

Until additional detailed stratigraphy of the deposits offset by faults of the Belair zone is defined, the rate and character of movement along the faults must remain uncertain. It is not yet possible to establish whether movement has been by creep, which would not necessarily be accompanied by earthquake activity, or by sporadic, sudden displacements that may have been associated with seismicity.

These uncertainties may be resolved if additional studies reveal varied displacements for a number of different dated stratigraphic horizons offset by faults of the zone. Careful analysis of precise survey lines across the fault zone and recording of possible seismicity in the vicinity of the Belair fault zone are other techniques that could yield data on recent or current activity and character of movement along the fault zone.

3. Uncertainties regarding the significance of the Belair fault zone in the regional tectonic framework of the eastern United States

Post-Cretaceous fault movements have not been generally recognized and accepted up to now in the eastern U.S. Displacements of Cretaceous and younger strata have recently been found in several areas between Washington, D.C. and Augusta, most of them at or near the inner edge of the Coastal Plain. Recognition of Holocene movement on the Belair fault zone thus raises the possibility of Holocene movement on other faults in the eastern United States. This possibility may significantly affect interpretation of the modern tectonics of eastern North America and the assessment of ground displacement and earthquake risks in the eastern United States.

Just as it is no longer valid to assume *a priori* that any fault in the eastern United States has not moved during Holocene time, it is not necessary to assume that any given fault has moved that recently. Faults of concern must be considered individually and the timing and character of movement established on the basis of local evidence. The potential of the Belair fault zone for generation of earthquakes is not known presently; its potential may not be necessarily similar to Holocene faults in California because eastern U.S. is in a different tectonic regimen.

The Geological Survey, through its basic research investigations and its programs for Reactor Hazards Research and Earthquake Hazards Reduction, is attempting to develop and evaluate geologic and geophysical evidence that may shed light on the age and pattern of faulting and other crustal movements in the eastern United States. Ultimately, this research will lead to development of more satisfactory tectonic models for the eastern part of the continent in the context of the new theories of plate tectonics.

Director

Preliminary Evidence for Holocene Movement Along the Belair Fault Zone Near Augusta, Georgia

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Abstract

The Belair fault zone has the youngest displacement recognized to date in the southeastern United States and is the only fault zone dated as having moved in Holocene time. A trench cut across one of the faults in the zone shows lenses of organic material cut by and dragged into the fault. Radiocarbon dates indicate that this organic material is younger than 2500 years.

Introduction

The Belair fault zone is in eastern Georgia (Richmond County) a few miles west of Augusta. Figure 1 shows the relationship of the fault zone to the regional geology and surrounding landmarks. The first reported exposure of the zone (O'Connor and others, 1974) is in a clay pit 170 years (155 m) south of U.S. Highway 78-278, about 10 miles (16 km) west of Augusta. At this locality, weathered phyllite of the Little River Series of Crickmay (1939) of probable Precambrian Z age has been thrust over Coastal Plain (Tuscaloosa Formation) sediments of Late Cretaceous to Early Tertiary(?) age by a reverse fault trending N. 25° E. and dipping 50° SE. Detailed mapping and extensive augering

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and drilling by the United States Geological Survey and the Georgia Department of Natural Resources, Earth and Water Division indicate that this fault is one of a zone of en echelon faults. The fault zone is at least 13 miles (21 km) long, and maximum known cumulative vertical displacement across the zone is 100 feet (30 m).

This study is part of the Reactor Hazards Program of the U.S. Geological Survey; the program is directed toward identifying and determining the geographic distributions of geologic processes that might affect the safe siting of nuclear power reactors.

