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# PALEONTOLOGY AND GEOLOGY OF THE BADWATER CREEK AREA, CENTRAL WYOMING

## Part 12. Description and Review of Late Eocene Multituberculata from Wyoming and Montana

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## INTRODUCTION

Remains of a late Eocene multituberculate were first discovered (Robinson, et. al., 1964) at two Badwater localities, 5 and 5A, in the Hendry Ranch Member of the Tepee Trail Formation (as used by Tourtelot, 1957). There is now almost overwhelming evidence that these sediments do not represent eastern equivalents of the Tepee Trail Formation. Rather, these volcanic rich silts and clays were probably deposited at the same time as, or somewhat later than, the volcanic conglomerates of the Wiggins Formation, which overlies the Tepee Trail Formation in its type area (Love, 1939). But until a thorough geologic review of the area can be completed, we shall continue to follow Tourtelot's usage. The multituberculate remains were described by Sloan (1966) as *Parectypodus lovei. P. lovei* has also been reported (Black, 1967) from the late Eocene Shoddy Springs local fauna, Climbing Arrow Formation, Montana, but this material has not been described or discussed in systematic detail. A larger sample of multituberculate teeth has since been recovered from three different Badwater localities, 6, 20, and Wood. Our re-examination of the late Eocene multituberculate remains from Wyoming and Montana indicates the occurrence of a greater diversity of

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taxa than hitherto reported, and provides evidence for referral of *Parectypodus lovei* to *Ectypodus.*

All measurements are given in millimeters. Abbreviations are as follows: CM, Carnegie Museum of Natural History; UCM, University of Colorado Museum; UCMP, University of California Museum of Paleontology; KU, University of Kansas Museum of Natural History.

## Systematic Description

### Family Neoplagiaulacidae Ameghino, 1890

### *Ectypodus* Matthew and Granger, 1921

The genus *Parectypodus* was named by Jepsen (1930), but he later (1940) synonymized it with *Ectypodus.* McKenna (1960) reviewed the species of *Ectypodus* in some detail and concurred with Jepsen's conclusions. But Sloan (1966) claimed that the genoholotype of *Parectypodus, P. simpsoni,* was distinct from other species of *Ectypodus,* and revived the genus to include *P. simpsoni, P. laytoni,* and the late Eocene *P. lovei.* Additional species may be referred to *Parectypodus* in Sloan's unpublished manuscript concerning Puercan multituberculates (Sloan, 1966).

The extensive definition of *Parectypodus* presented by Sloan (1966) utilizes only characters of the fourth premolars. Only five posterior fragments of $P_4$ comprise the fourth premolar sample in the original collection of multituberculate remains from Badwater, and these do not lend themselves to the criteria of Sloan's diagnosis. Two partial fragments of $P^4$ and a nearly complete $P_4$, subsequently recovered from Badwater and the Shoddy Springs locality, do not agree with the description of these teeth given for *Parectypodus.* Rather, as described below, they closely resemble *Ectypodus* in comparable parts of the dentition (McKenna, 1960; Krishtalka, 1973). All material described by Sloan (1966) from Badwater localities 5 and 5A as *P. lovei,* as well as additional material from locality 6 and Wood are here referred to *Ectypodus lovei.* Material recovered from the Climbing Arrow Formation, Montana, and Badwater locality 20 seems distinct from *E. lovei,* and is here assigned to *Ectypodus* sp. Available material does not warrant description of a new species.

### *Ectypodus lovei* (Sloan, 1966)

Figures 1-8, Table 1

*Parectypodus lovei* Sloan, 1966

TYPE: CM 15126, right $M_1$.

REFERRED SPECIMENS: $P_4$, UCM 28358, CM 15053, 15629, 16980, 16984, 27626; $M_1$, UCM 27096, 28359, CM 15129, 16982, 16983, 17513, 18256, 21336; $M_2$, CM 21335; $P^4$, CM 21641, 27628; $M^1$, UCM 25681, 27076, 28360, CM 15084, 15085, 15133, 16981, 21334, 21640; $M^2$, UCM 25255, 27094, CM 15054, 15086, 21642.

