A DESCRIPTION OF THE PLEISTOCENE FAUNAL REMAINS RECOVERED FROM FINGER QUARRY, BLOUNT COUNTY, TENNESSEE

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Knoxville, Tennessee 37916

ABSTRACT

The skeletal remains of at least 16 species of vertebrates were recovered from Finger Quarry in Blount County, Tennessee. At least five of the 16 species represented in the faunal sample are extinct, North American, Pleistocene animals (Dasyops bellus, Felis onca, Equus, sp., Tapirus cf. veroensis, and Mylohyus sp.). Descriptions are provided for elements of both the extant and the extinct vertebrates recovered from the quarry.

INTRODUCTION

The assemblage of Pleistocene skeletal remains described in this report was recovered from Finger Quarry in Blount County, Tennessee, by Mr. John J. Craig and several of his employees. Finger Quarry is located at 35°45'56" north latitude, and 84°7'7" west longitude (U.S.G.S. Louisville, Tennessee Quadrangle, 7.5' series, 1968). This places the quarry just slightly outside of and to the northeast of Friendsville, Tennessee, near Vinegar Valley Road. The skeletal remains were removed from the marble quarry in ca. 1968-69, but have not been described until now. An earlier find of fossil materials was made at another Blount County quarry operated by Mr. Craig and should not be confused with this separate discovery. Corgin (1976) recorded the earlier find in his book on Tennessee vertebrate fossils.

DESCRIPTION OF SITE

At Finger Quarry, the Pleistocene skeletal materials were found in the clay fill of a solution pocket in the Ordovician Holston marble formation (Stuart Maher, Tennessee Division of Geology, personal communication). The solution pocket containing the fossil materials was a nearly vertical fissure approximately 30 feet long and between 12 and 18 inches wide. Bone fragments and teeth were found mixed throughout the clay fill of the solution pocket, starting at approximately 30 to 35 feet below the present ground surface. No stratigraphy was noted within the clay fill; all osteological materials were removed by hand from the clay matrix. The solution pocket no longer exists since the clay and the marble surrounding it were removed.

RESULTS

Most of the material in this faunal sample consists of teeth (of 88 identifiable skeletal elements, 60 are teeth). Remains of at least 15 species of mammals and one avian species, representing 14 families, comprised the skeletal collection (Table 1). In addition, there were also 30 indeterminate mammal and three indeterminate bird bone fragments present. Nearly all of the bone remains as well as the roots of the teeth were severely gnawed by rodents.

TABLE 1: Fauna Identified from Finger Quarry, Blount County, Tennessee

<table>
<thead>
<tr>
<th>Species</th>
<th>No. of Pieces</th>
<th>MNI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aves</td>
<td></td>
<td></td>
</tr>
<tr>
<td>cf. Bonasa umbellus (Linnaeus)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ruffed Grouse</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Mammalia</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Didelphidae</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Didelphis marsupialis Linnaeus</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>Opossum</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dasypodidae</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dasyops bellus Simpson</td>
<td>6</td>
<td>1</td>
</tr>
<tr>
<td>&quot;Beautiful Armadillo&quot;</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Leporidae</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sylvilagus and/or Lepus—Cottontail and/or Snowshoe Hare</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Sciuridae</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Marmota monax (Linnaeus)</td>
<td>7</td>
<td>2</td>
</tr>
<tr>
<td>Woodchuck</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cricetidae</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Neotoma floridana (Ord)</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>Eastern Woodrat</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Canidae</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Urocyon cinereargenteus (Schreber)</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Gray Fox</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Canis sp.—Indeterminate Canid</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Ursidae</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ursus americanus Pallas</td>
<td>10</td>
<td>1</td>
</tr>
<tr>
<td>Black Bear</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Procyonidae</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Procyon lotor (Linnaeus)</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Raccoon</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Felidae</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Felis onca Linnaeus—Jaguar</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Equidae</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Equus sp.—Horse</td>
<td>16</td>
<td>4</td>
</tr>
<tr>
<td>Tapiridae</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tapirus cf. veroensis Sellards—Tapir</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>Tayassuidae</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mylohyus sp.—Long-nosed Peccary</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>Cervidae</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Odocoileus virginianus (Zimmerman) —White-tailed Deer</td>
<td>14</td>
<td>4</td>
</tr>
<tr>
<td>Cervid sp.</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

