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GEOLOGIC MAP OF THE PEACH ORCHARD FLAT QUADRANGLE, CARBON COUNTY, WYOMING, AND DESCRIPTIONS OF NEW STRATIGRAPHIC UNITS IN THE UPPER CRETACEOUS LANCE FORMATION AND PALEOCENE FORT UNION FORMATION, EASTERN GREATER GREEN RIVER BASIN, WYOMING-COLORADO

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INTRODUCTION

Geologic mapping of the Peach Orchard Flat 7.5-minute quadrangle (sheet 1) was done as part of a larger effort to acquire detailed data on coal-bearing Upper Cretaceous and Paleocene strata in parts of the eastern Washakie Basin and southeastern Great Divide Basin, an area extending approximately from Rawlins, Wyo., in the north to the Wyoming-Colorado State line in the south (fig. 1). Such data provide vital information critical for resource assessments and land-use-planning studies. This work included (1) mapping of individual coal beds and the boundaries of coal-bearing and adjacent formations, (2) measuring and describing surface stratigraphic sections, with the main focus on coal-bearing units, and (3) study of geophysical logs to determine subsurface coal thicknesses and formation boundaries. The primary coal-bearing unit is the Paleocene Fort Union Formation, with minor coal being present also in the Upper Cretaceous Lance Formation; coal in older Cretaceous strata was not addressed. Surface and subsurface correlations of coal-bearing and adjacent strata are illustrated on sheet 2 and drill holes used for correlations are identified in table 1. Additional data for several isolated coal sections are provided in table 2.

Four new lithostratigraphic units are proposed in this report: the Red Rim Member (new) is assigned to the Lance Formation, and the China Butte Member (new), Blue Gap Member (new), and Overland Member (new) are assigned to the Fort Union Formation. Locations and type sections of these new units are shown in figures 1 and 2, respectively. These four lithologically distinct units are exposed along the east flank of the Washakie Basin, southeast flank of the Great Divide Basin (except for the Blue Gap Member), and locally in the eastern Sand Wash Basin. They are also traceable in the subsurface over large distances in the eastern Washakie and Sand Wash Basins (figs. 1, 3). These units have been identified in numerous subsurface studies, including our own, and informal nomenclatures have been variously applied. Until recently, published surface mapping did not show the lithologically distinct and mappable rock units within the two formations. Several recent studies, however, have allowed initial lithologic subdivision of outcrops previously mapped as Lance and Fort Union Formations (Honey and Robinson Roberts, 1989; Honey, 1990; Hettinger and others, 1991). In this report we modify our own previous informal nomenclature and establish a formal nomenclature for major subdivisions of the Lance and Fort Union Formations. We also demonstrate the mappability of these units at a scale of 1:24,000 in the Peach Orchard Flat 7.5-minute quadrangle (sheet 1).

The areal distribution of the newly named Red Rim, China Butte, Blue Gap, and Overland Members in the eastern Washakie and southeasternmost Great Divide Basins is shown in figure 1. With the exception of the Blue Gap Member, these members are mappable at the surface from the Little Snake River to north of Interstate 80 (I-80), a distance of about 60 mi. The Blue Gap Member is present from north of the Little Snake River to the Dad arch (fig. 1), where it pinches out. Limited exposures demonstrate the presence of these units along the east flank of the Sand Wash Basin and along the east flank of the Great Divide Basin to where they are truncated by the Paleocene and Eocene Battle Spring Formation. Their areal distribution has also been

demonstrated in the subsurface of the Washakie Basin, eastern Sand Wash Basin, and extreme southeastern Great Divide Basin, where their geophysical signatures have been correlated by Honey and Hettinger (1989b), Hettinger and others (1991), and Hettinger and Kirschbaum (1991).

