STRATIGRAPHY OF UPPERMOST CRETACEOUS AND PALEOCENE NONMARINE MOLLUSCA IN THE CRAZY MOUNTAINS BASIN, SOUTH-CENTRAL MONTANA

by

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ABSTRACT

Nonmarine Mollusca are the most abundant animal macrofossils in uppermost Cretaceous and Paleocene continental strata in western North America. Their biochronologic potential, however, has yet to be realized due primarily to a lack of research focused on the determination of biostratigraphic ranges of molluscan taxa in thick sequences of strata temporally organized by mammalian local faunas into land-mammal ages. Cenozoic mammals are the present basis for the chronostratigraphic correlation of continental strata in North America (Archibald et al., 1987; Sloan, 1987). The eastern portion of the Crazy Mountains Basin of south-central Montana contains the thick sequence of nonmarine strata with multi-horizon occurrences of datable mammal local faunas, and numerous molluscan localities, necessary to permit construction of a detailed nonmarine molluscan biostratigraphy. A framework for a molluscan chronostratigraphy has been accomplished by placing all of the molluscan localities from the eastern portion of the basin into a composite reference section correlated with land-mammal ages. This column includes the revised stratigraphic placement of the nearly 100, almost entirely unpublished, historically collected molluscan localities, along with the over 200 localities discovered as part of the present research program. This locality record provides the basis for systematic, environmental, and paleobiogeographic studies of the molluscan fauna of the Crazy Mountains Basin.

INTRODUCTION

Biostratigraphic investigations in the Crazy Mountains Basin represent an important component of an ongoing project to construct a nonmarine molluscan composite reference section for the northern Great Plains. The three main areas upon which a northern Great Plains nonmarine composite section must be based are the northern Powder River Basin of southeastern Montana and northeastern Wyoming, the Williston Basin of western North Dakota, and the eastern portion of the Crazy Mountains Basin. These areas, along with shorter sections of lower Paleocene in the Fort Peck area of northeastern Montana, and lower and middle Paleocene in the Cypress Hills and the Big Muddy River drainage of southern Saskatchewan, collectively provide a relatively complete fossiliferous sequence of strata from the Cretaceous Hell Creek Formation, and lateral equivalents, through the Paleocene Fort Union Group, and into the uppermost Paleocene and lower Eocene “Wasatch” Formation. The region of importance in establishing a nonmarine molluscan biozonation for the early Paleocene through early late Paleocene is the Crazy Mountains Basin (Fig. 3), where mammalian and molluscan localities are most common through this interval. Biochronologic correlation of this section with those constructed for the Williston and Powder River Basins (Hartman, 1984) will permit the construction of a nonmarine molluscan biochronology for the entire Paleocene.

All topographic maps mentioned in this paper are U.S. Geological Survey (USGS) 7.5' series provisional quadrangles at a scale of 1:24,000. All field notebooks herein referenced (e.g., Stone, 1907, no. 2652) are from the Field Records Library of the U.S. Geological Survey in Denver. The number cited is the accession number and is unique to each field notebook. Field notes from the Archives of the Department of Vertebrate Paleontology of the American Museum of Natural History are referenced as AMNH-Archives. USGS correspondence referred to in this report is housed in the Smithsonian Institution Archives and is referenced by an SIA accession number. All Crazy Mountains Basin mollusk localities are referred to by unique “L-numbers” (e.g., locality [HMH-] L0126) assigned by me.

GENERAL STRATIGRAPHY

The sequence of nonmarine strata in the eastern portion of the Crazy Mountains Basin consists of the uppermost Cretaceous Hell Creek Formation, and the conformable Paleocene Bear, Lebo, and Melville Formations (Table 1, Fig. 1). The nomenclature and recognition of these units is unsettled (Balster, verbal communication, 1988). The traditional approach, following the USGS, is to rank the Paleocene units as members, represented by the Tullock, Lebo, and Tongue River, and include them within the Fort Union Formation. This organization does not reflect the distinctiveness of the Crazy Mountains section. Simpson (1937) introduced the formation names Bear and Melville in recognition of discrete lithologies of formational scope. They are used here knowing that additional study of their sedimentology and provenance is necessary to justify their continued use. In addition, shales and sandstones of the Hell Creek Formation in the northeastern portion of the Crazy Mountains Basin, where it has been most intensively examined, are also lithologically unlike age-equivalent strata in the type-area of the Hell Creek Formation in Garfield or McCone Counties, Montana. In summary, the Hell Creek, Bear, Lebo, and
Upper Cretaceous and Lower Tertiary Stratigraphic Units in the Eastern Portion of the Crazy Mountains Basin

