ISSN 0010-7980

Vol. 18, No. 2 Reprinted from Spring, 1980

CONTRIBUTIONS TO GEOLOGY

Elk Mountain structure (see back cover)

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Early Cenozoic mammalian paleontology, geologic structure, and tectonic history in the overthrust belt near LaBarge, western Wyoming

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ABSTRACT

Three fossil mammalian faunules from the Chappo Member of the Wasatch Formation west of LaBarge, Wyoming, range from middle Tiffanian to early Wasatchian in age. Thus the minimum age range of the Chappo Member is middle late Paleocene to early Eocene. Other synorogenic deposits in the overthrust belt have been dated previously. The uplifted Darby (=Hogsback) Thrust yielded synorogenic conglomerates beginning in Torrejonian time and it was overlapped by the Chappo Member by middle Tiffanian time. Therefore, the time of movement of the Darby Thrust was middle Paleocene. The Prospect (=Cliff Creek=Jackson) Thrust cuts the Darby Thrust. It has been dated as post-Tiffanian and pre-Wasatchian. The LaBarge (="Hilliard") Thrust deformed the Chappo Member, and was overlapped by the LaBarge Member of the Wasatch Formation of latest Wasatchian (Lostcabinian) age. Therefore, the LaBarge Thrust is Wasatchian in age and younger than the Prospect Thrust. The progression of datable west-dipping thrusts in the Wyoming-Idaho Overthrust Belt can now be shown to be, from old on the west to young on the east, the Paris, Crawford, Absaroka, Darby, Prospect, and LaBarge thrusts in that order. The concept of Royse and others (1975) that the Prospect Thrust ramped up into the Darby (=Hogsback) Thrust, producing simultaneous late movement along a single plane in a linked system consisting of all three thrusts, is contradicted by both geometrical and temporal evidence.

INTRODUCTION

This paper deals with an area west of LaBarge, Wyoming, along the western margin of the Green River Basin and eastern margin of the overthrust belt (Figs. 1 and 2). The purposes of the paper are to: (1) report additions and revisions of fossil mammalian taxa from previously known localities in the Chappo Member of the Wasatch Formation; (2) report taxa from a newly discovered locality, stratigraphically higher in the Chappo Member; (3) reassess the age of the Chappo Member based on these mammalian faunules; (4) discuss the structural geology of the area; and (5) discuss the geometric and temporal relationships of the Darby (=Hogsback), Prospect (=Cliff Creek), and LaBarge (="Hilliard") thrust faults.

The general geology of the southern part of the study area is thoroughly described by Oriel (1961, 1962, 1969), who should be consulted for more extensive background than we provide here, especially with respect to general structural relationships and for descriptions of the early Cenozoic stratigraphic units to which we refer. We have modified slightly the geological mapping of Oriel (1969), and extended it several kilometers northward and eastward to encompass more of Hogsback Ridge and the town of LaBarge itself, and to include the site of a new fossil mammalian locality within the Chappo Member of the Wasatch Formation. Earlier geologic maps of this area, at various scales, are in Bertagnolli (1941), Blackstone (1977, 1979), Oriel (1969), Royse and others (1975), Schultz (1914), Wach (1977), and Webel (1977).

ACKNOWLEDGMENTS

The stratigraphic terminology for early Cenozoic units, dating of those units (except for the Chappo Member), and structural relationships discussed here and portrayed on Figure 3 all are modified from the papers by Steven S. Oriel (1961, 1962, 1969), except as we have added new data. We are indebted to him for introducing us to the significance of this area in the field. We also thank Mr. David W. Krause and Dr. Kenneth D. Rose, the University of Michigan, for identifications of some fossil mammals, and Dr. D. L. Blackstone, Jr., University of Wyoming, for his very helpful critique of our original manuscript. Mr. Leo Hakola of LaBarge, Wyoming, kindly allowed us access to his property along Chappo Gulch in order that we might pursue field work there. This research was supported in part by NSF grant DEB 77-13465.

STRATIGRAPHY AND PALEONTOLOGY

The mammalian paleontology of the Buckman Hollow locality in the Chappo Member was originally treated by C. L. Gazin (1942, 1956). Gazin also identified and dated specimens from the type locality of that member in the South Fork of Chappo Gulch, as reported by Oriel (1962). New taxa, and altered identifications of some taxa previously reported by Gazin under different names, are listed in our tables, together with revised age determinations for those levels in the Chappo Member. The stratigraphic terminology for early Tertiary units in this area used by Gazin and other earlier workers differs from that used by Oriel and by us. The rationale for these changes is fully discussed in Oriel's papers. Briefly, however, what is now called Hoback Formation (subsurface only) was previously called "Evanston," and the Chappo and LaBarge members of the Wasatch Formation were earlier referred to as "Almy" and "Knight," respectively.

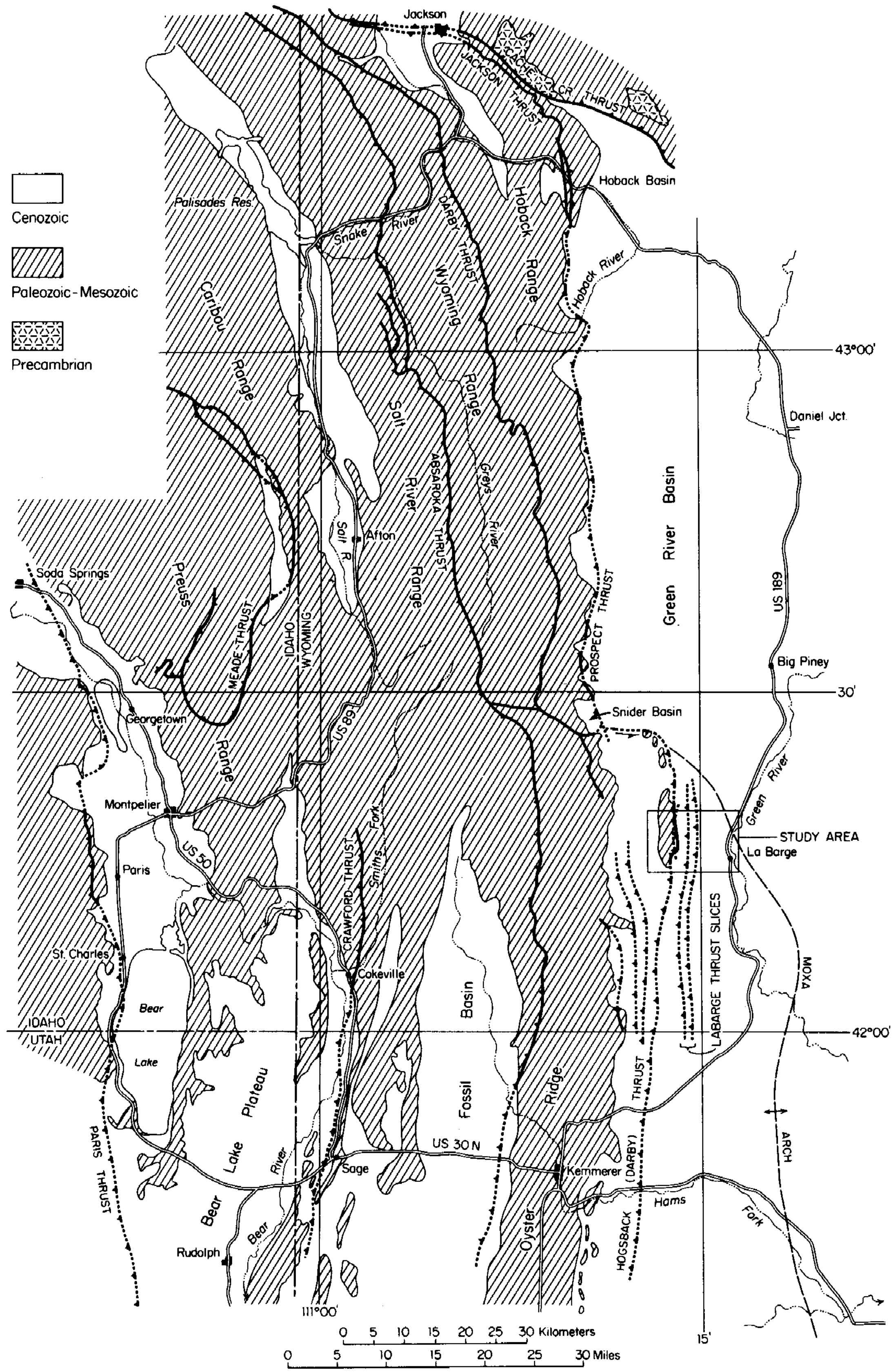


Figure 1. Regional map of major overthrusts. Modified from Blackstone (1977, Fig. 1 and pocket map), with additions from Dorr and others (1977a, pocket map), Oriel (1969, pocket map and cross sections), Royse and others (1975, pocket cross sections and Fig. 1), Wach (1977, Fig. 1), and Webel (1977, Fig. 4).

