Nomenclature and Correlation of Lithologic Subdivisions of the Jefferson and Three Forks Formations of Southern Montana and Northern Wyoming

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CONTRIBUTIONS TO STRATIGRAPHY

GEOLOGICAL SURVEY BULLETIN 1194-N

UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON : 1965

UNITED STATES DEPARTMENT OF THE INTERIOR

STEWART L. UDALL, *Secretary*

GEOLOGICAL SURVEY

Thomas B. Nolan, *Director*

The U.S. Geological Survey Library catalog card for this publication appears after page N18.

For sale by the Superintendent of Documents, U.S. Government Printing Office
Washington, D.C., 20402 - Price 15 cents (paper cover)

CONTENTS

ILLUSTRATIONS

NOMENCLATURE AND CORRELATION OF LITHOLOGIC SUBDIVISIONS OF THE JEFFERSON AND THREE FORKS FORMATIONS OF SOUTHERN MONTANA AND NORTHERN WYOMING

By Charles A. Sandberg

ABSTRACT

The Jefferson Formation (Upper Devonian) comprises a thick lower member and the Birdbear Member. The overlying Three Forks Formation (Devonian and Mississippian) comprises the Logan Gulch, Trident, and Sappington Members. These members are described at the classic type section of the Jefferson and Three Forks Formations near Logan, Mont., and their distribution in southern Montana and northern Wyoming is shown. The members are correlated with stratigraphic units in adjoining parts of Montana, Idaho, Wyoming, North Dakota, and Canada.

INTRODUCTION

Lithologic subdivisions of the outcropping Jefferson Formation of early Late Devonian (Frasnian) age and Three Forks Formation of latest Devonian (Famennian) and earliest Mississippian (Tournaisian) age have long been recognized in southern Montana and northern Wyoming. They have been determined to be exact equivalents of previously recognized subsurface units in the Williston basin and surrounding areas. A uniform subsurface nomenclature for Devonian rocks in the Williston basin and in Montana and northern Wyoming east of the 111th meridian was proposed by Sandberg and Hammond (1958). This subsurface nomenclature, however, is not directly applicable to equivalent outcropping rocks because of different concepts of subsurface and surface mappability. A similar uniform surface nomenclature is here proposed to replace various informal subdivisions, such as those used by Haynes (1916), McMannis (1962), Robinson (1963), and Sandberg (1962, 1963), and also to replace one subsurface member, which was proposed by Sandberg and Hammond (1958).

The Jefferson Formation is here divided into a thick lower member and the thin Birdbear Member. The Three Forks Formation is here divided into three members, which are, in ascending order, the Logan Gulch and Trident Members of Late Devonian age and the Sappington Member (formerly Sappington Sandstone Member) of Late Devonian and Early Mississippian age. The distribution of these members and the location of Logan, Mont., the type locality, are shown on figure 1.