<table>
<thead>
<tr>
<th>Stratigraphic Unit</th>
<th>Land-Mammal Biochrons</th>
<th>Type-Section/Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tertiary</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tu - Fort Union Group</td>
<td>To3a?, To3b-Ti3a, Ti3b,Ti4?</td>
<td>local, near Melville</td>
</tr>
<tr>
<td>Tm - Melville Formation</td>
<td>Pu3?, To1-Ti3a, To3b?</td>
<td>local, Lebo Creek area</td>
</tr>
<tr>
<td>Ti - Lebo Formation</td>
<td>La?, Pu, To1?</td>
<td>local, near Bear Butte</td>
</tr>
<tr>
<td>Tb - Bear Formation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cretaceous</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Khc - Hell Creek Formation</td>
<td>La (at least in upper half)</td>
<td>Garfield County, MT</td>
</tr>
<tr>
<td>Km - Montana Group</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kl - Lennep Formation</td>
<td></td>
<td>local, near Lennep</td>
</tr>
<tr>
<td>Kb - Bearpaw Formation</td>
<td></td>
<td>Bearpaw Mountains, MT</td>
</tr>
</tbody>
</table>

Table 1.

1 Cretaceous and Paleocene land-mammal ages (see Fig. 3): La = Lancian (latest); Pu = Puercan (early), To = Torrejonian (middle), and Ti = Tiffanian (late). Mammalian biochrons e.g., To1) are after Archibald et al. (1987), and Sloan (1987; for subdivisions of To3 and Ti3).

Melville Formations represent a distinctive clastic sequence, and are not lithologically equivalent to similarly organized successions to the east and northeast. Comments by Stow (1946) suggest more general comparability to strata to the southeast in the nearly contiguous Bighorn Basin.

As part of present fossil studies in the eastern portion of the Crazy Mountains Basin, the formation contacts of the Lennep, Hell Creek, Bear, Lebo, and Melville were mapped from field observations, paleogeologic observations, and other unpublished interpretations (Fig. 1). In the southeastern portion of the basin, the Hell Creek, Bear, and Lebo contacts are based primarily on paleogeologic work. The basis for recognizing these formations is consistent with Simpson’s (1937) usage, but the criteria for placing unit contacts in gradational or interbedded sequences has been slightly modified (see, for example, the Bear/Lebo contact in Hartman et al., this volume). Simpson’s geologic map (1937, pl. 1) of the northeastern portion of the basin, referred to by him as the Crazy Mountain Field, was based on A.C. Silberling’s unpublished stratigraphic observations taken primarily during the first decade of this century. The same distinctive lithologies were observed, although different stratigraphic nomenclature was employed, in measured sections by R.W. Stone, T.W. Stanton, C.A. Fisher, and others in field notebooks (Stone, 1907, no. 2652; Stanton, 1907, no. 6507, 1906, no. 6508; Fisher, 1907, no. 2744); and to some extent in publication (Stone, 1909; Stanton, 1909; Stone and Calvert, 1910c; see discussion below).

Paleontologic and Stratigraphic Research in the Basin

The study of fossil mollusks and mammals in the Crazy Mountains Basin is closely related with the study of the stratigraphy. Three main research groups in the basin can be identified, including: 1) research undertaken by the USGS from about 1894 to 1917, 2) the work of A.C. Silberling, which spanned nearly 40 years from the turn of the century, and 3) current studies by D.W. Krause of the State University of New York at Stony Brook and me.

The first collections of nonmarine mollusks, and subsequent recognition of “Fort Union” age strata in the eastern portion of the Crazy Mountains Basin, were made by D.N. Force, Jr., in 1894 on Lebo Creek (Fig. 2). These fossils were identified by T.W. Stanton of the USGS and reported by W.H. Weed (1896). The presence of the thick section of “Laramie, Livingston and Fort Union” documented by Weed led Earl Douglass, as part of a 1901 Princeton University expedition, to search for “the long sought ancestors of the placental mammals of the Puercan” in the Crazy Mountains Basin (1902a, p. 273). Douglass (1902a, b, 1908) discovered “Torrejon” fossil mammals, and associated mollusks and plants, in the Bear Butte area in the northeastern portion of the basin.

