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DRAINAGE HISTORY OF THE TENNESSEE RIVER: REVIEW AND NEW METAMORPHIC QUARTZ GRAVEL LOCATIONS

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ABSTRACT

The strange course of the Tennessee River (TR) has mystified observers for more than a century. There are three seemingly unlikely course changes: 1) west of Chattanooga, Tennessee, where the river leaves the Valley and Ridge province and cuts through Walden Ridge; 2) near Guntersville, Alabama, where it leaves the southwestward trending Sequatchie anticlinal valley and assumes a northwesterly course; 3) near the juncture of the Alabama, Mississippi, and Tennessee borders, where it turns north to cross Tennessee and join the Ohio River. These abrupt changes suggest the possibility of former courses of the TR much different from the present one. Prominent in discussion of such courses is the "Appalachian River," a hypothesized river system that flowed through the Great Valley and continued its course southwestward to the Gulf Coast, through what is now the Alabama River system or via other routes farther west. An early argument for the course change 1) by stream capture of the Appalachian River by a westward-flowing tributary of the Sequatchie River during the late Tertiary appears weak; probably the Walden Ridge gorge is no younger than early Cenozoic, and may even a have been carved by a consequent stream of the Paleozoic Appalachians. To explain 2) and 3), several efforts have been made to show that these courses show adjustment to bedrock structure. Small Cenozoic crustal movements may have been equally as important in influencing the course, so such efforts cannot be conclusive. Evidence from deposits of former stream courses would be much more convincing. Heavy-mineral suites and metamorphic quartz (MQ) derived from the crystalline Appalachians are widespread on the coastal plain, attesting to an ultimate source in the Blue Ridge as early as Cretaceous. Although some efforts involving subsurface data have been made, most attempts to demonstrate former TR courses have been based on surface or near-surface gravel deposits. Such courses are likely to be no older than Miocene, as older surficial deposits probably would have been removed by erosion. We here give locations of more than 100 gravel sites in Alabama, Mississippi, and western Tennessee with high MQ contents. These locations provide constraints on possible former courses of the TR. A major problem is whether the MQ in the deposits came directly from the Blue Ridge via an ancestral TR or whether it came from the reworking of older formations containing MQ, particularly the Pennsylvanian sandstones and the Tuscaloosa Formation, by local streams. In some cases, this problem can be avoided by confining attention to MQ clasts that are cobble-size or larger, and/or to areas in which the Tuscaloosa lacks significant MQ. We suggest that future study of possible old TR courses begin with study of high terraces along the present TR, concentrating on dating and lithology studies of the deposits.

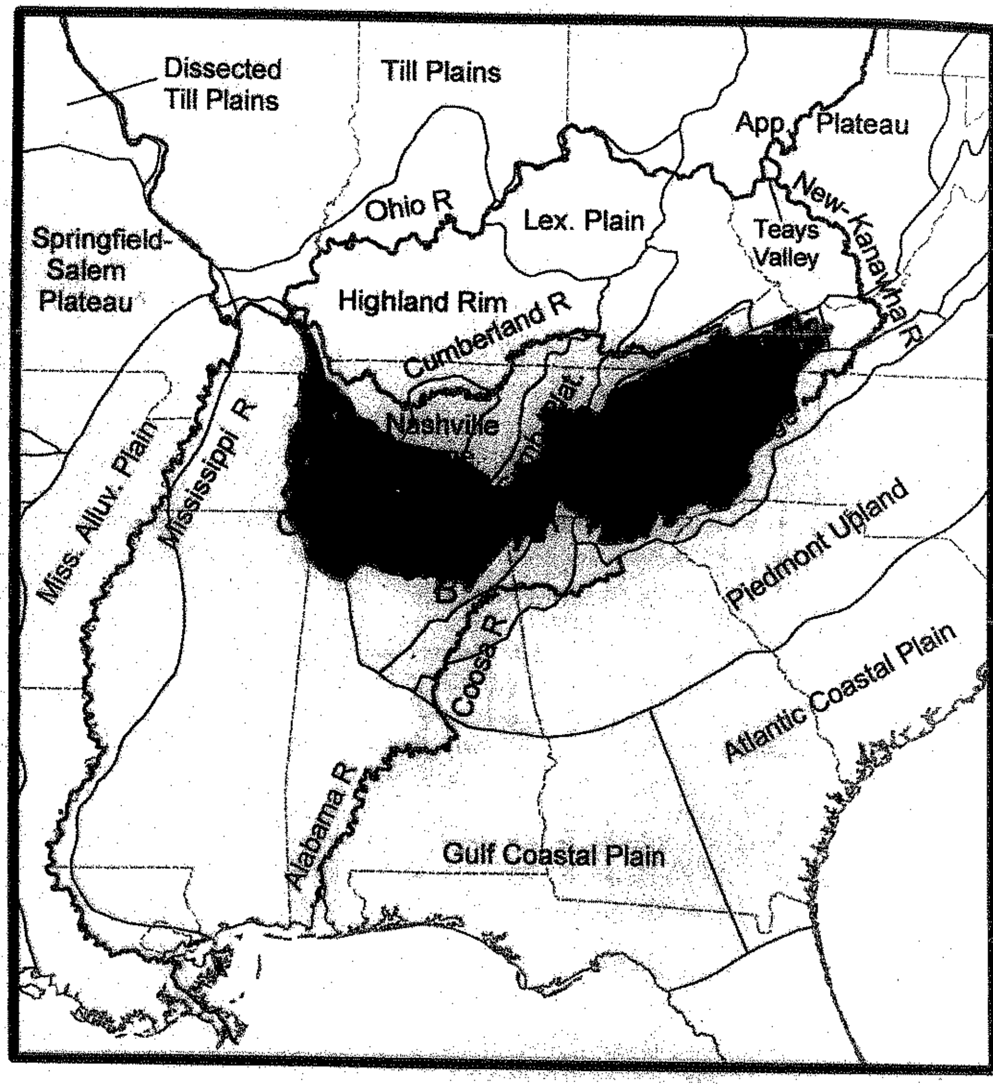
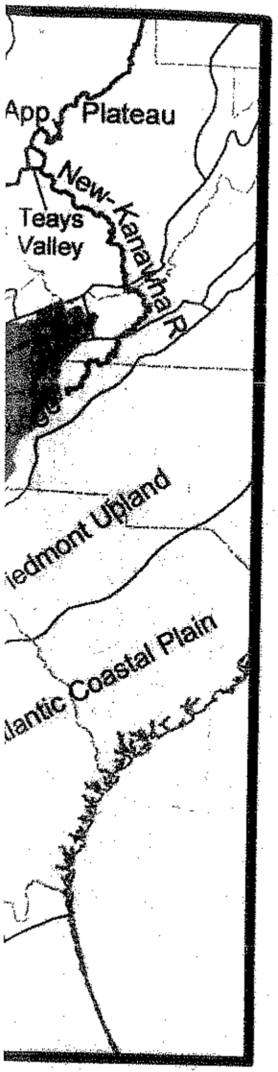


Figure 1. Regional setting of the Tennessee River, showing major rivers and physiographic provinces. Shaded area is drainage basin of Tennessee river.

INTRODUCTION

The course of the Tennessee River (TR) seems a geological anomaly. Arising in Virginia, the TR follows strike valleys in the Valley and Ridge province as far southwest as Chattanooga (Figs. 1-3). At this point, a continuation down the Great Valley to the coastal plain and thence to the Gulf of Mexico via what is now the Coosa-Alabama River system seems the path of least resistance. Instead, the river course abruptly turns west and cuts through the 300-m-high, sandstone-capped Walden Ridge (A in Fig. 1), entering the valley of the dissected Sequatchie anticline, although a divide only 75 m high separates it from headwaters of the Coosa-Alabama drainage system (Fig. 2). In the valley of the Sequatchie anticline, the TR again heads for the Gulf. However, when it reaches the vicinity of Guntersville, Alabama, instead of continuing a course into the headwaters of what is now the Black Warrior River, it once again takes



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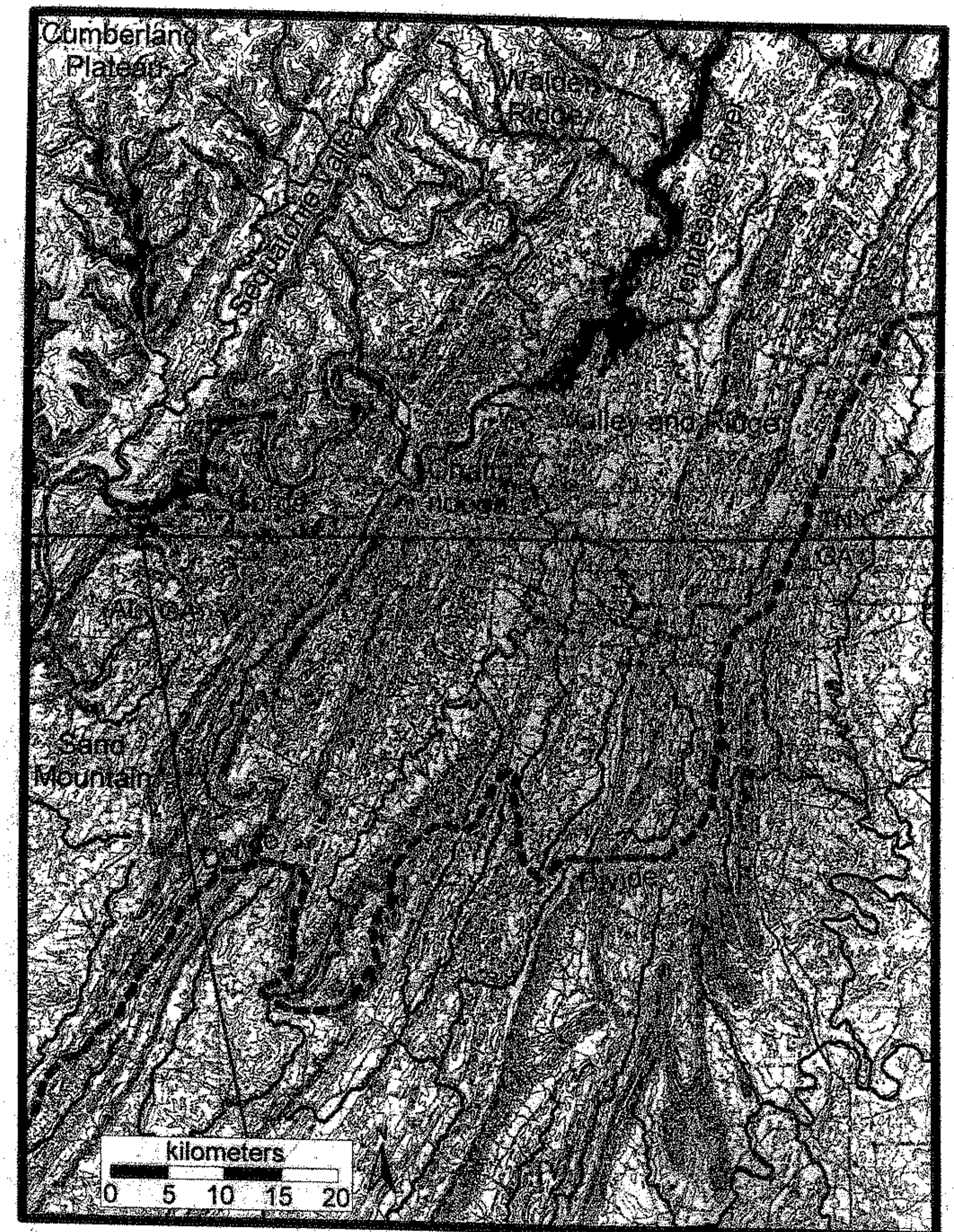