Figure 3, modified from Oriel (1962, Fig. 2, and 1969, Fig. 3), with additions, shows generalized stratigraphic and structural relationships west of the town of LaBarge. The basal Cenozoic unit is the Hoback Formation, which is encountered in wells, but does not crop out locally. It was deposited here with angular unconformity on the late Cretaceous Adaville and Hilliard formations. The Hoback Formation correlates lithologically, by stratigraphic position, and to a large extent temporally with the type Hoback Formation, which is exposed in the Hoback Basin, about 97 km (60 mi) due north (Dorr and others, 1977a, 1977b; Dorr, 1978). East of Hogsback Ridge (Fig. 3), units of middle Tiffanian age low in the Chappo Member lie conformably above the Hoback Formation; approaching the ridge, however, the upper part of the Hoback Formation grades into the basal Chappo in the subsurface (Oriel, 1969, p. M15). Still farther west, the Chappo Member overlaps rocks of Paleozoic age in the Hogsback thrust plate in Hogsback Ridge. Because of this progressive overlap, somewhat younger (Clarkforkian) parts of the Chappo, on the west side of the Hogsback Ridge in Buckman Hollow, rest with angular unconformity on the Ordovician Bighorn Dolomite and other Paleozoic rocks. Deeper and older parts of the Chappo Member are present but not exposed west of Hogsback Ridge. Subsequent to deposition, the Chappo Member was deformed by basin subsidence (Lawrence, 1965, p. 186) and by movement of the LaBarge Thrust, and truncated by erosion prior to deposition of the LaBarge Member of the Wasatch Formation. Thus there is an angular unconformity between the Chappo and LaBarge members. As noted by Oriel (1962, p. 2164-65), these two members of the Wasatch Formation, both fluviatile, both color-variegated with red beds, and both with the same sedimentary provenance, are so similar as to be virtually indistinguishable in field mapping were it not for the angular unconformity between them. The two together constitute the lower "Main Body" of the Wasatch Formation.

Above lie alternating lacustrine tongues of the Green River Formation and fluviatile tongues of units higher in the Wasatch Formation. The LaBarge Member and overlying units of the Green River and Wasatch Formations grade and interfinger westward into a thick, basin edge conglomerate which Oriel did not formally name, but which we correlate with the Lookout Mountain Conglomerate Member of the Wasatch Formation farther north (Dorr and others, 1977a). Not adequately portrayed on the highly generalized Figure 3 is the fact that locally, and at certain levels, both the Chappo and LaBarge members are conglomeratic, in some cases coarsely so. The proportion of conglomerate in the Chappo Member increases westward so that in Buckman Hollow, on the west side of Hogsback Ridge, conglomerates are a conspicious part of the unit (see measured sections). Parts of the Lookout Mountain Conglomerate Member extended sufficiently far eastward to overlap both Hogsback Ridge and the Hogsback Thrust trace along the eastern side of that ridge. The conglomerate also overlaps the Prospect Thrust farther north (Fig. 1).

The ages of the early Cenozoic units are shown along the right side of Figure 3. (Because of constraints of the diagram they cannot be projected to the left.) The Hoback Formation has been dated on the basis of pollen from the subsurface (Oriel, 1969, p. M15) in the LaBarge area, and by fossil mammals from surface exposures at its type locality in the Hoback Basin to the north (Dorr and others, 1977a; Dorr, 1978). The ages of several levels in the Chappo Member are discussed below. The ages of the LaBarge Member and New Fork Tongue have been determined on the basis of fossil mammals (Gazin, 1952, 1962; West, 1970). The age of the upper tongue of the Wasatch Formation is not yet firmly established in the LaBarge area, and may be latest Wasatchian or early Bridgerian.

Collections of fossil mammals from three localities indicate that the minimum age range of the Chappo Member is from middle Tiffanian into, but not through, Wasatchian. The three fossil localities (see symbols in Figs. 2 and 3 for approximate locations) are, from oldest to youngest:

1. The type locality for the Chappo Member (TL).
2. The Buckman Hollow locality west of Hogsback Ridge (BH).
3. A newly discovered mammal locality, the Oil Well Locality (OW).

No complete stratigraphic section of the Chappo Member is exposed at any of these localities, nor is it possible by means of surface outcrops to determine the relative stratigraphic positions of the exposed partial sections. Their relative temporal positions can only be determined from age determinations based upon the fossil mammals. Stratigraphic relationships are further complicated by the lensing and highly variable lithologic character of the Chappo Member over short distances, and by the fact that during deposition the Chappo filled in around and then overlapped topographic irregularities, including Hogsback Ridge. Thus the basal beds of the Chappo Member are of different age at different places. It is probable that certain beds low in the section on the west side of Hogsback Ridge in Buckman Hollow never did have lithologic continuity with their temporal equivalents east of Hogsback Ridge. Finally, it should be noted that no short time range fossils have been found in the Chappo beds which cap Hogsback Ridge and overlap the Hogsback Thrust there between Chappo Gulch and LaBarge Creek.

Type Locality of Chappo Member

Oriel (1962, p. 2164) named the Chappo Member of the Wasatch Formation and designated its type locality as the "incompletely exposed sequence in the N.E. ¼, sec. 17, T. 26 N., R. 113 W. at Chappo Gulch." This locality (Figs. 2 and 3) is, in fact, on the South Fork of Chappo Gulch, about 1.6 km (1 mi) east of the eastern escarpment of Hogsback Ridge. Chappo beds at the type locality strike east-west and dip due south at about