It is difficult to determine the contemporaneity of the materials found in the fissure at Finger Quarry. The fissure may have remained open for some time, thus allowing for a slow accumulation of osteological
materials, or it may have filled rapidly, with the materials being deposited during a very short time period. Faunal materials within the solution pocket may either have washed into the fissure, or may represent, in part, board objects accumulated by woodrats. That woodrats were in the vicinity is attested to by the presence of their remains in the deposit. Accumulation by either means, natural wash or woodrats, does not preclude the possibility that older faunal materials may have been mixed with those from a more recent time period.

Because of the small size of the collection and the unknown means or rate of deposition, it is not possible to determine whether or not the species present coexisted during the time period of bone accumulation. The collection is, however, significant in that it documents range extensions in Tennessee for a number of extinct Pleistocene species.

All of the faunal materials described in this report, with the exception of one deer and three horse elements, are in the possession of James H. Craig, son of John J. Craig, owned by Craig Marble Company. These four skeletal elements were retained by John A. Coffey, Sr., an employee of the Craig Marble Company.

Accounts of Species

Class Aves
Order Galliformes

Family Tetraonidae

*Bonasa umbellus* (Linnaeus)—Ruffed Grouse

*Material:* 1 proximal half of a left humerus, MNI (Minimum Number of Individuals): 1.

*Remarks:* Enough of this fragmentary humerus was present to definitely assign it to the Family Tetraonidae, but it could only be tentatively identified as ruffed grouse. Ruffed grouse are currently part of the fauna in East Tennessee (White and Dimnick, 1979).

Class Mamalia
Order Marsupialia

Family Dasyopidae

*Didelphis marsupialis* Linnaeus—Opossum

*Material:* 1 left P4; 2 left M1, or M2; 1 left M3 or M4; MNI: 1.

*Remarks:* All of the teeth in this sample show very little wear and are probably from a single young individual. Because of the close similarity in size and configuration of the M1 and M3, and respectively the M2 and M4, no further attempt was made to specifically designate each as to position.

Since all the bone materials in the fissure are not necessarily contemporaneous, it cannot definitely be stated that the opossum recovered at the site coexisted with the extinct giant armadillo, tapir, jaguar, or peccary. Guilday, et al. (1978) note that opossum remains have been found in good context with Pleistocene materials only as far north as Bartow County, Georgia. In late prehistoric archeological sites, however, opossum remains are commonly found as far north as west-central West Virginia.

Order Edentata

Family Dasypodidae

*Dasyus bellus* Simpson—"Beautiful Armadillo"

*Material:* 6 fragmentary dorsal scutes, MNI: 1.

*Remarks:* In addition to the Finger Quarry material, giant armadillo remains have been recovered from only three other Tennessee sites, Robinson Cave (Guilday and McCrady, 1966), Baker Bluff Cave (Guilday, et al., 1978), and Cheek Bend Cave (Kryzani, n.d.). The former occurrence of armadillos in Tennessee, and as far north as West Virginia, suggests that the climate at some period during the late Pleistocene was much milder than at present (Guilday and McCrady, 1966).

Order Lagomorpha

Family Leporidae

*Sylvilagus* and/or *Lepus*—Cottontail? and/or Snowshoe Hare?

Remarks: Based upon a fragmentary mandible and an isolated mandibular incisor, it was not possible to more specifically identify these Leporidae remains. While *Sylvilagus floridanus* is currently found in the vicinity of the quarry, Burt and Grossenheider (1976) feel that *Lepus americanus* does not occur in Tennessee. Today only in the higher elevations of the Appalachian Mountains. If this is correct, it is quite possible that *L. americanus* inhabited lower elevations within the adjacent Ridge and Valley Province during the Pleistocene. Guilday, et al. (1977) also report the occurrence of either *Sylvilagus* or *Lepus* from Baker Bluff Cave deposit, Sullivan County, in northeastern Tennessee.

Order Rodentia

Family Sciuridae

*Marmota monax* (Linnaeus)—Woodchuck

*Material:* 3 upper incisors; 3 lower incisors; 1 incisor fragment, MNI: 2.