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DISCUSSION OF NEW MEMBERS OF THE LANCE AND FORT UNION FORMATIONS

RED RIM MEMBER (NEW) OF THE LANCE FORMATION

The Red Rim Member is herein named for the sandstone-dominated upper part of the Upper Cretaceous Lance Formation in the eastern Sand Wash, Washakie, and southeastern Great Divide Basins; it lies stratigraphically between the superjacent China Butte Member (new) of the Fort Union Formation and the subjacent lower member of the Lance Formation. It is named for Red Rim, a prominent ridge extending southwest from I-80 in sec. 13, T. 21 N., R. 89 W. (just north of top border of fig. 1) to Separation Creek in sec. 9, T. 19 N., R. 90 W. (fig. 1). The cliffs and dip slopes of Red Rim are composed of sandstones that characterize the member. Hettinger and others (1991, their measured section J) measured a partial section at the south end of Red Rim (loc. J on fig. 1). However, the sandstones in the lower and upper parts are not well exposed at locality J. Consequently, we chose an area farther south as the type section, where good exposures show both the upper and lower contacts of the member. The type section (loc. 4 on fig. 1) is in an area referred to locally as the "Cedars," located astride the Dad arch near State Highway 789. The base of the section is located 2,500 ft FEL (from the east line) and 700 ft FSL (from the south line), and the top is located 1,200 ft FWL (from the west line) and 1,000 ft FSL, in sec. 3, T. 16 N., R. 92 W., in the Doty Mountain 7.5-minute quadrangle (fig. 1). The measured type section is shown graphically in figure 2.

The Red Rim Member is widely distributed across the eastern part of the Greater Green River Basin, where its exposures form prominent reddish-orange cliffs in the southeastern Great Divide Basin, just north of Separation Creek at the south end of the Riner 7.5-minute quadrangle (fig. 1). Exposures are discontinuous south of Separation Creek and lack red coloration, being light gray to yellowish gray. Outcrops of the member have been correlated with subsurface homotaxial rocks in the eastern Washakie and Sand Wash Basins (Honey and Hettinger, 1989b; Hettinger and others, 1991), and westward across the Washakie Basin nearly to the Rock Springs uplift where the unit is absent due to pre-Fort Union erosion (Hettinger and Kirschbaum, 1991). The Red Rim Member is equivalent to the lower and middle zones of the unnamed Cretaceous and Tertiary sandstone unit of Honey and Hettinger (1989b), Hettinger and others (1991), and Hettinger and Kirschbaum (1991). Additional studies by Tyler and McMurry (1994) also showed that equivalent sandstones are present throughout the Sand Wash Basin, but thin considerably toward the northwest corner of the basin, and are removed entirely by erosion near the Rock Springs uplift.

The Red Rim Member is about 685 ft thick at the type section. It thins to the south to about 370 ft near Baggs, Wyo., just north of the State line (fig. 1), and to about 210 ft in the southeast Sand Wash Basin. To the north it thickens to about 915 ft in the subsurface near Red Rim. Regional thickness trends are shown in figure 3. The member consists of thick, superposed, multistoried sandstone bodies as much as 200 ft thick that are separated by relatively thin layers of silty shale, carbonaceous shale, and mudstone that are typically less than 20 ft thick, but may be as much as 100 ft thick. In the Washakie Basin, the Red Rim Member displays an overall coarsening-upward grain size, as described for the lower and middle zones of the unnamed Cretaceous and Tertiary sandstone unit by Hettinger and others (1991). The lower part of the member contains fine- to medium-grained sandstone with rare chert pebbles, and the upper part contains medium- to coarse-grained sandstone with abundant chert pebbles. Individual sandstones in multistoried units are commonly trough crossbedded with basal lag deposits consisting of claystone and siltstone clasts (lower parts of the Red Rim Member), or siltstone and claystone clasts and chert pebbles (higher parts of the Red Rim Member). We interpret these sandstones as fluvial channel deposits. Their physical characteristics and thickness trends are discussed more fully in Hettinger and others (1991).

The base of the Red Rim Member is generally poorly exposed, and is placed at the base of the first major sandstone in a succession of thick sandstones that characterize the upper part of the Lance Formation. On geophysical logs, individual sandstones are recorded with blocky signatures and may be several hundred feet thick (fig. 2). Subsurface correlations by Hettinger and others (1991) showed the basal contact to intertongue with underlying strata; however, abrupt increases in sandstone thickness and grain size above the contact indicate the contact may in fact be unconformable. Where exposed on outcrop, the Red Rim Member overlies the lower member of the Lance Formation along a sharp contact. If an unconformity exists at

this level, it is probably of lesser magnitude than the Cretaceous-Tertiary unconformity that marks the top of the member (see discussion under China Butte Member). The magnitude of the Cretaceous-Tertiary unconformity increases westward across the Washakie Basin, as indicated by its angular discordance with underlying strata (Hettinger and Kirschbaum, 1991).