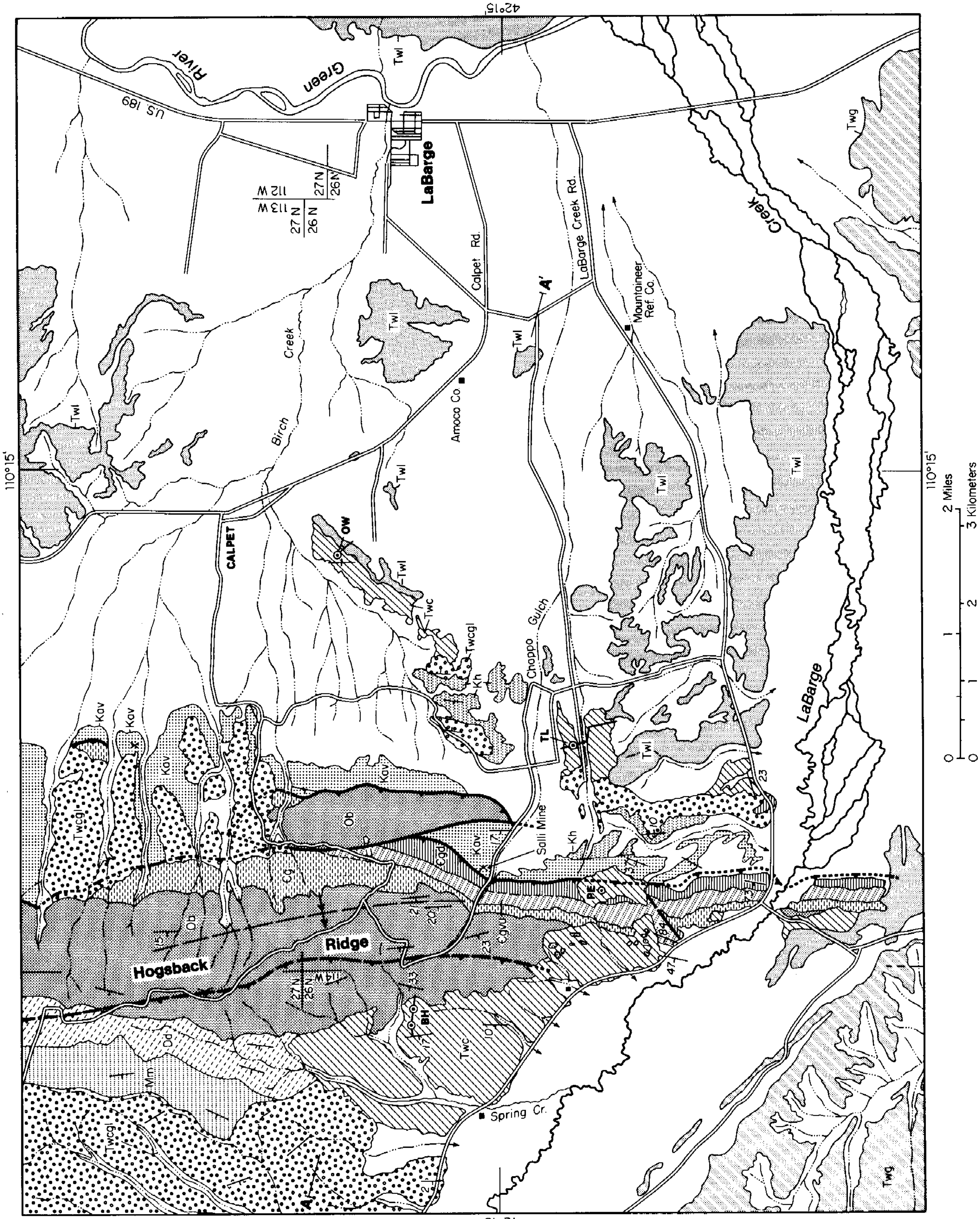
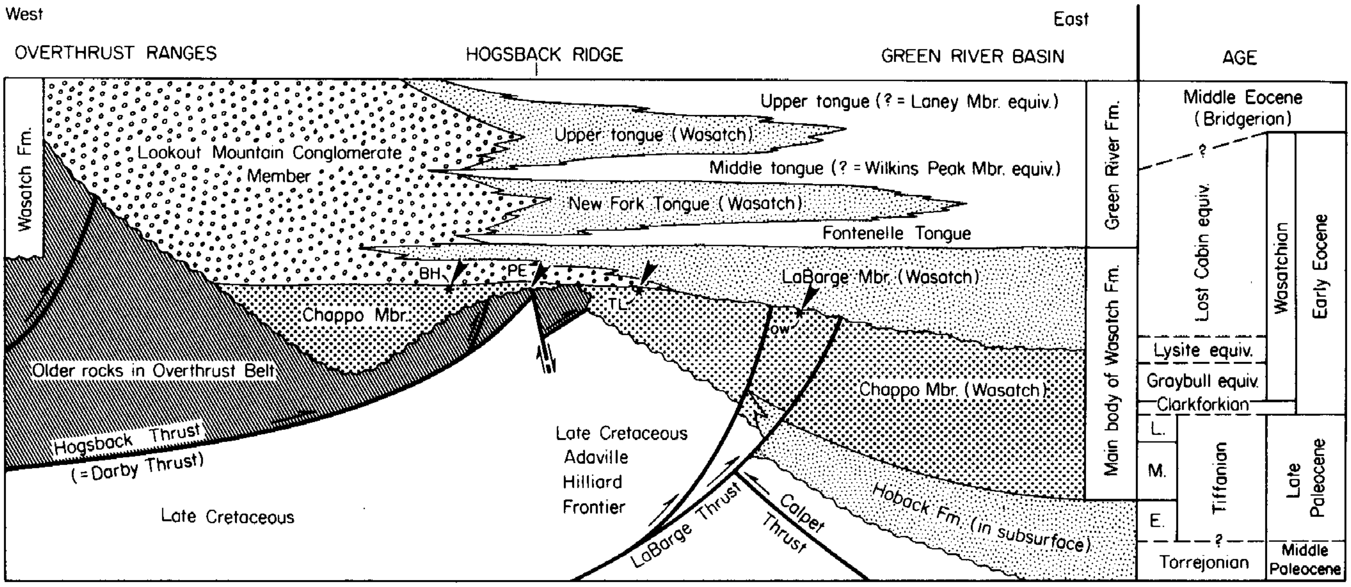


Figure 2. Geologic map of Hogsback Ridge-LaBarge area, northern Lincoln and southern Sublette counties, Wyoming. Generalized from field mapping on aerial photographs.



ow = Oil well Locality (new), Chappo Mbr., Early Wasatchian mammals
BH = Buckman Hollow Locality, Chappo Mbr., Clarkforkian mammals
TL = Type Locality, Chappo Mbr., S. Fk. Chappo Gulch, Mid-Tiffanian mammals
PE = Phenacodus and Ectocion occur in Chappo Mbr. here also

Figure 3. Cross sectional diagram of structural, stratigraphic, and temporal relationships and fossil localities in vicinity of Hogsback Ridge, west of LaBarge, Wyoming. Section, restored to pre-erosion condition, generalized approximately along A-A' on Figure 2. For less generalized cross sections, see McDonald (1973), Murray (1960), Oriel (1969), Webel (1977), and Blackstone (1979).

Explanation for Figure 2

Quaternary	(blank)	(Unpatterned). Extensive, undifferentiated alluvium, colluvium, terrace gravels, talus, debris and rock slides, and alluvial fans.
Early Cenozoic (details in Figure 3)	Twg	Intertonguing, higher members of Wasatch and Green River Formations.
	Twcgl	Lookout Mountain Conglomerate Member of Wasatch Formation.
	Twl	LaBarge Member of Wasatch Formation.
	Twc	Chappo Member of Wasatch Formation.
Late Cretaceous	Kav	Adaville Formation.
	Kh	Hilliard Formation.
Mississippian	Mm	Madison Limestone.
Devonian	Dd	Darby Formation.
Ordovician	Ob	Bighorn Dolomite.
Cambrian	€g	Gallatin Limestone.
	€gvu	Upper (shale) member of Gros Ventre Formation.
	€gd	Death Canyon Limestone Member of Gros Ventre Formation.

Thrust fault. Sawteeth on upper plate.
Normal fault. U= up, D= down.
Formation contact.
Road. Named if paved.
⊗ Fossil locality. Line indicates measured section.
OW= Oil Well Locality.
BH= Buckman Hollow Locality.
TL= Type Locality of Chappo Member.
X Old coal mine or coal prospect pit.
A—A' Approximate line of geologic cross-section for Figure 3.

16 degrees. The LaBarge Member of the Wasatch Formation overlies the Chappo Member with angular unconformity there, striking north 35 degrees east and dipping southeast at about 7 degrees. The lower part of the Chappo Member at the type locality is concealed by Quaternary terrace gravels on a low ridge crest along the north side of the gulch; the central part is partially concealed by Quaternary alluvium, and the upper part lies beneath the LaBarge Member and Quaternary colluvium which cap the ridge on the south side of the gulch. Measured section number 1 is included to illustrate the lithological variations within the Chappo Member and to show the levels at which fossils were found. The section was measured in two closely adjacent, north-south legs tied together by a common horizon traced between them (Unit 9 in Leg B can be traced to Unit 11 in Leg A). The line of traverse was north to south across the W ½, NE ¼, sec. 17, T. 26 N., R. 113 W. as located on the 1945 U.S. Geological Survey Fort Hill Quadrangle 15 minute topographic map, Lincoln County, Wyoming. The aggregate thickness of legs A and B of this measured section is 124.09 m. Along the line of section, the Chappo Member passes beneath the LaBarge Member. However, west of the line of section, where the LaBarge Member has been eroded away, the Chappo Member continues stratigraphically upward for a minimum of another 40 m before passing beneath Quaternary colluvium. Thus the minimum stratigraphic thickness of the Chappo at the type locality is 164.09 m (=538.35 ft).

The fossil mammalian specimens that we have collected and used to determine the age of the Chappo

Measured Section 1

Leg A (western leg); correlation with eastern leg shown by asterisks

Unit No.	Thickness in Meters	Description
12	not meas.	Covered, colluvium to top of ridge.
11	0.15	*Limestone*, light gray, irregularly bedded, nodular, caps cuesta. *******
10	9.3	*Claystone* and *siltstone*, interbedded, poorly exposed, weathering yellow-tan, large *fossil wood* fragments, base covered by alluvium.
9	60.8	Covered by Quaternary alluvium along South Fork of Chappo Gulch.
8	3.08	*Siltstone*, calcareous, weathering light yellow-tan, capped by 35 cm of *limestone*.
7	0.77	*Limestone*, medium grained, gray, poorly bedded.
6	0.62	*Siltstone*, poorly exposed, gray weathering.
5	0.51	Mudstone, red, same as 1.
4	4.09	Mudstone, gray, same as 2, *Phenacodus*.
3	8.46	*Mudstone*, red, same as 1 but richer in *algal pisolites* ranging from 0.5-10.0 cm in diameter, including two 70 cm gray bands alternating with the red near top, fossil *mammals, alligator, turtle, wood* scraps occur near boundary between this unit and Unit 2 below.
2	4.61	*Mudstone*, same as 1 below but gray, *fossil mammals*.
1	2.31	*Mudstone*, calcareous abundant *algal pisolites* and irregularly shaped calcareous nodules, poorly bedded, bright red, base not exposed.
		Quaternary terrace gravel and colluvium capping ridge along north side of South Fork of Chappo Gulch.