Figure 2. Drainage and topography in the vicinity of Chattanooga, Tennessee. Divide shown is between the Tennessee River system to the north and the Coosa River system to the south, and is only 75 m high in some places.

an abrupt right-angle turn to the northwest (B in Fig. 1), where it follows the strike of Mississippian strata and then assumes a more westerly course. At this point, the river course seems to be headed to the Mississippi River. Instead of continuing this westerly course, the TR takes its strangest turn of all. Near the Alabama-Mississippi border (C in Fig. 1), it turns north across

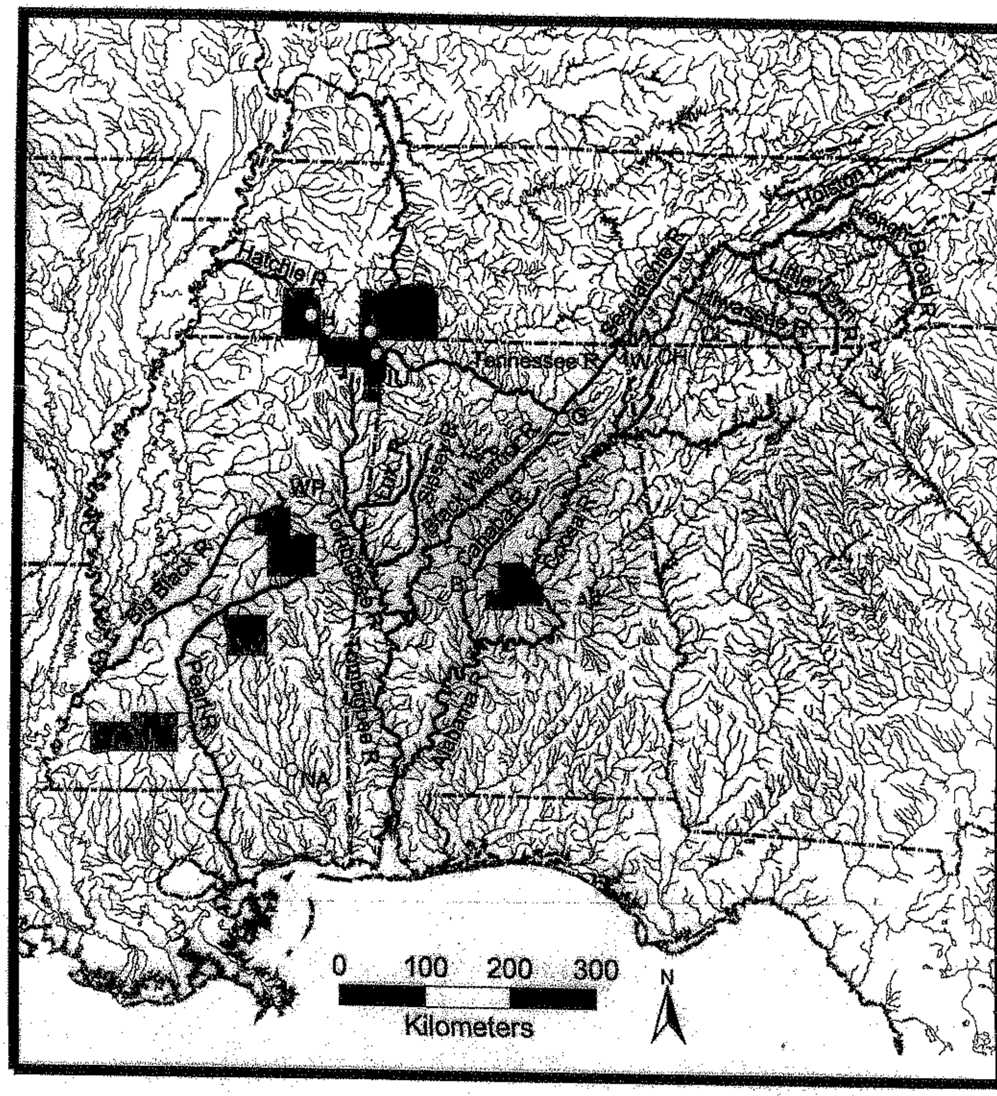
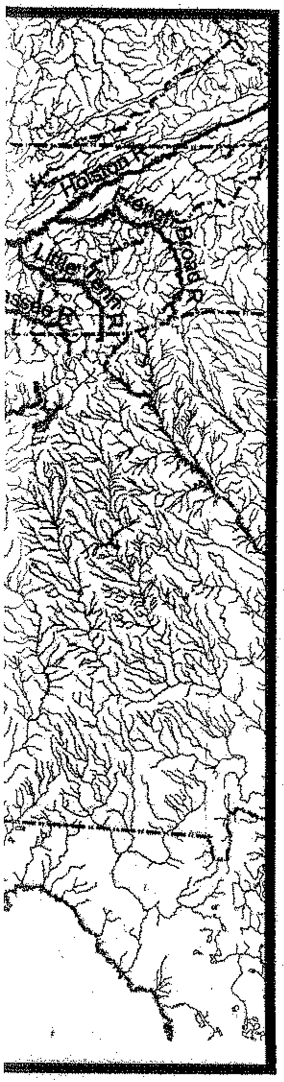


Figure 3. Location map showing rivers and sites discussed in text. Abbreviations: B = Brent, Alabama; Tennessee; CH = Chattanooga, Tennessee; CL = Cleveland, Tennessee; G = Guntersville, Alabama; H = Hebron, Tennessee; IU = Iuka, Mississippi; NA = New Augusta, Mississippi; PD = Pickwick Dam, Tennessee; WP = West Point, Mississippi; Lux. R = Luxapalila River, Mississippi. Shaded counties: AL = Alcorn County, Mississippi; CH = Chilton County, Alabama; CT = Choctaw County, Mississippi; FR = Franklin County, Mississippi; HM = Hardeman County, Tennessee; HN = Hardin County, Tennessee; LI = Lincoln County, Mississippi; SC = Scott County, Mississippi; TI = Tishomingo County, Mississippi; WA = Wayne County, Tennessee; WI = Winston County, Mississippi. Note that the Tennessee River formally begins at the junction of the Holston and the French Broad Rivers.

Tennessee and Kentucky until it finally joins the Ohio River.

Despite the striking nature of this geomorphic problem, after the early 1900's most papers addressing the course of the TR have done so only in passing; there have been very few studies devoted exclusively to it. This paper attempts to bring together the scattered previous



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work on the TR, provide new data bearing on the problem, and suggest avenues of future work.

INITIAL WORK: THE APPALACHIAN RIVER AND WALDEN RIDGE

A former course for the TR from Chattanooga to the Gulf of Mexico via the Coosa River system (Fig. 1) was suggested as early as 1875 (Long, 1875, p. 16). The first geomorphological work on this question was by Hayes and Campbell (1894). Based on the depositional history of the coastal plain, they hypothesized that there had been two major episodes of crustal uplift and quiescence. Uplift preceding and during the earlier part of the Cretaceous was followed by a long period of baseleveling in the Late Cretaceous, during which a well-developed peneplain formed. In the early Tertiary uplift again occurred, followed by a quiescent interval somewhat shorter than that of the late Cretaceous, so that only a small part of the Cretaceous peneplain was removed during the formation of the partial Tertiary peneplain. Hayes and Campbell (1894) hypothesized that by late in the Cretaceous, the Appalachian Valley southward of the New-Kanawha system constituted a single drainage system whose main trunk was a large river flowing southwestward into the Cretaceous sea, occupying approximately the present position of the Coosa River (Fig. 1). They called this hypothetical ancestor of the TR the "Appalachian River," and proposed that this river was diverted across Walden Ridge (Fig. 2) in the late Tertiary. A large westward flowing tributary of the Sequatchie in nearly the position of the present Tennessee was able to erode its headwaters eastward and divert the Appalachian River through Walden Ridge into the course of the Sequatchie River, which at that time flowed to the Gulf via a course approximately corresponding to the present-day Black Warrior River (Fig. 3). The capture was facilitated by the elevation of the Sequatchie, which was about 30 m lower than the Appalachian River, and by the more direct course of the Sequatchie to the Gulf, thus providing a steeper gradient.

Hayes and Campbell's (1894) arguments for this late Tertiary capture, however, appear dated, particularly in their reliance on peneplains. Although the concepts of erosion surfaces, together with tilting and warping of these surfaces, are sound enough, these authors were too facile in their identification of erosion surfaces and deformations of these surfaces. Some of their surfaces are now considered stripped or structural surfaces. Also, Hayes and Campbell (1894) believed that erosion surfaces essentially erase the previous landscape, allowing radical changes in drainage systems. Presently, the belief is that long-continued erosion during a tectonically quiescent interval (i.e., the latter stage of an erosion cycle), although greatly reducing relief, leaves the divides roughly in the same place (Cleaves, 1989; Costa and Cleaves, 1984; Poag and Sevon, 1989).