Albert C. Silberling, a local resident, participated in M.S. Farr’s Princeton University expeditions to the Crazy Mountains area, an event that commenced his long and distinguished association with eastern universities and institutions collecting vertebrate, mollusk, and plant fossils. Silberling discovered most of the important mammal localities presently known from the middle and upper Paleocene Lebo and Melville Formations, which he referred to as Fort Union No. 1 (lower Lebo), Fort Union No. 2 (upper Lebo), and Fort Union No. 3 (Melville) (see Simpson, 1937, for Silberling’s stratigraphic nomenclature). Silberling had the good fortune to receive advice and guidance from a number of geologists and paleontologists who visited this area near the turn of the century, and his independently derived stratigraphy of the basin is essentially equivalent to the units proposed by Stone and others from mapping done by U.S. Geological Survey geologists in 1907 (Stanton, 1908, no. 6508). In addition to the more than 60 mammal localities that Silberling found, he also discovered a number of mollusk localities in 1908 (Fig. 2) and made substantial collections from many of them. These mollusk specimens are now part of the collections of the Department of Paleobiology of the U.S. National Museum.

Silberling’s early period of collecting was concurrent with the first detailed mapping of the basin, done by USGS personnel as part of the first phase of a congressionally mandated program to classify coal lands in western states. As a result of this program, a tremendous number of Upper Cretaceous and Paleocene mollusk localities were discovered and sampled in the Western Interior in order to derive a chronostratigraphy. In 1907 alone, more fossil mollusk localities were collected as part of western U.S. coal studies than in the entire previous history of exploration of the Western Interior (Hartman, 1984).

In the Crazy Mountains Basin, the first detailed mapping and stratigraphic work was done in 1907 by R.W. Stone and members of his field party: F.D. Morrison, J.H. Cather, and M.I. Goldman.
Uppermost Cretaceous and Paleocene Nonmarine Mollusk Localities in the eastern portion of the Crazy Mountains Basin

Figure 1. Distribution of mollusk and mammal localities known from the Crazy Mountains Basin. Locality map symbols may represent several localities. The geology is based on field observations, photogeologic interpretations, other unpublished data, and (Simpson, 1937, pl. 1).
**Eastern Crazy Mountains Basin**

**Collection of Nonmarine Mollusca**

![Graph showing number of localities by decade from 1890-1970.]

**Figure 2.** The list of collectors includes individuals and institutions. USGS collectors include D.N. Force, Jr. (presumably of the USGS), T.W. Stanton, C.A. Fisher, R.W. Stone, J.H. Cather, F.H. Knowlton, W.R. Calvert, M.R. Campbell, C.J. Hares, C.F. Bowen, and E.T. Hancock. M.S. Farr, of Princeton University, and A.C. Silberling, a local rancher, participated in the collection of some USGS localities. Earl Douglass’s mammal collections and report of mollusks were geographically located by Simpson (1937). A.C. Silberling discovered numerous mollusk localities independent of the USGS, and also with G.G. Simpson in the ’30s, and J.A. Bell, III, in 1940. Collectively, a few localities were discovered by W.H. Utterback (USNM collections), Rohwer and Kneale (University of Colorado Museum collections), and local interested parties, including the Glass-Lindsay Land Company and H.H. Graff of Big Timber, Montana. The sole record in the ’70s was collected by Hartman and R.C. Holtzman. The collectors from the ’80s represent the activities of Krause and Hartman field parties. Important contributions in the discovery of mollusk localities were made by K.D. Enebo, S.G. Strait, K. Phelps, E.R. Dumont, G.A. Buckley, D.R. Riel, and T.J. Kroeger.

Their efforts focused on the northeast, north, and west portions of the basin rim. The stratigraphic succession reported by Stone and Calvert (1910c) substantially revised the stratigraphy presented by Weed (1896). This revision resulted from the concerted efforts of a number of USGS geologists, who assisted Stone through interpretations made from field observations and collections. These geologists were important to the success of this early phase of western coal exploration: T.W. Stanton, F.H. Knowlton, C.A. Fisher, W.R. Calvert, C.F. Bowen, and M.R. Campbell. The interpretations and portions of the data collected were subsequently published (Fisher, 1908; Stanton, 1909; Knowlton, 1909; Stone, 1909; Stone and Calvert, 1910a-c) and formed the basis for all subsequent studies of the basin.

According to Stone and Calvert (1910c), the uppermost Cretaceous and Paleocene succession consisted of the Lennep and Lance Formations, and Lebo and unnamed members of the Fort Union Formation. As defined by Stone and Calvert, the Lennep occupies the stratigraphic position of the Fox Hills Formation, which is subjacent to the Hell Creek Formation in eastern Montana. The Lance Formation of Stone and Calvert (1910c) was interpreted during field work as the equivalent of the Laramie Formation (sensu Weed), while the Lebo Member of the Fort Union was recognized as equivalent to Weed’s Livingston Formation (see Stone, 1909; 1907, no. 2652). The conformably overlying strata were recognized as Fort Union in the sense of the type-area of the Fort Union in the Missouri- Yellowstone River confluence near the North Dakota-Montana state line.