Leg B (eastern leg)

Unit No.	Thickness in Meters	Description
14	3.08	*Sandstone*, quartzose, coarse-grained, poorly bedded, irregularly weathering, yellow to dark brown, with ferruginous nodules.
		Angular unconformity. LaBarge Member above; Chappo Member below (top not exposed)
13	4.61	*Siltstone* and *claystone*, poorly bedded, poorly exposed, weathering light gray. *Turtle* bone fragments.
12	0.62	*Sandstone*, quartzose, medium-grained, poorly sorted, poorly bedded, irregularly weathering, weakly cropping out, red blotched with yellow, weathering blotchy yellow to brown.
11	10.46	*Siltstone*, siliceous, poorly to unbedded, poorly exposed, weathering light yellowish tan.
10	13.70	Covered, nonresistant unit on back (south) slope of upper, gray cuesta formed by units 9 and 8 below.
9	0.15	*Limestone*, light gray, caps second (upper) light gray cuesta. Abundant *snails*.
8	16.92	*Claystone* and *siltstone* thinly interbedded, calcareous, poorly bedded, nonresistant, lower half gray, grading up into light yellow-tan.
7	0.15	*Sandstone*, thin, slabby brown, poorly exposed.
6	1.54	Covered, nonresistant, tan and gray weathering, on back slope of minor cuesta.
5	0.31	*Limestone*, gray, thin and irregularly bedded, caps lower of two minor cuestas. *Snails, plant* fragments, *bone* scrap.
4	4.61	*Mudstone*, unbedded, calcareous, weathering to light gray, forms prominent light gray band on face of lower minor cuesta, *bone* scrap.
3	1.85	*Sandstone*, siliceous, medium salt and pepper grains, poorly bedded, poorly exposed, irregularly weathering, light tan, weathering brown.
2	1.54	*Siltstone*, calcareous, poorly bedded, weathering gray.
1	9.23	*Siltstone* and *mudstone*, siliceous, calcareous cement, poorly exposed, little bedding apparent, weathering yellow-tan, base not exposed.
		Alluvium edge on south side of South Fork of Chappo Gulch

here, all came from within a few meters (on the surface) of the boundary between units 2 and 3 of Leg A of measured section number 1. The U.S. National Museum of Natural History collection of fossil vertebrates, made and identified by Gazin (*in* Oriel, 1962, p. 2167), also came from low in this partially exposed section at the type locality. We intend to continue collecting by quarrying, screening, and washing to determine exactly which level is the producing horizon. Meanwhile, however, it seems unlikely that there are significant stratigraphic or temporal differences among the specimens available. They all came from a relatively restricted stratigraphic interval. Contrary to Gazin (*in* Oriel, 1962, p. 2167), this faunule is older than that from Buckman Hollow. Our assessment places it in the middle Tiffanian, whereas the faunule from Buckman Hollow is Clarkforkian in age. The fauna is listed in Table 1.

Buckman Hollow Locality in Chappo Member

This locality lies on the west flank of Hogsback Ridge, about 2.1 km (1.3 mi) north of the LaBarge Creek Road (Fig. 2). Buckman Hollow is at the head of the first main tributary entering Spring Creek from the east, north of the LaBarge Creek Road, in NW ¼, NE ¼, sec. 12, T. 26 N., R. 114 W., U.S. Geological Survey LaBarge Topographic Quadrangle Map, Lincoln County, Wyoming. Oriel (1962, p. 2164) designated this locality as a secondary reference section for the Chappo Member of the Wasatch Formation. Gazin (1942, 1956) placed the beds here and the fossil mammals from them in the "Almy" Formation, a usage which Oriel (1962, p. 2163) has shown should be abandoned. The secondary stratigraphic reference section of the Chappo Member in Buckman Hollow is also incomplete. The lowest beds exposed, on the east side of Buckman Hollow, dip 18 degrees west and lie with angular unconformity upon the Ordovician Bighorn Dolomite, which dips 33 degrees west. Older beds in the Chappo Member here are covered because of the transgressive overlap of higher units onto the Paleozoic rocks on the west flank of Hogsback Ridge. The age of the covered, older Chappo in Buckman Hollow is not known, but it could be equivalent to that of units exposed at the type locality east of Hogsback Ridge (middle Tiffanian). The upper part of the Chappo Member here is covered by Quaternary alluvium in the valley of Spring Creek. West of the Spring Creek valley, the Chappo Member is overlapped both by the LaBarge Member and the basin edge conglomerate facies of the Wasatch Formation, and the contacts between these units are poorly exposed (Oriel, 1962, p. 2166). Therefore, measured section number 2 provides only a minimum thickness for the Chappo Member, but it does show the relatively low stratigraphic position of the fossil producing horizons within Buckman Hollow. Gazin (1956, p. 2-3) judged that the Chappo beds here are conformable with the underlying Paleozoic strata, but this is not the case. Neither does Gazin's suggestion of a possible stratigraphic difference between fossil producing

TABLE 1. MAMMALIAN FAUNA FROM CHAPPO TYPE LOCALITY, LOWER PART OF TYPE SECTION OF CHAPPO MEMBER, WASATCH FORMATION, SECTION 17, T 26 N, R 113 W, LINCOLN COUNTY, WYOMING.

MULTITUBERCULATA
Ptilodus sp. (UM 72061)
Neoplagiaulacid sp. indet., large (UM 72063)
Neoplaciaulacid sp. indet., small (UM 72062)
MARSUPIALIA
Peradectes elegans (UM 70264, 72065)
PROTEUTHERIA
Cf. *Prodiacodon* sp. (UM 72066)
Propalaeosinopa sp. (UM 72067, 72068)
INSECTIVORA
Erinaceoid sp. (UM 72069)
PRIMATES
Ignacius frugivorus (UM 72070)
Carpodaptes sp. (UM 72071)
Chiromyoides minor (USNM 208976-type, 208977; UM 68377)
Plesiadapis rex (USNM 186790; UM 68372, 69545, 72072)
CONDYLARTHRA
Hyopsodontid sp. small (UM 68375, 72073, 72074)
Thryptacodon australis (USNM 214539; UM 68376, 69542)
**Claenodon* sp. small (USNM uncat.)
**Claenodon* sp. large (USNM 214540; UM 69544)
Ectocion wyomingensis (USNM uncat.; UM 69543)
Phenacodus grangeri (USNM 214541; UM 68378)
Dissacus sp. (UM 68373)
CARNIVORA
Protictis sp. (USNM 214542 and uncat.)
TAENIODONTA
Cf. *Lampadophorus* (USNM uncat.; UM 68379)

*Two species of two genera of arctocyonid condylarths are clearly represented here, but which one is properly called *Claenodon* and which one is new awaits revision of this family.

Notes on Table 1:

Gazin (*in* Oriel, 1962) originally reported *Plesiadapis rubeyi*, two "*creodonts*," two species of *Ectocion*, and two species of *Phenacodus* from this locality in the type section of the Chappo Member. The only taxon Gazin identified that has a restricted stratigraphic and chronological distribution is *Plesiadapis "rubeyi."* On this evidence, Gazin equated the fauna with that of Buckman Hollow, implying that it was probably Clarkforkian in age. Subsequent restudy (Gingerich, 1976) of this *Plesiadapis "rubeyi"* in the context of a general revision of the family Plesiadapidae indicated that it represented the older, middle Tiffanian species *Plesiadapis rex* and not the Clarkforkian *P. rubeyi*. Our study of the original material available to Gazin, and further collecting, have added 16 additional mammalian taxa to the fauna reported by Gazin. *Chiromyoides minor* and *Lambertocyon* sp. are both more primitive than congeneric species known from the late Tiffanian, and these together with new specimens of *Plesiadapis rex* substantiate a middle Tiffanian age for this fauna and for the lower part of the Chappo Member (Gingerich and Dorr, 1979; Gingerich, 1979). Numbers in parentheses refer to specimens in the National Museum of Natural History, Washington (USNM), or University of Michigan Museum of Paleontology, Ann Arbor (UM).