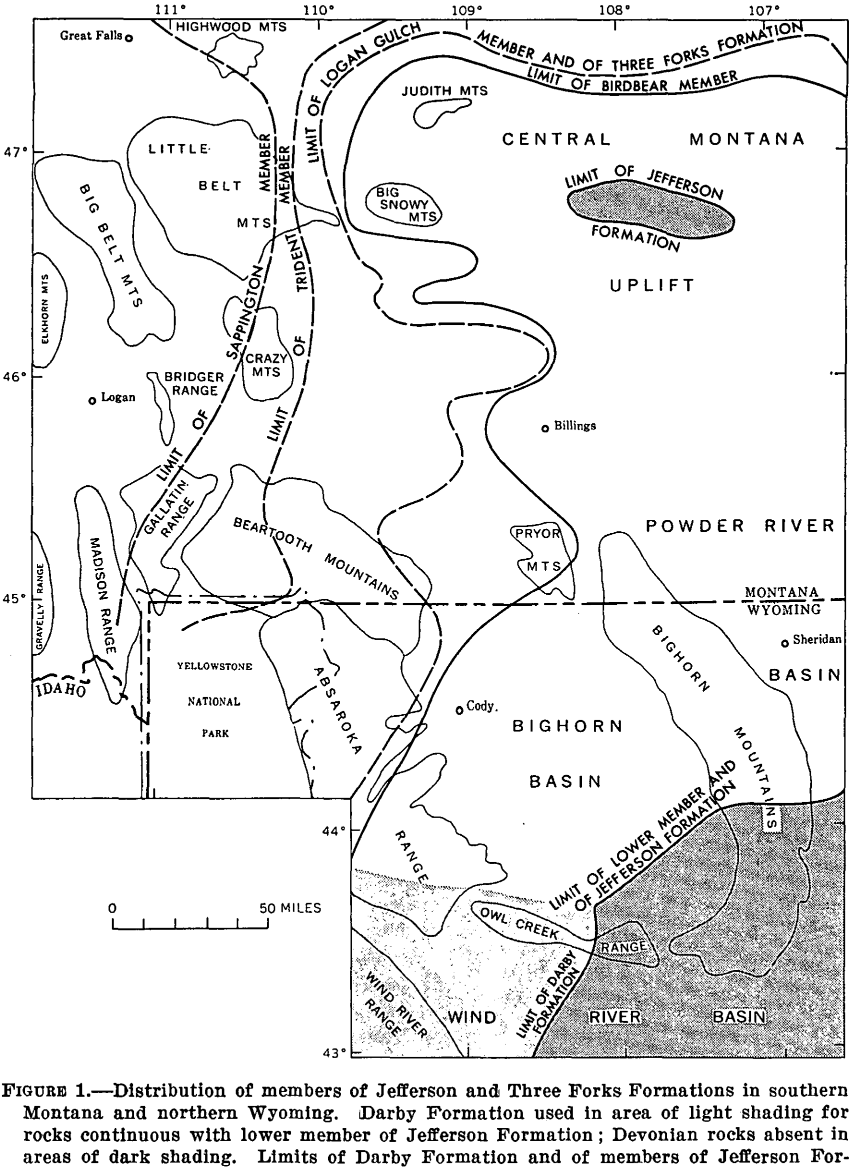

FIGURE 1.—Distribution of members of Jefferson and Three Forks Formations in southern Montana and northern Wyoming. Darby Formation used in area of light shading for rocks continuous with lower member of Jefferson Formation; Devonian rocks absent in areas of dark shading. Limits of Darby Formation and of members of Jefferson Formation, solid lines; limits of members of Three Forks Formation, dashed lines; members or formations absent on side of lines without wording.

The assistance of several colleagues is gratefully acknowledged. P. W. Richards helped measure about a third of the 50 detailed sections upon which the present nomenclature is based. W. G. Pierce and A. E. Roberts helped measure several sections in their areas of mapping. Special thanks are expressed to G. D. Robinson for his assistance in evolving this nomenclature through his mapping of the Jefferson and Three Forks Formations in the Three Forks (Robinson, 1963) and Toston quadrangles just west and north, respectively, of their type locality.

STRATIGRAPHIC RELATIONS

The Jefferson and Three Forks Formations constitute a sequence of dominantly marine rocks that reaches a maximum thickness of about 1,150 feet in southwestern Montana. This sequence thins southeastward to extinction partly by transgressive onlap at the base but largely by erosion beneath a regional unconformity at the top. Only minor hiatuses and erosional episodes interrupted deposition of this sequence. There was no break in cyclical deposition between the lower member and the Birdbear Member of the Jefferson. The Jefferson and Three Forks are generally conformable except in the eastern Beartooth and eastern Little Belt Mountains, where they are separated by a minor unconformity. Each member of the Three Forks is a discrete lithogenetic unit deposited under different environmental conditions. The restricted-marine Logan Gulch Member and the open-marine Trident Member are commonly conformable but are locally disconformable. A widespread disconformity separates the Trident from the marginal-marine largely regressive Sappington Member.

The Jefferson Formation conformably overlies the Maywood Formation of Late Devonian age in and northwest of the northern Beartooth Mountains and northern Gallatin Range and the Souris River Formation, an equivalent of the Maywood, farther east in Montana (Sandberg and McMannis, 1964). Beyond the southern limits of the Maywood and Souris River in parts of central and south-central Montana and northern Wyoming, the Jefferson unconformably overlies the Bighorn Dolomite of Late Ordovician age, rocks of Early Ordovician and Late Cambrian age, or locally the Beartooth Butte Formation of Early Devonian age. In the northern Powder River Basin (fig. 1) the Jefferson unconformably overlies a thin wedge of Silurian rocks.

The Sappington Member at the top of the Three Forks Formation is overlain by the Mississippian part of the dark shale unit of Devonian and Mississippian age (Sandberg, 1963, fig. 64.2). The dark shale unit truncates progressively older beds from Logan, Mont., eastward and southeastward, and it rests unconformably on all members of the Three Forks and Jefferson Formations in descending order. The magnitude of this post-Three Forks unconformity is illustrated by close spacing of the limits of all members except the thick lower member of the Jefferson (fig. 1). Beyond the limit of the dark shale unit (Sandberg, 1963, fig. 64.1), the lower part of the Madison Limestone or the equivalent Lodgepole Limestone of the Madison Group of Mississippian age overlies this regional unconformity.

JEFFERSON FORMATION

The name Jefferson Formation was first used by Peale (1893, p. 27–29) to describe brown and black crystalline "limestones" that underlie his Three Forks Shales and overlie his Gallatin Formation of Cambrian age on both sides of the Jefferson River west of the junction of the three forks of the Missouri River. Although he did not designate a type section, Peale (1893, pl. 6) sketched the excellent exposures on the north side of the Gallatin River near the present town of Logan, Mont., where Sloss and Laird (1946, 1947) later established the type section. Sloss and Laird (1947, p. 1410) suggested a higher content between the Jefferson and Three Forks Formations than Peale had apparently described, but Sandberg and Hammond (1958, p. 2314–2315) and most other workers, for example, McMannis (1955, p. 1396; 1962, p. 5) and Robinson (1963, p. 28), have reverted to Peale's original contact. A detailed stratigraphic section of the type Jefferson Formation in the S½SE¼ sec. 25, T. 2 N., R. 2 E., Gallatin County, Mont., was presented by Sandberg (1962).

The Jefferson Formation was divided, by Sloss and Laird (1947, p. 1409), into a limestone member and an overlying dolomite member of roughly equal thickness. These members appear to be unrecognizable even short distances from the type section (McMannis, 1955, p. 1397; Robinson, 1963, p. 28), and the terminology is therefore not in common use. Sandberg and Hammond (1958) recognized that the type Jefferson comprised exact equivalents of the Duperow and Birdbear Formations of the Williston basin area and designated the Jefferson a group in the subsurface east of the 111th meridian in Montana. Since then, the widespread distribution of the thick Duperow equivalent and thin Birdbear equivalent in the outcropping Jefferson Formation have been widely recognized (McMannis, 1962; Sandberg, 1963). To forestall the eventual use of these commonly unmappable equivalents as formations conflicting with the long-established Jefferson Formation, a nomenclature based on lithologic subdivisions of the Jefferson is proposed.