The Red Rim Member is distinguished from the lower member of the Lance by having (1) thicker and more laterally extensive sandstones that become increasingly coarser grained higher in the member and (2) little to no mudrock (fig. 2). In contrast, the lower member of the Lance is generally characterized by thick units of gray and yellow-brown mudstone, siltstone, and carbonaceous shale, with subordinate amounts of thin lenticular sandstone; a few coals are also present mainly in the basal 100 ft. The Red Rim Member is separated from the overlying coal-bearing China Butte Member of the Fort Union Formation by a conglomerate marking a regional unconformity. A detailed measured section of the Lance Formation was illustrated in Hettinger and others (1991, lower part of their measured section C). The line of measured section C is shown as locality C on figure 1 and the described lithologies are shown in figure 2. The part of measured section C that extends across the Lance Formation is labeled MSA (secs. 28, 29, 32, and 33, T. 15 N., R. 91 W.) on the geologic map of the Peach Orchard Flat 7.5-minute quadrangle (sheet 1).

Based on palynological analysis, the Red Rim Member is Late Cretaceous in age (late but not latest Maastrichtian). Sample localities and palynomorphs for the member in the eastern Washakie Basin are listed in Hettinger and others (1991); palynomorph localities D6473 and D6474 are shown on the geologic map in the vicinity of MSA (sheet 1).

CHINA BUTTE MEMBER (NEW) OF THE FORT UNION FORMATION

The China Butte Member of the Fort Union Formation is named herein for an interval of interbedded sandstone, siltstone, mudstone, carbonaceous shale, and coal that constitutes the lower part of the Fort Union Formation in the eastern Washakie, Sand Wash, and Great Divide Basins; the basal part also contains some conglomerate. In the eastern Sand Wash and southeastern Washakie Basins, the member lies stratigraphically between the underlying Red Rim Member of the Lance Formation and the overlying Blue Gap Member (new) of the Fort Union Formation (fig. 3). North of the Dad arch the Blue Gap Member pinches out (see below), and the China Butte Member lies between the Red Rim Member of the Lance Formation and the Overland Member (new) of the Fort Union Formation. The name is derived from China Butte, located in the northeastern part of the Doty Mountain 7.5-minute quadrangle. Because only part of this coal-bearing unit is present at China Butte, the type section (loc. 3, fig. 1) is located in the "Cedars" area: the base of the measured section is 1,200 ft FWL and 1,000 ft FSL of sec. 3, T. 16 N., R. 92 W., in the Doty Mountain 7.5-minute quadrangle; the top of the measured section lies on the section line between secs. 4 and 9, and 1,950 ft from the southeast corner of sec. 4, T. 16 N., R. 92 W., in the Duck Lake 7.5-minute quadrangle. Lithologies in the type section of the China Butte Member are shown in figure 2 and were previously shown as part of measured sections G and H in Hettinger and others (1991). Equivalent strata were previously assigned to the lower zone (or lower part) of the Fort Union Formation and the upper zone (or upper part) of the unnamed Cretaceous and Tertiary sandstone unit (Hettinger and others, 1991; Honey and Hettinger, 1989b).

Exposures of the China Butte Member typically form valleys and ridges, with the valleys formed by gray and brown mudstone and claystone, and the ridges capped by yellowish-gray sandstone. Clinker locally forms prominent red outcrops, as at China Butte itself. The member is mappable at the surface and traceable in the subsurface over the same area as the Red Rim Member of the Lance Formation. Westward across the Washakie Basin, the upper part has been correlated with the lower part of the Fort Union Formation on the east flank of the Rock Springs uplift, indicating that rocks equivalent to the lower part of the member were probably not deposited in the Rock Springs area (Hettinger and Kirschbaum, 1991). Equivalent coal-bearing rocks are present throughout the Sand Wash Basin (Tyler and McMurry, 1994).

Lithologies and thickness trends of the China Butte Member (fig. 3) were summarized in Hettinger and others (1991), and detailed lithologic descriptions from exposures in the Baggs 15-minute quadrangle (includes the Peach Orchard Flat, Smiley Draw, Dixon, and Baggs 7.5-minute quadrangles) were provided by Honey (1984). Cross references between measured sections shown on the geologic map of the Peach Orchard Flats 7.5-minute quadrangle and Honey (1984) are given in table 3. The China Butte Member contains repetitive, fining-upward cycles consisting of a thick basal sandstone overlain successively by siltstone, claystone, carbonaceous shale, and coal. The basal sandstone may be as thick as 220 ft, although it is generally much thinner, and the finer grained upper coaly part is as much as 80 ft thick. Coals vary in thickness to a maximum of 40 ft and are commonly overlain by a few feet of mudrock; the coal or the overlying mudrock is overlain directly by the basal sandstone of the next cycle. These basal sandstones are typically light to yellowish gray and multistoried, and vary in grain size from fine to coarse with the medium- and coarse-grained sandstones confined to the lower part of the member. Coal distribution and continuity in the China Butte Member are shown in various reports including Edson (1979), Hettinger and Kirschbaum (1991), Hettinger and others (1991), Honey (1990), Honey and Hettinger (1989a, b), and Honey and Robinson Roberts (1989), as well as on sheet 2 of this report.