The fossils collected by Stone’s party were sent to T.W. Stanton, molluscan paleontologist and stratigrapher for the U.S. Geological Survey, who identified all of the nonmarine mollusks collected in the Crazy Mountains Basin until 1932. Stanton reported most of his identifications in correspondence with project chiefs and other interested parties (Table 2). Not all of the collections made by Stone’s party, were reported in correspondence by Stanton, although Stanton’s identifications can be found on their respective museum collection labels. Stanton’s main report on the Crazy
**Table 2.**

1 Identifications are summarized from Stanton correspondence (SIA acc. 85004). Unspecifically identified taxa may be represented by different species in occurrences from different formations. The species are given as identified by Stanton.

2 Formations according to present usage. Formation abbreviations: H = Hell Creek, B = Bear, L = Lebo, M = Melville; L/M = Lebo/Melville undifferentiated.
Mountains Basin fossil mollusks was completed January 22, 1908 (SIA acc. 85004) for Stone. Reports by Stanton were also prepared for other USGS geologists including Weid (undated, see Weid, 1896), Calvert and Stone (November 23, 1909), Hancock (January 27, 1917), and Bowen (March 12, 1917).

In addition, he wrote reports for the Glass-Lindsay Land Company (February 13, 1922) and H.H. Graff (March 10, 1922) of Big Timber, Montana. The number of localities reported by Stanton, as well as his formation or age assignments, are presented in Table 3. This summary of Stanton's stratigraphic organization of localities in the eastern half of the Crazy Mountains Basin shows only two formational assignments: 1) an uppermost Cretaceous formation referred to either the Laramie, Lance or equivalents, and 2) the Fort Union Formation, which included the Livington beds recognized by Stone and later renamed by him as the Lebo Member. The Bear Formation, now known to be mostly lower Paleocene, was included in the Cretaceous by Stanton as part of the Lance or Laramie Formation (discussed below).

Of all the localities and identifications reported by Stanton in correspondence with geologists working on the relations of Crazy Mountains Basin strata (Table 3), only a few were mentioned in publication. The first taxa identified from the eastern portion of the basin were reported in Weid (1896) from the "Fort Union beds" of the Lebo Creek section (Fig. 1, area A). These beds probably correspond to the Melville Formation. The taxa identified by Stanton are not referred to a specific locality, but may correspond to the three localities (L514a-c) collected by D.N. Force Jr., in 1894. The fauna includes taxa characteristic of Tongue River or Bullion Creek Formation strata in the area of Fort Union near the confluence of the Missouri and Yellowstone Rivers. Other taxa of Campanian and Maastrichtian age from the Judith River and Lance Formations were also identified including Unio couesi (= Plesielihippus couesi), U. danae (= Plesielihippus danae), and U. primaevus (= Quadrula primaevus [see Taylor, 1975]), and Aplexa subelongata. These taxa have received minimal morphological review since they were named, and their mention by Stanton, should be taken only to indicate certain morphotypes.

Stanton (1909) reported on a few taxa in the context of interpreting the stratigraphic relations of the "Ceratops" beds of Wyoming and Montana. The only moluscan locality specifically reported on by Stanton from the Crazy Mountains Basin was near a horizon containing Triceratops fossils in the lower part of the Hell Creek Formation (USGS Mesozoic locality 4637; L2476). Taxa identified by Stanton included the bivalves Plesielihippus brachyopus (White) and Proparreyia retusoides (Whitfield), and the gastropods Campeloma sp. and Limnaea sp. (= Limnaea sp.).

Stanton's discussion of the "upper part of the Laramie," of which the Bear Formation represents the uppermost portion, made general reference to nonmarine moluscan taxa, mentioning "two or three species of Unio, a Viviparus, and Campeloma multilinea (= C. nebrascense Meek and Hayden)" (Stanton, 1909, p. 262). In Stanton's correspondence (SIA acc. 85004; Jan. 22, 1908, Nov. 23, 1909, and Mar. 10, 1922), the two or three species of unioids were reported as Unio brachyopus (White) and Unio gibbosoides Whitfield, and the viviparid as Tulotoma thompsoni. White. As identified, these taxa are typical of the Lancian, but are represented by specimens, which although morphologically similar, should be assigned to other taxa. The bivalves have a simple shape and possess valve sculpture of taxa assigned to Plesielihippus, which ranges through the Cretaceous and Paleogene, and are not part of the Lancian bivalve fauna. Likewise the gastropods representing the taxa Tulotoma thompsoni are not assignable to that species, and are referable in part to Viviparus sp. nov.-P (Hartman, 1984). This taxon is known from Puercan and lower Torrejonian age strata in the Tullock and Ravenscrag Formations of the Williston Basin (Hartman, 1984). The other specifically identified gastropod, Campeloma nebrascense, is assignable to Campeloma sp. nov.-A (Hartman, 1984), which is known from both Lancian and Puercan age strata throughout the northern Great Plains. Stanton also reported on dinosaur bones from the "Laramie," but to date no in situ dinosaur fossils have been found in strata assigned to the Bear Formation. Simpson (1937, p. 17) stated that he had not seen any dinosaur fossils in the Bear, but that Silberling had found "isolated, rare, and very fragmentary specimens in the lower part of the formation." Various taxa of Unio, a Viviparus, and Campeloma multilinea were also mentioned by Stanton to occur in Silberling's Fort Union No. 1 and No. 2, which correspond to the lower and upper Lebo Formation of Simpson's (1937) usage.