Measured Section 2

Unit No.	Thickness in Meters	Description
Top—Covered into valley of Spring Creek and beyond.		
20	4.69	*Conglomerate*, coarse, clasts up to 5 cm in diameter are mainly quartzose sandstone or quartzite, well cemented brown sand matrix, ledge former, caps second north-south trending ridge west of Buckman Hollow, saddle in weak red beds on this ridge yielded one *fossil mammal* specimen.
19	26.6	Covered, but with patches of red and gray, color-banded mudstone cropping out north of line of section, nonresistant, crops out in small saddle on crest of first ridge west of Buckman Hollow.
18	0.31	*Sandstone*, conglomeratic, and with scattered *algal pisolites*, localized lens.
17	13.70	Covered, with red soil littered with well rounded quartzose sandstone cobbles, red mudstones in this interval patchily exposed north of line of section.
16	1.52	Covered, nonresistant fine clastic beds, surface almost completely covered by *algal pisolites* ranging from pea-sized to 8 cm in diameter.
Main badland exposures are in units below this stratigraphic level		
15	0.91	*Sandstone*, very fine grained, quartzose, mottled red and gray, weathering brown, strongly cemented ledge former.
14	9.89	*Mudstone*, red, soft, nonresistant, surface littered with *algal pisolites*, produced specimen of *Ectocion*.
13	1.52	*Algal pisolite*, local lens with limited lateral extent, pisolites pea-sized up to 7 cm in diameter, well cemented ledge former.
12	7.61	*Mudstone*, red, calcareous, surface littered to covered with *pisolites* weathering down from Unit 13 above, weak nonresistant unit.
11	0.15	*Sandstone*, as in Unit 9 below but without snails.
10	1.52	*Siltstone*, light gray and yellow banded, poorly cemented, nonresistant.
9	0.61	*Sandstone*, fine grained, gray, weathering brown, lensing, poorly and irregularly bedded, with numerous algae-coated large *snails*.
8	4.57	*Siltstone*, buff to yellow, and *mudstone*, gray, alternating, weak, non-resistant zone forming lowest part of an east-west trending saddle at south end of Buckman Hollow.
7	3.04	*Siltstone*, tan to yellow, and *sandstone*, gray, fine grained, alternating, irregularly bedded, three sandstones and three siltstones, forms weak zone with minor ledges.
6	3.04	*Sandstone*, brown, irregularly bedded, lensing, with several thin weak zones of gray, calcareous siltstone; this unit splits toward the north, over a distance of about 20 m, around a lens of red mudstone and evidently is a meandering sand channel climbing section; *most productive fossil mammal horizon* in 1977 was the mudstone lens within the sandstone envelope.
5	3.80	*Mudstone*, gray at base grading up into red, calcareous, nonresistant, with abundant *algal pisolites*, algae-coated large *snails* and algae-coated plant stems, pisolites up to 8 cm in diameter.
4	13.70	*Mudstone*, red, nonbedded, clayey and calcareous; zone of 60 cm of gray, irregular, up to 10 cm in diameter limestone nodules at base; weak nonresistant zone covered by calcareous red colluvium; surface littered with allochthonous, well rounded, orthoquartzite cobbles let down from a terrace gravel; upper half with thin gray zones in red, and surface littered with gray limestone nodules and *algal pisolites*; this unit yielded a specimen of *Plesiadapsis dubius* near the top but from an isolated small butte south of the main line of the section.
3	3.04	*Sandstone*, brown, weathering brown, fine grained and well sorted, but locally conglomeratic, quartzose with calcareous cement, resistant, forms ledge on dip slope.
2	6.09	*Conglomerate*, poorly sorted, with angular to rounded clasts ranging in diameter from 0.5 to 45 cm, mostly of Bighorn Dolomite, dark chert and well-rounded orthoquartzites; red clay matrix gives unit red color and red clay colluvial cover; unit generally poorly cemented and nonresistant; two 30-60 cm, lensing, salt and pepper sandstones and local, small pods of *algal pisolites*; grades upward into alternating red and gray banded calcareous mudstone (4 or 5 bands) mixed with conglomerate; fine grained gray clastics at top of this heterogeneous unit in 1978 yielded *Probathyopsis, Lampadophorus*, and *Ectocion*.
1	2.44	*Conglomerate*, basal (transgressive); Bighorn Dolomite clasts, highly angular, ranging from 1.0-30 cm in diameter, predominate in basal 60 to 100 cm; clasts become smaller and more well rounded above; unit with strong calcareous cement and deep, reddish-brown color.
Angular unconformity		
		Bighorn Dolomite, highly fractured, deeply solution pitted, brown weathering, allochtonous in Darby (=Hogsback) thrust sheet.

Contributions to Geology, University of Wyoming, v. 18, no. 2, p. 101-115, 3 figs., 3 tables, April, 1980.

horizons at the southeastern margin (saddle) of the hollow and an exposure a short distance to the south appear to be significant. Exposures of the Chappo Member yielding mammalian fossils north and west of Buckman Hollow also appear to be about the same stratigraphic level as those in Buckman Hollow.

Stratigraphic section number 2, which falls within the N ½ of section 12, begins on the east at the angular unconformity between the Bighorn Dolomite and the Chappo Member, and proceeds westward to the crest of the ridge along the east side of Spring Creek (Fig. 2). It was terminated there because a dip projection from the ridge crest put any higher beds which may exist in the Chappo Member beneath the alluvium of Spring Creek Valley. At the beginning of the section, the Bighorn Dolomite below strikes N.8°E. and dips 33°W. The Chappo Member above strikes N and dips 18°W. The dip of the Chappo Member decreases gradually westward, and midway up section is 12°W.

The aggregate thickness of partial stratigraphic section number 2 in the Chappo Member is 108.75 m (356.79 ft). The majority of the fossil mammal specimens came from units 2, 4, and 6 near the base of the section. The faunal list (Table 2) that follows includes specimens previously reported by Gazin (1942, 1956), which we have restudied and in some cases reidentified, as well as new taxa which our collections have added. Gazin and Oriel (Oriel, 1962, p. 2167) assigned a Clarkforkian age to the beds at Buckman Hollow. We concur with their age assessment. However, there is a minor terminological problem. When Gazin studied this faunule, the Clarkforkian was considered to be a North American land mammal "age" at the end of the Paleocene, hence Oriel's conclusion that the beds at this locality are "latest Paleocene." It now appears that most of the Clarkforkian, including the biozone represented by the Buckman Hollow fauna, is early Eocene rather than late Paleocene (Gingerich, 1976; Rose, *in preparation*).

Chappo Oil Well Locality

Oriel (1962, p. 2166) mentioned these exposures of the Chappo Member in the LaBarge oil field, 1.6 km (1 mi) south of Calpet, but no datable mammals were reported. We subsequently discovered a few temporally diagnostic specimens (Table 3), providing a new fossil locality. The locality is on the north side of a small gulley, about 45 m west of Texaco LaBarge Unit Well E303, Lot 5, in the SW ¼, NW ¼ sec. 3, T. 26 N., R. 113 W., Lincoln County, Wyoming. The specimens come from the surface of a gray-weathering, clay-rich siltstone, within a brightly color-variegated sequence of red, purple, and gray claystones and tan and brown sandstones. The Chappo Member here strikes due north and dips vertically due to deformation within the LaBarge Thrust sheet (Figs. 2 and 3). The LaBarge Member, which is angularly unconformable above the Chappo here, dips gently north-eastward at 7 degrees. The mammalian fossils are sufficient to show that the beds are Wasatchian in age, but that is the present limit of their geochronologic resolution. The rocks at this locality clearly are younger than Clarkforkian, and the overlying LaBarge Member has been dated elsewhere (Gazin, 1952, p. 10) as latest Wasatchian (Lostcabinian). This is sufficient to show that certain horizons in the Chappo Member are considerably younger than those at either the type locality or at Buckman Hollow. The minimum age range now demonstrated for the Chappo Member is from middle Tiffanian through early or middle Wasatchian, inclusive.

TABLE 2. MAMMALIAN FAUNA FROM BUCKMAN HOLLOW LOCALITY, CHAPPO MEMBER, WASATCH FORMATION, SECTIONS 1 & 12, T 26 N, R 114 W, LINCOLN COUNTY, WYOMING.