LOWER MEMBER

The bottom 470 feet of the type Jefferson Formation (Sandberg, 1962, p. 48–50), which is the equivalent of the subsurface Duperow

Formation, is here designated the lower member. Application of the name Duperow to this member is intentionally avoided because upper and lower parts of the lower member can be readily differentiated in the Beartooth, Pryor, and Bighorn Mountains. These parts may be named in a later report.

The lower member at Logan (fig. 2) consists largely of dark-yellowish-brown, brownish-gray, medium-dark-gray, and light-olive-gray finely crystalline fetid dolomite and calcitic dolomite and of cryptocrystalline to dense fetid limestone and dolomitic limestone, which stand in cliffs and thick ledges, separated by a few thin reentrants of yellowish-gray and light-olive-gray dolomitic siltstone and argillaceous or silty dolomite, limestone, and limestone breccia.

The lithologic character of individual beds changes in such short distances that a comprehensive regional description of the lower member would be extremely long. Several generalizations can be made, however, regarding the ratios of argillaceous to nonargillaceous beds and of calcareous to dolomitic beds. Southeastward from Logan, the number and aggregate thickness of silty or argillaceous beds increase progressively with a corresponding increase in the content of glauconite. Silty or argillaceous beds make up less than 10 percent of the member at Logan, but 50 percent or more of the member in the Bighorn Mountains. The ratio of calcareous to dolomitic beds changes southeastward. Dolomite constitutes about two-thirds of the total thickness of the member in the Bridger Range and areas to the north and west. Calcareous beds make up one-half to three-quarters of the member in the northern Beartooth Mountains and in the Pryor Mountains. The aggregate thickness of calcareous beds decreases eastward from one-fourth to one-twentieth of the total thickness of the member across the southern Beartooth Mountains, and calcareous beds are almost entirely absent in the Bighorn Mountains.

The lower member ranges in thickness from about 665 feet in the southern Elkhorn Mountains to about 200 feet in the northern Bighorn Mountains, whence it abruptly thins southward toward its erosional limit. It is absent from a small area east of the Big Snowy Mountains (fig. 1) owing to earliest Mississippian erosion.

The lower member of the Jefferson is continuous with the bulk of the Darby Formation of Late Devonian age in the Owl Creek and Wind River Ranges, Wyo. (fig. 1), although the Darby Formation of that area also includes at the top the dark shale unit of Devonian and Mississippian age (Sandberg, 1963) and at the base discontinuous channel-fill deposits equivalent to the Maywood Formation (Sandberg and McMannis, 1964). West of the Wind River Range in Wyoming, the so-called Darby is much thicker, and its upper part