In the eastern Washakie Basin, the lowest unit in the China Butte Member (shown by a pattern on the geologic map) is a multistoried sandstone, as much as 220 ft thick. This unit typically grades upward from a conglomerate and (or) conglomeratic sandstone in the basal 2–75 ft to a medium- to coarse-grained sandstone. Conglomerate pebbles are predominantly gray and black chert, with minor white and pink quartzite, quartz, and porphyritic felsic igneous rock. This lowest multistory sandstone previously constituted the upper zone (or part) of the unnamed Cretaceous and Tertiary sandstone unit of Honey and Hettinger (1989b) and Hettinger and others (1991). The basal conglomerate overlies an unconformity that separates rocks of Late Cretaceous age from rocks of Tertiary age; the youngest Maastrichtian is missing as indicated by the highest palynomorph samples obtained from the underlying Red Rim Member of the Lance Formation. This multistoried sandstone unit is the basal fluvial channel deposit of the Fort Union Formation and is part of the lowest fining-upward cycle, inasmuch as it is overlain by mudstone and coal.

The China Butte Member was mapped from the Wyoming-Colorado State line north to I-80. North of I-80, the member forms steeply dipping exposures on the west flank of the Rawlins uplift. The prominent basal conglomerate and conglomeratic sandstone have also been traced from a few miles north of the Little Snake River to the southern part of the Riner 7.5-minute quadrangle (fig. 1). From there north to I-80, exposures are poor and the base of the member is inferred from aerial photographs. As explained in Hettinger and others (1991), the basal conglomeratic interval on well logs was picked as a strong deflection (representing coarse-grained lithologies) at a stratigraphic position compatible with that known from surface studies. Logs were supplemented with descriptions of drill hole cuttings, where available. The upper contact of the China Butte Member is placed at the base of the massive claystones and siltstones of the overlying Blue Gap Member from the southeastern Sand Wash Basin to the Dad arch in the eastern Washakie Basin, where the Blue Gap Member pinches out. Farther north, the upper contact of the China Butte Member is placed beneath the basal sandstones of the Overland Member, which are coarse grained to granulitic from the Dad arch to the Continental Divide, and locally conglomeratic north of I-80 on the west flank of the Rawlins uplift. Extensive cover is present between the Continental Divide and I-80, and the top contact of the member is necessarily inferred from aerial photographs.

The China Butte Member is about 1,060 ft thick at the type section. It thins to the south, to about 735 ft near Baggs, and to as little as 500 ft in some wells in the eastern Sand Wash Basin. It thickens north of the type section, to between 2,000 and 2,160 ft in the subsurface near Red Rim; this thickening is accomplished in part through the addition of coal-bearing beds in the lower part of the member, and in part by the inclusion of beds in the upper part of the member that are laterally equivalent to the Blue Gap Member (fig. 3). Just north of I-80 on the west flank of the Rawlins uplift, a measured surface section shows the China Butte Member to be at least 2,180 ft thick; however, the member thins farther north due to facies changes and erosional truncation (Honey and Roberts, 1994).

As detailed in Hettinger and others (1991), the age of the China Butte Member is early Paleocene. Palynological samples collected in the eastern Washakie Basin from the basal sandstone and basal coal beds contain early Paleocene palynomorphs typical of zone P2 of Nichols and Ott (1978). U.S. Geological Survey (USGS) palynomorph localities D6779A and D6779B (Hettinger and others, 1991) were collected from the member's lowest coal bed in the Peach Orchard Flat 7.5-quadrangle (sheet 1) and dated as early Paleocene (zone P2). Palynomorphs characteristic of zone P1 have not been found south of the Rawlins uplift. Vertebrate fossils also indicate a Paleocene age for the China Butte Member; fossils from the middle and upper parts in the Blue Gap quadrangle (fig. 1) are Torrejonian (early Paleocene) in age (Rigby, 1980—Swain Quarry and other localities; Hettinger and others, 1991). Although vertebrate fossils have not been reported previously from the base of the China Butte Member, work in progress by J.G. Honey and M.C. McKenna (Adjunct Professor, Laramie, Wyo., University of Wyoming; Curator Adjunct, Boulder, Colo., University of Colorado) indicates that north of the Dad arch the stratigraphically lowest beds are as old as Puercan (earliest Paleocene).