HORIZON AND LOCALITY: Late Eocene, Badwater localities 5, 5A, 6, Wood, Hendry Ranch Member, Tepee Trail Formation, Natrona County, Wyoming.

DESCRIPTION AND DISCUSSION: The five posterior fragments of $P_4$ from localities 5 and 5A described by Sloan (1966) are of little diagnostic value. Neither the standard length, nor the height of the first serration above the anterior enamel base can be measured, nor can the number of serrations be counted or reliably estimated. The orientation of the ridges at the posterolabial corner of $P_4$ is similar in most ectypodontids except for *Mimetodon*. However, the angle formed at the posterodorsal corner of $P_4$, between the slope and the vertical posterior border of the blade, may be indicative of the generic affinities of $P_4$ among certain ectypodontids (Krishtalka, 1973, from Sloan, pers. comm.). The slope is quite steep in *Parectypodus* (approximately 140 degrees), but less so in *Ectypodus* and *Mesodma* (approximately 110-125 degrees). The five posterior fragments of $P_4$ referred here to *E. lovei* have a posterior angle of approximately 120 degrees. These fragments are also included in *E. lovei* through parsimony, by tentative association with the remaining isolated teeth from localities 5 and 5A, all of which seem attributable to one species.

In terms of numbers of complete isolated teeth, the record of lower first molars from Badwater is best. All but one have a cusp formula of 6:4, with labial and lingual margins that converge anteriorly and are more nearly straight than convex. The cusps on $M_1$ are crescentic, and the length-to-width ratio ranges from 1.66 to 1.75. $M_1$'s of *E. lovei* are smaller than are those referred below to *Ectypodus* sp. They also possess a lower cusp formula, a more nearly straight external border, and more nearly parallel labial and lingual margins in occlusal view. Sloan (1966) correctly noted that $M_1$ of *E. lovei* closely resembles UCMP 44009, $M_1$ of *E. tardus* from the early Eocene Four Mile fauna (McKenna, 1960). This, and the diagnostic structure of $P^4$ described below, imply that the multituberculate remains from Badwater localities 5, 5A, 6 and Wood are more closely allied to *Ectypodus* than to *Parectypodus*.

Only CM 21336, $RM_1$ from locality 6, with a cusp formula of 7:4, more nearly resembles $M_1$ of *Ectypodus* sp. CM 21336, however, is tentatively referred to *E. lovei,* since the remaining sample of isolated teeth from locality 6 resembles the comparable teeth of *E. lovei* from localities 5 and 5A. A second $M_1$ from locality 6, CM 18256, is extremely worn, but in size and cusp formula (6:4) is typical of *E. lovei.* If CM 21336 is properly an $M_1$ of *E. lovei,* the range of variation in $M_1$ of that species is large, and its structure may imply the ancestry of the younger *Ectypodus* sp. from *E. lovei.* On the other hand, a larger sample from locality 6 may imply the presence of both species of *Ectypodus* at one horizon.

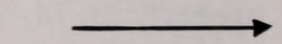
$M_2$ of *E. lovei* was not known at the time of Sloan's (1966) original description. Three specimens of $M_2$ have since been recovered, one of

*E. lovei* from locality 6, and two of *Ectypodus* sp. from the Climbing Arrow Formation. CM 21335, $RM_2$ from locality 6, is much shorter than $M_2$ from Montana, and possesses a lower cusp formula (3:2 as opposed to 4:2). The anterior end of CM 21335 is of suitable width and shape to abut against the posterior end of $M_1$ of *E. lovei.*