## Regional stratigraphy

### Piedmont rocks

The Belair fault zone cuts both Piedmont and Coastal Plain rocks and the unconformable contact between them. Piedmont rock involved in the faulting is mostly low-grade metavolcanic phyllite of the Little River Series (Precambrian Z?). Cleavage in the phyllite strikes generally northeast and dips southeast. Locally, the phyllite is highly contorted, and small tight folds are common. Surface exposures of phyllite are highly weathered to white, orange, red, gray, or green saprock and saprolite. The saprolite layer over the hard unweathered phyllite is commonly more than 100 feet (30 m) thick. Less than a mile (about 1 km) north of the northernmost known trace of the fault zone (where it is tentatively extrapolated into the Piedmont) the phyllite is in high-angle contact with a coarse-grained muscovite-biotite gneiss. Displacement of this contact by the fault zone is not known.

## Coastal Plain deposits

The basal unit in the Coastal Plain in the Augusta area is the Tuscaloosa Formation, which unconformably overlies the weathered phyllite of the Little River Series. It is generally less than 200 feet (60 m) thick and is characterized by micaceous, kaolin-rich, medium- to coarse-grained arkosic sands of fluvial origin. Discrete kaolin lenses as much as tens of feet (about 8 m) thick, many gravel layers, and crossbedding are common. The base of the Tuscaloosa is characterized by a layer of gravel 6 to 12-inches (15-30 cm) thick. Oxidation of iron-bearing heavy minerals commonly stains the Tuscaloosa red, orange, tan, or purple. The Tuscaloosa Formation has been traditionally dated as Late Cretaceous in eastern Georgia and has been correlated with the Tuscaloosa Formation of Alabama. The equivalent unit in South Carolina is called the Middendorf Formation.

The upper unit of the Coastal Plain in the Augusta area is the Barnwell Formation. The Barnwell is largely a fine- to medium-grained argillaceous quartz sand commonly stained dark red. Small gravel lenses and thin discontinuous kaolin layers are common. The well sorted, strongly crossbedded nature of the sands and the local callianassid burrows indicate that this part of the Barnwell is a shallow marine deposit. Spore-rich horizons in the Barnwell southwest of Augusta contain Eocene (Claiborne to Jackson age) floras. Because Tuscaloosa material has been reworked into the basal Barnwell, the unconformity between them has not been accurately mapped.

## Surficial deposits

Minor accumulations of eolian sand and small peat deposits have been recognized in the vicinity of the fault zone. The eolian sand is a fine-grained quartz sand containing bits of organic matter. Its thickness rarely exceeds 20 feet (6 m), and it commonly occurs on high ridges. It is generally considered Pleistocene, although its true age is not known. The sand overlies the fault zone in several places, but we do not know whether its base has been offset.

Other surficial deposits include alluvial and colluvial debris locally including a peat bed of Holocene age and lenses containing Holocene organic material.

## Description of fault zone

The Belair fault zone is a series of at least seven en echelon reverse faults extending from Old McDuffie Road on the Fort Gordon Military Reservation to the quarry on the Savannah River north of Augusta (fig. 1). The unconformity at the base of the Tuscaloosa is the only easily recognized marker horizon offset by the fault. Individual faults are approximately 1 to 3 miles (2 to 5 km) long and gouge zones are only a few feet wide at most. The vertical separation of the unconformity across the zone increases from south to north, and the zone comprises more individual faults in the north. At the northernmost known extent of the fault zone, the total cumulative vertical separation is about 100 feet (30 m). The southernmost control points near the south end of the military reservation, however, indicate separation of about 15 feet (5 m). The southward slope of the unconformity on the southeast block is more than twice the normal slope of the unconformity in this part of Georgia, suggesting that the southeast block was the active block, moving up and tilting southward during faulting.

Faults in the zone are exposed at two localities about 4 miles (7 km) apart. The first locality is in the clay pit near U.S. Highway 78-278 mentioned in the introduction (locality A, fig. 1). There the fault can be traced for a distance of approximately 2,500 feet (760 m). The fault plane strikes N. 25° to 30° E. and dips 50° SE. This fault offsets the basal Tuscaloosa unconformity 60 feet (18 m)(vertical component of movement) and juxtaposes phyllite and Tuscaloosa sands. Distinct slickensides in the fault plane are in two sets, one plunging directly downdip and the other plunging S 50° E. Bedding in the Tuscaloosa is slightly warped by the fault within about 20 feet (6 m) of the fault plane, and small fault splays commonly offset bedding in the Tuscaloosa west of the principal fault plane. The phyllite is commonly leached white along the fault plane, making it similar in color to kaolinitic Coastal Plain sands.

