Twenty-Seventh Annual Field Conference—1975
Wyoming Geological Association Guidebook

PALEOCENE AND LOWER EOCENE ROCKS IN THE SAND CREEK – NO WATER CREEK AREA, WASHAKIE COUNTY, WYOMING

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INTRODUCTION

Early Tertiary rocks in the Sand Creek — No Water Creek area of this report consist of a southeast-plunging prism of sediment which comprises the youngest exposed rock in the southeast axial region of the Bighorn Basin (Figs. 1, 2). Two formations have been designated for these rocks: Jepsen (1930b) assigned the Paleocene Series of the Bighorn Basin to the "Fort Union" Formation and Van Houten (1944) named overlying variegated Early Eocene strata the Willwood Formation, supplanting Cope's (1882) name Bighorn "Wasatch." Following a decade of field studies in the northern part of the basin, Jepsen (1940) abandoned the term "Fort Union" for the Bighorn Paleocene and introduced a new name, Polecat Bench Formation; an appellation which has, unfortunately, not been widely received in spite of Jepsen's perceptive discussion of problems concerning the correlation of these rocks with the type Fort Union Formation of western North Dakota. These correlation problems are not solely homotaxic; lithologic subdivisions of the Fort Union which are recognized in Montana (e.g. Lebo and Melville members; Simpson, 1937) are not discernable as such anywhere in the Bighorn Basin. In view of a lack of lithologic and physical continuity between Paleocene deposits of the Bighorn Basin and the Williston, Powder River and Crazy Mountain Syncline basins, the Paleocene Series of the Bighorn Basin is assigned to the Polecat Bench Formation of Jepsen (1940).

Wortman (1882) presented the first map of Tertiary deposits in the Bighorn Basin. Subsequent maps have variously depicted the surface distribution of these rocks. Well-exposed Paleocene and Early Eocene strata east of the Bighorn River have not previously been adequately described or accurately delineated. A field party from the University of Wyoming Geology Museum surveyed this area in 1974 to determine the extent of fossiliferous exposures of the Willwood Formation and to collect fossil vertebrate remains. On the basis of continuing studies, this writer offers a preliminary report on the areal distribution, lithology and intrabasinal correlation of Early Tertiary rocks in the Sand Creek — No Water Creek area.

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Acknowledgements

The writer is much indebted to P. O. McGrew and J. D. Love for their critical review of the manuscript and to P. O. McGrew, J. D. Love and D. L. Blackstone for informative discussion. Daniel N. Miller, Jr. kindly provided the facilities of the Geological Survey of Wyoming for the final draft of Figure 2. The able field assistance of M. C. Campbell, R. W. Jones, M. J. Kraus, K. D. Rose and J. S. Schweitzer is acknowledged. This work was supported by National Science Foundation Grant GA-35754 to Paul O. McGrew, Department of Geology, University of Wyoming, Laramie.

TERTIARY SYSTEM

DISTRIBUTION

East of the valley of the Bighorn River the Polecat Bench and Willwood Formations are exposed over approximately 300 and 150 square miles, respectively. The attitude of these rocks as well as their somewhat lunate surface outcrop are controlled by several anticlinal folds which border and roughly parallel the southeast axial region of the Bighorn sedimentary basin (Fig. 2). Earlier geologic maps of the southeastern Bighorn Basin (i.e., those of Wortman, 1882; Fisher, 1906; Weitz and Love, 1952; and U.S.G.S. Wyoming State Geologic maps, 1925 and 1955) have depicted the Willwood ("Wasatch") outcrop south of the East Fork of No Water Creek as more or less coincident with that of the Polecat Bench outcrop as mapped in Figure 2. Field studies in 1974 demonstrate these earlier maps to be in error; the Willwood Formation is largely restricted to exposures north of the East and Cabin Prong Forks of No Water Creek. Van Houten (1944, p. 183) mentioned the No Water Willwood exposures in passing but apparently did not visit the area south of No Water Creek. A map published by Eldridge (1894) has, previous to this paper, most accurately defined the distribution of Eocene rocks in this area.