MULTITUBERCULATA
Prochetodon (?) (UM 68358)
PRIMATES
Carpolestes (UM 68366; USNM 21280)
Plesiadapis dubius (UM 68357, 71332; USNM 16696, 20786, 20787)
Plesiadapis cookei (UM 68369; USNM 16698, 20785)
RODENTIA
Paramys sp. (UM 68368)
CONDYLARTHRA
Thryptacodon pseudarctos (UM 68355; USNM 244264)
Anacodon (?) nexus (USNM 21282)
Apheliscus nitidus (UM 68356)
Phenacodus almiensis (UM 68364, etc; USNM 16691, etc.)
Phenacodus grangeri (UM 68359; USNM 20644, 21287, etc.)
Ectocion osbornianus (UM 71333, etc.; USNM 20736, etc.)
Dissacus sp. (USNM 16699)
TAENIODONTA
Lampadophorus sp. (UM 71330)
DINOCERATA
Probathyopsis sp. (UM 71331; USNM 21283, 21284)
PANTODONTA
Cf. *Titanoides primaevus (?)* (UM 71339)

Notes on Table 2:

Gazin (1942, 1956) reported twelve mammalian species from the Buckman Hollow locality. Gingerich (1976) subsequently synonymized *Plesiadapis rubeyi* with *P. fodinatus*, and *P. pearcei* with *P. dubius*. New specimens indicate that both *P. rubeyi* and *P. pearcei* are synonymous with *P. dubius*, and thus *P. fodinatus* is not present at Buckman Hollow. We here add six new taxa to the Buckman Hollow mammalian fauna: most important are the first records from this locality of Multituberculata and Rodentia as well as *Apheliscus* and *Titanoides*. The concurrent range of these newly reported taxa and the previously known index species *Plesiadapis cookei* confirm Gazin's (1956) determination of the age of this fauna as Clarkforkian. Abbreviations as in Table 1.

TABLE 3. MAMMALIAN FAUNA FROM CHAPPO OIL WELL LOCALITY, LABARGE OIL FIELD, CHAPPO MEMBER, WASATCH FORMATION, SECTION 3, T 26 N, R 113 W, LINCOLN COUNTY, WYOMING.

CARNIVORA	
	Viverravus (?) (UM 71347)
ARTIODACTYLA	
	Diacodexis sp. (UM 71343)
PERISSODACTYLA	
	Hyracotherium sp. (UM 71345, 71348)
PANTODONTA	
	Coryphodon sp. (UM 71344)

Notes on Table 3:

This is a new fauna not previously reported. The locality includes abundant seeds of *Celtis*, which Leo J. Hickey (pers. comm.) indicates became abundant only at the beginning of the Wasatchian. The presence of *Diacodexis*, *Hyracotherium*, and *Coryphodon* at the same locality indicates that this fauna is Wasatchian in age, but the precise position within the Wasatchian cannot be determined from the evidence available. Numbers in parentheses refer to specimens in the University of Michigan Museum of Paleontology.

Other Exposures of Chappo Member

We have had only limited success in our search for fossil mammals at other exposures of the Chappo Member. None of the exposures at Wasatchian age mammal localities mentioned by Privrasky (1963, sheet 2) appears to fall within the Chappo Member. Our search of exposures of the Chappo Member (Oriel, 1962, p. 2166) along the Black Canyon Road, north of the Dry Piney Creek Road north of Hogsback Ridge yielded no mammals. Likewise, exposures of the Chappo Member (Oriel, 1962, p. 2166) north of Cretaceous Mountain along the south side of the Pine Grove Ridge Road yielded no mammals.

Exposures of the Chappo Member also occur along the crest of Hogsback Ridge between LaBarge Creek and Chappo Gulch in the center of sec. 18, T. 26 N., R. 113 W. (see Oriel, 1969, plate 1, Geologic Map of the Fort Hill Quadrangle). This area is especially critical for an interpretation of structural history. It is here that beds of the Chappo Member overlap the Darby (=Hogsback) Thrust, so the thrust must be older than those beds. We found scattered fragments of the condylarths *Phenacodus* and *Ectocion* during a brief search there (Fig. 3) in 1979, but the specimens are too incomplete to identify species. According to West (1976, p. 8-9), the genus *Phenacodus* has a temporal range of Tiffanian (late Paleocene) into Bridgerian (middle Eocene) inclusive, which in itself is not temporally diagnostic enough for our purposes. The genus *Ectocion*, according to West, ranges from the Tiffanian into the Lostcabinian (late Wasatchian). However, he pointed out (1976, p. 58) that "The holotype [of *E. superstes*] is the only specimen of *Ectocion* known from post-Graybull rocks . . ." and that other paleontologists have "suggested that it should be considered a slightly aberrant specimen of *Phenacodus*. . . ." From this evidence, it can only be said that the Chappo beds here on top of Hogsback Ridge are no older than Tiffanian nor younger than Lostcabinian, although if *E. superstes* is indeed, *Phenacodus*, then the beds are no younger than Graybullian. This matches closely, but not exactly, with our evidence that beds elsewhere in the Chappo Member range in age from middle Tiffanian (at the type locality), through the Clarkforkian (at Buckman Hollow), into the Graybullian or Lysitean, but not as young as Lostcabinian (at the Oil Well Locality). We plan further collecting at this locality to attempt to resolve this problem. However, the presently available fossil evidence at least shows that along the crest of Hogsback Ridge the Darby (=Hogsback) Thrust occurred no later than before the Lostcabinian (late early Eocene) and possibly even as early as before the Tiffanian (late Paleocene). A more thorough discussion of all evidence pertaining to that age of the thrust is presented later in this paper.

GEOLOGIC STRUCTURE AND TECTONIC HISTORY IN LABARGE AREA

The early Cenozoic synorogenic deposits of the LaBarge area are intimately related to the tectonic history of the region, each being derived from a particular uplift and subsequently involved in all later structural movement. Accurate dating of the deposits and mapping their relationship to structures allows timing of the successive tectonic events.

Oriel (1961, 1962, 1969) provided a thorough analysis of the depositional and structural history of the area, based upon the available data. Armstrong and Oriel (1965), Royse and others (1975), Blackstone (1977), and Dorr and others (1977a, 1977b) have analyzed the regional geologic history. Here we shall reexamine and refine certain previous conclusions, present an expanded description of local structural relationships which our added mapping permits, and focus on certain parts of the regional history.

The Darby (=Hogsback) Thrust overrode late Cretaceous rocks (Adaville and Hilliard formations) in the LaBarge area (Blackstone, 1979, p. 23). That thrust, and others farther west, formed prior to deposition of the Chappo Member of the Wasatch Formation and provided source areas for clastic sediments of the Chappo Member. The Chappo Member overlaps the Darby (=Hogsback) Thrust, as demonstrated by our mapping and that of others. Beds of Clarkforkian age in the gently dippng Chappo Member lie with angular unconformity on more steeply dipping Paleozoic rocks within the Darby (=Hogsback) overthrust plate on the west flank of Hogsback Ridge. The Chappo Member is nearly horizontal over very steeply dipping Paleozoic formations and also over late Cretaceous rocks along the crest of Hogsback Ridge, where it overlaps the Darby

(=Hogsback) Thrust trace. Chappo beds of middle Tiffanian age, consisting of conglomeratic sedimentary rocks presumably derived at least in part from the high-standing surface toe of the Darby (=Hogsback) Thrust, occur east of Hogsback Ridge. Thus the Darby (=Hogsback) Thrust is later than the late Cretaceous Adaville Formation and earlier than the middle Tiffanian lower part of the Chappo Member. These dating limits span a rather long chronologic range which cannot at present be narrowed; no known latest Cretaceous or early and middle Paleocene rocks occur either below or above the thrust plane in the LaBarge area. However, this date is more refined than that given by Oriel (1969), because he thought the Chappo Member was no older than Clarkforkian.

Well data show that the LaBarge ("Hilliard") Thrust, named by Bartram and Hupp (1929, p. 1284), occurs in the subsurface about beneath Calpet, but it does not crop out there, being covered by the undeformed LaBarge Member of the Wasatch Formation as shown in Figure 3 and in more detailed cross sections in McDonald (1973), Murray (1960), Webel (1977), and Blackstone (1979). The Chappo Member is deformed there, however, probably by movement on the LaBarge Thrust (Bartram and Hupp, 1929, Fig. 7). Therefore, movement on the LaBarge Thrust was post-Chappo Member and pre-LaBarge Member, which is to say early to middle Wasatchian and late Wasatchian, respectively. This dates the LaBarge Thrust as approximately middle Wasatchian (Lysitean). Although this still leaves some chronologic range in dating of the LaBarge Thrust, it is as well or better dated than most thrusts and it is without doubt younger than the Darby (=Hogsback) Thrust.