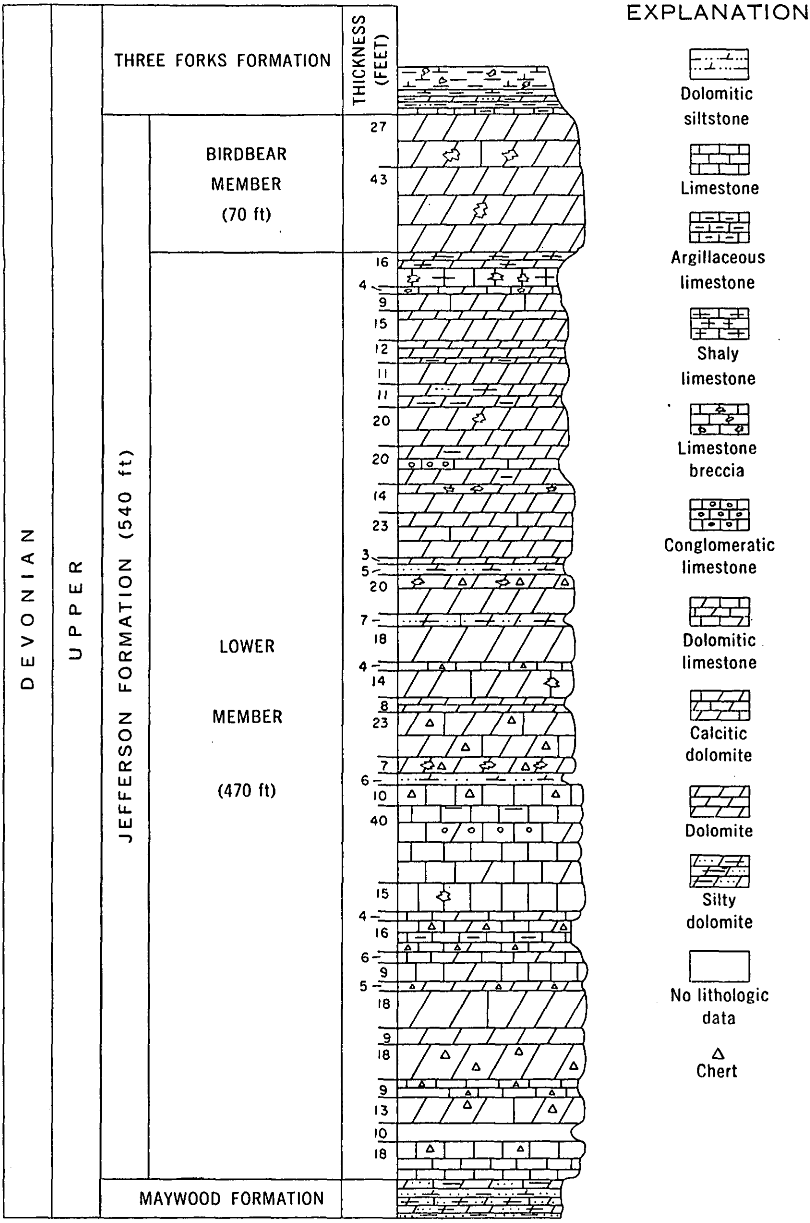

FIGURE 2.—Type section of Jefferson Formation. On north bank of Gallatin River at Logan, in S½SE¼ sec. 25, T. 2 N., R. 2 E., Gallatin County, Mont.

includes beds equivalent to the Birdbear Member of the Jefferson and to the Logan Gulch Member of the Three Forks Formation.

BIRDBEAR MEMBER

The upper 70 feet of the type Jefferson Formation (Sandberg, 1962, p. 48) is here designated the Birdbear Member. It consists of 43 feet of light-brownish-gray to medium-gray and mottled medium-dark-gray and light-brownish-gray very finely crystalline to microcrystalline rhombic sucrosic partly pseudobrecciated dolomite overlain by 27 feet of light-gray and yellowish-gray very finely to medium-crystalline sucrosic dolomite that is partly pseudobrecciated and partly calcitic.

Unlike the lower member, the Birdbear Member has remarkably uniform lithologic character. At Logan (fig. 2) and elsewhere, the Birdbear by its massive bedding, lighter color, pseudobrecciated texture, deeply pitted weathering surfaces, and greater resistance is readily differentiated from the lower member.

The Birdbear Member generally ranges in thickness from about 50 to 80 feet except close to its erosional limit. Although the Birdbear commonly is unmappably thin, it thickens westward to about 200 feet and has been mapped in the Sawtooth Range about 70 miles west of Great Falls, Mont. (M. R. Mudge, oral commun., Oct. 9, 1963).

THREE FORKS FORMATION

The name Three Forks Shales was applied by Peale (1893, p. 29–32) to beds resting on the Jefferson Formation and underlying his Madison Limestone of Mississippian age north of the Gallatin and East Gallatin Rivers and east of the junction of the three forks of the Missouri River. The name was changed to Three Forks Formation by Haynes (1916, p. 14) because "the strata called the Three Forks Shales by Dr. Peale are a composite series and include limestones and shales and some sandstones." Most later workers followed Haynes in using Three Forks Formation, although Robinson (1963, p. 32) preferred Peale's original usage of Three Forks Shale. The type section was established at Logan by Sloss and Laird (1946, 1947) on the basis of a sketch by Peale (1893, pl. 6) of the excellent exposures north of the Gallatin River there. A detailed stratigraphic section of the type Three Forks Formation in the SW¼SE¼ sec. 25, T. 2 N., R. 2 E., Gallatin County, Mont., by Sandberg (1962) supplemented the original section by Sloss and Laird (1947).

Realizing the complexity of rocks mapped as the Three Forks Formation, early workers proposed informal descriptive subdivisions, which could be recognized in measured sections and areas of good exposures. Peale (1893) divided the Three Forks into the "Lower and Upper shales" separated by a bed of grayish-brown limestone 15 to 20 feet thick and estimated a total thickness of about 135 feet for the formation in its type area. Haynes (1916) described the stratigraphy in considerably more detail; he divided the Three Forks into seven members, one of which is only half a foot thick at Logan. There, the thicknesses and lithologies of Haynes' members closely match those of beds shown on figure 3 and described by Sandberg