The evidence of Hayes and Campbell (1894) thus reduces to 1) the low, smooth divide between the TR and the Coosa River near Chattanooga (Fig. 2), with a wide valley upon the divide, suggesting to these authors that the drainages were connected in the recent past; and 2) the narrow, steep-walled nature of the Walden Ridge gorge (Fig. 2), suggesting a youthful age. Hayes and Campbell contrasted this gorge with an analogous valley, Scottsboro Valley in north Alabama, that is 10 km or more wide, suggesting to them a much greater age. Even this evidence was convincingly attacked by White (1904) and Johnson (1905b), using surprisingly modern-sounding arguments emphasizing the effect of structure on landforms. Concerning the TR-Coosa River divide, White (1904) and Johnson (1905b) pointed out that the low nature of this divide is easily explained by the bedrock, the area consisting almost entirely of dolomite and shale; the presence of a former large river is not required to explain the wide valley. Many of the northeast-southwest valleys characterizing the Valley and Ridge in this region show low, inconspicuous divides between their heads (Fig. 2), similar to that between the TR and the Coosa, even though they are occupied by insignificant streams. Concerning the Walden Ridge gorge below Chattanooga, White (1904) pointed out that the streams that run from Walden Ridge east into the Valley and Ridge have proportionally as narrow gorges with as steep slopes as has the TR in its gorge (Fig. 2). If the Appalachian River existed and the Tennessee Valley is older than Walden Ridge gorge, these side gorges are also older, and, according to this reasoning, should be wider. Concerning the contrast between the form of Walden Ridge gorge and that of Scottsboro Valley, Johnson (1905b) pointed out that Scottsboro has a sandstone cap less than one-third the thickness of that on Walden Ridge, so that the flanks of the former valley are mainly underlain by limestone, whereas those of the latter are mainly underlain by sandstone. Differences in the forms of the valleys should be expected from lithological differences alone. He also pointed out that the cross-sectional shape of Walden gorge is very similar to that of watergaps through hard sandstone ridges in Pennsylvania, which are attributed to structure.

Johnson (1905b) presented additional arguments opposing the capture of the TR in late Tertiary time: 1) the highly meandering nature of Walden Ridge gorge (Fig. 2) suggests a pattern inherited from a broad floodplain, rather than from a capturing stream; 2) streams along the margins of Walden Ridge and Sand Mountain have made little progress in dissection (Fig. 2), except at the gorge. If one stream was able to cut entirely through the ridge, then we should expect to find the ridge breached at other points, but it is not; 3) there is not enough elevation difference between valleys east and west of Walden Ridge to allow stream capture. In order that stream A may divert stream B from its course, A must occupy a level so much lower than B that even the uppermost headwater portions of the branch of A that effects the capture shall eventually be able to work at a lower level than that of B. That a small branch of the Sequatchie, a stream that is itself comparatively small, could work back through a high mountain barrier along a course many miles in length, and still have its headwaters low enough to capture the large Appalachian River, demands that the Sequatchie valley west of the ridge should have been much lower than the Appalachian valley to the east. There is no evidence of such a great disparity in elevations.

The proposal by Hayes and Campbell (1894) for a late Tertiary capture of the TR, diverting it into the valley of the Sequatchie anticline, thus seems unlikely. It appears that the current course of the TR through Walden Ridge was established not later than the early Cenozoic, and possibly sooner. The Appalachian River (at least the Coosa River version), if it ever existed, probably disappeared long before the late Tertiary.

Hayes and Campbell (1900) and Simpson (1900) also presented evidence from the distribution of freshwater mussels to support the stream capture hypothesis. Pleurobema, a genus of Unio, is plentiful in the TR. It is not found throughout the other portions of the Mississippi basin, but is found abundantly in the Coosa and Alabama Rivers. Simpson (1900) concluded that the upper TR at one time must have flowed southward into the Coosa-Alabama River. Johnson (1905a), however, pointed out the possibility of alternative explanations, noting, for example, that there are many reports of invertebrate organisms attaching themselves to the feet of birds, thereby possibly being spread between drainage basins. Arguments over biologic evidence of stream capture has continued to this day, in the Appalachians (Johnson, 1939, 1941, 1942; Van der Schalie, 1939; Holt, 1969) and elsewhere (e.g., Smith, 1999). Our opinion is that such evidence of former drainage connections is reasonable, but only as corroborating evidence, and is not strong enough to serve as the sole evidence of geomorphic change, unless the possibility of transfer of taxa by other than stream connections can be eliminated.

THE POSSIBLE INFLUENCE OF STRUCTURE AND LITHOLOGY ON THE COURSE OF THE TENNESSEE RIVER

Several investigators have pointed out the control of structure on the course of the TR. Hayes and Campbell (1894) speculated that after emergence of the Appalachian Mountains in the late Paleozoic, streams initially flowed to the west following the slope of the land. As the folds and faults of the Valley and Ridge became

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exposed, thereby exposing beds of varying resistance to erosion, longitudinal streams south of the New-Kanawha basin, aided by the southward plunge of the fold axes, gradually developed, diverting the original streams to southern courses. During the Mesozoic, the original Appalachians eroded, until by late in the Cretaceous, nearly the whole of the Appalachian Valley southward of the New-Kanawha (Fig. 1) constituted a single drainage system whose main trunk was the Appalachian River. White (1904) suggested that all but one of the original transverse streams was captured by subsequent streams, and that exception, which still maintains its original course across Walden Ridge, is the TR.

Adams (1928) attempted to relate the history of the TR to both the Cretaceous and Paleozoic stratigraphy of the region. When Cretaceous deposition ceased, the southern Appalachian region and the adjacent Coastal Plains apparently were elevated. Following this uplift, the TR apparently attained its present position in its lower portion by extending its course over the emerging land. It made a sharp bend near Guntersville (G in Fig. 3) and developed its valley in adjustment to the underlying Paleozoic rocks as they were re-exposed. In Alabama the TR parallels the present escarpment made by the Hartselle Sandstone and follows the strike of the Paleozoics (Fig. 4). The course of the Tennessee, where it flows northward, is along the strike of the Cretaceous formations, just as the course of the Tombigbee in general is along the strike of these same rocks in eastern Mississippi and western Alabama. The TR at the northwestern corner of Alabama, where it forms the state line, flows in a relatively narrow gorge (Fig. 3) and appears to have held this position for a long time, perhaps since it established its course over the newly emerged Cretaceous deposits during the interval that preceded Tertiary deposition.

Milici (1968) noted that because many of the Paleozoic formations in central and western Tennessee presumably had been exposed by the Late Cretaceous, the physiography at that time probably was roughly equivalent to that of the present. Because the TR follows a long arcuate course around the Nashville dome (Fig. 4), Milici suggested that it may have had an initial consequent course close to its present course, probably early in the Mesozoic, and that the current course simply reflects lateral migration off the dome. He proposed that southward migration was the mechanism for entrapment of the river in Sequatchie Valley. Milici (1968) also suggested that the northward trend of the lower TR may be attributed to the following of consequent lows on the emerging Cretaceous coastal plain which reflected Late Cretaceous crustal movements or buried pre-Late Cretaceous topography. Evidence presented by Marcher and Stearns (1962, p. 1383), for example, indicates that, prior to Late Cretaceous inundation, a lowland existed between the Ozark Highlands and the Nashville dome in the approximate position of the western valley of the TR. This lowland may have been occupied by the lower reaches of the ancestral Tennessee. It was drowned during late Cretaceous flooding and is now marked by Tuscaloosa deposits. After withdrawal of Late Cretaceous and Cenozoic epicontinental seas, this lowland would have been a suitable location for establishment of the northward course of the lower TR. He attributed the present course to capture by drainage tributary to the Ohio River. Isphording (1983) pointed out that a factor favoring this northern trend might have been isostatic uplift that occurred in the continental interior and coastal plain in response to sea-level changes during the Pleistocene.

Whereas Adams (1928) speculated that a position of the TR in the headwaters of the Black Warrior River during the Cretaceous seems likely, neither Adams nor Milici (1968) saw any reason to suppose that the ancestral TR ever flowed across Mississippi. Other researchers, however, as cited below, have reported evidence of former courses of the TR in Mississippi, but during the Tertiary rather than the Cretaceous.

Although the course of the TR may be adjusted to structure and lithology, small crustal movements might also have contributed to course changes. In addition, structural control certainly does not preclude former courses much different from the present one. The best evidence of former courses would come from