The second locality is at the intersection of Interstate Highway 20 and Bobby Jones Freeway (locality B, fig. 1). There, two reverse faults juxtapose phyllite and Tuscaloosa sediments along planes striking N. 29° E. and dipping 52° SE. One exposure shows the Piedmont-Coastal Plain unconformity dragged about 30° upward within about 10 feet (3 m) of the fault plane.

At both localities, all observed exposures of the faults have almost identical attitudes, generally parallel to cleavage in the phyllite.

However, because the faults in the zone are en echelon, the trend of the zone ranges from N. 20° to 50° E. (see fig. 1).

## Recency of faulting

Holocene faulting is indicated by structural-stratigraphic relations (fig. 3) exposed in a backhoe trench cut across the fault at locality A (figs. 1 and 2), on December 3, 1975, where drilling previously had demonstrated 55 feet (24 m) of vertical separation on the basal Tuscaloosa unconformity. The upper few feet (about 1 m) of material exposed by the trench is oxidized colluvial debris that has crude inclined bedding and consists of sand, clay, and angular fragments of phyllite and quartz. This debris contains some tree roots and has a distinct A soil horizon at its top. The colluvial debris does not appear to be cut by the fault. Below the colluvial debris is an accumulation of faintly and discontinuously bedded clayey sand which contains some small phyllite fragments and a few angular quartz fragments as much as 5 inches (13 cm) in diameter. This accumulation is interpreted as sediments reworked from the Tuscaloosa Formation on the upblock; it lacks sedimentary structures and textures characteristic of the Tuscaloosa.

Within the reworked Tuscaloosa sediments in the downblock are scattered light-gray lenses 3 inches (8 cm) thick and 18 inches (46 cm) long. These lenses, which consist of clayey sand and minor organic material, define a zone about 2 feet (60 cm) thick (fig. 3). A composite sample of organic material from these lenses yielded a radiocarbon age of 400 ± 300 years B.P. These reworked Tuscaloosa sediments are truncated by the fault at the east end of the trench. The faint layering in the reworked sediments is dragged upward 3-6 inches (8-15 cm) within about 12 inches (30 cm) of the fault plane.

On the upblock, similar reworked Tuscaloosa sediments overlie a 1- to 2- foot (30-60 cm)-thick remnant of Tuscaloosa Formation containing the characteristic basal gravel. This gravel in turn unconformably overlies white phyllite. A gray lens containing minor organic material in the reworked Tuscaloosa sediments is dragged down about 3 inches (8 cm) within a foot of the fault and truncated by the fault (fig. 4). The unreworked Tuscaloosa Formation and the unconformity have been dragged downward about 5 feet (1.5 m) within 10 feet (3 m) of the fault plane.

Clayey sand containing minor organic material similar to that in the lenses in the reworked Tuscaloosa sediments on both sides of the fault is incorporated in the fault gouge (fig. 4). A composite sample from this material and lenses in the upblock yielded a radiocarbon age of 2,450 $\pm$ 1,000 years B.P. From these relations, we conclude that the latest movement on the fault postdates deposition of the reworked Tuscaloosa sediments and the gray lenses contained therein.

A clay pit about 100 yards (35 m) east of the trench (fig. 2) exposed a 0-5-foot (0-1.5 m)-thick peat lens.1/ The base of this lens was at the same elevation as the ground surface at the trench. The top of the peat lens contained many large horizontal tree trunks. Radiocarbon dates on wood from the top of the peat lens indicate an age of 1,540 $\pm$ 200 years B.P. Similar material from near the base yielded an age of 2,200 $\pm$ 300 years B.P. The exact relations between the peat lens and

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1/ Subsequent excavation in the clay pit has completely removed this lens.

the reworked Tuscaloosa cut by the fault are uncertain, but the peat and the reworked material may have been contemporaneous, or the organic material in the gray lenses may have been derived from the peat lens.