Stone and Calvert (1910c, p. 750) listed a few nonmarine moluscan faunules, as identified by Stanton, in describing their revision of the stratigraphic succession for the north rim of the Crazy Mountains Basin. Two localities (USGS Mesozoic localities 4637 [L2476] and 6038 [L2534]) were reported from the lower part of the Lance (= Hell Creek) Formation. A list of these taxa, with nomenclatural updates, is as follows: Plesielihippus brachyopus, P. stantoni, Plathobasus bieesoides, Probrareysia holmesiana, P. pyramidatoideus, P. sp. nov.? (P. aff. P. retusoides), P. verrucosiliformis, "Unio" sp. nov., Sphaerium sp., Campeloma sp., Elima sp., Physa sp., and Limnaea sp. In the Lebo Member of the Fort Union Formation, Stone and Calvert (1910c) reported Stanton's
identifications from USGS Mesozoic locality 4744 (L1411) in the Lebo Creek section: "Unio" sp. and Viviparus retusus. Stone and Calvert (1910c) also reported nonmarine mollusks from geographically unspecified localities in the upper Lebo Member and overlying basal portion of the unnamed member (= Melville Formation) of the Fort Union Formation from the northeast rim of the basin. Stanton's identifications were reported as follows: "In the upper beds of the Lebo member and in the overlying gray massive sandstone fresh water shells are common. They include Viviparus, several species of Unio, most of which appear to be undescribed, and Campeloma multilineta (= C. nebrascense...)." (Stone and Calvert, 1910c, p. 755).

The fossil nonmarine mollusk localities reported by Stone and Calvert (1910c) included localities from strata of Lancing, Puercan, and Torrejonian age. At the time Stanton was identifying freshwater bivalves and gastropods, the "classic" Fort Union of Meek and Hayden (1862), which is primarily Tiffanian in age, was believed to represent the entire Paleocene. Older Placocene mollusk localities had not been differentiated. The Hell Creek, Lance, and "Ceratops" beds of various authors have a recognized assemblage of distinctive mollusks that have been assigned to the Lancing landmammal age. Stanton thus utilized the existing species concepts from the Fort Union and Hell Creek to identify all of the mollusk taxa from Crazy Mountains section. Stanton also noted the absence of undescribed unionids, but probably considered their differentiation more from a geographic rather than a chronostratigraphic perspective.

In the 1930s, Silberling renewed his participation with the mammal project begun by J.W. Gidley (e.g., 1909) of the U.S. National Museum in the first part of the century. The study of the Crazy Mountain Field mammals was completed by G.G. Simpson of the American Museum of Natural History. Silberling's collaboration with Simpson resulted in the documentation of the geographic location of all of the vertebrate-containing localities, many of which also produced mollusks, and the stratigraphic horizons of a few of Silberling's localities. A few "mollusk only" localities were not relocated, which is unfortunate, as they are now difficult to find. In the relocation process, some of Silberling's earlier locality records were substantially revised, and then accurately plotted on Simpson's base map for the field (Simpson, 1932, field notes, AMNH-Archives: 1937, pl. 1). In addition to reevaluating old geographic and stratigraphic records, mollusks were collected from a few vertebrate localities for the first time. The mollusk collections made by Silberling and Simpson in 1932 and 1935 are housed at the American Museum of Natural History.

Of the 30-plus mollusk localities collected by Silberling, only three received published notice. As stratigraphically placed at that time, the published record represented one locality per formation. The fossils from these localities were identified by L.S. Russell and reported in Simpson (1937) (Table 4). Simpson used Russell's interpretations and his own general knowledge of locality abundance to report that freshwater mollusks "at the top of the Bear can be regarded with some confidence as Paleocene in age" and that mollusks were "thickly populated...throughout the deposition of the Fort Union" (Simpson, 1937, p. 17, 59). Russell (1934) also described a new subspecies of freshwater bivalve, *Medionidus senectus declives*, which would be subsequently reassigned as *Rhabdotrophus declives* (see Russell, 1935, 1974).