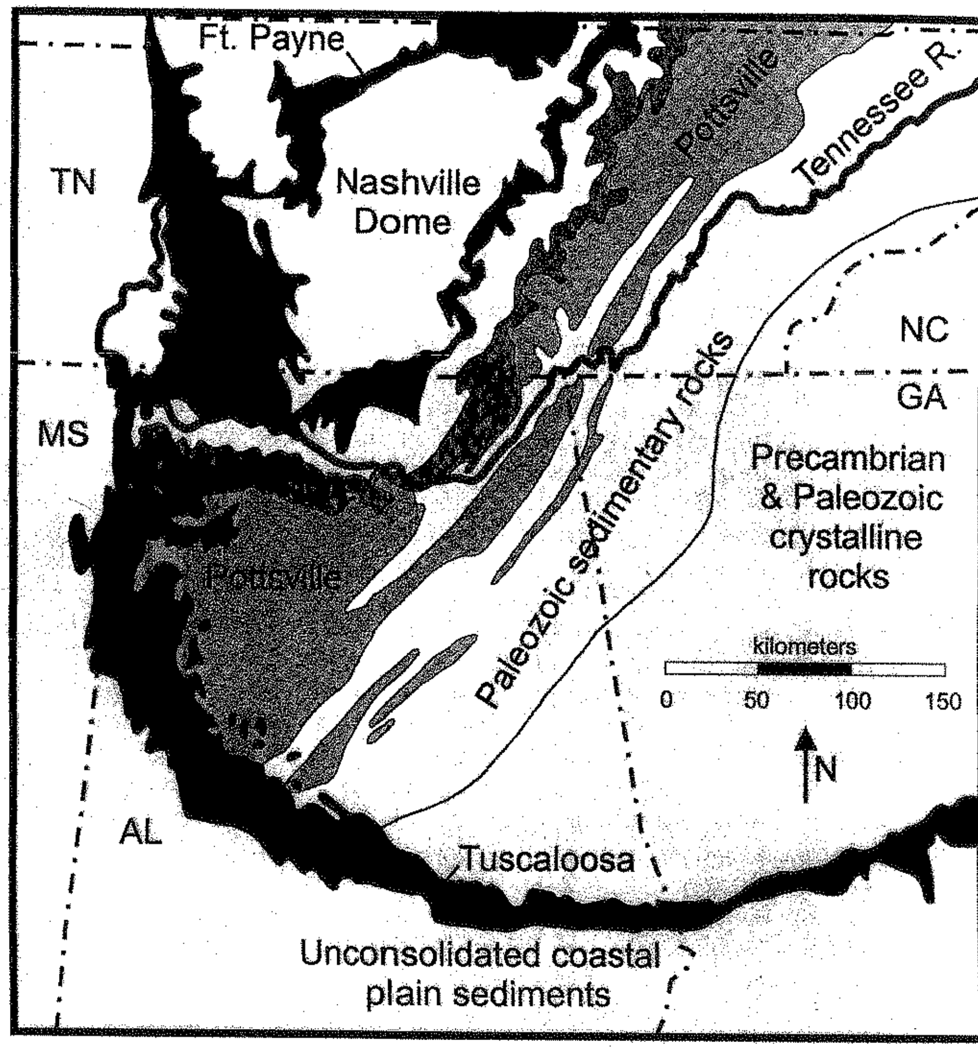


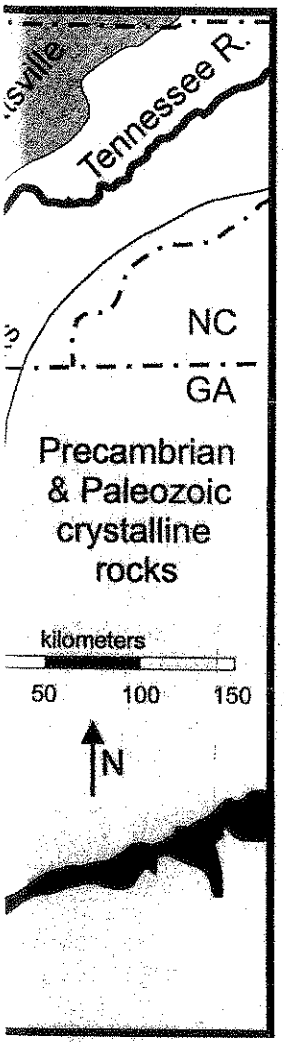
Figure 4. Important geological units and features in the vicinity of the Tennessee River.

the geographic distribution of stream deposits.

GEOLOGIC TRACERS FROM THE CRYSTALLINE APPALACHIANS

The two most easily recognized geologic tracers that indicate a crystalline Appalachian provenance are 1) distinctive suites of heavy minerals, usually rich in high-grade metamorphic minerals; and 2) metamorphic or vein quartz (subsequently these both will be referred to collectively with the abbreviation MQ, as vein quartz occurs mainly in metamorphic rocks; the fraction coming from Paleozoic sedimentary terrane is minute). The former is usually studied in the sand fraction and the latter in pebble or larger fraction.

Upstream of Chattanooga, the TR acquires abundant amounts of these metamorphic tracers from tributaries that head in the Blue Ridge province (Figs. 1 and 3). As the river crosses the sedimentary rocks downstream from Chattanooga, the metamorphics constitute distinctive markers that distinguish deposits of the Tennessee from those of streams that head in the sedimentary Appalachians. No tributaries of the TR



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downstream of Walden Ridge head in metamorphic terrane. Study of geographic and temporal distribution of these tracers may help unravel the mystery of the ancestral TR. The problem of reworking of tracers will be addressed below.

Heavy Minerals

In the western part of the southern U.S., heavy-mineral suites generally can distinguish sediments from the southern Appalachians from those originating from the craton, the Rocky Mountains (via the Missouri and Mississippi rivers), and from the Canadian shield (i.e., Pleistocene glacial deposits) (Goldstein, 1942). Suites from the Appalachians are characterized by abundant high-grade metamorphic minerals, including kyanite, staurolite, and sillimanite, although the details of the suites vary. The presence of minerals from the crystalline Appalachians is to be expected, but the exact geographic and temporal distributions of these minerals may have important implications for former drainage courses.

Most heavy-mineral studies in this region have dealt with Cenozoic deposits. Grim (1936) studied heavy minerals of the Eocene sediments of Mississippi. He found that for both the Wilcox and the Claiborne, the abundant heavy minerals are uniformly present laterally across the state and vertically through the section, and therefore concluded that all the deposits of both these units had the same ultimate source area, the crystalline Appalachians.

Isphording (1983) studied the mineralogy of Miocene coastal plain sediments, and found a marked contrast in the heavy-mineral suites from Texas eastward to Florida. Texas and western Louisiana are dominated (especially in the lower Miocene) by exceptionally high zircon, apatite, pyroxene, and amphibole, derived mainly from igneous (volcanic) source areas. Upward in the section, east Texas and Louisiana Miocene sediments undergo a marked change, with a distinct decrease noted in the quantity of garnet, zircon, apatite, sphene, and especially amphibole. This reflects the decreasing effect of igneous source areas in during middle (and late) Miocene time. Instead, these sediments (as well as those from Mississippi and Alabama) became dominated by a suite typical of the crystalline Appalachians, indicating that the southern Appalachians had become the dominant source for Gulf Coast sediments.

Several studies have also been carried out on the heavy minerals of Pliocene(?) deposits. Potter (1955) studied the mineralogy of the Lafayette gravel [Pliocene(?)] deposits in the northern Mississippi embayment. He was able to divide these deposits into three geographic groups, which he considered the remnants of three coalescing alluvial fans related to the ancestral Mississippi, Cumberland-Ohio, and TR. The heavy-mineral suite for western Kentucky (i.e., the deposits associated with the ancestral TR fan) differs greatly from that of deposits from the other rivers, showing a strong metamorphic affinity suggestive of a source in the crystalline Appalachians.

Blankenship (1956) observed that the mineral suite for Pliocene(?) terrace deposits of the Mississippi in western Tennessee was markedly different from that of recent deposits of the Mississippi and also from that of older, Paleozoic formations of the continental interior. It was, instead, similar to suites from Pliocene(?) and Pleistocene deposits of the TR. He concluded that the source for the Mississippi Pliocene(?) deposits must have been sediments derived from the ancestral TR to the east. Rosen (1969) analyzed heavy minerals in the Citronelle Formation (Pliocene?) from southwestern Mississippi to the Florida panhandle. He found the heavy-mineral suite of this deposit, indicative of a metamorphic source, to be similar to that in the older underlying deposits, and therefore argued that the Citronelle represented reworked sediments from now-eroded deposits once located farther inland.

Goldstein (1942) studied the mineralogy of modern coastal sediments in the northern Gulf of Mexico. He found that the Eastern Gulf province differed greatly in its heavy mineral suite from provinces farther west, showing a relatively high content of metamorphics, reflecting a crystalline Appalachian source. Some of these minerals may be coming from the Coosa-Alabama, which has headwater branches in the

Blue Ridge and Piedmont of Georgia, but probably a substantial part are coming from the reworking of Coastal Plain sediments originally deposited there by now-defunct streams from the crystalline Appalachians.

A southern Appalachian metamorphic suite thus seems to be ubiquitous in the eastern Gulf Coastal Plain, in Eocene and younger deposits, indicating an ultimate source in the crystalline Appalachians, but leaving unanswered the question of the immediate source of the minerals.

Metamorphic Quartz Gravels

The great bulk of gravels on the Gulf Coastal Plain consist of chert, with MQ making up only a tiny fraction of the deposits. Clasts of MQ have been the most widely cited evidence for former courses of the TR. MQ gravels have the advantage over heavy mineral suites that they can be seen readily in the field. Also, the MQ gravels resist weathering more than all but the most-resistant heavy minerals.

MQ gravels have the same problem as heavy minerals, in that the ultimate source is readily identified but the immediate source is more difficult to ascertain due to reworking by streams. It may be possible to alleviate this problem for certain time ranges or geographic locales. The first restriction is that MQ associated with the Coosa-Alabama river system cannot be assumed to be derived from a former course of the TR, as the Coosa has headwaters in the Piedmont and Blue Ridge of Georgia (Figs. 1 and 4). Gulf rivers west of the Coosa-Alabama (Fig. 3), however, must ultimately have derived their MQ from the headwaters of the TR or its ancestor.

The two most likely immediate sources of MQ other than the TR are the Pennsylvanian Pottsville-equivalent conglomerates and the Late Cretaceous Tuscaloosa Formation (Fig. 4). Pottsville outcrops in the Appalachians display MQ clasts no larger than a large marble. It is possible that up-section beds long since removed had larger clasts, but it seems unlikely that Cenozoic deposits with MQ clasts larger than this were obtained from the Pennsylvanian formations.

Large MQ clasts do occur in Tuscarora deposits. However, the Tuscaloosa varies greatly from place to place in the amount of MQ clasts present. Marcher and Stearns (1962), for example, found that in Tennessee, lithologies of the Tuscaloosa differ from west to east. The western facies, typical of the formation in most parts of the western Highland Rim, consists of poorly sorted chert gravel with a small percentage of sandstone pebbles. Most of the gravel is Devonian chert, apparently from the Pascal arch, an eastward-sloping extension of the Ozark dome that extended into west Tennessee as far as the Tuscaloosa sea. A smaller amount of gravel is Mississippian chert of local origin.

The eastern facies, located near the eastern erosional limit of the Tuscaloosa in Tennessee, is similar to the western but with the fines winnowed out and MQ sand and pebbles added. Locally there are beds and pods of well sorted, heavy-mineral-bearing MQ sands. Beds of well sorted gravel that locally contain an abundance of MQ pebbles also occur. Marcher and Stearns (1962) suggest that the MQ and Blue Ridge-type heavy minerals in this eastern facies may have been derived from Pennsylvanian sandstone and conglomerates that cropped out north and south of the Pascola arch. The abrupt appearance of abundant MQ pebbles in the eastern facies of the Tuscaloosa coincides with an equally abrupt improvement in sorting. This coincidence suggests that MQ pebbles were brought into the Highland Rim area from the north or south and that they were deposited under different conditions than was the main mass of chert gravel.