## CONCLUSIONS

The evidence from the trench indicates movement on the fault since 2,450 ± 1,000 years B.P. The dip-slip component of this movement must have been at least 3 feet (1.2 m) in order to account for the length of gray lens material in the fault plane (a to b, fig. 4). Shearing out of this gray lens material is the only logical explanation for its alignment in the fault plane. At least 3 feet (1 m) of displacement must have taken place since deposition of the zone of gray lenses in the reworked sediments on the downblock. This distance is measured along the fault plane from the base of the zone of gray lenses on the downblock (c, fig. 4) to the top of the gray lens truncated by the fault in the upblock (d, fig. 4). If the date of 400 ± 300 years B.P. on the gray lenses from the downblock is valid (see appendix A), this movement must have taken place in the last few hundred years.

## REFERENCES CITED

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O'Connor, B. J., Carpenter, R. H., Parris, T. A., Hartley, M. E., and Denman, H. E., 1974, Recently discovered faults in the central Savannah River area [abs.]: Georgia Acad. Sci. Bull., v. 32, p. 15.

## Appendix A

### Radiocarbon dates and their significance

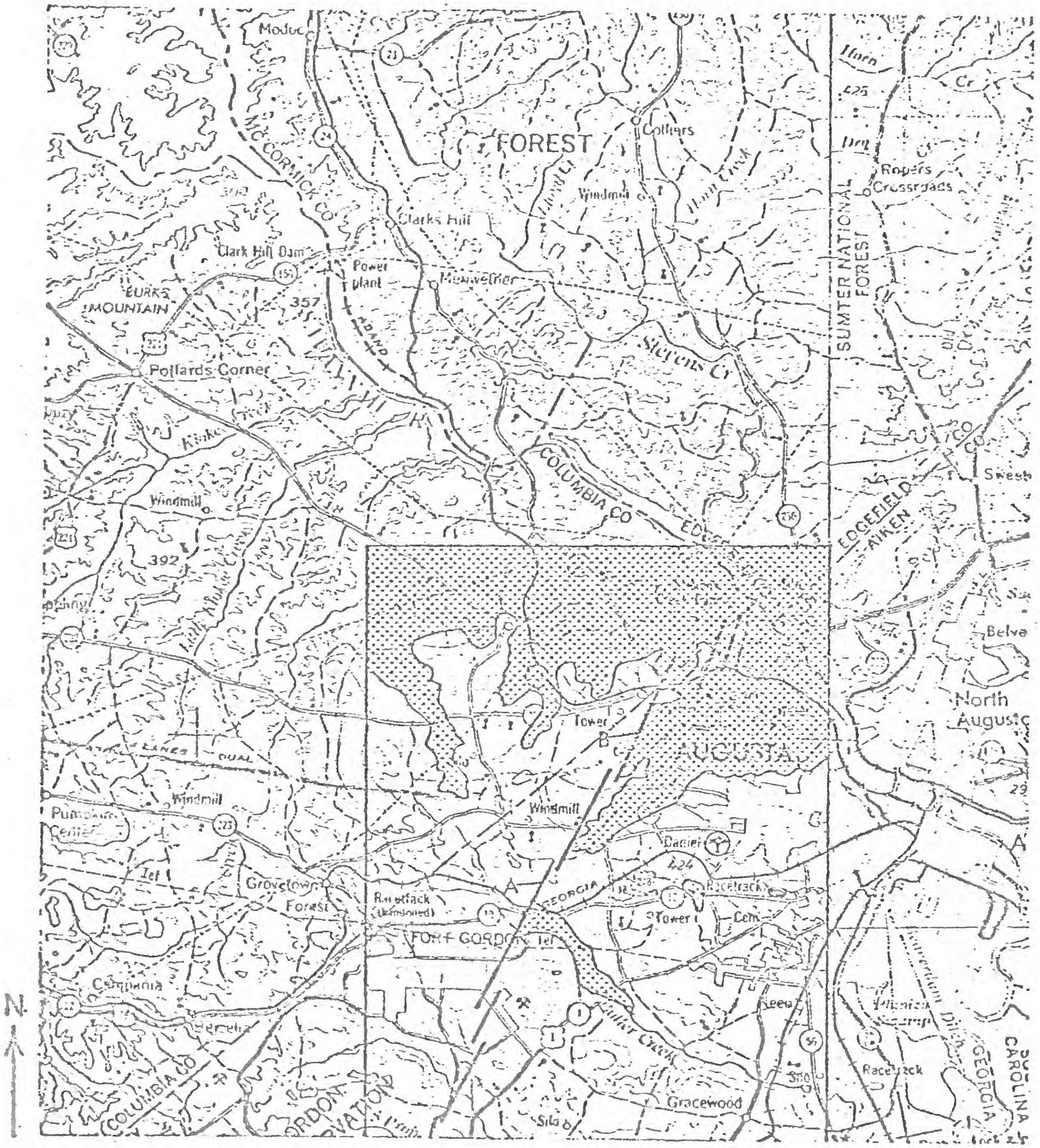
Two groups of materials related to the Belair fault at locality A (figs. 1 and 2) have been dated: 1) five samples from the peat lens formerly exposed in the clay pit, and 2) two composite samples from the gray lenses exposed in the trench. The top of the peat lens was dated by three samples, and gives ages of 750 years, 1,020 years, and 1,540 years, all with a possible error of 200 years. The bottom of the peat lens was dated by two samples, 2,020 and 2,390 years old, again with a possible error of 200 years. We believe that the dates on the wood are the most reliable. Samples from the gray lenses in the upblock and from a lens incorporated in the sheared material of the fault were combined to yield a very small amount of carbon that gave an age of 2,450 ± 1,000 years B.P. A composite of samples of gray lens material from the downblock yielded a small amount of carbon having an age of 400 ± 300 years B.P.