The three Paleocene faunas identified by Russell in Simpson (1937) were reported from, the following horizons: 1) the lens of shells used arbitrarily to mark the top of the Bear Formation east of Bear Butte (USGS Mesozoic locality 16500; L128, L4661), 2) strata in the upper portion of the Lebo Formation near Upper Glaston NONMARINE MOLLUSCA AS IDENTIFIED BY I.S. RUSSELL FROM THE NORTHEASTERN PORTION OF THE CRAZY MOUNTAINS BASIN

<table>
<thead>
<tr>
<th>Taxa</th>
<th>Stratigraphy</th>
</tr>
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<tbody>
<tr>
<td>Unionidae</td>
<td></td>
</tr>
<tr>
<td><em>Fusconaia danze</em> (Meek and Hayden)</td>
<td>LL</td>
</tr>
<tr>
<td><em>Nedinionidus</em> [†Medionidus] senectus (White)</td>
<td>LL, M</td>
</tr>
<tr>
<td><em>Nedinionidus</em> [†Medionidus] senectus declives Russell</td>
<td>LL</td>
</tr>
<tr>
<td><em>Elliptia prisca</em> (Meek and Hayden)</td>
<td>LL</td>
</tr>
<tr>
<td>Gastropoda</td>
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<tr>
<td><em>Viviparididae</em></td>
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<td><em>Campeloma nebrascense white</em> Russell</td>
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</tr>
<tr>
<td><em>Campeloma limnaeforme</em> (Meek and Hayden)</td>
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</tr>
<tr>
<td><em>Viviparus latus</em> Meek</td>
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</tr>
<tr>
<td><em>Viviparus planolater</em> (Russell)</td>
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</tr>
<tr>
<td><em>Viviparus cf. V. planolater</em> Russell</td>
<td>M</td>
</tr>
<tr>
<td><em>Viviparus retusus</em> (Meek and Hayden)</td>
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</tr>
<tr>
<td><em>Viviparus trochiornis</em> (Meek and Hayden)</td>
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<tr>
<td>Pleuroceridae</td>
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<tr>
<td><em>Lioplax nebrascensis</em> (Meek and Hayden)</td>
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<tr>
<td>Physidae</td>
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<tr>
<td><em>Physa cf. P. canadensis</em> Whiteaves</td>
<td>LL</td>
</tr>
</tbody>
</table>

Table 4.

1 from Russell (1934) and Russell in Simpson (1937)
2 Formations according to present usage. Formation abbreviations:
   LL = lower Lebo, UL = upper Lebo, M = Melville.
3 nomen nullum of *Medionidus* in Simpson (1937).

Lake (Lake Adam of Simpson) (USGS Mesozoic locality 16502; Simpson, 1937, #24; L973), and 3 upper Melville Formation strata on Porcupine Butte (USGS Mesozoic locality 16501; Simpson, 1937, #67; L981, L4934). The locality (L128) reported by Simpson from the top of the Bear Formation was reinterpreted by me as occurring 17 ft (5.2 m) above the base of the Lebo. Taxa occurring at this locality are bracketed by mammalian local faunas of mid Puercan and early Torrejonian age. Taxa as identified by Russell are given in Table 4 and are reidentified and nomenclaturally updated in Table 5. The viviparid taxa present at this locality also indicate a Puercan or early Torrejonian age. The unionids are rather nondescript and poorly preserved as steinkerns. A few external impressions show *Plesielliipto sculpure. Specimens assigned to Viviparus meeki and compared to *Physa canadensis* are under study.

Simpson (1937) reported locality #24 (L973) from the upper Lebo Formation, approximately 800 ft (243.8 m) above its base and 540 ft (164.6 m) below the base of the Melville. The locality is mid Torrejonian (To2) in age on the basis of mammals, and has not been relocated. The fauna from this locality is still under study, but the following revisions, nomenclatural updates, and comments can be made to Russell's identifications: 1) Specimens assigned to *Viviparus retusus* from mid and late Torrejonian faunas show considerable morphological variation, especially when compared to the range of variation found in mid Tiffanian populations. 2) *Viviparus planolater* is not present. A more similar morphology is represented by *Viviparus sp. nov.-H* from the Powder River Basin (Hartman, 1984), and 3) the specimen identified by Russell as *Lioplax nebrascensis* is without apex, complete aperture, or shell material, but can be assigned to *Lioplaxodes nebrascensis* nebrascensis (Meek and Hayden).