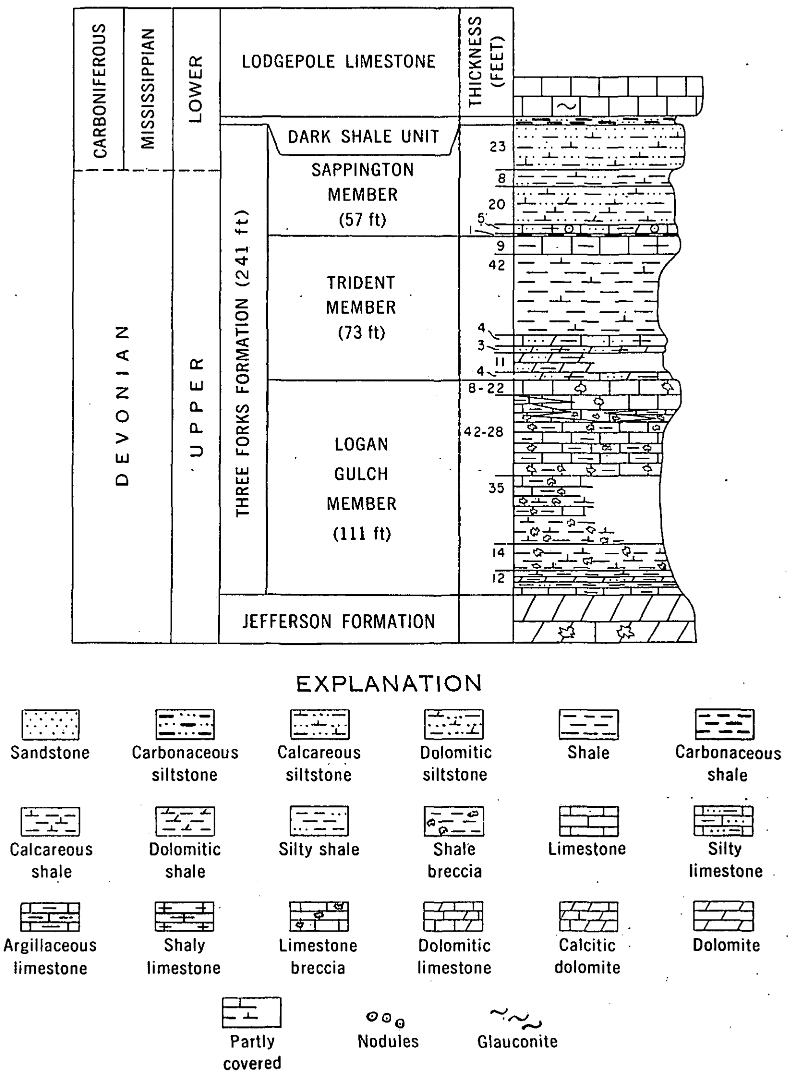

FIGURE 3.—Type section of Three Forks Formation. On north bank of Gallatin River at Logan, in SW¼SE¼ sec. 25, T. 2 N., R. 2 E., Gallatin County, Mont.

(1962), and the total thickness of 222 feet measured by Haynes (1916) is more comparable to the 241 feet measured by the author.

The status of the Three Forks Formation remained unchanged for half a century until the 1940's, when new workers proposed drastic changes in the upper and lower boundaries. So much controversy ensued, particularly over the upper boundary, that only some of the crucial proposals and counterproposals can be briefly summarized here. The reader is referred to Robinson (1963, p. 34–38) for a more complete discussion of the so-called "Sappington problem."

The upper arenaceous part of the Three Forks Formation, which bears a *Syringothyris* fauna considered by Haynes (1916) to be transitional between Devonian and Mississippian, was excluded and termed the Sappington Sandstone of Mississippian age by Berry (1943, p. 14–16). Supposed interbedding of strata bearing the *Syringothyris* fauna with strata bearing a *Cyrtospirifer* fauna of Late Devonian age was mentioned by Sloss and Laird (1947, p. 1411), who considered the Sappington to be wholly Devonian and a member of the Three Forks. The so-called Sappington Formation, which was little more than a faunal unit as originally described by Berry (1943), was redefined and expanded by Holland (1952) to include underlying beds of similar lithology and a black shale at its base.

Later workers used the Sappington basically as defined by Holland (1952) except to include or exclude another thin black shale at its top, but the controversy over its age and stratigraphic assignment has continued to the present. In accordance with Peale's original definition of the formation, the Sappington Sandstone was retained as a member of the Three Forks by Sandberg and Hammond (1958), who considered it to be Devonian and Mississippian. Fossil collections reported by Robinson (1963) supported a dual age for the Sappington, and recent collections by the author suggest that only the uppermost beds are Mississippian. Recent stratigraphic workers, including Christopher (1961) and Rau (1962), also retained the Sappington in the Three Forks, but others, including Achauer (1959), Gutschick, Suttner, and Switek (1962), and McMannis (1955, 1962), continued to consider the Sappington as a separate formation. Despite his use of Sappington Formation, McMannis (1955) did not attempt to map it separately in the Bridger Range, 20 miles east of Logan. More significantly, Robinson (1963, p. 37) found the Sappington too thin to map by itself and perforce mapped it with the Three Forks in the area immediately west of the type locality and also in the Toston quadrangle to the north.

Removal of the lower shales and medial limestone of Peale (1893) from the Three Forks Formation was proposed by Sloss and Laird

(1947, p. 1410) despite their stated intention not to revise Peale's classification. Possibly they attempted to match Peale's unrealistic total thickness of 135 feet rather than Peale's and Haynes' lithologic units; the thickness of beds in the restricted Three Forks of Sloss and Laird (1947, p. 1411) actually totals 141 feet but is rounded to 150 feet. Supporting this exclusion as well as the exclusion of the Sappington, Wilson (1955) considered the restricted Three Forks to include only the medial shale. This shale occupies the middle of covered or partly covered valleys and is unmappable. Even if only the upper or the lower restriction of the Three Forks were accepted, one contact would be unmappable. Consequently, Sandberg and Hammond (1958) reverted to Peale's original definition of the Three Forks at Logan and implied its threefold subdivision there. Recent workers almost unanimously have used Peale's lower contact.

The Three Forks Formation at Logan is here divided into three lithogenetic units, which in ascending order are named the Logan Gulch, Trident, and Sappington Members (fig. 3). These names replace the evaporitic member, shale member, and Sappington Sandstone Member, respectively, of Sandberg (1962). The Logan Gulch Member comprises the beds that Sloss and Laird (1947) excluded from the base of the formation and that Sandberg and Hammond (1958) correlated with the subsurface Potlatch Member. The Trident Member comprises the beds that Wilson (1955) considered the restricted Three Forks. The Sappington Member at this locality comprises the beds that Holland (1952, fig. 6) correlated with his redefined type Sappington Formation nearby.

LOGAN GULCH MEMBER

The lower evaporitic nonfossiliferous part of the Three Forks Formation, which overlies the Jefferson Formation and underlies the Trident Member, is here named the Logan Gulch Member after the gulch where it crops out north of the Gallatin River at Logan, Mont. The type section of the member (Sandberg, 1962, p. 47–48) is included in the type section of the Three Forks. The member generally forms a covered or partly covered strike valley in the hilly area around Logan, but at the type section and elsewhere the upper part locally forms a low hogback in the middle of a valley.