Exposures of Polecat Bench strata are best developed: (1) in a narrow belt east of the Sand Creek divide and marginal to the southwest flanks of Bonanza and No Wood anticlines; (2) in the vast badland tract south of the East Fork of No Water Creek (known locally as the "Honeycombs"); and (3) south of the axis of Neiber anticline. Poorer exposures exist north of the axis of Neiber anticline, north of U.S. Highway 16 in T47N, R90W, and on the high South Butte divide in the E¼ T44N, R90W and W½ T44N, R89W. Harris (1952, p. 123) has earlier noted exposures of "Fort Union" in part of the Sand Creek Oil field (Sec. 26, T46N, R91W).

The Willwood Formation is exposed: (1) as a thin veneer of rock capping the Polecat Bench in the N¼ T45N, R92W, and NW¼ NW¼ T45N, R91W, near the

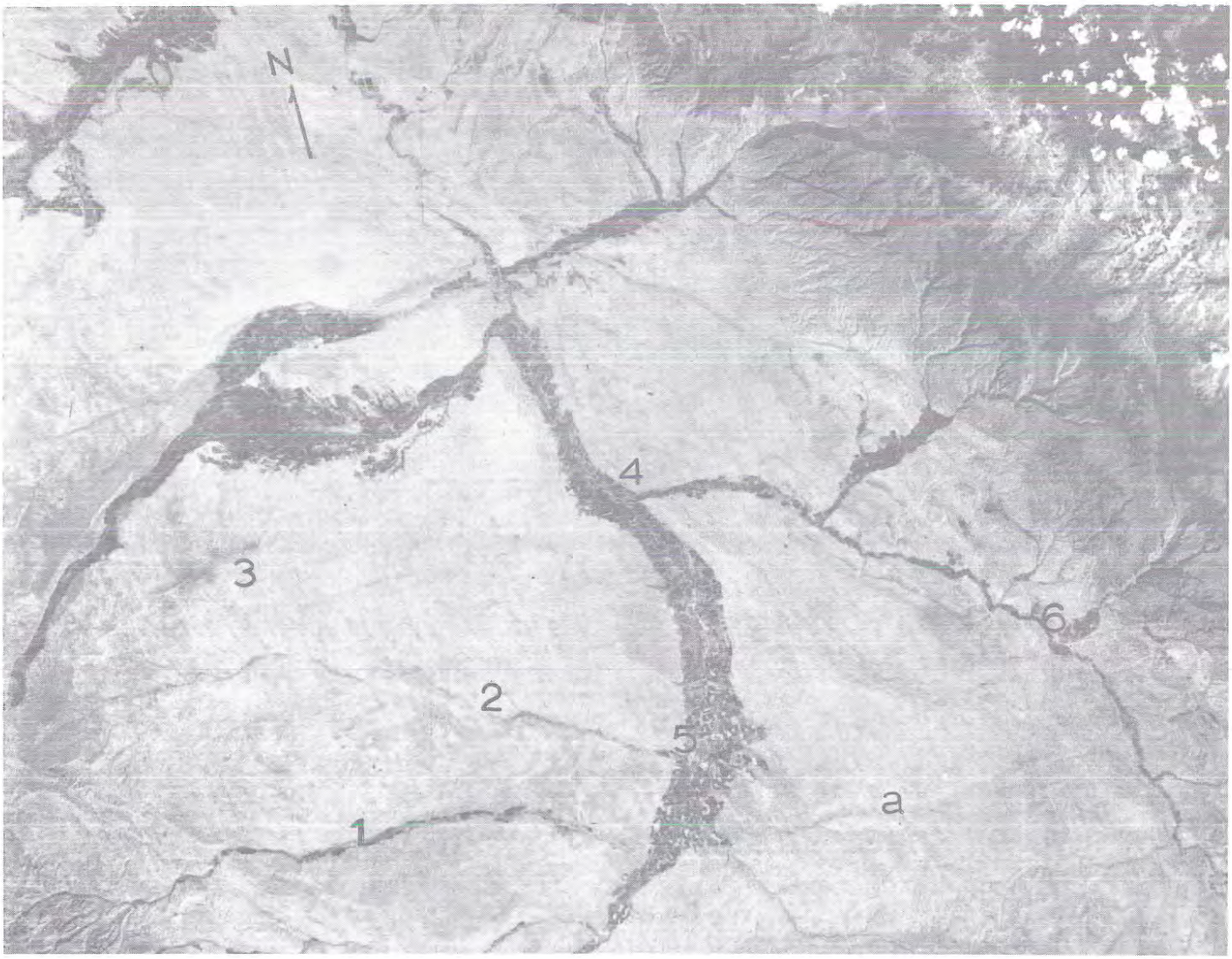

Figure 1. View of a portion of the southern and eastern Bighorn Basin showing areal relationships of the report area to significant physical and cultural features. a-Center of study area at the confluence of Wagon Prong and Cabin Prong Creeks, tributaries to the East Fork of No Water Creek; 1-Gooseberry Creek; 2-Fifteenmile (Dry Cottonwood) Creek; 3-Tatman Mountain; 4-townsite of Manderson; 5-townsite of Worland in the Bighorn River valley; 6-townsite of Tensleep, Wyoming. Printed from Earth Resources Technology Satellite (ERTS) image 1013-17291-5; Courtesy of National Aeronautics and Space Administration. Scale: 1 inch = approximately 16 miles.

confluence of the East and South Forks of No Water Creek; (2) in an extensive badland region north of the East Fork of No Water Creek between North (Devil's) Butte* on the east and the Bighorn River valley; (3) on the Sand Creek divide, a high northerly-extended salient which forms the high cliffs east and northeast of the town of Worland; and (4) as two infolded remnant outliers, one in Neiber Syncline (Sections 18 and 19, T45N, R93W) and a second in a small unnamed syncline in Sections 17 and 20, T45N, R90W. Hewett and Lupton (1917, p. 140) noticed "Wasatch" deposits in Neiber syncline but did not map them and these rocks have eluded detection on other maps of the area. This interesting remnant may be seen from U. S. Highway 20, east of Tiedown Flats and about three miles south of the town of Neiber. The two Willwood outliers plotted in the SW¼ T45N, R92W on the Geologic Map of the Southern Bighorn Basin (Weitz and Love, 1952) are high, gravel-capped surfaces developed on Polecat Bench rocks.