The remaining published locality, #67 of Simpson (1937) (L981), is from the upper part of the Melville Formation, roughly 4050 ft
PRELIMINARY REIDENTIFICATION OF NONMARINE MOLLUSCA FROM USGS MESOZOIC LOCALITY 16500 NEAR SIMPSON (1937, P. 17, PL. 1) LOCALITY #65

Bivalvia
Unionidae
Gen. & sp. undet.
Plesielliptio danai (Meek and Hayden)  
Plesielliptio priscus (Meek and Hayden)
Rhabdotophorus senectus (White)

Gastropoda
Viviparidae
Campeloma sp. nov.-A (see Hartman, 1984)
Campeloma nebrascense whitei Russell
Viviparus cf. V. sp. nov.-P (see Hartman, 1984)
Viviparus fomosus Meek
Viviparus sp. undet.
Viviparus meeki Wenz
 [= V. trochiormis (Meek and Hayden)]

Physidae
Physa cf. P. canadensis Whiteaves
incertae sedis
Gen. nov. limneiformis (Meek and Hayden)  

Table 5.

1 Mollusks are from USGS Mesozoic locality number not noted in Simpson (1937).
2 Generic reassignment according to Taylor (1975).
3 Generic reassignment according to Taylor (1975), who also placed the taxon within the Viviparidae.

(1234.4 m) above its base. The locality is at least as young as mid Tithonian on the basis of datable mammals that occur 1050 ft (320.0 m) lower in the section. This locality was relocated (L4934), and consists of two shell-bearing horizons separated by about 10 ft (3.0 m). The upper horizon has produced two mammal teeth (L4934c); no other vertebrate material has been found. The lower horizon (L4934a) is the type-locality for Rhabdotophorus declivis (Russell), which is common, but seldom found well preserved. Specimens of Viviparus retusus are very abundant. As indicated by Russell’s comparison to Viviparus planolaterale, morphologically similar specimens do occur at this locality, yet they differ from V. planolaterale in significant ways. Unfortunately, few good specimens have been found at this or other localities high in the Melville Formation. Additional collections will be needed to better document this taxon. This assemblage of taxa is present in strata of Tithonian age elsewhere in the northern Great Plains and, as currently known, is represented in the mid Tithonian (T13). The diversity is too low, however, to restrict this occurrence to this biochron.

One other study that reported nonmarine Mollusca from the eastern Crazy Mountains Basin was done by J.A. Bell, II, and was presented as a Princeton University senior thesis. With the assistance of Silberling and others, Bell (1941) placed six new and three old localities into a composite section that illustrated their relative stratigraphic position. A few of the new mammal and mollusk localities discovered by Silberling and Bell were outside the Crazy Mountain Field previously investigated by vertebrate paleontologists, including localities to the west in metamorphosed strata adjacent to the Crazy Mountains, and to the south in the Bear Formation. These localities have not been relocated and new localities have not been found in these areas. Bell did not identify molluscan taxa beyond reporting that "Unios, gastropods, or small invertebrates" were present. Unfortunately, these collections are unavailable for study.

STRATIGRAPHIC ORGANIZATION OF NONMARINE MOLLUSCAN LOCALITIES

The Land-Mammal Age Context

The study of the nonmarine Mollusca of the Crazy Mountains Basin is part of a larger effort to construct a composite reference section that provides an overall framework for Paleocene biostratigraphic and biochronologic correlation in the northern Great Plains. This composite section is predicated on thick, continuous, stratigraphically well-controlled intrabasinal surface and subsurface measured sections that can be biostratigraphically correlated with confidence. In addition, interbasinal reference sections must have sufficient biochronological overlap to permit recognition of equivalent biochrons from one area to another. Regions to be correlated must also be sufficiently fossiliferous in both mammals and mollusks to provide reasonably rigorous constraints to the correlation. Fossil mammals, which provide the only reasonably well constrained biochronology for the northern Great Plains at the present time, are uncommon relative to the generally ubiquitous nonmarine mollusks. A correlated series of mammalian and molluscan assemblage biozones, along with biostratigraphic organizations from other plant and animal taxa, will provide the strongest framework for biochronologic resolution and subsequent interpretation of geologic history.