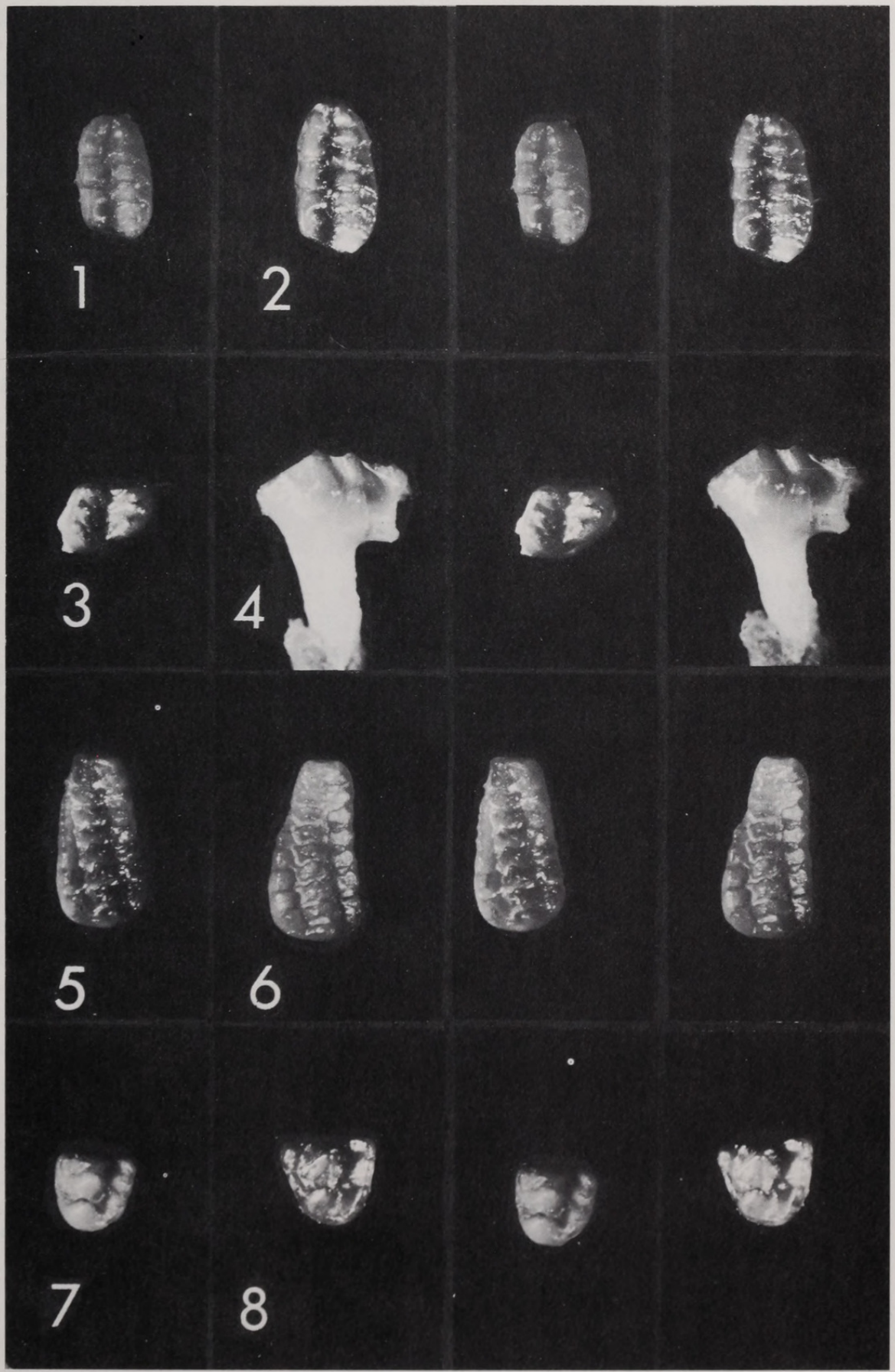
Upper fourth premolars of *E. lovei* did not occur in the original sample from Badwater. One specimen, CM 21641 from locality 5A, comprises approximately the posterior three-quarters of $P^4$, which is highly diagnostic in ectypodontids (Krishtalka, 1973). The preserved anterior profile of CM 21641 is straight and bears four cusps, of which the last is highest on the crown. The posterior slope is straight and short, and a posterobasal cuspule appears to have been present in the unworn condition. Among ectypodontids known to us, these features are diagnostic of $P^4$ of *Ectypodus.* In contrast, on $P^4$ of *Parectypodus* and *Neoplagiaulax,* the anterior slope is convex in labial view, the antepenultimate or penultimate cusp is highest in the internal row, and the posterior slope is concave. On $P^4$ of *Mesodma,* as in *Ectypodus,* the anterior profile is straight and the ultimate internal cusp is highest on the crown. The posterior slope, however, is usually convex in *Mesodma,* and the anterior profile is lower than in *Ectypodus.*

A second specimen, CM 27628 from locality 6, comprises approximately the anterior one-quarter of $P^4$ and preserves the first three cusps of the internal row and two external cusps. The latter are situated opposite the second and third internal cusps, respectively. CM 27628 is of a size and structure consistent with that of CM 21641, the posterior fragment of $P_4$ from locality 5A.