From Figure 2 it may be seen that the actual Willwood outcrop is approximately 130 square miles less extensive than portrayed on the 1955 State Map and that the southern lower contact of this unit has been relocated 2 to 14 miles to the north.

*Devil's Butte of Woodruff (1910, Pl. 12) is a synonym of North Butte. The North Butte of Woodruff = Middle Butte of current local usage.

PALEOCENE SERIES — POLECAT BENCH FORMATION*

East of the Bighorn River the Polecat Bench lies with marked angular unconformity on Late Cretaceous Lance and Montana Group rocks; a relationship which is noticed on the upturned margins of the Bighorn Basin in general. Woodruff (1910, p. 176) mentioned this unconformity between the "Fort Union" and "undifferentiated Montana" in the east and southeast parts of the study area. The discordance is most easily seen where a thick Polecat Bench channel sandstone complex is incised in the Cody Shale and younger Late Cretaceous rocks on a large fishook-shaped salient near Sand Point in the NW¼ T43N and SW¼ T44N, R89W. Here, Cody shales which dip 30-50 degrees NE are truncated by flat-lying Polecat Bench beds. From this site, the unconformity was traced westward along the high divide separating the South and East Forks of No Water Creek and northward to the vicinity of Middle Butte in the SW¼ Section 17, T45N, R89W. (Figure 2). West of the Sand Draw Oil Field and north of Middle Butte the contact between the Lance and Polecat Bench is largely obscured by surface cover. The degree of Paleocene overlap onto Cretaceous rocks at the eastern reaches of No Water Creek appears to be more extensive than that at any other point in the Bighorn Basin.

A well drilled near South Butte (Sec. 15, T44N, R90W; Moore, 1961) penetrated 110 feet of Polecat Bench Formation. From this wellsite, the Polecat Bench rapidly increases in thickness basinward, attaining more than 2,000 feet at Worland. The formation is presumably thickest in the Paint Creek area north of Cody, Wyoming, where subsurface data indicates more than 9,000 feet is preserved in a structural deep along the Bighorn Basin axis.