The Logan Gulch is the most extensive member of the Three Forks Formation, and its limit coincides with that of the formation (fig. 1). The Logan Gulch ranges from 90 to 150 feet in thickness in and west of the northern Gallatin Range, Bridger Range, and Big Belt Mountains. East of the limit of the overlying Trident Member, however, it thins abruptly beneath the unconformity at the base of the dark shale unit.

The Logan Gulch Member at Logan is 111 feet thick (fig 3). It consists largely of yellowish-gray and grayish-red argillaceous limestone breccia and shale breccia, interbedded in the basal 12 feet with dolomitic shale and siltstone and silty dolomite and capped by an 8- to 22-foot lenticular bed of brownish-gray limestone and limestone breccia. Regionally, the upper part contains more and thicker beds of limestone and limestone breccia than the lower part, but individual beds are generally not persistent for many miles. A bed of brownish-gray limestone, similar to the one at Logan, caps the member in the Bridger Range and northern Gallatin Range (fig. 1).

Most of the member in the vicinity of Logan is brecciated, probably owing to solution of irregular lenses and pods of anhydrite and to consequent collapse of the enclosing and overlying strata. The many small caverns and dikes of collapse breccia at Logan support this interpretation. The breccias resulting from this process were described in detail by Sloss and Laird (1947, p. 1422–1423), who termed them evaporite-solution breccias. Christopher (1961) attributed similar breccias in southern Saskatchewan to intraformational weathering

The section at Logan is characteristic of the member in the Bridger Range and areas to the west and north. The member changes facies across the northern Gallatin Range, however, and its lithologic character is somewhat different but still recognizable as evaporitic in the Beartooth Mountains (fig. 1). There, the Logan Gulch consists of grayish-orange, yellowish-gray, grayish-red, and greenish-gray dolomitic siltstone, dolomitic quartzose shale, and silty dolomite. These rocks commonly contain hopper-shaped crystals of dolomite pseudomorphous after halite and display ripple marks, mud cracks, and other shallow-water depositional features. Beds of evaporite-solution breccia are uncommon but are locally present in the lower part.

The Logan Gulch Member was deposited in the southern part of a large evaporite basin that centered in northwestern Montana and extended into southwestern Montana, southern Alberta, and southwestern Saskatchewan. The type Logan Gulch represents a western offshore evaporitic facies, whereas the member in the Beartooth Mountains represents an eastern near-shore evaporitic facies.

The Logan Gulch Member has been correlated from Logan northward by means of measured sections and wells. It is equivalent to and continuous with the upper part of the subsurface Potlatch Anhydrite of the Sweetgrass arch area in northwestern Montana, the subsurface Stettler Formation of the Wabamun Group of Wonfor and Andrichuk (1956) in Alberta, and the subsurface Torquay Formation of the Three Forks Group of Christopher (1961) in Saskatchewan.

The subsurface name Potlatch Member, which Sandberg and Hammond (1958) proposed for evaporitic beds in the lower part of the Three Forks Formation in northern Montana east of the 111th meridian, is here abandoned in favor of Logan Gulch Member. The name Potlatch Member was used to designate a tongue of evaporitic rocks that extends eastward from the main body of the Potlatch Anhydrite into the Three Forks Formation (Sandberg and Hammond, 1958, p. 2323). The Logan Gulch includes the Potlatch Member and the basal beds of the Three Forks, as shown on the section by Sandberg and Hammond (1958, fig. 4, cols. 1–2), and is equivalent to all but the upper few feet of the formation in the Williston basin, as shown on the same section (cols. 3–7).

The Logan Gulch Member is lithologically and stratigraphically identical with the outcropping Potlatch Member and equivalent to most of the carbonate member of the Three Forks Formation, as used in southwestern Montana by McMannis (1962). It is recommended that this usage also be discarded in favor of Logan Gulch. The carbonate member was considered by McMannis (1962) to be a facies both of the Potlatch and of his overlying green shale member, but the author was able to differentiate the two members at most localities where McMannis combined them as the carbonate member. Because of deep erosion beneath the dark shale unit, the so-called carbonate member includes beds higher than the Logan Gulch only in the western Beartooth Mountains (fig. 1), where a thin wedge of dolomite that forms the base of the type Trident Member (green shale member of McMannis) is present.

In the same symposium volume in which Sandberg (1962) used evaporitic member and McMannis (1962) used Potlatch Member for the lower part of the outcropping Three Forks Formation, Rau (1962) proposed still another member name. However, the member proposed by Rau crosses the lower boundary of the Three Forks at Logan and several other localities and cannot be considered an equivalent of the Logan Gulch Member. That Rau (1962) may have taken the widespread bed of sucrosic dolomite at the top of the Birdbear Member of the Jefferson Formation for sandy dolomite and sandstone and hence included it in the Three Forks is suggested by a comparison of his cross sections with those of McMannis (1962) and with the type section of Sandberg (1962).

TRIDENT MEMBER

The middle, open-marine, highly fossiliferous part of the Three Forks Formation is here named the Trident Member after the town of Trident on the Missouri River about 5 miles northwest of Logan.