*Remarks:* Because of their burrowing habits, woodchuck remains are common in most Pleistocene deposits in the eastern United States. It is thought here, however, because of the deep, rather narrow nature of the Finger Quarry solution cavity, that the woodchuck remains may have washed into the deposit or been carried there by woodrats. An interesting dental anomaly was noted in this sample of woodchuck incisors. Most frequently, woodchuck incisors are white in color, but four of the six nearly complete incisors in this sample are yellow.

Family Cricetidae

*Neotoma floridana* (Ord)—Eastern Woodrat

*Material:* 2 right anterior mandible fragments, each with incisor present: 1 right proximal femur; 1 right innominate, MNI: 2.

*Remarks:* The woodrat is still known to occur in the vicinity of the site today. Although its modern distribution is primarily temperate in nature, Guilday, et al. (1977) suggest that the woodrat may also have been part of the boreal Pleistocene fauna during the Wisconsinan glaciation. It is quite possible that the woodrat may have been the principal rodent responsible for gnawing away much of the bone found at Finger Quarry.

Order Carnivora

Family Canidae

*Urocyn cinereorogensis* (Schreiber)—Gray Fox

*Material:* 1 right M1, MNI: 1.

*Remarks:* The fox carnial from the Finger Quarry deposit compared very favorably in size and cusp configuration with those from a series of *U. cinereorogensis* recently collected in Tennesee and Illinois. The right M1 recovered from Finger Quarry had a length of 12.9 mm and a width of 5.8 mm. In examining a sample of seven modern gray foxes, the observed range of right M1 length was 11.7-14.0 mm; the observed range of width was 5.0-6.3 mm. The tooth was from an adult animal and is slightly worn. Currently, the gray fox is found over most of Tennessee.

*Canis sp.*—Indeterminate Canid

*Material:* 1 left P4; MNI: 1.

*Remarks:* A left P4 from an indeterminate species of *Canis* was also recovered from Finger Quarry. This specimen was from an immature animal, the roots having not yet fully developed. The tooth compares favorably with the same tooth from a modern dog, the size of a beagle. Crown length is 15.1 mm, width is 7.5 mm.

Family Ursidae

*Urus americanus* Pallas—Black Bear

*Material:* 1 right M2, 1 left M1; 1 left M2; 1 right M1; 1 right lower C; 3 C fragments; 1 second phalanx; cf. 1 left radius shaft, MNI: 1.

*Remarks:* All the measureable black bear teeth found at Finger Quarry compared closely in size with those of modern local black bears (Table 2). In addition to the teeth and a second phalanx, another bone element was recovered which may be black bear. Although the element is badly eroded and rodent gnawed, it most closely approximates the left radius shaft of a bear. Bear skeletal remains are reported to be some of the most commonly found Pleistocene fossils (Guilday, et al., 1978).
TABLE 2: Dentition measurements (mm) of Uraeus americanaus from Finger Quarry compared with bears taken in the Great Smoky Mountains, Tennessee (Coll. UTK, Forestry/Wildl. Mgt. Dept.)

<table>
<thead>
<tr>
<th>Tooth</th>
<th>Finger Quarry Bear</th>
<th>Modern Black Bears</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td>Measurement</td>
</tr>
<tr>
<td>M + length</td>
<td>1</td>
<td>31.7</td>
</tr>
<tr>
<td>M + width</td>
<td>1</td>
<td>16.4</td>
</tr>
<tr>
<td>M1 length</td>
<td>1</td>
<td>20.3</td>
</tr>
<tr>
<td>M1 width</td>
<td>1</td>
<td>9.5</td>
</tr>
<tr>
<td>M2 length</td>
<td>1</td>
<td>19.1</td>
</tr>
<tr>
<td>M2 width</td>
<td>1</td>
<td>12.1</td>
</tr>
<tr>
<td>M3 length</td>
<td>1</td>
<td>17.2</td>
</tr>
<tr>
<td>M3 width</td>
<td>1</td>
<td>12.5</td>
</tr>
</tbody>
</table>

Family Procyonidae
Procyon lotor (Linnaeus)—Raccoon
Material: 1 metapodial, MNI: 1.
Remarks: The metapodial was from a large adult animal.