In the Sand Creek — No Water Creek area the lower part of the Polecat Bench is composed of a complex of thick channel and sheet sandstones which are intertongued with thin lenticular deposits of siltstone and mudstone. To the north and northwest, in and west of the Honeycombs, the middle and upper parts of the formation are exposed. In these rocks, fine-grained clastics predominate and consist, in the main, of a monotonous sequence of siltstones and mudstones with a few beds of lignitic claystone or lignitic paper shale and a few seams of coal. Channel and shoestring sands occur but are relatively rare and no sheet sands were seen. The siltstones and mudstones are generally a drab yellow-brown or bluish-gray in color and the somber aspect of these deposits offers a sharp contrast with overlying exposures of the brightly variegated Willwood Formation. Dark brown to black manganiferous concretions, varying from three inches to more than a foot in diameter, are abundant in the middle and upper Polecat Bench and shards of these nodules characteristically litter much of surface outcrops.

Interestingly, Polecat Bench outcrops in the Sand Creek — No Water Creek area are quite similar in broad aspect to outcrops of this formation in the northern Bighorn Basin. The basal part of the sequence in both areas is dominated by sandstones; the middle consists of roughly equal amounts of mudstone and sandstone, and the top is characterized by fine-grained clastics. The Polecat Bench is considerably thicker to the north, however, and these relationships have been telescoped in the rocks southeast of Worland. It is presently unknown to what extent temporal and lithologic subdivisions of the Polecat Bench may be correlated within the Bighorn Basin.

A sequence of coals, lignitic mudstones and red clinker is well-developed along the eastern margin of the area, in the W½ of T44, 45 and 46N, R89W. Woodruff (1910) has earlier described the occurrences of coal in the southeastern Bighorn Basin. The development of red clinker beds in the middle and upper parts of the Polecat Bench Formation is of interest since the distribution of these beds is frequently coincident with the lower boundary of the Willwood Formation as mapped on the Geologic Map of the Southern Bighorn Basin (Weitz and Love, 1952) and State Geologic Map of Wyoming (Weitz, Love and Hose, 1955). It would seem that these clinker beds were mistaken by earlier workers for the basal beds of the Willwood Formation, a unit which is frequently differentiated from the upper part of the Polecat Bench by the first persistent occurrence of "red beds" (Van Houten, 1944).

Polecat Bench exposures were fruitlessly, albeit briefly, prospected for vertebrate fossils in the summer of 1974. Clay gall conglomerates containing much carbonized plant material were located near the bases of three sandstones at the western edge of the Honeycombs. Such clay gall-plant associations occasionally yield fossil vertebrate remains in Paleocene rocks elsewhere in the Bighorn Basin. These and other outcrops will be prospected further in succeeding seasons.

EOCENE SERIES — WILLWOOD FORMATION

The Early Eocene Willwood Formation in most places lies with conformity atop Polecat Bench deposits in the Bighorn Basin. Striking angular discordant relationships with Polecat Bench and older rocks are locally encountered, e.g. on Heart Mountain north of Cody and at Hole-in-the-Ground, southeast of Meeteetse. In the drainage of Antelope Creek, southwest of the town of Basin, the lowest beds of the Willwood appear to be discordant beneath younger Willwood beds. The Polecat Bench — Willwood contact was examined in some detail at several points in the southeastern Bighorn Basin and adjacent areas; slight angular unconformities mark this contact: (1) in the SE¼ T47N, R91W where Willwood and Polecat Bench strata outcrop along U. S. Highway 16 east of Worland and (2) in the southern Bighorn Basin in bluffs along the drainage of Cottonwood Creek and on Blue Mesa where a complex of sandstone and pebble conglomerate channels make up the basal beds of the Willwood. The formation is conformable on the Polecat

* Surface stratigraphic sections of the Polecat Bench and Willwood Formations in the report area are in preparation.