BLUE GAP MEMBER (NEW) OF THE FORT UNION FORMATION

The name Blue Gap Member of the Fort Union Formation is herein applied to an interval of predominantly olive- to brownish-gray claystone and mudstone between the overlying Overland Member (new) and the underlying China Butte Member of the Fort Union Formation in the southeast Washakie Basin, and between overlying rocks assigned to the Wasatch Formation and underlying rocks equivalent to the China Butte Member of the Fort Union Formation in the eastern Sand Wash Basin (fig. 3). The Blue Gap Member is mappable at the surface along the southeast margin of the Washakie Basin (fig. 1), and is traceable on subsurface geophysical logs from the Dad arch south to Craig, Colo. (Honey and Hettinger, 1989b). The Blue Gap Member is named for Blue Gap Draw, which is located directly west of outcrops of the member in sec. 24, T. 15 N., R. 92 W., Blue Gap 7.5-minute quadrangle (fig. 1). Outcrops of the Blue Gap Member are sporadic, because these clay-rich rocks are easily weathered and obscured by vegetation. However, prominent exposures are on the east bank of Muddy Creek in SE1/4 sec. 10, and NE1/4 sec. 15, T. 13 N., R. 91 W. These exposures, which show the claystone lithology most typical of the member, are visible from Wyoming State Highway 789. The type section of the Blue Gap Member (loc. 1 on fig. 1) was measured along a line beginning about 550 ft

FSL and 1,850 ft FEL, and ending about 250 ft FSL and 2,600 ft FEL, in sec. 10, T. 13 N., R. 91 W., in the Dixon 7.5-minute quadrangle. The lower part of the member is not exposed at the type section. However, complete thicknesses were obtained in the Blue Gap and Doty Mountain 7.5-minute quadrangles, where the member is considerably thinner than at the type section and in numerous well logs from the southeastern Washakie and eastern Sand Wash Basins. The entire Blue Gap Member can be seen at a location approximately 1,500 ft FEL and 1,800 ft FNL (from the north line) of sec. 34, T. 17 N., R. 92 W., in the Doty Mountain 7.5-minute quadrangle (fig. 1). On geophysical logs, the member is marked by a distinctive low resistivity interval (fig. 2), which has long been recognized by subsurface stratigraphers (Colson, 1969; Beaumont, 1979; Honey and Hettinger, 1989b; Tyler and McMurry, 1994).

Lithologies at the type section of the Blue Gap Member are shown in figure 2. Hettinger and others (1991) previously included these rocks within their upper zone of the Fort Union Formation and depicted the strata in their measured sections A, D, and G. Measured section A of Hettinger and others (1991) is here designated the type section of the Blue Gap Member. The dominant lithologies are claystone and mudstone; however, some thin interbeds of fine-grained sandstone, siltstone, rare ironstone, and carbonaceous shale are also present. Plant rootlets and fragments are common. A detailed description of the type section is given in this report in the "Description of Map Units" on sheet 1. In the southeastern Washakie Basin, from the "Cedars" area south to Muddy Creek (fig. 1), the base of the Blue Gap Member is marked by thick massive claystone, silty claystone, or siltstone resting on a dip-slope-forming ironstone that is 0.5–1 ft thick, reddish purple to grayish black, silty, sandy, and commonly concretionary. South of Muddy Creek the basal strata are commonly covered, as at the type section, but where exposed the claystones are in sharp contact with the underlying medium-grained sandstone. The upper boundary in the eastern Washakie Basin is also sharp, being recognized by the abrupt grain-size increase in the basal sandstones of the overlying Overland Member. Near Craig, Colo., in the southeastern Sand Wash Basin, the Blue Gap Member is directly overlain by a conglomerate and arkosic sandstones assigned to the basal part of the Wasatch Formation (M. Brownfield, USGS, oral commun., 1985). Based on earlier subsurface correlations (Honey and Hettinger, 1989b), the lower part of the Wasatch Formation in the southeastern Sand Wash Basin was interpreted to be equivalent to the lower part of the Overland Member of the Fort Union Formation to the north.