The Crazy Mountains Basin Reference Section

Current nonmarine molluscan studies in the Crazy Mountains Basin stem from a revision of the taxonomy and biostratigraphy of the gastropod family Viviparidae in the northern Great Plains (Hartman, 1984). The emphasis of that study was on the fossils and strata of the Powder River and Williston Basins. The biostratigraphic and biogeographic distribution of Cretaceous and Paleocene taxa for the Crazy Mountains Basin was also summarized and displayed. In many cases, taxon ranges were based on a limited number of occurrences, and in a few situations, the horizons of historically collected localities were not delimited geographically or stratigraphically. Fieldwork was undertaken in the Crazy Mountains Basin in 1985 to redocument the molluscan and mammalian occurrences of Simpson (1937) and earlier collectors. This study, which is ongoing, has been a collaborative program with D.W. Krause’s study of mammalian evolution through the Torrejonian-Tithonian transition, an interval that is well-represented in the basin. In the process of relocating old sites, many new localities, some of which are important to constraining the geologic history of the basin, were discovered (see Buckley and Krause, 1987; and Hartman et al., this volume). Of the approximately 315 localities that are known from the eastern portion of the basin, about 225 are the result of the mammal/mollusk surveys undertaken from the 1985 field season to the present (Fig. 2). The review and mapping of the formational boundaries and the evaluation of the stratigraphic position of the localities was the focus of the 1988 field season and will continue next year. The stratigraphic distribution of eastern Crazy Mountains Basin mollusk localities is summarized in a composite reference section in Figure 3. This section is correlated with the estimated stratigraphic range of mammal ages. The concentration of localities near the Lebo/Melville contact (see Figure 1, area G), reflects not only their general abundance in this interval, but also the effort given to collecting through the Torrejonian-Tithonian transition.

The 1988 field season also located the stratigraphically lowest (L5107) and highest (L4934) mammal occurrences in the Crazy Mountains Basin section. The oldest record is from about 29 ft (8.7 m) above the base of the Bear Formation in the Lebo Creek section, while the youngest is about 5860 ft (1786.1 m) above the base of
A breakdown of the stratigraphic distribution of uppermost Cretaceous and Paleocene nonmarine mollusk localities in the eastern portion of the basin, as summarized in Figure 3, is as follows:

1) The strata of the Hell Creek Formation are represented by 27 localities, most of which are in the northeastern portion of the basin. A relatively small amount of time has been given to exploration for localities in the Hell Creek Formation because of the focus of present studies, and also because Hell Creek strata are easily eroded and form a valley used in agriculture or grazing. Nevertheless, good, and apparently fossiliferous, exposures are found in the northeast part of the basin and to the south, east of Big Timber.

2) The Bear Formation, for the extent of its exposure, is relatively unfossiliferous. The 26 molluscan localities are distributed along the eastern rim of the basin. To date, studies in the Bear have focused on Simpson Quarry (L4675), the first datable Puercan age mammal and mollusk locality known from the basin (see Hartman et al., this volume). Stratigraphic and general locality survey work completed during the 1986 field season permitted a reinterpretation of the location of molluscan localities collected by Stanton and Fisher in the Lebo Creek section (Fig. 1, area A).

Field study of this section along an unnamed tributary of Big Elk Creek resulted in the discovery of an excellently preserved mammal jaw from the lowest occurrence of mammals known from the Bear Formation. This locality also includes an assemblage of mollusks from a lacustrine environmental setting not previously reported from the Bear. The stratigraphic placement of localities in area C (Fig. 1), along tributaries of Sweet Grass Creek, is uncertain and still under study. On the basis of available datable mammal localities, Bear mollusk localities may range in age from latest Larcian (L), through the entire Puercan (Pu), and possibly into the earliest Torrejonian (To1) (Table 1).

3) The Lebo Formation is represented by 101 localities, which may range in age from latest Puercan (Pu3) to nearly the end of the Torrejonian (To3a). Most of the localities known from the upper Lebo (sensu by Simpson, 1937) are from a stratigraphic interval within a few hundred feet of the base of the Melville (Fig. 3).

4) The Melville Formation is represented by 159 mollusk localities that range in age from latest Torrejonian (To3b) to middle Tiffanian, or younger. The Melville Formation is generally fossiliferous. Fossil surveys during 1988 concentrated on the stratigraphic interval representing the Torrejonian-Tiffanian transition, and strata representing much younger deposits. Considerable areas of outcrop the upper part of the Melville adjacent to the Crazy Mountains have yet to be studied. I anticipate that these strata will be fossiliferous and provide an even better context for comparison to documented upper Tiffanian or younger faunas elsewhere in the northern Great Plains.

SUMMARY

Recent investigations conducted by Hartman and Krause in the eastern portion of the Crazy Mountains Basin have produced a large number of nonmarine mollusk localities and significant additions to the mammalian locality data base. These localities, along with historically collected mollusk and mammal occurrences, are placed into a lithostratigraphic context to construct a summary biostratigraphic reference section for the basin. This section will be used to biochronologically correlate Paleocene nonmarine Mollusca, and thus chronostratigraphically organize Paleocene strata throughout the northern Great Plains and elsewhere in North America.
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