Bench in beds exposed on the Sand Creek divide and in exposures north of the East Fork of No Water Creek where the lowest persistent red beds were seen to intertongue with Polecat Bench strata.

On a basinwide scale, unconformities or the gradual transition from drab to variegated rocks are the only reliable criteria for separating the Willwood and Polecat Bench Formations. The procedure of differentiating the two units on the basis of diagnostic fossil content is impractical in most areas and is unacceptable if formations are to be considered solely lithostratigraphic units. The distinction of these units on the basis of heavy minerals (Stow, 1938) invalidates the concept of formations as entities which are mappable in the field. What Stow has differentiated are heterochronous "petrographic facies." The suggestion by the above author (Stow, 1938, p. 736) that the base of the "Wasatch" is placed "at the bottom of the lowest persistent conglomerate" is unrealistic in view of the absence of conglomerates in most places where this contact is exposed.

A Tertiary well log north of Worland and west of the Bighorn River (Sec. 28, T47N, R93W) has recorded 700+ feet of Willwood Formation (W.G.A., 1968). Surface stratigraphic sections in the study area will be measured and described during the summer of this conference; however, surface relationships suggest a maximum of 500 feet of Willwood strata are present in the badlands south and east of the Slick Creek Oil field. The most recent complete surface section of the Willwood Formation was measured by Neasham (1970) along the drainages of Antelope and Elk Creeks, southwest of the town of Basin, Wyoming. His studies indicate a thickness of about 2,300 feet for the exposed central basin Willwood; however, this lateral-line section probably represents somewhat less than the actual preserved thickness of the subsurface section.

In the valley of the East Fork of No Water Creek the lowest beds of the Willwood Formation consist of an alternating sequence of highly variegated siltstones, mudstones and claystones. Thin channel and shoestring sandstones are infrequently present. The coloration of the well-exposed Willwood sediments is striking; shades of gray, brown, yellow, blue, red, maroon and purple combine to give a rainbow effect. This varicolored aspect is similarly well developed in the Slick Creek Basin (NE¼ T46N, R92W and NW¼ T46N, R91W) and in salient bluffs along the headwaters of Sand Creek. Elsewhere, on the Sand Creek divide and around the base of North Butte, the lowest beds of the Willwood consist principally of alternating thick red and gray mudstones. Shaly carbonaceous claystones and lignitic mudstones yielding selenite and jarosite are commonly associated with the suspended sandy bedloads of ancient stream channels.

In several respects the Willwood Formation southeast of Worland contrasts sharply with penecontemporary Willwood deposits elsewhere in the Bighorn Basin. Some of these differences may be briefly described as follows:

1. Sand is not a significant constituent of Willwood lithology in the Sand Creek — No Water Creek area. Channel fills are relatively rare and where present may contain poorly developed zones of small "pipy" concretions. Shoestring sandstones, while more common than channels, often are exceedingly thin and rarely exceed two feet in thickness. Allen and Friend (1968) have attributed a predominance of overbank mudstones to confinement of the stream within an entrenched meander belt. If one is to assume that conditions of aggradation prevailed in the No Water area in Early Eocene times, such confinement would probably result in rapid aggradation of the stream thalwegs and the ultimate preservation of very thick meander belt deposits. The presence of high alluvial ridges in the Early Eocene distributary floodplain deposits has yet to be documented by large scale geometric relations of stream channel systems in these deposits.

2. The small, brown, "earthy" calcareous nodules mentioned by Wortman (1892) which are so abundant elsewhere in the Bighorn Basin Willwood and which "strew the badland slopes in countless numbers" (Sinclair and Granger, 1911) are almost totally absent on the outcrops examined in 1974. Instead, light purple, sandy and sometimes botryoidal nodules are common, structures which are extremely rare in Willwood strata west of the Bighorn River.

3. Basal Willwod beds in the study area appear, on the whole, to be more brilliantly variegated than such beds elsewhere where essentially drab sediments predominate in the lowest levels of the section. Only in exposures along Paint Creek (T55 and 56N, R103W) and at Bone Hill (T45N, R97W) are beds of similar variegated aspect encountered at comparable levels of the Willwood Formation. This judgment, basically subjective and impossible to describe in quantitative terms, has been reinforced by impressions over several years of visiting the exposures involved.