Most of the Tuscaloosa Formation is believed to be of nonmarine origin, although the eastern facies is believed to be partly marine in origin, the exotic components having been swept in by longshore currents. The Tuscaloosa generally is thin, preserved only as caps on outlying hills. In Wayne and Hardin counties, in the southwestern part of the Highland Rim (WA and HN in Fig. 3), the gravel is intermixed with residuum derived from the underlying rocks. The greatest thickness is in parts of southwestern Wayne County, where 150 ft of gravel has

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In western Alabama, Monroe and others (1946) reported that only the Gordo Formation of the Tuscaloosa Group contained substantial gravel. The gravel consists predominantly of chert pebbles derived in large part from the Mississippian limestones of northern Alabama and southern Tennessee. Locally, however, as many as one fourth of the pebbles are MQ, perhaps derived from the much nearer conglomerates of the Pottsville formation. The Gordo Formation has been recognized as far east as Chilton County and as far north as the TR, where it includes the large gravel deposits mined extensively in the Iuka area in Tishomingo County, Mississippi (IU in Fig. 3).

These studies show that locally the Tuscaloosa may have a relatively high (i.e., up to 25%) content of MQ clasts, but that, overall, the Tuscaloosa is composed primarily of chert, so that reworking of this unit by streams is unlikely to produce a deposit high in MQ clast content. Marcher and Stearns (1962) suggest that, at least within the area covered by the western facies of the Tuscaloosa, there should be little difficulty in differentiating remnant Tuscaloosa deposits from TR deposits on the basis of MQ clast content. In fact, the authors point out that in this area, the general absence of MQ pebbles, together with the absence of waterworn ironstone pebbles, are the main criteria for distinguishing the Tuscaloosa from much younger terrace gravel. In the eastern facies, however, differentiation of the two types of deposits may be difficult.

Since the percentage of MQ clasts deposited at a given time is a function of the rate of chert deposition as well as that of MQ deposition, it is of interest to ascertain the factors affecting the former. The rise of the Pascola arch in the Late Cretaceous produced a flood of Devonian chert (Marcher and Stearns, 1962). A much later event which may have been important is the breaching of the Nashville dome (Fig. 4). Reesman and Godfrey (1981), based upon erosion rates calculated from dissolved loads measured in streams in the Central Basin and the Highland Rim of Tennessee, estimated that the Fort Payne Chert would have begun to be breached about 5-6 Ma ago, leading to a flood of cherty gravels in the Gulf Coastal Plain and Mississippi embayment (Self, 1993). Although this inference from erosion rates provides a hypothesis that can be tested by future dating, it is rather speculative and can be used to establish only a very approximate age. The problem is, that although the reconstruction of the Nashville dome based on denudation rates may be reasonable with respect to the rock volume, it minimizes the probable irregularity of fluvial erosion. Deep fluvial erosion may have cut down into the Fort Payne, supplying much debris from this formation while most of the formation was still covered by younger rocks. Thus, debris from the Fort Payne might have been voluminous much earlier than 5-6 my ago. Russell and Parks (1975) attributed the sudden influx of chert to a completely different cause. According to them, in southern Tennessee when the river was flowing at what are now elevations of 700 ft and above, the TR was carrying mainly MQ and sandstone gravels. As it migrated westward and cut below what is now the 700-ft level, the Tuscaloosa Formation was unroofed, releasing a flood of chert to the TR.

MQ clasts may thus serve as indicators of immediate, as well as ultimate, sources of late Cenozoic fluvial deposits if attention is confined to larger clasts and/or to areas where MQ-rich Tuscaloosa deposits do not crop out up gradient.

HIGH TERRACES AND THE STUDY OF TENNESSEE RIVER DEPOSITS

One problem in studying abandoned river courses of the TR, or even in evaluating possible scenarios of drainage evolution, is our lack of knowledge concerning how TR terraces change with age and how long they survive. One way to improve this knowledge base is to study high-level terraces near present-day river courses, where the terraces can be associated with specific streams with near certainty, and their ages roughly estimated from their elevation above modern river level (AMRL), assuming incision rates are approximately known. Understanding of these terraces can then help to evaluate hypothesized stream deposits or courses far from modern streams.

Such a study has been carried out along a reach of the New River in southwestern Virginia (Mills and Wagner, 1985; Bartholomew and Mills, 1991) (Fig. 1). The New River heads in the Blue Ridge province of North Carolina, and carries a large load of MQ gravel. In the study area in southwestern Virginia, tributaries head only in the Valley and Ridge, and thus carry no MQ gravel. Therefore, high terraces of the New River can readily be identified and distinguished from those of other streams by the presence of rounded MQ gravels. At the time this study was done, incision rates of the New River could only be estimated. However, a rate of 27.3 m/m.y. has since been measured by Granger and others (1997) by means of cosmogenic isotope dating of MQ clasts in riverside caves. Ages of terraces can now be approximately dated in millions of years by dividing terrace elevations AMRL by 27.3.

Mills and Wagner (1985) studied erosional and weathering characteristics of the New River terraces. They found that the original surface of terraces less than 25 m AMRL is largely intact. The surface of terraces 25-50 m is highly dissected, but remnants of the original surface remain. Above 50 m, little or no original surface remains; terraces have been transformed into rolling, irregular topography, with numerous prominent sinkholes in areas underlain by carbonates. Deposits survive much longer over a limestone substrate than over a shale one (Houser, 1981). Reworking of alluvium by hillslope processes is very common on high "terraces", and on terrace remnants higher than 100 m AMRL, there appears to be little in situ alluvium remaining. In deposits above 50 m AMRL, most crystalline rock clasts are decomposed, and in the sand fraction, most feldspar grains are gone, as are the less-resistant heavy minerals.

Despite the intense weathering and erosion of the high-level deposits, colluviated remnants of terrace deposits, recognizable by their MQ clasts, occur as high as 300 m AMRL, translating roughly into an age of 11 Ma. Deposits 185-275 m AMRL (6.8-10.1 Ma) are widespread, although they occur in small isolated patches (Bartholomew and Mills, 1991). Some of these deposits are very near the modern river, whereas others are located as far away as 11 km and describe, in some cases, river courses much different than the modern one.

The work on the New River in southwestern Virginia shows that fluvially deposited MQ gravels remain as testimony to the former presence of a stream for long time periods, even though original terrace surfaces are gone by 2 my and original deposits are almost completely reworked by slope processes by 4 my. This work points out the importance of determining both the locations and elevations AMRL of the deposits, and provides a model that could be used for study of the TR, although incision rates and survival times of terrace surfaces and original deposits may differ. There are certainly more difficulties involved with study of TR than New River terraces. On high terraces of the New River, most of the deposits are reworked, but generally they can be readily identified as coming from the New River by their MQ content. This is not the case for gravels of the TR, where MQ may come from Paleozoic or Mesozoic sources, as well as from late Cenozoic ones. This problem is more manageable for terraces near the modern Tennessee, but becomes very serious for deposits of possible former courses of the Tennessee tens or even hundreds of kilometers from the present river, especially where they overlie Gulf Coastal Plain deposits.

Few detailed terrace studies have been carried out along the TR. Delcourt (1980), provided a basic study of the Little Tennessee River, a tributary of the TR that heads in the Blue Ridge province (Fig. 3). He included high terraces, but did not include information on still higher deposits above the highest preserved terrace surfaces. Archaeological studies have dealt only with low TR terraces. In the upper reaches of the TR, there have been some observations on high-level gravels. Swingle (1959), for example, described high-level gravels east of the river near Cleveland, Tennessee (CL in Fig. 3), ranging up to 700 ft (213 m) AMRL, although the highest ones consist mainly of quartzite rather than MQ.

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One test of the Walden Ridge late-Tertiary capture hypothesis might be to compare heights of gravels upstream and downstream of the ridge. If the upstream reach is substantially older than the downstream, gravels might be expected to occur at higher elevations AMRL upstream than downstream. Hayes and Campbell (1894), for example, claimed that they found MQ gravels upstream of the ridge up to 250 ft (76 m) AMRL, but downstream only up to 150 ft (46 m). However, Johnson (1905b) claimed to have found MQ gravels up to 265 ft (81 m) AMRL downstream of the ridge, and we have found them at similar heights. Thus, the data do not support the capture hypothesis.

For the lower reaches of the TR, aside from the deposits near the junction with the Ohio studied by Potter (1955), the most extensive terrace deposits occur just north of the bend at Pickwick Dam (PD in Fig. 3), where the TR assumes its northward course across Tennessee, with few terraces occurring north of this area. These deposits have been mapped by Russell (1964, 1967, 1968), Russell and Wilson, 1970; Russell and others (1972), Wilson and others (1971, 1982), and have been discussed by Russell and Parks (1975). Self (2000) divided these deposits into five levels, with heights AMRL of the treads ranging from 80-140 ft (24-43 m) for the lowest to greater than 360 ft (110 m) for the highest. (Self reported tread heights in altitudes, but we have transformed these into heights AMRL by subtracting the approximate pre-dam level of the TR from the altitudes). Thickness of the deposits ranges from 40 to 60 ft (12-18 m). Only the lower two terraces, those with treads with heights AMRL of 160 ft (49 m) or lower, show well preserved surfaces.

Dating these deposits from their heights AMRL is impeded by the lack of a measured incision rate. The rate is probably lower than the previously cited 27 m/my of the New River in southwestern Virginia, owing to lower relief along the lower TR. However, a compilation of incision rates in the eastern United States (Mills, 2000) suggests only a weak correlation between relief and incision rate, so that the TR rate is probably not greatly less than that of the New River rate. If we assume that the TR incision rate is, say, between one half and one times that of the New River rate (range of 13.5 - 27 m/my), the age of the highest terrace would be 4.1 to 8.2 Ma. Self (2000), by means of lithology counts, found that the clasts on the highest terraces are largely MQ, whereas those on lower terraces are largely chert. He attributed this change from predominantly MQ to predominantly chert to the breaching of the Nashville dome, estimated by Reesman and Godfrey (1981) to have begun about 5-6 Ma. The incision rates estimated here support this timing.