The following table summarizes this data:

| Lab No. | Field No. | Description | Age (Years B.P.) |
|---|---|---|---|
| W-3452 | Awt 2, 5, 6a, 6b | From lenses in trench | 400 ± 300 |
| W-3447 | Awt 8a, 8b, 8d | From upblock and shear of fault | 2,450 ± 1,000 |
| W-3208 | RIC-4 | Wood and peat from top of swamp | 750 ± 200 |
| W-3209 | RIC-4 | Alkali soluble fraction of W-3208 | 1,020 ± 200 |
| W-3212 | RT1b | Wood from top of swamp | 1,540 ± 200 |
| W-3210 | RIC-6 | Wood and organic matter from bottom swamp | 2,020 ± 200 |
| W-3211 | RT-3 | Wood from base of swamp | 2,390 ± 200 |

Taken as a group, all samples are younger than 2,500 years. The large error quoted is due to the fact that the samples had such small quantities of carbon. Three of the samples had to be diluted with 6, 7, and 24 times the yield of carbon dioxide with a gas of known age in order to count their radioactivities. This dilution reduces the reliability of the age to the errors given in the table. As much as 1,300 grams of the gray lens material was burned in order to obtain even these low quantities of carbon dioxide. Ordinarily, 10 grams of peat or wood would be sufficient. This means that small amounts of contaminants could make a significant contribution to the total carbon treated.

Carbon in the samples of the gray lens materials was in the form of 1- or 2-mm particles of fibrous woody material widely dispersed among the sand grains, and a few twigs 20 mm long and 1 mm thick. No staining indicative of soluble carbon was seen on the grain surfaces. The visible particles could account for the carbon obtained in each burn. Pollen and spores were very rare in the clay-size fraction. Cuticular material was abundant, possibly from a leaf source. Because of its particulate form, the carbon is probably indigenous to the sediments rather than having been subsequently introduced.