4. The distribution of Willwood fossil vertebrate remains in the Sand Creek — No Water Creek area is largely confined to certain gray mudstone units. In most instances, these mudstones (termed "Class A gray" units in the field) are remarkably persistent over a wide lateral extent of outcrop and yield fossil vertebrate remains wherever they are well exposed. Random prospecting for vertebrate fossils in the Willwood exposures of the report area was relatively fruitless when compared with the procedure of exploiting these Class A gray beds. Similar occurrences were noted in Willwood exposures west of the town of Basin; however, the development of these units is believed to be rare in the northern and

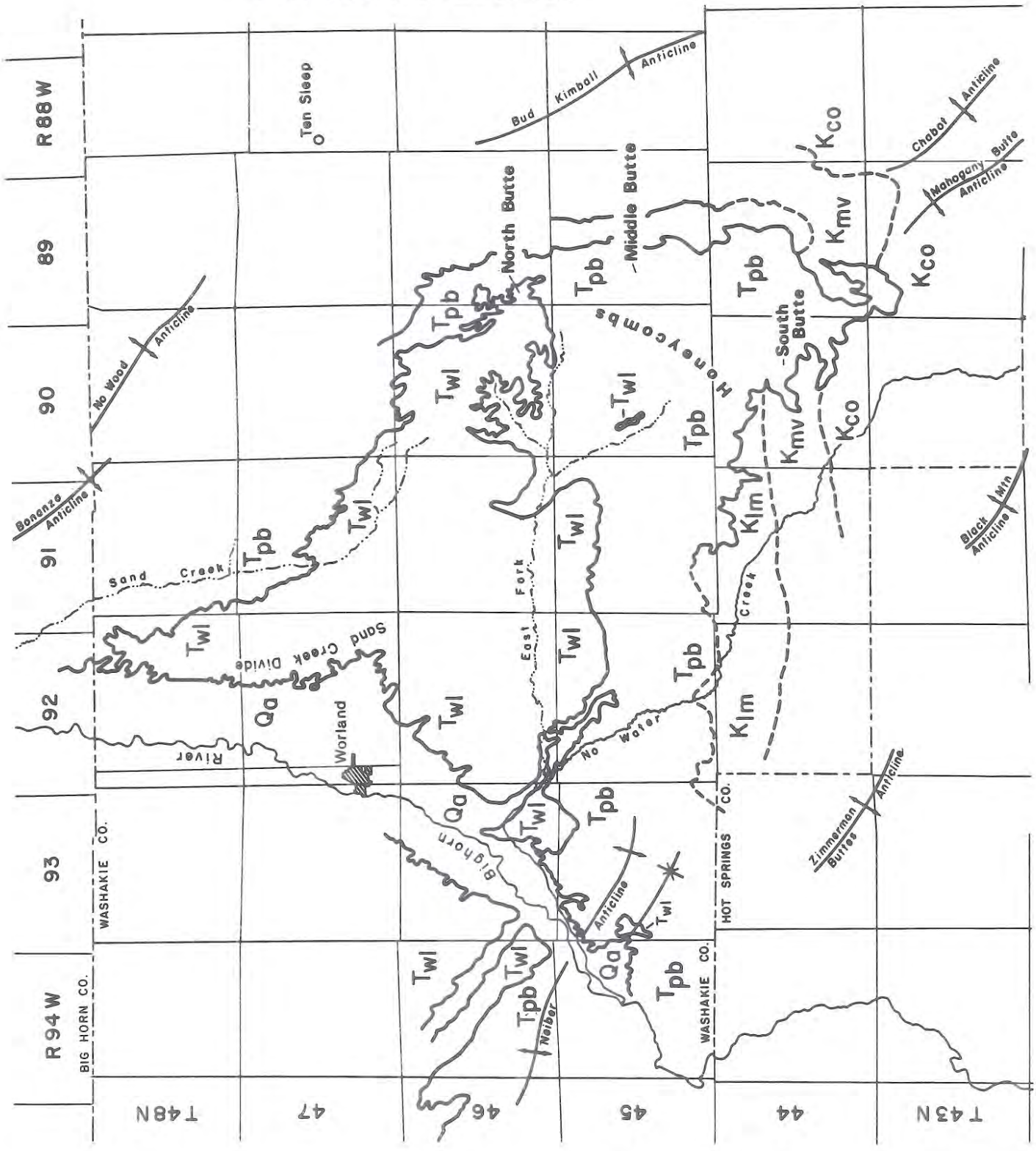

Figure 2. Preliminary map of Tertiary Rocks in the Southeastern Bighorn Basin, Wyoming (Qa = alluvium, Twl = Willwood Fm., Tpb = Polecat Bench Fm., Klm = Lance Fm - Meeteetse Fm., Kmv = Mesaverde Fm., Kco = Cody Fm.)

central basin Willwood. "Pockets" of fossil vertebrate material have been encountered before in Willwood strata (e.g. Jepsen, 1930a) and it is not known if these discoveries were associated with unrecognized Class A gray units. The sedimentology and geometric relationships of these interesting beds is currently under study.

5. Neasham (1970) and Neasham and Vondra (1972) described sedimentation cycles in a section of Willwood rocks measured along the bluffs bordering Antelope and Elk Creeks, southwest of the town of Basin. For the lower 700 feet of this section, rhythmic deposition was defined in the upward sequence; sandstone, drab mudstone, carbonaceous shale or red mudstone, drab mudstone, sandstone. Preliminary data from the report area suggest that rhythmic cycles, if developed in this area, were defined by different sedimentary controls than those operating to the west and north. This premise appears to be corroborated by the other contrasting lithologic criteria outlined above. Jepsen (1971, oral communication) has likened the differential depression of the Bighorn Basin in Early Tertiary time to the inside of a peanut shell in which separate intrabasinal areas were disjunct or were aggrading at different rates at different times. It seems unlikely that the alternative (i.e. uniform subsidence and aggradation) can have prevailed anywhere in the basin for prolonged periods of time. It appears that the autocyclic sedimentary control mechanisms envisaged by Beerbower (1964) were not uniformly operative during the deposition of wide intrabasinal tracts of Willwood molasse in the Bighorn Basin.