The eastward dipping Calpet Thrust, known only from subsurface data, is cut by and thus is older than the LaBarge Thrust. The Calpet Thrust is said by Blackstone (1979, p. 24) to have moved before deposition of the Hoback Formation, which would be a movement during the early Paleocene.

Farther west, within and along the eastern front of Hogsback Ridge, the Darby (=Hogsback) Thrust is cut by a fault whose nature is unclear. Oriel (1969, Pl. 2, cross section A-A[1]) showed it as one of several slices of the LaBarge Thrust, but this is inconsistent with the termination of the fault at depth in his cross section (Blackstone, 1979, p. 24). We show it as a minor normal fault, perhaps a gravity slide block, on Figure 3. In either case the fault is younger than the Darby (=Hogsback) Thrust. The surface relationships are most easily seen along the north side of Chappo Gulch around the old Salli Coal Mine. Here all these structures are exposed in an erosional reentrant which is open to the south. West of Salli Mine, the Darby Thrust trace is in its expected position with Cambrian Death Canyon Limestone resting on Cretaceous Adaville Formation. East of Salli Mine, the above mentioned fault repeats the Darby Thrust. There the Bighorn Dolomite in the Darby Thrust plate lies on Adaville Formation below, and is downfaulted against the Adaville to the west.

The fault continues northward, for a distance of about 3.2 km (2 mi) from Chappo Gulch, cutting Paleozoic rocks which were part of the pre-existing Darby Thrust plate. The Paleozoic rocks of the Darby Thrust plate are duplicated in outcrop by this fault. This duplication, coupled with the very gentle dip of Paleozoic rocks east of a monoclinal flexure lying west of the crest of Hogsback Ridge, and duplication by a subsidiary slice of the Darby Thrust on the west flank of that ridge (see Fig. 2, and Beyer and Clutsom, 1978), combine to produce an anomalously broad east-west outcrop belt of the Death Canyon Limestone, Gallatin Limestone, and Bighorn Dolomite. This, misleadingly, suggests that these stratigraphic units are of greater than normal thickness here. The situation is especially confusing where the Bighorn Dolomite is duplicated several times against itself. The fault passes northward beneath unaffected Wasatch conglomerate about 3.2 km (2 mi) north of Salli Mine and cannot be mapped on the surface thereafter. The Darby (=Hogsback) Thrust also continues northward, east of Hogsback Ridge, passing beneath a cover of Wasatch conglomerate where its trace can no longer be mapped on the surface (Fig. 1).

Subsurface data (Oriel, 1969, p. 26, and cross sections; Royse and others, 1975; Blackstone, 1979) show that middle Cambrian rocks occur at the base of the hanging wall of the Darby (=Hogsback) Thrust, lying upon late Cretaceous rocks over an enormous area of more than 518 km^2 (200 mi^2) to the north, south, and west of Hogsback Ridge. This relationship is almost completely exposed, and reasonably can be interpreted from outcrops visible looking north from the road where LaBarge Creek transects the overthrust plate plus underlying rocks near the south end of Hogsback Ridge. There the Cambrian Death Canyon Limestone lies on the Adaville Formation. The Death Canyon Limestone remains at the sole of that thrust plate northward along its trace to Chappo Gulch where, just west of Salli Mine, the Death Canyon also rests on Adaville. Northward from there, the thrust climbs stratigraphically upward along its present trace over a straight line distance of about 136 km (85 mi), eventually reaching the level of Jurassic rocks (Blackstone, 1979, p. 24-28). Moreover, to the east and northeast of Salli Mine, where the Hogsback Thrust has been cut and dropped down by faulting, the Bighorn Dolomite soles the Hogsback overthrust plate, lying on Adaville Formation. Thus it appears that, in spite of the widespread lateral persistence of middle Cambrian rocks at the sole of the Hogsback Thrust elsewhere, the sole cuts up stratigraphic section along its present trace both northward and eastward from the vicinity of Salli Mine. The rapid eastward stratigraphic rise suggests that the Hogsback Thrust ramped upward there and that the original surface toe of that thrust was nearby. This may account for Hogsback Ridge itself, which clearly was a topographic high in Chappo Member time, was overlapped by subsequent early Tertiary deposits, and then was exhumed by erosion. Thus Hogsback Ridge may represent a remnant of the thrust toe. Both the northward and eastward stratigraphic rises of the thrust plane may have been caused by the Moxa Arch (LaBarge Platform), which formed prior to the Darby Thrust (Wach, 1977; Blackstone, 1979, p. 27-29). The crest of that arch lies a few miles east of Hogsback Ridge, but north of LaBarge it veers westward to pass beneath the Darby (=Hogsback) Thrust (Fig. 1).

SOME PROBLEMS OF REGIONAL OVERTHRUST RELATIONSHIPS

The major overthrusts of the region are shown on Figure 1. The figure is compiled from Blackstone (1977, Fig. 1 and pocket map), Dorr and others (1977a, pocket map), Oriel (1969, pocket map and cross sections), Royse and others (1975, pocket cross sections and Fig. 1), Wach (1977, Fig. 1), and Webel (1977, Fig. 4), with modifications and additions from our present work. Many structural details, including most minor thrusts, folds, and normal faults, have been omitted, but these can be found on Blackstone's map.

There has been and still is some confusion regarding the names applied to the overthrusts. Blackstone (1977, p. 372; 1979, p. 18-19) reviewed these problems of nomenclature. Some are easily resolved; others stem from problems of structural or historical interpretation.

North of Snider Basin, the frontal thrust long has been called the Prospect Thrust. It can be traced northward into the Cliff Creek Thrust along the west side of the Hoback Basin, and from there northwestward as the Jackson Thrust, past the town of Jackson, and thence over Teton Pass at the south end of the Teton Range (Dorr and others, 1977a). Thus, simply, Prospect=Cliff Creek=Jackson, and we use the name Prospect Thrust here.

North of Snider Basin, the Darby Thrust is the next major thrust west of the Prospect Thrust. The Darby Thrust forms the front of the Wyoming Range there and the Prospect Thrust lies to the east, largely concealed by early Cenozoic cover. The Absaroka Thrust lies west of the Darby and can be dated farther south (Armstrong and Oriel, 1965; Dorr and others, 1977a, 1977b; Royse and others, 1975). The Absaroka Thrust is older than the Prospect Thrust, and a common presumption has been that since the major overthrusts farther south can be shown in some cases to be progressively younger eastward, the same holds true farther north. In other words, the thrust time progression was eastward from Absaroka to Darby to Prospect. The difficulty with this concept has been that the Darby Thrust has not yet been exactly dated north of Snider Basin, and there has not been complete agreement as to the fate of the Darby Thrust south of that point. The original interpretation of Schultz (see Blackstone, 1977) was that the south-trending Darby Thrust trace swings abruptly eastward at Snider Basin for about 21 km (13 mi), then trends southward again along the eastern faces of Cretaceous Mountain and Hogsback Ridge (known collectively, earlier, as LaBarge Ridge) where it is sporadically exposed, and then continues under early Cenozoic cover southward to a termination at the north flank of the Uinta Range. The validity of this interpretation was questioned by Armstrong and Oriel (1965) and by Oriel (1969), who applied the name Hogsback Thrust to the southern part of that feature, from Cretaceous Mountain south to the Uinta Range; their point was that the Hogsback and Darby thrusts were not proven to be parts of the same thrust. Still more recently, Royse and others (1975) and Blackstone (1977, 1979) have returned to Schultz' original interpretation and usage, applying the name Darby Thrust to the entire Darby (=Hogsback) feature. Royse and others (1975), however, used the term Darby "zone" for the Darby, Prospect, and Hogsback thrusts, which they believed to be linked into a single system. We believe that our work in the LaBarge area and the work of others combine to invalidate this concept. For the sake of clarity in the discussion that follows, we use the names Hogsback, Prospect, and Darby separately, avoiding implications of a proven linkage.