Self (2000) also found that both terraces and the underlying Claiborne Formation (middle Eocene) in the Hatchie River west of his study area showed a high content of MQ clasts. He therefore suggested that the ancestral TR flowed through the Hatchie River valley prior to the breaching of the Ft. Payne Formation, and that it may have followed that course at least since the Eocene. He noted that additional support is provided for this concept by the width of the upper Hatchie valley, which suggests that the present Hatchie River is underfit, and by the alignment of the Hatchie valley with the axis of the TR before it turns to the north.

Self's (2000) hypothesis could be tested by correlating the terraces in the two valleys. No absolute dates are available for terraces, nor is the stream incision rate for either stream. However, correlation can be attempted by comparing the elevation AMRL and degree of preservation of terraces. Parks (1968, 1992) studied terraces along the Hatchie River valley near Hebron, Hardeman County, Tennessee (H in Fig. 3). He found that four levels of terraces occur on the southwestern valley wall, their treads ranging in elevation AMRL from 14 to 60 m. Only the lowest terrace, at 14 m AMRL, is well preserved. This contrasts with the TR, where, according to Self (2000), the highest terrace is 110 m AMRL, and the highest well preserved terrace is at 49 m AMRL. These discrepancies, particularly the 14 m vs. 49 m elevation of the highest preserved terrace, suggests that the terrace sequence between the two valleys are not correlative, unless the incision rates differ by more than a factor of 3, which seems unlikely

A further attempt at chronology can be made by using a correlation suggested by Saucier (1987). He named and described four lower-level terraces along five West Tennessee streams that drain to the Mississippi. From highest to lowest these are the Henderson terrace, the Humbolt, the Hatchie, and the Finley. The lower three were recognized along the Hatchie river, but only the Hatchie terrace was recognized on the Hatchie River as far upstream as the vicinity of Hebron. This corresponds to the low terrace of Parks (1992). Saucier (1987) postulated that the Hatchie is the stratigraphic equivalent of the Prairie Terrace, which is the Prairie Complex of Autin and others (1991).The latter authors report that age estimates for the Prairie Complex range from Sangamon to late Wisconsin. (These estimates are compatible with Parks' [1992] suggestion that all the Hebron terraces are Pleistocene.) If we assume a Sangamon age (on the order of 120 ka), then if the Hatchie terrace does indeed correlate with the 49-m-high TR terrace near Pickwick, the implication would be that the highest TR terrace, at 110 m AMRL, is probably less than 1 Ma. As an age this young seems unlikely, the inference must be, once again, that the highest preserved terraces at the two locales probably are not correlative. Hence, terrace correlation provides no support for Self's (2000) interpretation of the Hatchie as the former course of the TR, as the Hatchie River deposits appear to be substantially younger than the TR deposits near Pickwick. However, the evidence has too many uncertainties to dismiss his hypothesis. Much more study of TR terraces, particularly dating, is required before significant progress will be made on the drainage history of the TR.

THE UPLAND DEPOSITS

Sands and gravels that unconformably overlie Paleozoic to Miocene formations and underlie Quaternary formations are widespread in the Gulf Coastal Plain and the upper Mississippi embayment. These coarse deposits contrast sharply with the fine sands, silts, and clays that characterize the Quaternary and much of the Tertiary in the Gulf Coastal Plain (Self, 1993). Names for these deposits include the Citronelle of the Gulf Coast, the Lafayette gravels of the Upper Mississippi embayment (Autin and others, 1991, have pointed out that the name Lafayette is now obsolete, but it will be used herein), and the Upland Complex in the Lower Mississippi Valley (Autin and others, 1991). The latter name, modified to Upland deposits, will be used here for all these deposits. The gravel fractions are dominated by rounded, iron-stained, honey-colored chert, whereas the sand fractions are largely MQ. Potter (1955) proposed that the gravel comes mainly from the sedimentary Appalachians and the sand mainly from the crystalline Appalachians. The deposits are generally assumed to be Pliocene or early Pleistocene in age, although age control is poor. Because these deposits commonly contain crystalline Appalachian suites of heavy minerals, and often some MQ gravel as well, they may be related to the former drainage of the TR.

Although some Upland deposits include high-level terrace deposits associated with specific streams, generally these deposits are located away from large modern streams so that their origin is more uncertain. Shaw (1918) suggested four possible origins of the Upland deposits:

1) they were deposited by floodwaters of Pleistocene glaciers;

2) they were laid down during a marine submergence of the Coastal Plain;

3) they were produced by stream deposition induced by broad uplifts of the Appalachians;

4) they are for the most part simply weathered portions of older, underlying formations of the region, with a small part being made up of material of other kinds.

The first two can now be largely eliminated as possibilities, although ice-rafting of rock debris by streams during glacial climates may have been significant. The second two, however, remain viable. Origin 3) seems to be the most broadly accepted today. The idea is that increased uplift of the Appalachians during the Pliocene increased the load of the streams, and that this load was too great to be carried across the coastal plain to the sea. As the uplift progressed, the deposit was spread farther and farther toward the sea. The basic evidence for this interpretation is that the deposits roughly form

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an arc around the Appalachians. Self (1993) thought this uplift to be concentrated in the vicinity of the Nashville Dome, which Reesman and Stearns (1989) hypothesized to have undergone extensive isostatic uplift during late Tertiary and Quaternary time owing to rapid erosion following the breaching of the capping Ft. Payne Formation. The coarse texture of the deposits, in contrast to the fine texture of most of the Tertiary coastal plain deposits, suggests a unique depositional regime (Self, 1993). Autin (1991) suggested that the deposits represent erosional remnants of a once regionally extensive blanket, commonly capping hilltops or on well-dissected interfluve ridge crests. Potter (1955) and Self (1984, 1993) suggested that the Upland deposits were laid by braided streams.

Shaw (1918) has given the most complete discussion of origin 4). Working in northern and central Mississippi, he opined that 75% to 90% of the supposed "Lafayette" deposits appear to be material from the underlying formation subjected to weathering and reworked by colluviation. As evidence, he noted that the supposed formation shows little detailed or consistent relationship to altitude, topography, or geologic features. Further, the surficial material often differs from the intact pre-Pliocene formation beneath only in being more reddened and otherwise weathered. In addition, the unconformity that should occur beneath the deposit either cannot be found or cannot be agreed upon.

On the other hand, Shaw (1918) found that clasts on or within a few feet of the surface of the Upland deposits in many cases are much larger than any found in the underlying formations, or, in fact, in any other formation in the region. Clasts may rarely be as large as boulder size; Mellen (1939) reports a boulder weighing 905 lbs. These large clasts evidently are remnants of strata now worn away, and the question arises of whether these strata belonged to a single formation or several formations, some or all of which are now represented by the Upland deposits. Shaw argued that if the clasts had been let down from a single formation they should show some relationship to altitude and surface features, but they do not, and so derivation from multiple formations seems more likely. As a source of the large clasts, Shaw (1918) pointed out that the landward part of many coastal-plain deposits is likely to be coarser than the seaward part, and it is thus probable that the now-eroded landward parts of the formations in the study area once contained clasts coarser than those found in the present-day outcrops.

Shaw (1918) also addressed the question of when the clasts moved from their positions in the last formation they were part of to their present position. He argued for a Pliocene age as follows. The present rate of erosion is about 100 ft/my (an estimate that remains today the right order of magnitude). The clasts are likely to have been let down many feet, for they are found only in colluvium. If they had been lowered much less than 100 ft, one might expect to find remnants of the beds from which they were derived, but no such remnants have been found. The clasts have not been let down many hundreds of feet, however, for they are fairly evenly distributed and are almost as common on divides as elsewhere.

The other 10% to 25% of "Lafayette" deposits, which are clearly different from the underlying formations and separated from them by an unconformity, Shaw (1918) attributed to terrace deposits, and noted that most of them are in the vicinity of large streams. These deposits have been modified in a way similar to the other Upland deposits. As an example, he pointed out gravel deposits near the junction of the Tombigbee and Black Warrior rivers, which he attributed to remnants of several different terraces that stood at different heights, and hypothesized that the large bodies of gravel have been let down, with lateral shifting, as the underlying materials eroded.

Although the consensus today favors origin 3) for the Upland deposits, certainly Shaw's (1918) account seems reasonable, and should be kept in mind as a possible explanation of at least some of the Upland deposits.

Concerning courses of the TR, although origin 3) considers many coarse gravels to be part of an eroded sediment blanket surrounding the Appalachians, it does not eliminate the use of gravel deposits as evidence for former stream courses. It does imply, however, that the simple presence of such deposits does not, by itself, demonstrate the existence of such courses.

INFERRED FORMER COURSES OF THE TENNESSEE RIVER

Previous Work

Most studies of Upland deposits were not concerned with specific relict stream courses. An exception is that of Potter (1955), discussed earlier, who associated part of the Upland deposits of western Kentucky with the ancestral Tennessee. His evidence seems to imply that the lowermost reach of the TR was established by Pliocene, which implies that upstream reaches of the TR most likely had been established by that time as well. Of terrace studies, only that by Self (2000) bears on previous TR courses. Based on the presence of abundant MQ on terraces and in the Eocene cropping out in the Hatchie Valley, as well as other evidence discussed in the previous section, Self suggested that this valley had been the course of the TR as early as Eocene, and that this course had been abandoned by the time the TR began carrying abundant chert gravel at about 5-6 Ma.

Most reconstructions of former courses of the TR have been based on gravel deposits, particularly those rich in MQ. The only such studies to deal with pre-Tertiary courses are those by Monroe and others (1946) and by Conant (1964). Monroe and others (1946), during mapping of Cretaceous units in Alabama, found that the sediments in nearly every formation were somewhat coarser near the present Black Warrior River, suggesting to them that the Black Warrior may follow the approximate course of a Cretaceous stream, possibly the ancestral TR. Conant (1964) discussed this subject in more detail. He noted that a water well at Brent, Alabama (B in Fig. 3), penetrated Cretaceous gravel and other sediments in a paleochannel in Paleozoic bedrock that was about 40 feet deep. Thus, during Cretaceous time a major stream may have had a course similar to that of the present Cahaba River (Fig. 3) in the Brent area, and was entrenched at least 40 feet in the Paleozoic rocks. About 12 miles downstream from this well, an exploratory well penetrated 30 feet of gravel at the base of the assumed Vick Formation (?). The Cahaba River is directly in line, geographically and structurally, with the TR above Chattanooga. The Black Warrior River is directly in line with the TR in its southwest course along the breached Sequatchie anticline. Conant (1964) suggests that in Cretaceous times the TR continued southwest from Chattanooga to the course of the present Cahaba River, and that the Sequatchie River flowed into the course of the present Black Warrior River. Such courses would explain the greater abundance of gravel in the Cretaceous sediments near the present rivers. Neither Monroe and others (1946) or Conant (1964) discussed gravel lithologies.