$M^1$ of *E. lovei* is known from 10 specimens, only two of which are complete. The cusp formula is 7:9-10:5-6, which is very similar to that of *E. tardus* from Four Mile (McKenna, 1960). The cusps are crescentic and progressively decrease in size anteriorly in each row. The most variable character on $M^1$ is the length of the internal row and its point of origin anteriorly from the medial row. The internal row originates at the level of the fourth and fifth medial cusps on UCM 25681 (cusp formula 7:10:5), the third medial cusp on CM 21334 (cusp formula 7:9:6) and CM 21640 (an anterior fragment), and the second medial cusp on CM 15133 (an anterior fragment). $M^1$ of *E. lovei* is shorter than $M^1$ of *Ectypodus* sp. described below, and possesses fewer cusps in the external row (7:9-10:5-6 as opposed to 9:9:6).



Figs. 1-8. Stereophotographs of teeth of *Ectypodus lovei,* all approx. x 10. Fig. 1. CM 15126, $RM_1$, occlusal view. Fig. 2. CM 21336, $RM_1$, occlusal view. Fig. 3. CM 21335, $LM_2$, occlusal view. Fig. 4. CM 21641, $LP^4$, labial view. Fig. 5. CM 21334, $LM^1$, occlusal view. Fig. 6, UCM 25681, $LM^1$, occlusal view. Fig. 7. CM 15086, $RM^2$, occlusal view. Fig. 8. CM 21642, $RM^2$, occlusal view.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The four specimens of $M^2$ from Badwater localities 5 and 5A that were described by Sloan (1966) are here assigned to *E. lovei*. The cusp formula is 1:3:3, but the external cusp is extremely weak, low and flattened; and, as Sloan points out, it is merely part of the crest that forms the anteroexternal corner of the crown. In occlusal view, the crown is very nearly triangular except for the posterior margin, which is not angular but conspicuously rounded. The reverse is true of $M^2$, referred below to *Ectypodus* sp., on which the external cusp is more distinct and the posterior margin of the crown not rounded, but angular.