The Blue Gap Member is wedge shaped in a north-south direction in the eastern Washakie and Sand Wash Basins, thinning from a maximum thickness of about 570 ft in the eastern Sand Wash Basin to 0 ft in the "Cedars" area on the Dad arch (fig. 3). At the type section a partial thickness of 290 ft was measured. It is not present north of the Dad arch and its westward extent across the Washakie Basin is unknown. Tyler and McMurry (1994) noted that the member (their "gray-green mudstone unit") is present and thick along the east and west margins of the Sand Wash Basin, but is absent in the center of the basin because of erosion by the superjacent Overland Member of the Fort Union Formation (their "basin sandy unit" of the Fort Union Formation). Our geologic mapping in the Blue Gap 7.5-minute quadrangle just north of the Peach Orchard Flat 7.5-minute quadrangle shows local removal of the Blue Gap Member beneath the basal sandstone of the Overland Member in SW1/4 sec. 34, T. 16 N., R. 92 W. This evidence for erosion of the upper part, combined with the abrupt upward grain-size change at the boundary, indicates a probable unconformity between the two units.

No fossils useful for dating purposes have been found in the Blue Gap Member. However, its age is constrained by the early Paleocene (Torrejonian) Swain Quarry fossil mammal locality in the underlying China Butte Member, and by late Paleocene palynomorphs and transitional early/late Paleocene (Torrejonian/Tiffanian) vertebrate fossils in the lowest part of the overlying Overland Member (see respective discussions).

OVERLAND MEMBER (NEW) OF THE FORT UNION FORMATION

The Overland Member of the Fort Union Formation is here designated for a distinctive succession of predominantly light-gray sandstone, siltstone, and mudstone that crops out between overlying variegated mudstones of the Wasatch Formation and underlying claystones of the Blue Gap Member along the southeast margin of the Washakie Basin. Farther north, beyond the pinchout of the Blue Gap Member, the Overland Member lies between the main body of the Wasatch Formation (and its Battle Spring Formation equivalent) and the underlying China Butte Member of the Fort Union Formation. The Overland Member commonly weathers to light-gray to white, fluted badlands topography. The name is taken from the Overland Trail, which passes across exposures in the Doty Mountain 7.5-minute quadrangle (fig. 1). The type section is located in the "Cedars" area (loc. 2 on fig. 1). The base of the section is about 2,150 ft FEL and 1,300 ft FSL, in sec. 34, T. 17 N., R. 92 W., and the top is 600 ft FWL and 1,150 ft FSL of sec. 34, T. 17 N., R. 92 W., in the Doty Mountain 7.5-minute quadrangle. Lithologies at the type section are shown in figure 2. These rocks were previously referred to as the "unnamed upper Paleocene unit" (Honey and Hettinger, 1989b; Hettinger and others, 1991), and lithologies at the type section were shown as part of measured section G of the latter report. The member forms intermittent, light-gray badlands from the banks of the Little Snake River in the south to the west flank of the Rawlins uplift in the north, with the most spectacular badlands present in the "Cedars" area and in prominent escarpments along the Continental Divide in the southwestern part

of the Seaverson Reservoir 7.5-minute quadrangle (fig. 1).

The Overland Member is 925 ft thick at its type section (loc. 2 in fig. 1). It thins considerably to the south and is 425 ft thick in sec. 21, T. 14 N., R. 91 W., in the Peach Orchard Flat 7.5-minute quadrangle (measured section B in Hettinger and others, 1991; measured section S17 of this report). To the north, the Overland Member thickens to at least 2,271 ft on outcrop (Hettinger and others, 1991, their measured section K); the location of measured section K is shown on figure 1. Regional variations in lithology and thickness are shown in figure 2 and have been described previously by Honey and Hettinger (1989b) and Hettinger and others (1991) (their "unnamed upper Paleocene unit").

Regional studies show that the Overland Member is widespread in the eastern Greater Green River Basin (fig. 3). Outcrops are present along the entire eastern margin of the Washakie Basin and extend northward into the southeast Great Divide Basin. In the subsurface of the Washakie Basin, the member is characterized by a variety of geophysical signatures. In that area, the base is recognized by prominent resistivity deflections that record the influx of abundant, generally thick sandstones atop the Blue Gap or China Butte Members (fig. 2). The remainder of the Overland Member is characterized mainly by subdued deflections characteristic of fine-grained lithologies, except where coal signatures are present in the Cherokee coal zone. The resistivity change between the Blue Gap Member and the Overland Member can be traced southward in geophysical logs along the eastern margin of the Sand Wash Basin to just north of Craig, Colo. (Honey and Hettinger, 1989b). Rocks equivalent to the Overland Member have also been correlated in the subsurface westward across the Washakie Basin to the upper part of the Fort Union Formation on the east flank of the Rock Springs uplift (Hettinger and Kirschbaum, 1991, their "unnamed upper Paleocene unit").