Concerning Tertiary courses, Grim (1936), based on heavy-mineral data, suggested that sediments from the crystalline Appalachians accumulated in the northeast-central part of Mississippi, probably in the form of a huge delta into the embayment fed by a large river, perhaps the Appalachian River of Hayes and Campbell (1894) during Midway and Wilcox time in the Eocene. On the other hand, during the younger Claiborne time, there is no evidence of such a river or delta in this location. As an explanation, Grim favored the idea that capture of the Appalachian River took place approximately at the beginning of Claiborne time. He offered no evidence of specific courses, however.

Most speculations concerning former courses of the TR have dealt with the late Tertiary.

Hayes and Campbell (1894) hypothesized that at the close of the Cretaceous a small river flowed westward across northern Alabama and emptied into the sea in the northeast corner of Mississippi. During the late Tertiary one or more of the head branches of this stream then captured some eastern TR course that had been going to Mobile Bay, and upon the withdrawal of the sea this stream then followed the course of the Big Black (Fig. 3) to the Mississippi. Shaw (1918) agreed with the concept of a former course in Mississippi, but thought a course down the Big Black in Pliocene time unlikely, for no high terraces occur along this river

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and there is no abandoned valley between the two streams. He thought a more likely route to be down the Tombigbee, for along this river there are somewhat extensive high terraces, particularly in the vicinity of West Point, Mississippi (WP in Fig. 3), and to the southeast in Alabama. If this course existed, some parts of it have not been found.

Shaw (1918) also considered the Pearl River in Mississippi (Fig. 3) to be underfit to its valley; as an explanation he suggested that the western headwaters of the Pearl were captured by the Big Black River, perhaps in late Pliocene time. Perhaps another possibility might be, however, that the Pearl was once occupied by the lower end of the ancestral TR or other stream from the Appalachians.

Brown (1967) hypothesized that a large river flowed southwesterly through southern Mississippi in Pliocene times, based on the discontinuous gravel-defended ridges extending along this trend, particularly in Scott, Lincoln, and Franklin counties (SC, LI, and FR in Fig. 3). The thick superficial deposits that underlie the ridges, which contain very coarse gravel, have been mapped as Citronelle. He suggested that many deposits considered to be Eocene or even Cretaceous might in fact prove to be part of this hypothesized river. The alignment of the gravel-defended ridges in southern Mississippi suggests a flow direction compatible with the undated and somewhat anomalous gravel deposits of Tishomingo, Choctaw, and Winston counties (TI, CT, and WI in Fig. 3). Brown did not discuss the lithologies of the gravels.

Isphording (1983) reported a local anomaly in the heavy mineral suite at a site south of the town of New Augusta in southeast Mississippi (NA in Fig. 3) which led him to hypothesize a former river course. Samples from numerous drill holes from this location showed that significant amounts of hornblende, epidote, and garnet were present in the Miocene Hattiesburg clay. Samples from the same formation to the east and west of this location, however, did not contain these minerals. Similarly, these minerals are completely absent in contemporaneous sediments eastward in Alabama. As this suite is contained within sediments having an obvious fluvial origin, he suggested that they may have been transported into the area by some ancestral river system originating in a metamorphic rock terrane. Isphording suggested that an ancestral TR may have flowed southwesterly across the state of Alabama into eastern Mississippi, and discharged into the Gulf of Mexico in eastern Louisiana.

The above course reconstructions are not very satisfying. In the first place, many of them do not address adequately the content of tracers from the crystalline Appalachians. Secondly, they deal mostly with deposits in a relatively restricted area, avoiding the question of how the stream got to that location and where it went afterwards. Related to this problem are the missing parts of hypothesized courses, referred to by Shaw (1918). Although part of a former river course may have been down the valley of a present-day stream, there are bound to be divergences of old and new courses where the old stream joined the present one. For abandoned courses of Pleistocene or Pliocene age, some remnants should remain.

New Data Bearing on Former Courses of the TR

Figure 5 shows locations of surficial gravels that contain high fractions of MQ clasts. We think that many of these are remnants, commonly colluviated, of high-level fluvial deposits of Plio-Pleistocene age that potentially represent the TR. These deposits lie on the surface, and in many cases overlie deposits composed mainly of chert. Although we cannot prove beyond a doubt that these gravels are not remnants of pre-Pliocene formations, they constitute data that should be considered in any reconstruction of former river courses. The altitude ranges of the deposits (Fig. 5) may bear on the relative ages of possible previous courses of the TR, although the resistance of the underlying formations plays an important role in determining the rate of gravel lowering. For example, the gravels on the Hartselle Sandstone have probably been let down much less than those overlying the chalk belt.

The cluster of sites near A in Figure 5 include

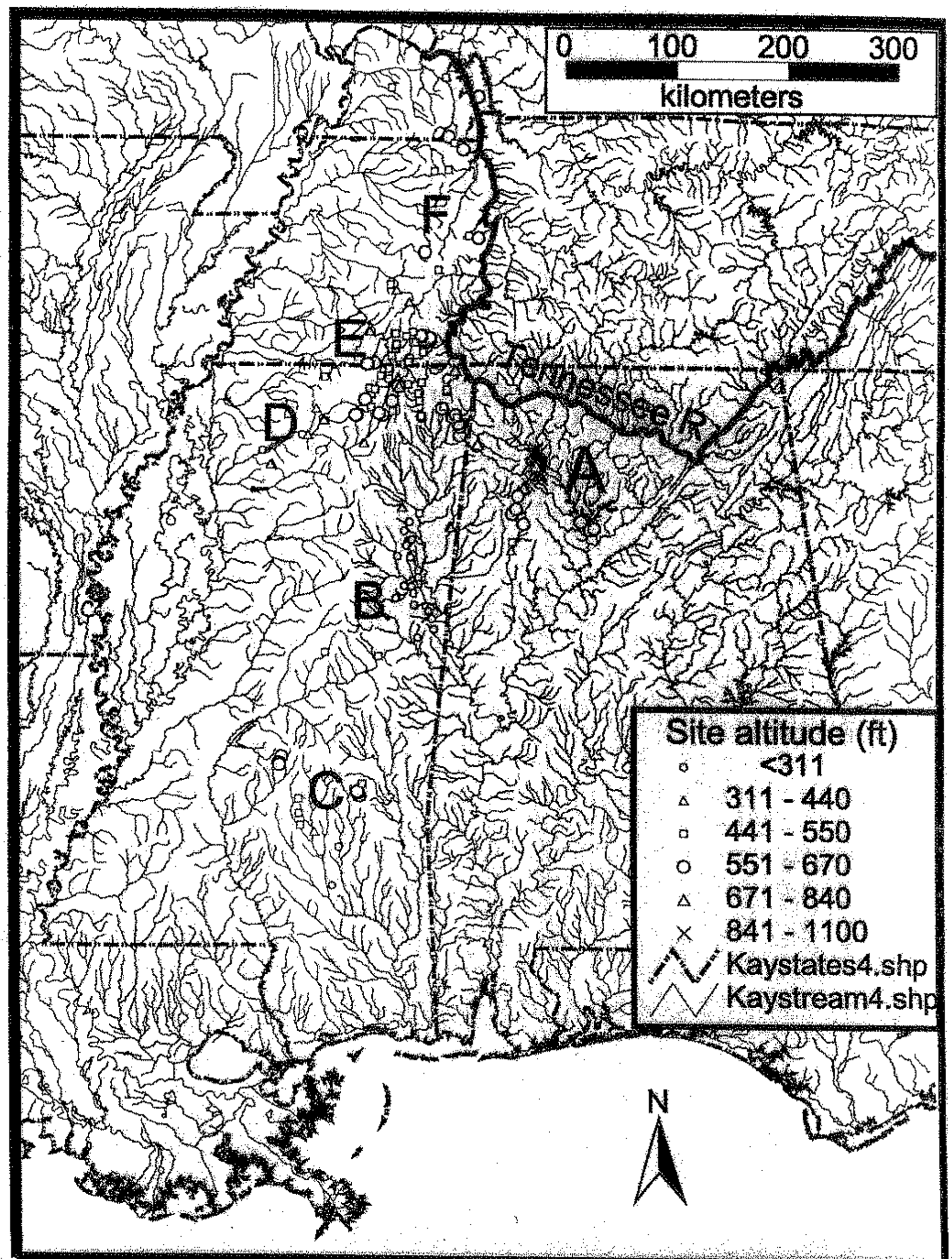
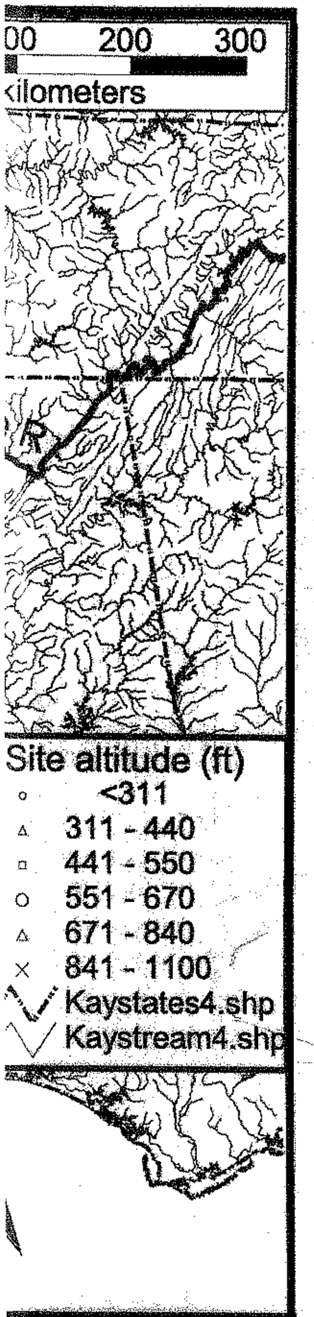


Figure 5. Map showing locations of sites with high MQ gravel contents. Six altitude intervals are shown.