Family Felidae
Felis onca Linnaeus—Jaguar
Material: 1 P 3, M1, M 2, M 3, M 4, P 1; MNI: 1.
Remarks: A single, incomplete jaguar fourth mandibular premolar was recovered from the clay pocket at Finger Quarry. This tooth is most probably from F. o. augusta, the extinct late Pleistocene jaguar sub-species known to have inhabited Tennessee. Additional jaguar (F. o. augusta) remains have been found at six other locations in Tennessee (all in caves) and are described in reports by Guilday and Mcginnis (1972) and Guilday et al. (1978).

Perissodactyla

Family Equidae
Equus sp.—Horse
Material: 1 right DP 2; 2 right DP 3; 1 left P 1; 2 right M 2; 1 left M 3; 2 right maxillary premolar/molars; 3 tooth fragments; 1 first phalanx. MNI: 4.
Remarks: In examining the horse teeth, the author found that it was not possible to identify the exact placement of each tooth in the dental arcade. Only the second anterior premolars and the fourth molars, in addition to the deciduous first premolar, were easily recognizable. It is relatively easy to differentiate horse maxillary cheek teeth from mandibular cheek teeth and to determine whether they are from the right or left side, but it is extremely difficult to specifically identify which molar or premolar one is examining.

Maher (T. J.), in his unpublished list of nearby Craig Quarry skeletal remains, refers to his horse material as Equus complicatus one of the more common late Pleistocene, North American equine species. Making specific identification on the basis of isolated teeth is rather dubious since Corgin (1976) states that there may have been at least three different horse species (Equus leidyi, E. complicatus, and E. convergens) present in Tennessee during the Pleistocene.

Family Tapiridae
Tapirus cf. veroensis Sellards—Tapir
Material: 1 left P 2; 1 right P 3; 3 tooth crown fragments. MNI: 1.
Remarks: Both of the recovered left and right P 2 are from young individuals and neither displays much occlusal wear. Because of differences in their size, it is obvious that these two teeth are from separate animals. Measurements of both teeth suggest that they at least tentatively be placed in the species T. veroensis (Lundelius and Slaughter, 1976) (Table 3). Tapir remains are commonly found in Pleistocene fossil deposits in the Eastern United States; the animal’s distribution extended from Pennsylvania to Florida. Bogdan et al. (1980) summarize the tapir remains found at 10 additional localities within Tennessee.

TABLE 3: Measurements (mm) of Tapirus Teeth from Finger Quarry

<table>
<thead>
<tr>
<th>Tooth</th>
<th>Finger Quarry Tapir</th>
<th>Tapirus veroensis</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td>Measurement</td>
</tr>
<tr>
<td>left p 1 length</td>
<td>1</td>
<td>19.4</td>
</tr>
<tr>
<td>left p 2 width</td>
<td>1</td>
<td>18.0</td>
</tr>
<tr>
<td>right p 1 length</td>
<td>1</td>
<td>17.4</td>
</tr>
<tr>
<td>right p 2 width</td>
<td>1</td>
<td>15.8</td>
</tr>
</tbody>
</table>

Order Artiodactyla

Family Tayassuidae
Mylohyus sp.—Long-nosed Peccary
Material: 1 left mandible fragment with P 1, M 1; 1 right M 2; 2 left P 3 or P 4. MNI: 1.
Remarks: There is some confusion as to whether both species of Mylohyus (M. nasutus and M. fossor) are found within Tennessee. Lundelius (1960) feels that M. fossor was an East Coast form ranging from Florida to Maryland, while M. nasutus is believed to have had a more westerly distribution. Corgin (1976) is of the opinion that both of the species occurred within Tennessee. Insufficient Mylohyus skeletal remains recovered at Finger Quarry prohibit positive species identification. Measurements of the complete teeth are presented here, however, for future reference (Table 4).

TABLE 4: Finger Quarry Mylohyus Tooth Measurements (mm).