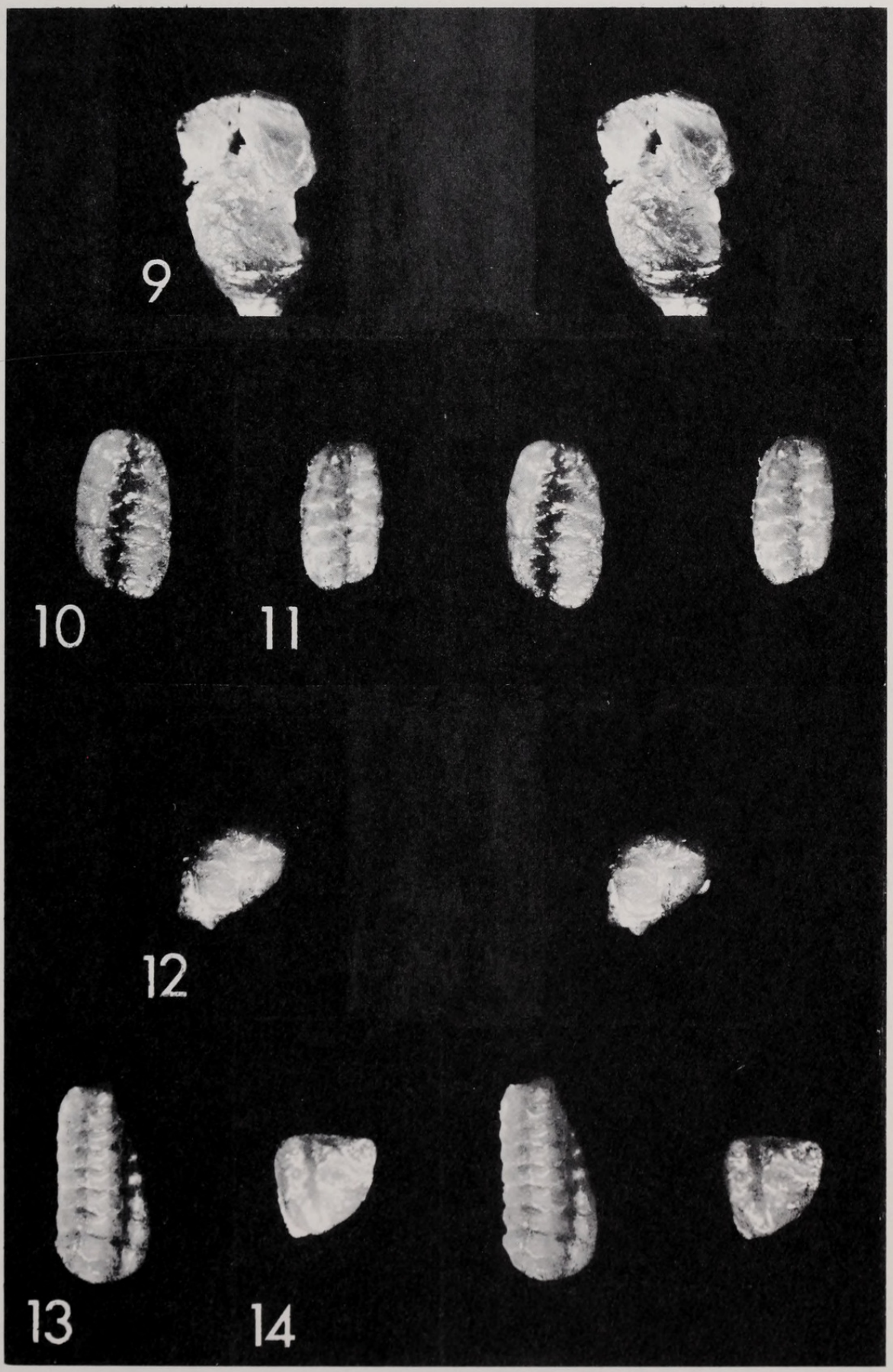
*Ectypodus* sp.
Figures 9-14, Table 2

REFERRED SPECIMENS: $P_4$, CM 18842, 18843, 21270, 21271, 27627, KU 17128; $M_1$, CM 18841, 18844, 18845, 18847, 21273, 21275, 26266, KU 17131; $M_2$, CM 21272, 21274; $M^1$, CM 18846, 27629, KU 17130, 17132, 17179; $M^2$, CM 26265.

HORIZON AND LOCALITIES: Late Eocene, Badwater locality 20, Hendry Ranch Member, Tepee Trail Formation, Natrona County, Wyoming; Climbing Arrow Formation, Shoddy Springs, Jefferson County, Montana.

DESCRIPTION AND DISCUSSION: Four fragments of $P_4$ have been recovered from Shoddy Springs, and two from locality 20. Two of the former (CM 18843, CM 21271) appear to be fragments of the same blade. The fracture pattern as well as the ridges on both the labial and lingual face of each fragment match extremely well when the two are united along the line of breakage. The anterior profile of this $P_4$, although somewhat altered by wear, is lower than that of *Parectypodus,* higher than that of *Mesodma,* but consistent with that of *Ectypodus,* e.g., $P_4$ of *E. tardus* from Four Mile (McKenna, 1960), or *E. powelli* (Jepsen, 1940). The ratio of the height of the first serration above the anterior enamel base (1.0 mm) to the standard length (3.2 mm) is 0.32, which is very close to that for known species of *Ectypodus* (0.33) and much lower than the 0.50+ value for *Parectypodus* (Sloan, 1966). Similarly, as in *Ectypodus,* the labial height of enamel at the anterior root (2.3 mm) is characteristically less than the standard length of $P_4$, whereas in *Parectypodus* it is greater (Sloan, 1966. The characters of $P_4$ of *Ectypodus* are from R. E. Sloan, completed manuscript on Puercan multituberculates from the San Juan Basin, which is referred to by Sloan, 1966). $P_4$ of *Ectypodus* sp. bears 10 serrations, as in *E. tardus* and *E. powelli.* $P_4$ of known species of *Parectypodus* have 12-14 serrations. The remaining fragments of $P_4$ from Climbing Arrow and locality 20 closely resemble the nearly complete $P_4$ of *Ectypodus* sp.