In the Washakie and southeastern Great Divide Basins, the Overland Member includes a basal sandstone zone and an overlying thick fine-grained interval. In the northeastern part of the Washakie Basin and extreme southeastern part of the Great Divide Basin, the highest part contains the Cherokee coal zone (fig. 3). The basal sandstone zone is less than 100 ft thick south of the Dad arch; it is mostly covered north of the arch but geophysical logs show it to be as much as 1,050 ft thick in the subsurface. The thickness variations seem to be related to facies changes with the overlying fine-grained interval (fig. 3). The basal sandstone zone consists of light-gray sandstones, which are generally coarse grained and contain lenses of quartz and feldspar granules and chert pebbles. To our knowledge, this marks the lowest stratigraphic interval containing coarse grains and pebbles above the basal sandstone zone of the China Butte Member of the Fort Union Formation. The overlying fine-grained interval is 200 to more than 1,050 ft thick (the 1,050-ft figure represents an incomplete thickness due to cover); thickness variations are related in part to an unconformity at the top of the Overland Member (fig. 3). The fine-grained interval consists of light-gray, massive, fine-grained sandstone, sandy siltstone, and mudstone; subordinate lithologies include crossbedded sandstone and thin, tabular, sandy ironstone. In the extreme southeastern part of the Great Divide Basin, the fine-grained interval is also characterized by carbonaceous shales, generally thin calcareous sandstones, and coals. Crayfish burrows are common in the fine-grained interval south of the Continental Divide, and in exposures of the Overland Member on the west flank of the Rawlins uplift (Hasiotis and Honey, 2000). Between the Continental Divide and the Rawlins uplift, however, crayfish burrows are rare in outcrops. In the Cherokee coal zone, coal beds as much as 35 ft are present (Sanders, 1975).

As discussed in Honey and Hettinger (1989b) and Hettinger and others (1991), previous studies have placed rocks equivalent to the Overland Member into either the Fort Union or Wasatch Formations. On the eastern flank of the Greater Green River Basin, outcrops of the Overland Member have typically been mapped as part of the Fort Union Formation for which Paleocene ages have been documented. However, in subsurface correlation studies of the eastern Greater Green River Basin, these rocks have usually been placed in the Wasatch Formation with an assumed Eocene age (see discussion in Hettinger and others, 1991). Recently, in the Sand Wash Basin, Tyler and McMurry (1994) divided these strata into two informal units of the Fort Union Formation: their "basin sandy unit" corresponding to our basal sandstone zone of the Overland Member, and their "upper shaly unit" corresponding to the higher, finer grained parts of the Overland Member in the Washakie Basin.

Over much of the study area the basal contact of the Overland Member with the underlying Blue Gap and China Butte Members is recognized by the abrupt upward increase in grain size, being marked by the appearance of sandstone containing a large allogenic component of quartz, feldspar, chert granules, and pebbles. Variations in grain size in the basal sandstone zone are common throughout the study area. Clasts are largest from a few miles north of the Little Snake River to Muddy Creek (fig. 1), but become progressively finer grained northward to the vicinity of I-80. For example, from the "Cedars" area north to the Continental Divide, exposures of the basal sandstones contain relatively minor amounts of granules and pebbles, and north of the Continental Divide limited exposures of the basal sandstone are characterized by medium- to coarse-grained sandstone. Farther north on the west flank of the Rawlins uplift, however, basal sandstones of the Overland Member are again coarse grained to conglomeratic. We interpret the widespread and sharp juxtaposition of these coarse-grained to pebbly sandstones at the base of the Overland Member atop finer grained strata of the Blue Gap and China Butte Members to represent a regional unconformity.

Additional lines of evidence that indicate the Overland Member was deposited on an unconformity extending across most of the Great Divide, Sand Wash, and Washakie Basins include:

(1) In the Sand Wash Basin, Tyler and McMurry (1994) contended that their "basin sandy unit" (lower sandy part of the Overland Member) lies disconformably on the "gray-green mudstone unit" (Blue Gap Member) or the "lower coal-bearing unit" (China Butte Member); they also indicated that the "gray-green mudstone unit" (Blue Gap Member) has been completely removed in the center of the Sand Wash Basin.