<table>
<thead>
<tr>
<th>Tooth</th>
<th>Finger Quarry Mylohyus</th>
<th>MNI: 1</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td>Measurement</td>
</tr>
<tr>
<td>left P 1 length</td>
<td>1</td>
<td>14.3</td>
</tr>
<tr>
<td>left P 2, AW*</td>
<td>1</td>
<td>12.5</td>
</tr>
<tr>
<td>left M 1 length</td>
<td>1</td>
<td>15.8</td>
</tr>
<tr>
<td>left M 1 AW</td>
<td>1</td>
<td>13.5</td>
</tr>
<tr>
<td>left M 1 PW</td>
<td>1</td>
<td>13.1</td>
</tr>
<tr>
<td>right M 2 length</td>
<td>1</td>
<td>21.9</td>
</tr>
<tr>
<td>right M 2 AW</td>
<td>1</td>
<td>21.0</td>
</tr>
<tr>
<td>right M 2 PW</td>
<td>1</td>
<td>16.1</td>
</tr>
</tbody>
</table>

*AW—Anterior Width
*PW—Posterior Width

Family Cervidae
Odocoileus virginianus (Zimmerman)—White-tailed Deer
Material: 2 left DP 3; 1 left P 1; 1 right M 1; 1 left M 2; 2 left P 3; 1 left M 3; 2 right M 2; 1 right scapula; 2 right metatarsal fragments; 1 left humerus shaft. MNI: 4.
Remarks: The skeletal remains of Odocoileus virginianus from the site closely approximate in size those of modern deer from Tennessee.

Cervid sp.
Material: 1 right mandibular molar fragment. MNI: 1.
Remarks: In addition to the Odocoileus material, another cervid element from a different species was found at the site. This piece consists of one half of a right mandibular molar from an animal the size of an elk, Cervus elaphus. The tooth was not complete enough to warrant a more exact identification.

ACKNOWLEDGMENTS

The author would most sincerely like to thank James L. Craig and John A. Coffey, Sr. for the loan of the faunal materials from Finger Quarry. A debt is also owed to John J. Craig, owner of the Craig Marble Company, and to Dr. Stuart W. Maher, Tennessee Division of Geology, Knoxville; both gentlemen graciously supplied information about Finger Quarry and its bone deposits. Dr. Paul W. Parmalee and Arthur E. Bogan are thanked for assistance with bone identifications and for making available their manuscript on Tennessee Pleistocene tapirs. In addition, Dr. Parmalee generously supplied records on dental measurements for modern black bears and gray foxes.
LITERATURE CITED

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AN OSCILLATION THEOREM FOR A SECOND ORDER SUBLINEAR DIFFERENTIAL EQUATION WITH DELAY

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ABSTRACT

Conditions are given which are necessary and sufficient for oscillation of second order sublinear differential equations with delay including functional equations.

INTRODUCTION

This paper gives necessary and sufficient conditions for oscillation of delay equations of the form

\[ y''(t) + f(t, y(t), y(g(t))) = 0 \quad (1) \]

and functional delay equations

\[ y''(t) + F(t, y) = 0 \quad (2) \]

In (1) \( f(t, u, v) \) satisfies the usual continuity and sign conditions (Erbe 1973; Wong 1971) and \( g(t) \leq t \), \( g(t) \) continuous, \( \lim_{t \to \infty} g(t) = \infty \).

In (2) \( F(t, y) \) satisfies the usual continuity and sign conditions (Burkowski 1971; Siam 1871) where \( y_\alpha \) is the restriction of \( y_\alpha \) to \([t, \infty)\). We will further follow the notation of Burkowski.

PRELIMINARY REMARKS

The following lemma will play a useful role in the two main theorems presented in this paper.

**Lemma.** Suppose \( y(t) > 0, y'(t) > 0, y''(t) \leq 0 \) or \( y(t) < 0, y'(t) < 0, y''(t) \geq 0 \).

\[ \frac{y(t)}{y'(t)} > \frac{t}{t_1} \text{ for } t > t_1 \text{ and } \frac{y(t)}{y'(t)} < \frac{t}{t_1} \text{ for } t < t_1 \]

(1)

\[ \frac{1}{y(t)} \leq k < \frac{1}{y'(t)} \leq \frac{1}{y(t)} \text{ for } t > t_1 \text{ and } \frac{1}{y(t)} \leq k < \frac{1}{y'(t)} \leq \frac{1}{y(t)} \text{ for } t < t_1 \]

(11)

**Proof.** The proof of the lemma follows the proof given in (Erbe, 1973) with some modifications.

We are now in a position to give our main results.