0 5 10 Miles

Scale 1:250,000

Figure 1. Regional geologic map of the area west of Augusta, Georgia, showing the extent of Coastal Plain (unpatterned) and Piedmont deposits (patterned), and the Belair fault zone (heavy lines). Letters A and B show localities mentioned in text. Base from U.S. Army Map Service Augusta, Georgia-South Carolina sheet, 1957, and from Athens Ga., S.C. sheet, 1953.

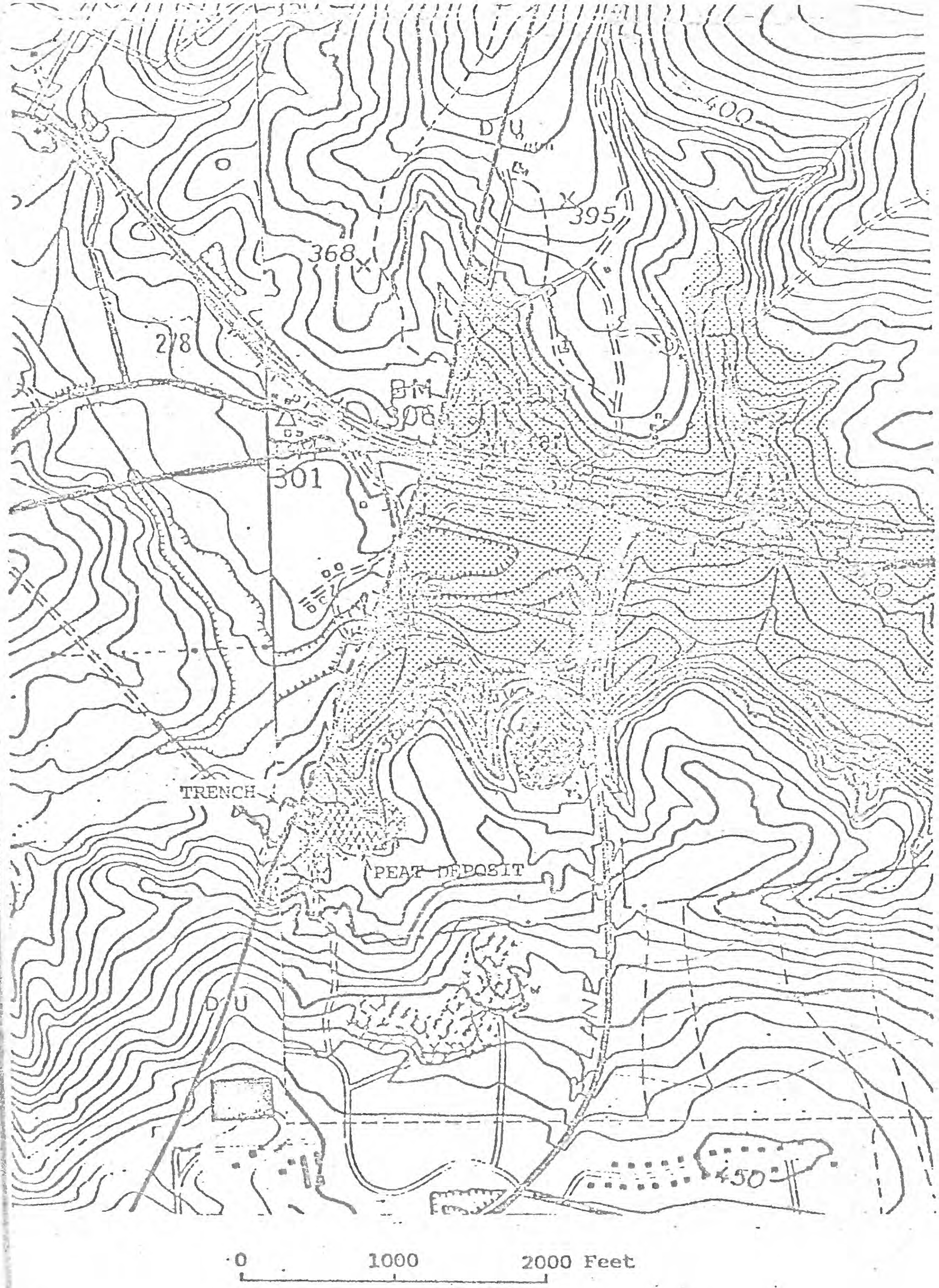



Figure 2. Geologic map of the clay pit area south of U.S. Highway 78-278, showing Coastal Plain (unpatterned) and Piedmont deposits (patterned), the Belair fault zone (heavy line), peat deposit and trench location. Base from U.S. Geological Survey Augusta West and Grovetown quadrangles, 1957. This is locality A of the text.