(2) Near Craig, Colo., greenish-gray sandy mudstones of the Blue Gap Member are sharply overlain by conglomerates assigned either to the Wasatch Formation or to the "basin sandy unit" of the Fort Union Formation (Honey and Hettinger, 1989b; Tyler and McMurry, 1994). Geophysical correlations (Honey and Hettinger, 1989b) indicate that these conglomerates are laterally equivalent to the lower sandstones of the Overland Member.

(3) In the southeast Washakie Basin (as noted in the discussion of the Blue Gap Member), the base of the Overland Member is marked by a sharp increase in grain size, and is locally erosional into the Blue Gap Member.

(4) Although the lower contact of the Overland Member is poorly exposed in the area between the Continental Divide and I-80, geophysical logs there and to the west record an influx of stacked, thick sandstone bodies above the contact. This thick, basal sandstone zone of the Overland Member is present in the middle of the Washakie Basin, but thins westward toward the Rock Springs uplift according to Hettinger and Kirschbaum (1991); their cross section indicates that the lower contact of the basal sandstone of the Overland Member may correlate with an intraformational unconformity on the east flank of the Rock Springs uplift noted by Roehler (1979a, b), which raises the possibility that the base of the Overland Member is disconformable across the entire Washakie Basin.

(5) On the west flank of the Rawlins uplift, the base of the Overland Member locally overlies the China Butte Member with angular discordance (Barlow, 1953, 1955; Honey and Roberts, 1994). Honey and Roberts (unpub. data) measured an angular discordance of 39°. Barlow previously measured a 45° discordance, and placed Overland Member-equivalent strata into the Wasatch Formation.

Upper contact relations of the Overland Member were discussed in detail by Hettinger and others (1991, their "unnamed upper Paleocene unit"). In general, the contact is marked by a sharp increase in grain size associated with the overlying Wasatch Formation. From just north of Baggs to the "Cedars" area, the base of the overlying Wasatch Formation is marked by conglomerate and conglomeratic sandstone that separates light-gray rocks of the Overland Member from variegated mudstones of the main body of the Wasatch. However, along the Little Snake River several thin conglomerates are near the top of the Overland Member, and the distinctive marker conglomerate at the base of the Wasatch is apparently absent; therefore, at that location, the top of the Overland Member is placed beneath the lowest variegated mudstones. North of the "Cedars" area, fine-grained rocks of the Overland Member are overlain by coarse-grained arkosic sandstone lithologically and stratigraphically equivalent to the Battle Spring Formation in the Great Divide Basin. North of I-80, on Windy Hill in T. 21 N., R. 91 W., the top of the Overland Member is marked by an intensively crayfish-burrowed, hard sandstone that separates dark-gray mudstones at the top of the Cherokee coal zone from siltstones and arkosic sandstones of the overlying Battle Spring Formation (Hasiotis and Honey, 2000, their fig. 10A). Farther north and east, on the west flank of the Rawlins uplift, arkosic sandstones of the Battle Spring Formation overlie burrowed sandstone of the Overland Member with angular discordance. These relations are interpreted to indicate that the upper contact of the Overland Member is probably an unconformity all along the eastern Washakie and southeastern Great Divide Basins and part way across the Washakie Basin to the west. However, in the northeast Sand Wash Basin, the more subtle lithologic change marking the Wasatch–Fort Union boundary raises the possibility that the two formations are locally conformable there.

The age of the Overland Member in the eastern Washakie and southeastern Great Divide Basins, based on palynomorphs, is late middle and late Paleocene (palynomorph zones P3 or P4 through P6 of Nichols and Ott, 1978), and vertebrate fossils indicate a latest Torrejonian to early Tiffanian age for the rocks at or near the base of the member (Hettinger and others, 1991). On the east flank of the Rock Springs uplift, probable correlative rocks of the upper part of the Fort Union Formation are Tiffanian and Clarkforkian in age (Hettinger and Kirschbaum, 1991).

In summary, the Overland Member is named in this report for lithologically distinctive rocks of late Paleocene age. These rocks have been traditionally mapped on outcrop in the eastern Greater Green River Basin as part of the Fort Union Formation, and we follow the traditional usage. The basal contact of the Overland Member and stratigraphically equivalent rocks is unconformable over large areas in the Sand Wash, Washakie, and southeast Great Divide Basins. The upper contact also represents an unconformity in the eastern Washakie and southeast Great Divide Basins. If continued study supports the presence, over wide areas, of unconformities at the base and top of the Overland Member, then this, in combination with the distinctive lithology of this rock unit, may warrant the eventual elevation of the Overland Member to formation status.

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