Many excellent exposures of the Trident Member are found within a 5-mile radius of this town. The previous usage of the name Trident as casually applied by Keyes (1926, p. 199) to a limestone of Early Mississippian age in Montana is concurrently abandoned. At its Logan, Mont., type section (Sandberg, 1962, p. 47), the Trident Member overlies the hogback-forming limestone at the top of the Logan Gulch Member and underlies a thin carbonaceous shale at the base of the Sappington Member.

The thickness of the Trident Member is 73 feet at Logan, but farther west it ranges from 100 to 225 feet. Beyond the eastern limit of the Sappington Member, the Trident is truncated by the dark shale unit in a belt only 8 to 50 miles wide (fig. 1).

At Logan, the Trident Member is largely greenish-gray, light-olive-gray, and yellowish-gray calcareous to slightly calcareous fossiliferous clay shale. The bottom 22 feet, however, is yellowish-gray, dark-yellowish-orange, and medium-gray dolomitic limestone, silty dolomite, and calcitic dolomite, and the top 9 feet is a massive bed of fossiliferous argillaceous limestone.

Farther west, the shale is much thicker and contains interbeds and nodules of medium-gray, greenish-gray, and light-brownish-gray highly fossiliferous argillaceous limestone, which increase in number and thickness toward the top. The capping limestone, which is commonly nodular, is not continuous. It grades laterally to interbedded fossiliferous limestone and shale or to very calcareous shale containing abundant nodules of limestone.

Where the lower contact of the Trident Member is not as well exposed as at Logan, it is arbitrarily placed at the base of nonbrecciated yellowish-gray and greenish-gray beds that overlie brecciated or salt-cast-bearing yellowish-gray beds. Nevertheless, a limestone that caps the underlying Logan Gulch has been recognized as far southeast as the northern Gallatin Range and the basal bed of the Trident has been recognized at two localities in the western Beartooth Mountains (fig. 1).

The Trident Member was deposited in the shallow muddy open, but locally restricted, marine waters of a large shelf area that extended northward from southwestern Montana through southwestern Saskatchewan and southern Alberta to at least central Alberta. As correlated northward, the Trident is equivalent to and continuous with the subsurface Big Valley Formation of the Wabamun Group of Wonfor and Andrichuk (1956) in Alberta and the subsurface Big Valley Formation of the Three Forks Group of Christopher (1961) in Saskatchewan. Limestone equivalents such as the upper part of the Palliser Formation of Alberta and the Three Forks Limestone of

Idaho were laid down contemporaneously in clearer and possibly deeper water on the west.

The name Trident Member replaces the informal shale member of Sandberg (1962, 1963) and the green shale member of McMannis (1962). A partly equivalent formal member that was proposed by Rau (1962) is disregarded because it includes the lower half of the Sappington, as identically defined by Holland (1952), Gutschick, Suttner, and Switek (1962), McMannis (1962), and Sandberg (1962) at Logan, Milligan Canyon, and other localities.

SAPPINGTON MEMBER

Yellowish-orange and yellowish-gray silty beds that disconformably overlie the Trident Member and unconformably underlie the dark shale unit or Lodgepole Limestone of the Madison Group are named the Sappington Member of the Three Forks Formation. The name is intentionally shortened from Sappington Sandstone Member, as used by Sloss and Laird (1946, 1947) and Sandberg (1962, 1963), because sandstone is a relatively minor constituent in comparison to siltstone, shale, and limestone (fig. 2). The type locality, as established by Berry (1943, p. 14–16), is in Milligan Canyon, 12 miles west of Logan and 7½ miles northeast of the village of Sappington, from which the name is taken. The type section is considered to be the redefined section that was described at that locality by Holland (1952, fig. 5). The type section of the Three Forks Formation at Logan, Mont., is considered the reference section of the Sappington Member, as described by Sandberg (1962, p. 47) and shown on figure 3. The Sappington of this section has been identically correlated with the type section by Holland (1952, fig. 6) and by the author.

The Sappington is the least extensive member of the Three Forks Formation (fig. 1). It is 57 feet thick at Logan and ranges from 75 to 100 feet in thickness in the area of maximum accumulation west of Logan. East and south of the Bridger Range, it is abruptly truncated by the dark shale unit. The Sappington is about 70 feet thick in the northern Big Belt Mountains, but farther north it thins abruptly beneath the Lodgepole Limestone so that only the basal carbonaceous shale is present in the subsurface, about 15 miles north of Great Falls, Mont. (fig. 1).

The Sappington Member consists of 5 persistent lithologic units that have been recognized at Logan (fig. 2) and at 9 of 10 other sections measured by the author in, north, and west of the Bridger Range. These units and their thickness ranges in the measured sections are from base to top as follows: (1) Slope-forming brownish-gray to black carbonaceous shale that commonly grades to light-brownish-gray shale containing black macerated plant remains and in the top 3–6 inches to greenish-gray shale, 1 to 13 feet; (2) ledge-forming light-olive-gray fossiliferous fetid nodular silty argillaceous limestone or argillaceous calcareous siltstone that is slightly more resistant than the overlying unit, 3 to 7 feet; (3) ledge-forming interbedded calcareous light-olive-gray, yellowish-gray, and dark-yellowish-orange siltstone, shaly siltstone, and shale, 15 to 25 feet; (4) slope-forming light-olive-gray, light-greenish-gray, and medium-gray slightly calcareous shale containing thin interbeds, laminae, and lenses of yellowish-gray and yellowish-orange calcareous siltstone, 8 to 28 feet; and (5) ledge-forming massive grayish-orange, dark-yellowish-orange, moderate-yellowish-brown, and yellowish-gray coarse-grained limonitic calcareous siltstone that locally grades in part to very fine sandstone, 22 to 34 feet.