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those at the highest observed altitudes, which overlie Mississippian Hartselle Sandstone. These deposits presumably are the oldest, and might even be as old as Miocene. Because the downdip migration of the TR here is south, these gravels weren't simply left behind as the river migrated. Rather, they suggest an older course of the TR to the south, although its route to the Gulf is unknown. In the southern part of this group, along the Sipsey River valley (Fig. 3), are voluminous deposits with some of the largest MQ clasts west of the Blue Ridge. Because these sites are much lower and therefore probably younger than those on the Hartselle, they may reflect a later course of the TR. These deposits contrast with those of the Luxapalila River Valley (Fig. 3), a short distance west of the Sipsey. This valley is dominated by chert gravel, thereby being typical of coastal plain streams. The easternmost sites in group A suggest a third alternative, a course to the southeast into the Black Warrior River basin. (Although the Black Warrior River is in line with the Sequatchie Valley anticline, a former route from the Sequatchie to the Black Warrior seems unlikely, as no MQ gravel has been found in the headwaters of the latter.)

The cluster at B, mainly on the west side of the Tombigbee River, has the lowest altitude of any of the clusters. Even though deposits with lower altitudes are generally younger than those with higher altitudes, these deposits are not younger than deposits along the present northern course of the TR. They may be former TR deposits that have been reworked by the Tombigbee, or TR deposits that have been let down by the rapid solution of the underlying chalk. The cluster at C might be a continuation of either cluster at B or C. It is close to, but still north of, the anomaly near New Augusta, Mississippi, reported by Isphording (1983) and attributed to a former course of the TR. We have not examined gravel lithologies in southwestern Mississippi, and therefore cannot evaluate Brown's (1967) hypothesis of a former TR courses in this area.

Cluster D suggests a former westerly course of the TR to the Mississippi River. Cluster E is associated with a fan-like deposit near the Mississippi-Tennessee border, discussed below, and also with the headwaters of the Hatchie River. If the Hatchie River does indeed represent a former course of the TR, as suggested by Self (2000), then it seems reasonable to infer that this course came after the course associated with cluster D. Cluster F shows MQ clasts west of the present Northern Valley of the TR, suggesting that the TR at some time occupied positions to the west of its present lower reach.

DISCUSSION AND CONCLUSIONS

Isphording (1983) suggested the possibility of northward diversion of drainage owing to crustal tilting caused by isostatic adjustment due to sea-level change during the Pleistocene. Crustal loading by the ice sheet covering the Midwestern U.S. is another possible cause. Presumably the first large glaciation would have been the one responsible for the diversion, probably the same glaciation that produced proglacial lakes extending far from the glacial margin, obliterating the Teays River, and creating the modern Ohio River. Granger and Smith (1998) have dated the proglacial lake sediment, by means of burial dating with cosmogenic isotopes, at 1.13 Ma. Although the most dramatic effects took place in the immediate vicinity of the ice sheet, farther south the crustal subsidence would have tilted the surface northward, thereby increasing the energy of streams flowing north and promoting capture of streams with different flow orientations. This effect might have diverted the lower reach of the TR to its junction with the Ohio.

Tilting to the north should have reduced the energy of south-flowing streams, potentially producing fan-like deposition where the slope became sufficiently reduced. Such a fan, now dissected, appears to be present in northeastern Mississippi and adjacent Tennessee. For example, in southernmost Alcorn County, Mississippi (AL in Fig. 3), extending over a wide area in the Rienz community, is a deposit of MQ pebbles in silty clay. Evidence of stream reversal in this area is also suggested by drainage maps of north-flowing streams in this area. A number of these streams have headwater tributaries that

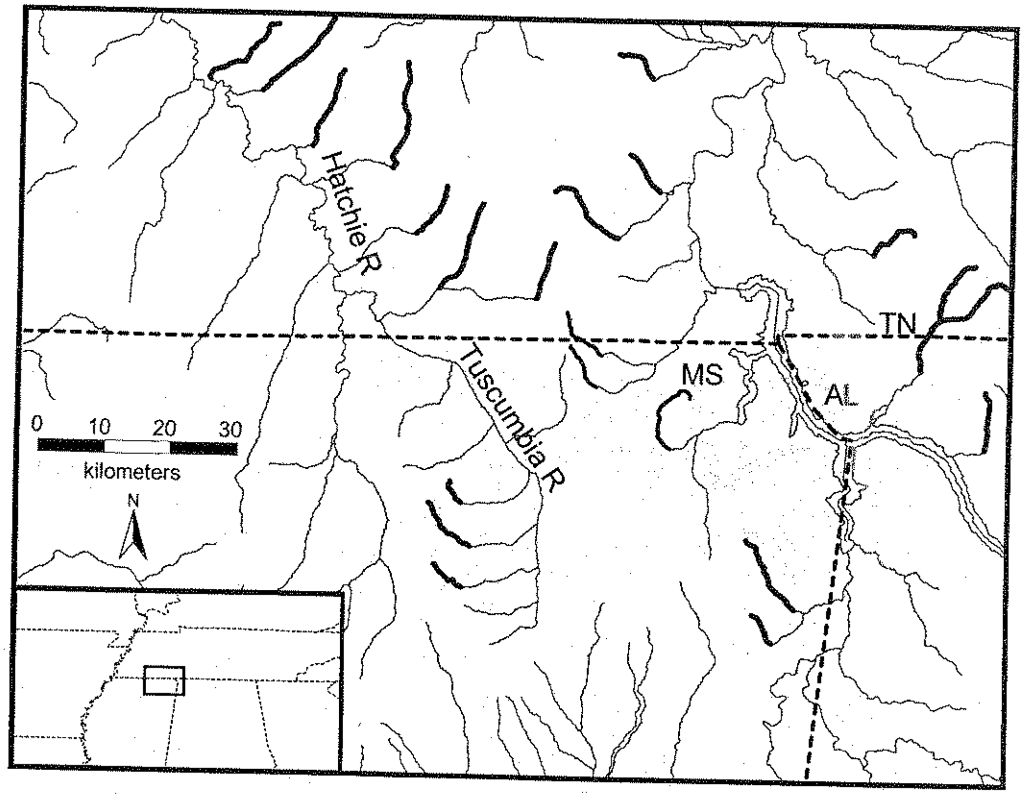
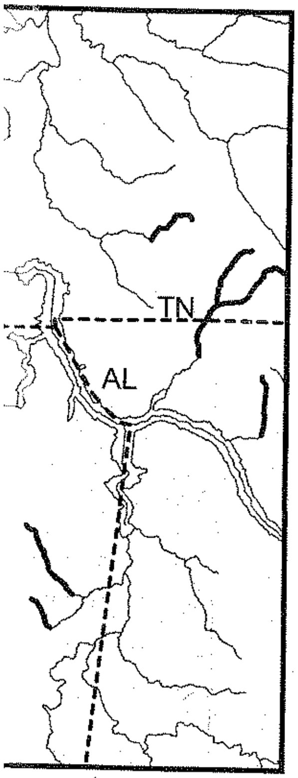


Figure 6. Map showing southward-flowing headwater tributaries, suggestive of stream capture, in northeastern Mississippi and adjacent Tennessee. Southern-flowing tributaries are shown by heavy solid lines.

flow south (Fig. 6), indicating a former drainage system flowing to the south.

Two objections that might be made to a stream capture resulting from isostatic adjustment of the ice sheet are that 1) the ice sheet has come and gone repeatedly during the Quaternary. Therefore, would not the stream course be diverted back to a southward course during each postglacial isostatic rebound? and 2) an age of 1.13 Ma seems too young, for if capture had taken place that recently, one might expect more evidence of the former stream course to remain. The first objection can be answered fairly readily - once a capture has taken place, hydrologic changes occur which provide the stream ability to persevere in its course despite later unfavorable tilting of the land surface. (The increased discharge resulting from the capture allows the stream to have more energy at a lower slope.) Concerning the second, the major question is just how well valley topography persists over time. The Teays Valley in West Virginia (Fig. 1), for example, is easily recognized despite a probable age of 1.13 Ma (Granger and Smith, 1998). Yet, there appear to be no comparable abandoned valleys in western Tennessee. The western Hatchie River Valley, discussed above, might be a candidate, but what is missing is a valley connecting the present course of the TR to the Hatchie - the divide between them seems more prominent than what should be expected in such a relatively short time interval. Self's (2000) suggestion of a minimum capture age of 5-6 Ma thus appears more compatible with the present topography. Such an age would eliminate ice sheets as the cause of diversion.

Future work should include mapping and attempted dating of terrace and other high-level deposits, more study of deposit lithologies, and



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attempts to trace possible former river courses over longer distances. Terrace mapping is particularly important in order to determine the heights of river deposits above the level of the modern river. Such work would be especially useful if accompanied by dates that would allow estimation of incision rates. At present the most feasible method of dating deposits of Plio-Pleistocene age in this environment appears to be the cosmogenic isotope burial dating. One approach might be to use MQ clasts in riverside caves along the TR in reaches where it flows on Paleozoic bedrock, as done by Granger and others (1997) on the New River in Virginia. Another might be to use MQ clasts buried beneath gravel deposits.

More lithology counts of gravel deposits, such as those by Kaye (1974) and Self (2000) should be carried out. An understanding of local variation and regional trends in MQ percentages, for example, would be useful for narrowing the possibilities of former river courses. Another valuable contribution would be quantitative comparisons between MQ clast size and abundance in pre-Pliocene deposits and those in Plio-Pleistocene deposits. Such comparisons would aid in determining the immediate source of high-level Plio-Pleistocene deposits. A desirable characteristic of future studies would be the consideration of longer reaches than have most previous studies. An anomaly at one location suggesting a former course of the TR, for example, has much more significance if it can be linked with a possible upstream or downstream continuation of the course. In addition, studies comparing terraces of upstream and downstream reaches of the TR would be very useful.

We think that one possible source of confusion in the study of MQ deposits is that some late-Cenozoic MQ-rich sites may have been misidentified as exposures of early to middle Tertiary or Cretaceous formations. A re-examination of MQ-rich exposures in these older formations may show that some of them are actually late Cenozoic.

In conclusion, a review of previous work on the geological history of the Tennessee River shows many suggestive findings, but few that are substantial. The problem of deciphering the complex and confusing evidence is inherently difficult. However, it is also true that intensive, detailed studies of this topic are still few in number.

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