Figs. 9-14. Stereophotographs of teeth of *Ectypodus* sp. Fig. 9. CM 18843 and 21271, $RP_4$, approx. x 5, labial view. Fig. 10. CM 26266, $RM_1$, approx. x 10, occlusal view. Fig. 11. CM 18847, $LM_1$, approx. x 10, occlusal view. Fig. 12. CM 21274, $LM_2$, approx. x 10, occlusal view. Fig. 13. CM 18846, $RM^1$, approx. x 10, occlusal view. Fig. 14. CM 26265, $LM^2$, approx. x 10, occlusal view.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Of the eight specimens of $M_1$ referred to *Ectypodus* sp., seven are complete. Six were recovered from Climbing Arrow and two from locality 20. All the isolated teeth have a cusp formula of 7:4 except for CM 26266, the only complete $M_1$ from locality 20, which has 8 cusps in the external row. Characteristically, the external margin of the crown is convex, with a distinct bulge occurring at the level of the fifth and sixth external cusps. This condition differs from the more nearly straight labial margin of the crown on $M_1$ of *E. lovei.* $M_1$ of *Ectypodus* sp. is also longer and wider than that of *E. lovei,* and has one or two more cusps in the external row. The length-to-width ratio of $M_1$ of *Ectypodus* sp. ranges from 1.6-1.8 and, as such, overlaps that of *E. lovei* (1.66-1.75).

The two $M_2$'s referred here to *Ectypodus* sp. are from Climbing Arrow. They are longer and have a higher cusp formula (4:2) than $M_2$ of *E. lovei* (3:2).

Of the five specimens of $M^1$, only one, CM 18846, from Climbing Arrow, is complete. The remaining four teeth are posterior fragments from locality 20 that yield little taxonomic information. CM 18846 is longer and has a higher cusp formula (9:9:6) than that of *E. lovei* (7:9-10:5-6). This is consistent with the larger size and higher cusp formula of $M_1$ and $M_2$ of *Ectypodus* sp. compared with that of *E. lovei.* As in *E. lovei,* the cusps on CM 18846 and the fragmentary teeth from locality 20 are crescentic, but they are also slightly broader at the base, especially in the medial row. The internal row on CM 18846 originates at the level of the second medial cusp.

The single $M^2$ of *Ectypodus* sp., from locality 20, shares the same structure and cusp formula (1:3:3) with $M^2$ of *E. lovei,* but is appreciably longer and wider.

## Remarks and Conclusions

The diagnostic criteria of Tertiary ectypodontid taxa given in the literature are almost exclusively concerned with the morphology of the fourth premolars (Sloan, 1966). This is of little value when considering a sample of mostly isolated molars and a few fragments of P4. As such, identification of the late Eocene multituberculates from Wyoming and Montana with any degree of confidence is problematical. The entire sample is very small, and is composed of only isolated teeth, most of which are fragmentary. Remains of each tooth type have not been recovered from each locality. Except for a single $M_1$ from locality 6, however, the isolated teeth comprising upper and lower M1 and M2 seem, in each case, to represent two morphological groups. These groups segregate into two sets of localities. All multituberculate teeth from Badwater localities 5, 5A, 6, and Wood seem referable to one species, *Ectypodus lovei.* Those from locality 20 and Shoddy Springs appear to represent a descendent species of *Ectypodus,* with molars of relatively larger size and

higher cusp formula. This is consonant with the growing evidence (Black, 1974) that the mammalian fauna from locality 20 is younger and more advanced than the fauna from localities 5, 5A, 6 and Wood. Larger samples of multituberculate remains from these localities would enhance the record of the range of variation of late Eocene species of *Ectypodus*. The present evidence does not deny the possibility of both species of *Ectypodus* occurring at locality 6, or the presence of a third species of *Ectypodus* at Shoddy Springs.