Fossil vertebrate remains are abundant in the Willwood Formation of the Sand Creek — No Water Creek area. Five microvertebrate quarries, nine wash sites and fifty surface concentrations were located by the University of Wyoming field party in 1974. All of the fossils are of earliest Eocene age ("Gray Bull") and appear to occupy a stratigraphic position above the range of *Plesiadapis dubius* and beneath the occurrence of *Homogalax protapirinus* (very early "Gray Bull"). Several new mammalian taxa are represented in the No Water collections.

STRUCTURE

Numerous gentle anticlinal folds are developed in the Sand Creek — No Water Creek area. Elsewhere in the Bighorn Basin, the Elk Creek anticline southwest of the town of Basin (Sinclair and Granger, 1911), McCulloch Peaks syncline northeast of Cody (Sinclair and Granger, 1912) and Neiber anticline (Hewett and Lupton, 1917) are evidence of post-Early Eocene deformation in the border belt of folds marginal to the structural axis of the Bighorn Basin. Seismically mapped anticlinal structures in the Worland, Slick Creek, South Frisby, South Fork and Sand Creek oil and gas fields are very poorly expressed in surface exposures of Polecat Bench and Willwood strata (Harris, 1952a,b; Wold, 1952). Since the Polecat Bench Formation is known to unconformably overlap the upturned Lance Formation at the basin margins, this minor folding of Willwood strata in the above oilfields probably reflects reactivated strain along buried structural trends. The very gentle basinward dip of the Tatman Formation on Hillberry Rim and the Squaw Buttes divide suggests that these deformations, if related, occurred in post-Tatman time (Sinclair and Granger, 1912).

Structural relationships in the NE¼ T43N, R89W indicate the structural axis of the Bighorn Basin syncline passes southeast between Mahogany Butte anticline and Chabot anticline in the E½ T43N, R89W and W½ T43N, R88W, respectively (Fig. 2).

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