On most published geologic maps, the Prospect Thrust trace appears to terminate on the south at Snider Basin. The interpretation of Royse and others (1975, p. 45) is that the Prospect Thrust cuts up section stratigraphically toward the south, and at the point of its apparent southern termination has gained sufficient altitude to link into the plane of the older Darby Thrust, the latter being also the Hogsback Thrust. By their interpretation, the Darby, Prospect, and Hogsback thrusts become linked south of Snider Basin where the Darby=Hogsback and Prospect thrust planes merge to become, in their words (1975, p. 45), "a composite plane of earlier Darby and later Prospect thrust motion." They apply Darby Thrust "Zone" to this system, linked to the south and bipartite to the north. However, recent work by Blackstone (1979, p. 10) shows that the Prospect Thrust neither ramps up to link into the Darby, nor terminates at Snider Basin. Instead, he shows that the Prospect Thrust dies out south of Snider Basin by passing into a plunging fold beneath the Darby Thrust. Thus the geometric relations show that the Prospect Thrust postdates the Darby Thrust. Our work shows that another difficulty with the Royse concept has to do with timing. Where the Prospect Thrust has been dated quite accurately in the Hoback Basin area to the north (Dorr and others, 1977a, 1977b, p. 51-52; Dorr and Steidtmann, 1977, p. 335-337), the time of movement was post-Tiffanian and pre-early Wasatchian (*i.e.*, sometime in the Clarkforkian). In the LaBarge area, as we have shown earlier, the Hogsback Thrust movement was pre-Chappo, which is pre-middle Tiffanian. Therefore, our evidence shows that the Prospect and Hogsback thrusts moved at different times, the latter being the older. This confirms the conclusions of Armstrong and Oriel (1965, p. 1857), Oriel (1969, p. m31-32), and Blackstone (1979, p. 22-25), although our dating of times of movement on the both thrusts is refined.

If the Prospect Thrust stepped up into the Hogsback Thrust plane, then the time of *last* movement on the linked thrusts should be the same, but it is not. Reversing the wording to say that a reactivated movement of the Darby (=Hogsback) Thrust stepped *down* northward into the Prospect Thrust leaves the same timing problem. Either way, it is clear that movements on the Prospect and Darby (=Hogsback) thrusts were not synchronous. If, as seems likely, the Darby and Hogsback thrusts are part of the same thrust sheet, then our date for the Hogsback Thrust is a date for the Darby Thrust. The fact that the Darby (=Hogsback) Thrust overrides the Adaville Formation but is overlapped by the Chappo Member proves that the Hogsback Thrust is older than the Prospect Thrust, but does not indicate how much older. If, however, basal conglomerates of Torrejonian age in the Hoback Formation, in the subsurface near LaBarge, are synorogenic derivatives from the uplifted toe of the Hogsback Thrust, then the time of movement of the Hogsback Thrust is no older than about middle Paleocene (Oriel, 1969, p. m14-15). The slightly younger overlying Chappo Member also contains conglomerate horizons, some quite coarse, which encircle Hogsback Ridge. If some of this is synorogenic debris from the Hogsback Thrust toe in Hogsback Ridge, then the uplift would be dated as having occurred in about the middle Tiffanian. Both of these lines of evidence from the ages of synorogenic clastic debris indicate that the time of movement of the Darby Thrust was later than the time of last movement on the Absaroka Thrust.

The LaBarge Thrust is younger than both the Darby (=Hogsback) and Prospect thrusts. The evidence for this is that the LaBarge Thrust deformed the Chappo Member but was overlapped by the LaBarge Member of the Wasatch Formation. Thus the movement was post-Chappo and pre-LaBarge, or post-early Wasatchian and pre-late Wasatchian, whereas the Prospect Thrust movement was pre-early Wasatchian and the Hogsback Thrust movement was even older. Lawrence (1965) ascribed the angular unconformity between the Chappo and overlying LaBarge members to a period of nondeposition, erosion, and basin subsidence between Chappo and LaBarge time. However, the vertical attitude of the Chappo Member beneath the nearly horizontal LaBarge Member at our fossil locality just south of Calpet seems too extreme a discordance to ascribe to basin subsidence alone; we attribute that discordance to deformation by movement of the LaBarge Thrust.

The Moxa Arch (Fig. 1), which in the LaBarge area lies just east of the overthrust belt, predates the Darby and later thrusts in time of origin. Blackstone (1979, p. 25, 27-28) suggested this arch played a role in controlling the geometry of the thrusts. Throughout much of its extent, northward from the Uinta Range to just south of LaBarge, the arch trends northward and may have caused the Darby (=Hogsback) and LaBarge thrusts to ramp up to the surface just west of the arch. This would explain why the Darby (=Hogsback) Thrust is soled throughout most of its extent by middle Cambrian rocks (Oriel, 1969) but cuts up section stratigraphically over a short distance eastward within Hogsback Ridge (see descriptive structure section above).

North of LaBarge, the Moxa Arch was portrayed by Royse and others (1975) and by Wach (1977) as turning northwestward toward the Darby (=Hogsback) Thrust. Blackstone (1979, Pl. 6) argued that it and the related LaBarge Platform lie beneath that thrust northwest of Snider Basin. We showed earlier that the Darby (=Hogsback) Thrust plane cuts up section northward along its trace in the Wyoming Range. It appears that the more western position of the arch-platform also may have caused this displacement where the Darby (=Hogsback) Thrust first impinged upon and completely overrode the arch.

An interesting question with regard to the mechanics of overthrusting is whether or not thrusts move simultaneously throughout their extent. There is no reason we know of to assume, *a priori*, that they do or do not, and in most cases the problem is insoluble; most thrusts cannot be closely dated anywhere, let alone at two or more separate places. Even in the area of our work, where certain thrust movements can be dated within relatively narrow time limits, it usually is not possible to do so at more than one place along their traces. A possible exception is the Prospect Thrust, although the evidence we shall discuss is still equivocal. Dorr and others (1977a, 1977b) and Dorr and Steidtmann (1977) have presented evidence which shows that a northern segment of the Prospect Thrust, called the Cliff Creek Thrust along the western side of the Hoback Basin, overrode and/or deformed Tiffanian age rocks at Battle Mountain and along Dell Creek, but was overlapped by rocks of early Wasatchian age about 27 km (17 mi) farther south, along the upper Hoback River north of Lookout Mountain. The fossil bearing rocks that were overridden at Battle Mountain are in the Hoback Formation. The beds that overlap the same thrust along the upper Hoback River are in a zone of interdigitated fine clastics near the base of the eastern margin of the Lookout Mountain Conglomerate Member of the Wasatch Formation. These fine clastics are lithologically and temporally equivalent to part of the Chappo Member of the Wasatch Formation which lies to the east in the Hoback Basin. Thus the Prospect Thrust in the Hoback Basin area is post-Hoback Formation and pre-Lookout Mountain Conglomerate, and probably also is pre-Chappo Member. This puts the time of movement there sometime in about the Clarkforkian. On the other hand, Rubey (1973) presented a series of cross sections, at intervals for some 56 km (35 mi) southward from the Hoback Basin almost to Snider Basin, in which he showed the Prospect Thrust overriding the Chappo Member. This appears to imply that the central and southern parts of the Prospect Thrust are post-Chappo, and we have shown earlier in this paper that the upper part of the Chappo Member in the LaBarge area is Wasatchian in age. This suggests that movement on the Prospect Thrust was: (1) pre-Wasatchian, and hence older, in the Hoback Basin area; and (2) mid-Wasatchian, and therefore younger, farther south near Prospect Mountain and Snider Basin. This evidence for different times of movement still is not to be trusted, however, for two reasons. First, so far as we know, the Chappo Member has not yet been dated by paleontological or other means anywhere in the area covered by Rubey's cross sections and map. Secondly, Rubey's cross sections all show the overridden Chappo Member, beneath the Prospect Thrust, interfingering eastward at both its top and bottom with the Hoback Formation in the subsurface. Therefore, all of the overridden Chappo Member shown on his cross sections could be age equivalent with the Hoback Formation, meaning that the youngest beds overridden by the central or southern segments of the Prospect Thrust are no younger than the part of the Hoback Formation which was overridden farther north at Battle Mountain. Rubey showed the LaBarge Member of the Wasatch Formation overlapping the Prospect Thrust. The LaBarge Member is late Wasatchian in age, which is younger than the early Wasatchian age beds that overlap the thrust along the upper Hoback River. This does not prove a different time of movement on the thrust, however, because the thrust may have moved well before the late Wasatchian time; but it may not have been overlapped until the late Wasatchian farther south. A more definite solution to this problem awaits better dating of the Chappo Member along the trace of the Prospect Thrust in the area of Rubey's map and cross sections.

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MANUSCRIPT RECEIVED JUNE 20, 1979
REVISED MANUSCRIPT RECEIVED NOVEMBER 2, 1979
MANUSCRIPT ACCEPTED NOVEMBER 23, 1979