Before the discovery of their remains in late Eocene deposits, multituberculates were thought to have become extinct in the early Eocene (Jepsen, 1930, 1949). It would be premature and perhaps naive to view this as merely a temporal range extension of the Allotheria, and thus to discount the possibility of the existence of a diversity of ectypodontids in western North America during the middle and late Eocene, perhaps surviving into the Oligocene, in ecological situations that have not been extensively sampled in the past (Black, 1967).

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TABLE 1.
MEASUREMENTS AND CUSP FORMULAE OF UPPER AND LOWER MOLARS OF *Ectypodus lovei*

| | | Locality | Length | Width | Cusp formula |
|---|---|---|---|---|---|
| $M_1$ | UCM 28359 | 5A | 1.5 | 0.9 | 6:4 |
| | CM 16983 | 5 | 1.55 | 0.9 | 6:4 |
| | CM 16982 | 5A | — | 0.8 | — |
| | CM 15129 | 5A | 1.5 | 0.9 | 6:4 |
| | CM 15126 | 5A | 1.5 | 0.9 | 6:4 |
| | CM 17513 | Wood | 1.4 | 0.8 | 6:4 |
| | CM 18256 | 6 | 1.6 | 1.0 | 6:4 |
| | CM '21336 | 6 | 1.75 | 1.0 | 7:4 |
| $M_2$ | CM 21335 | 6 | 0.8 | 1.0 | 3:2 |
| $M^1$ | UCM 25681 | 5A | 2.2 | 1.1 | 7:10:5 |
| | UCM 28360 | 5A | — | 1.2 | — |
| | CM 15085 | 5A | — | 1.0 | — |
| | CM 15084 | 5 | — | 1.2 | — |
| | CM 16981 | 5 | — | 1.0 | — |
| | CM 21334 | 6 | 2.1 | 1.1 | 7:9:6 |
| $M^2$ | UCM 25255 | 5A | 0.9 | 0.9 | 1:3:3 |
| | UCM 27094 | 5A | 1.0 | 1.0 | 1:3:3 |
| | CM 15086 | 5A | 0.9 | 0.9 | 1:3:3 |
| | CM 15054 | 5 | 0.9 | 1.0 | 1:3:3 |
| | CM 21642 | 6 | 1.0 | 1.1 | 1:3:3 |

TABLE 2.
MEASUREMENTS AND CUSP FORMULAE OF UPPER AND LOWER MOLARS OF *Ectypodus* sp.

| | | Locality | Length | Width | Cusp formula |
|---|---|---|---|---|---|
| $M_1$ | CM 21275 | Climbing Arrow | — | 0.9 | — |
| | CM 18847 | Climbing Arrow | 1.7 | 1.0 | 7:4 |
| | CM 18844 | Climbing Arrow | 1.85 | 1.1 | 7:4 |
| | CM 18841 | Climbing Arrow | 1.6 | 1.0 | 7:4 |
| | CM 18845 | Climbing Arrow | 1.6 | 1.0 | 7:4 |
| | CM 21273 | Climbing Arrow | 1.7 | 1.0 | 7:4 |
| | CM 26266 | 20 | 1.95 | 1.2 | 8:4 |
| | KU 17131 | 20 | 1.8 | 1.0 | 7:4 |
| $M_2$ | CM 21272 | Climbing Arrow | — | 1.0 | 4:2 |
| | CM 21274 | Climbing Arrow | 1.1 | 1.1 | 4:2 |
| $M^1$ | KU 17179 | 20 | — | 1.1 | — |
| | KU 17132 | 20 | — | 1.1 | — |
| | CM 27629 | 20 | — | 1.25 | — |
| | CM 18846 | Climbing Arrow | 2.4 | 1.1 | 9:9:6 |
| $M^2$ | CM 26265 | 20 | 1.2 | 1.2 | 1:3:3 |

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