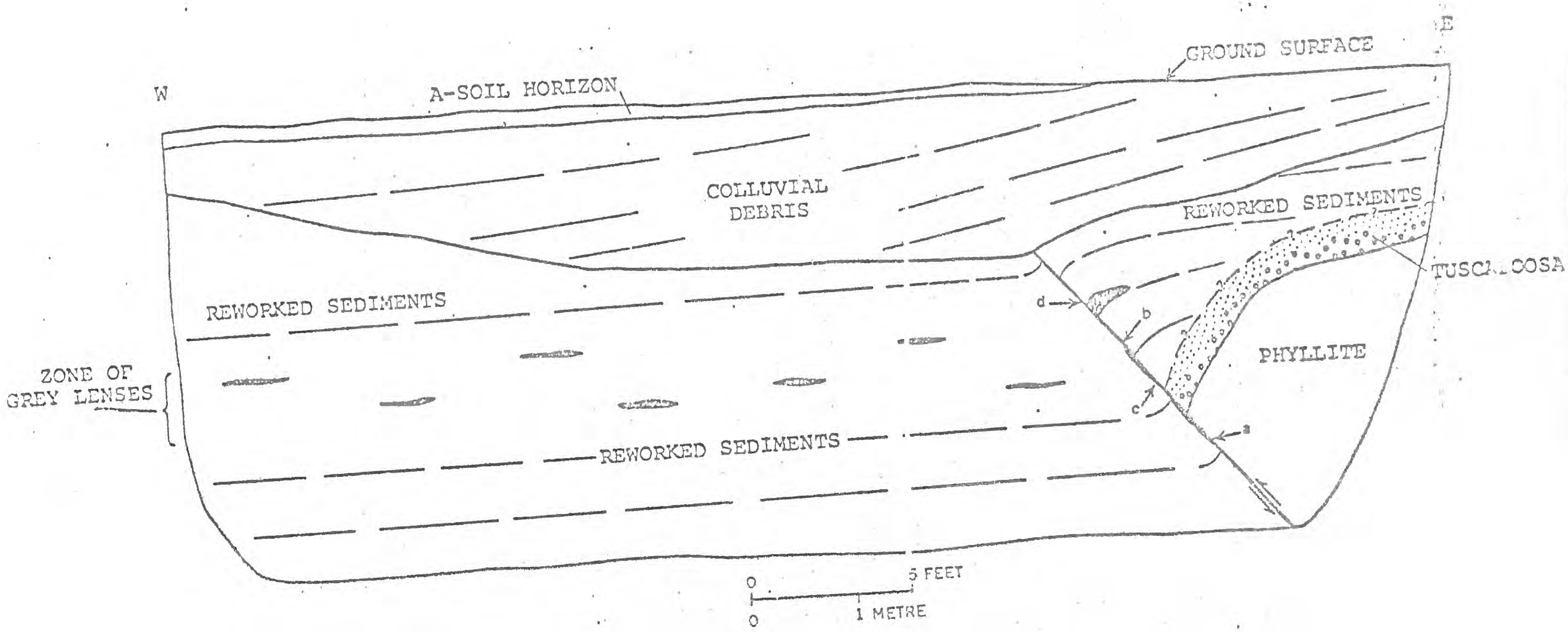



Figure 3. Generalized view of north wall of the trench across the Belair fault zone. Black lenses represent gray lens material described in text. Vertical scale equals horizontal scale. Points a, b, c, and d are explained in text.