The basal unit (1), which may not be as persistent as the other four units of the Sappington Member in the Logan area, is nevertheless apparently continuous in the subsurface for at least 215 miles to the north. It overlies a regional disconformity (Sandberg, 1963, fig. 64.2) along which as much as 8 inches of local relief was observed in good exposures such as the one on the north side of a small arroyo just west of Nixon Gulch, 6 miles northeast of Logan. In the Three Forks quadrangle, "an alternation of orange siltstone and sandstone beds of 'Sappington type' with green shale and dark limestone beds of 'Three Forks type' " was described by Robinson (1963, p. 37), who concluded that the rocks here called Trident Member grade by alternation into the Sappington Member. The author, however, has not observed any evidence for interbedding of these members in the Three Forks quadrangle or elsewhere. Beds of siltstone and dark shale within the Trident Member have been measured at several localities, but these lie below a recognizable disconformity and are excluded from the Sappington as described herein. This relation is well displayed on the north side of Antelope Creek, 15 miles southwest of Logan. There, a lenticular bed of Sappington-like yellowish-gray siltstone, 9 to 14 feet thick, grades in its upper part to greenish-gray shale of the Trident, 54 to 64 feet below a sharp contact at the true base of the Sappington.

The only significant change in the depositional pattern of the Sappington Member occurs in the westernmost measured section, 26 miles west of Logan. There, the medial shale, unit 4, is absent and the member is dominantly siltstone, containing in the upper part lenses of medium-gray crinoidal limestone. These lenses increase in number and thickness toward the top and are lithologically very similar to basal beds of the overlying Lodgepole Limestone. This apparent interbedding suggests that, although the Sappington and Lodgepole are unconformable near Logan and seemingly conformable in the intervening Three Forks quadrangle (Robinson, 1963, p. 31), they may be gradational in extreme western Montana.

The lithologic units of the Sappington Member that are described here and by Sandberg (1962) are similar to subdivisions of the Sappington Formation of Achauer (1959) and Gutschick, Suttner, and Switek (1962), although all three stratigraphic studies were independently and concurrently undertaken. The only minor difference is that Achauer (1959) and Gutschick, Suttner, and Switek (1962) included an upper black shale, which McMannis (1962) assigned to the Lodgepole Limestone and Sandberg (1963) referred to the dark shale unit. In addition, Gutschick, Suttner, and Switek (1962) studied the biostratigraphy of the Sappington in extremely fine detail and recognized four widespread lithologic subdivisions, some only a few inches thick, of the basal carbonaceous shale, unit 1.

Individual beds within the lithologic units of the Sappington Member have distinctive fossil assemblages that are indicative of deposition in marine, brackish-water, or continental environments. The biota and inferred environments of some of these beds have been described in detail by Gutschick, Suttner, and Switek (1962). Units 1, 2, and 3 in the lower part of the Sappington were deposited in several different marginal-marine environments of an extremely shallow, regressive sea. A widespread concentration of brachiopods, many of which were buried in growth position, in the top few inches of unit 3 may have resulted from a sudden influx of mud. The overlying sparsely fossiliferous medial shale, unit 4, probably represents fluctuating brackish- and fresh-water conditions. A marine or brackish-water fauna from a channel-fill deposit within the unit was described by Gutschick, Suttner, and Switek (1962, p. 85), and a large diversified continental spore flora was collected from a bed of medium-dark-gray shale in the upper 2 feet in the Bridger Range by the author. This flora was determined by R. H. Tschudy (written commun., Feb. 14, 1962) to be latest Devonian (Famennian). The upper part of the Sappington, unit 5, apparently represents a return of shallow-water marginal-marine conditions.

The Sappington Member has been correlated northward through measured sections and wells, and has been found to be equivalent in the subsurface of northwestern Montana and southern Alberta to the Devonian Exshaw Shale of Warren (1937), which consists of a basal black shale and an overlying thick siltstone. The basal shales of the Sappington and Exshaw are continuous, but a 40-mile-wide area of erosional thinning just north of Great Falls, Mont. (fig. 1), separates the upper units 2 to 5 of the Sappington from the upper siltstone of the Exshaw. In turn, the Exshaw is equivalent to and continuous with only the lower black shale and medial siltstone of the subsurface Bakken Formation of Devonian(?) and Mississippian age in southeastern Alberta and southwestern Saskatchewan. Thus at least the basal part of the Sappington Member is directly connected to the Bakken Formation of the Williston basin area, as previously suggested by Sandberg and Hammond (1958, p. 2326).

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U.S. GOVERNMENT PRINTING OFFICE: 1965

The U.S. Geological Survey Library has cataloged this publication as follows:

Sandberg, Charles Albert, 1929–

Nomenclature and correlation of lithologic subdivisions of the Jefferson and Three Forks Formations of southern Montana and northern Wyoming. [Washington, U.S. Govt. Print. Off., 1965]

iii, 18 p. map, diagrs. 24 cm. (U. S. Geological Survey. Bulletin 1194–N)

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1. Geology, Stratigraphic—Paleozoic. 2. Geology—Montana. 3. Geology—Wyoming. 4. Geology—Nomenclature. I. Title. II. Title: Jefferson and Three Forks Formations of southern Montana and northern Wyoming. (Series)