RESULTS

1. The following theorem gives necessary and sufficient conditions for oscillation of delay equations of type (1) in the introduction.

THEOREM I. Suppose that for \( uv > 0 \),

- \( f(t, u, v) \) is nonincreasing in \( |u| \) for each \( v \)
- \( f(t, u, v) \) is nonincreasing in \( |v| \) for each \( u \)

for some \( d_1, d_2 \) with \( 0 < d_1 + d_2 < 1 \). Then a necessary and sufficient condition for (1) to be oscillatory is that \( \int_0^\infty f(t, g(t)) \ dt = \infty \).

**Proof.** For sufficiency, if \( y(t) > 0 \) is a non oscillatory solution we have

\[ \int_0^t \frac{y''(s)}{(y'(s))^{d_1 + d_2}} \ ds \quad \int_0^t \frac{f(s, y(s), y(g(s)))}{(y'(s))^{d_1 + d_2}} \ dt \]

From concavity, since \( y'(g(s)) \geq y'(s) \) \( y(s) \leq y_\alpha \) for some \( M \geq 1 \), we have from the hypothesis and lemma,

\[ f(s, y(s), y(g(s)) \quad \frac{1}{(y'(s))^{d_1 + d_2}} \]

Since the first integral is finite, we get an immediate contradiction if \( \int_0^\infty f(t, g(t)) \ dt \equiv \infty \),

[References and equations follow]
For necessity assume \( f(0,0) = 1 \). Choose \( T > 0 \) so that \( \int_0^T \frac{1}{T} \, dt < \frac{1}{2} \) and consider the solution \( y(t) \) satisfying \( y(0) = 0, \quad t \leq T \) and \( y'(T) = 1 \). The rest of the argument follows as in (Gollwitzer, 1969). This completes the proof of the theorem. Theorem I improves results of Bradley and Gollwitzer (Bradley, 1970; Gollwitzer, 1969). Though Erbe and Wong (Erbe, 1973; Wong, 1972) discuss sublinear equations of the form (1) they do not have results contained in theorem I.

2. For functional delay equations of type (2) in the introduction we have the following result where we will follow the notation of Burkowski and further denote constant functions by bars.

**Theorem II.** Suppose \( F(t, z) \) is nondecreasing with respect to \( C^2 \) and \( C^4 \) and further let \( |F(t, z)| \) be nonincreasing in \( u \) for some \( a, \quad 0 < a < 1 \). Then a necessary and sufficient condition for equation (2) to be oscillatory is that

\[
\int_0^\infty F(t, t) \, dt = \infty.
\]

**Proof.** As in Theorem I let \( y(t) > 0 \) to be a nonoscillatory solution. Then

\[
\int_0^t \frac{y''(s)}{(y'(s))^{4}} \, ds + \int_0^t \frac{F(s, y_s)}{(y'(s))^{4}} \, ds = 0.
\]

The first term is finite and using Lemma and noting \( y(s) \leq M, M = 1 \) we get

\[
F(s, y_s) \leq F(s, F(s)) \quad \frac{y''(s)}{(y'(s))^{4}} \quad (s > 0)
\]

Further

\[
F(s, y_s) \leq BF(s, s) \quad \frac{y''(s)}{(y'(s))^{4}} \quad (s > 0)
\]

and this leads to a contradiction to \( t \to \infty \).

For necessity we follow the same method as in Burkowski and thus complete the proof.

Theorem II includes Theorem I in case \( g(t) = 0 \). Theorem II could be modified as follows: Assume exist \( F(t, y_s) \) such that

\[
F(t, y_s) = \frac{|F(t, y_s)|}{|F(t, y_s)|} = \frac{|F(t, y_s)|}{|F(t, y_s)|} \quad \text{for} \quad C^2 \quad \text{or} \quad C^4 \quad \text{or} \quad C^4.
\]

It is readily seen that Burkowski's results would be included in Theorem II with appropriate modifications as indicated above.

**Literature Cited**