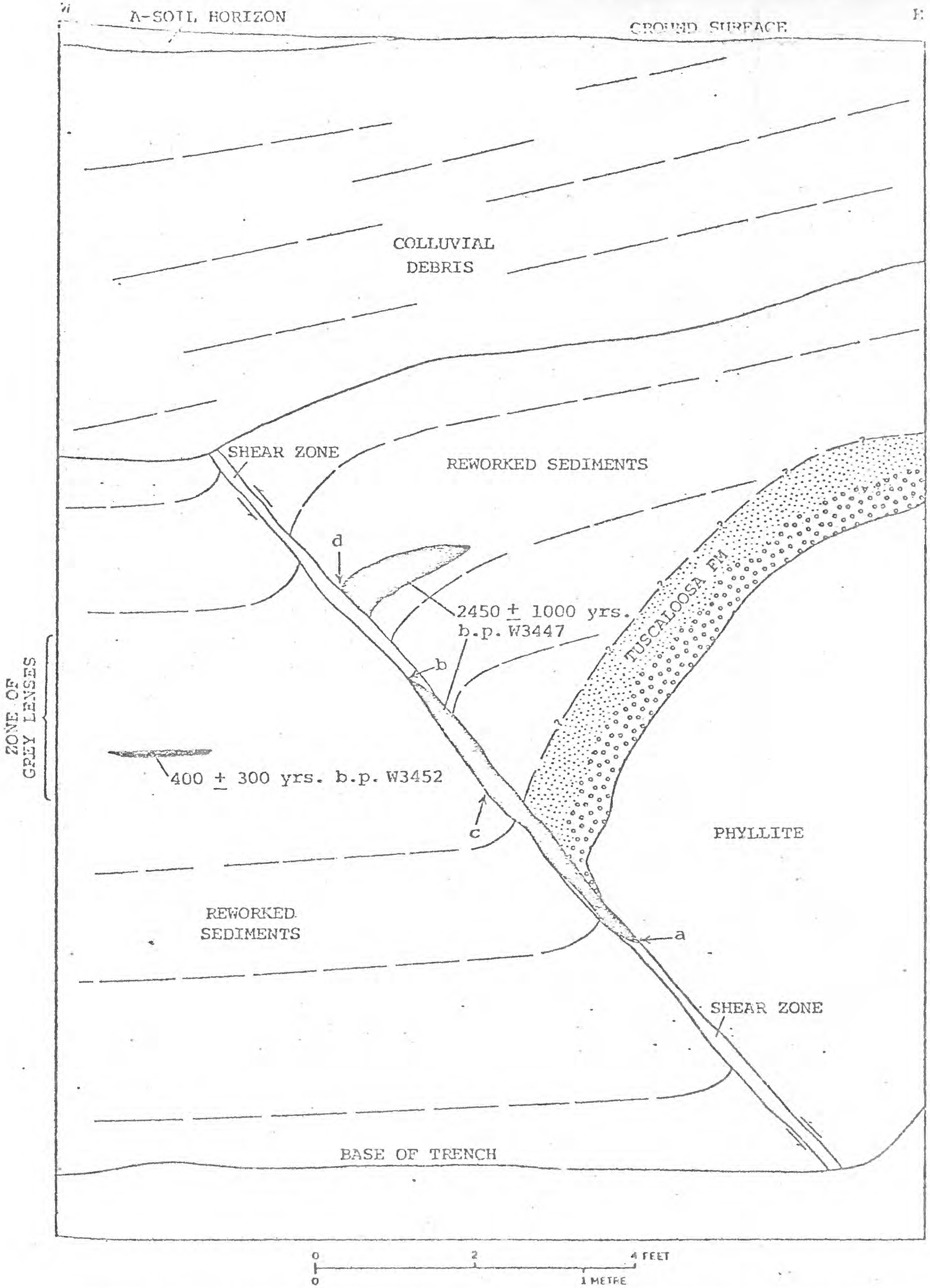



FIGURE 4: Detailed sketch of the east end of trench showing relationships of grey lenses to the fault (view looking north). Points a, b, c, and d are explained in text.