STRATIGRAPHY OF POST-MESAVERDE CRETACEOUS ROCKS, SAND WASH BASIN AND VICINITY, COLORADO AND WYOMING

By

John D. Haun[1]

INTRODUCTION

The interrelationship between the Upper Cretaceous Mesaverde, Lewis, Fox Hills, and Lance formations of Northwestern Colorado and south central Wyoming, and the position of the Cretaceous-Tertiary boundary in this area, have been studied in detail for over 50 years. With the addition of considerable subsurface control in the past few years, it is now possible to present a more complete picture of the stratigraphy of this part of the section. Additional paleontological collections are needed and, in the deeper parts of the Sand Wash and Washakie basins, there are large gaps in the subsurface control. Detailed surface mapping of the intertonguing relationships of the Upper Cretaceous formations could add immeasurably to the stratigraphic knowledge of this area. The occurrence of gas, and possibly oil, in this part of the stratigraphic column, creates an economic reason for more precise knowledge of environments of deposition and paleogeography. The purpose of this paper is to review the origin of stratigraphic nomenclature now in use and to add new information regarding regional stratigraphy and its relationship to gas entrapment.

The Cretaceous classification of the King and Hayden surveys, which had been previously established in the Missouri River region by Meek and Hayden (Dakota, Benton, Niobrara, Pierre, Fox Hills, and Laramie), was found by Fenneman and Gale (1906, p. 17-20) to be inappropriate in the Yampa region of northwest Colorado. They decided, on the basis of similarity of succession, to adopt the nomenclature that Whitman Cross, *et al.* (1899) had applied to the Cretaceous rocks in the Teluride and La Plata quadrangles of southwest Colorado (Dakota, Mancos, Mesaverde, Lewis, and Laramie). The name Lewis was extended into the Rock Springs uplift by Schultz (1920). Additional stratigraphic terminology is discussed below.

LEWIS SHALE

The Lewis-Mesaverde contact is usually distinct in the subsurface, but in some areas it is more difficult to define in surface sections. As indicated on plates I through VI (in pocket), the lower marine shale of the Lewis interfingers with the uppermost transitional sandstones and nonmarine beds of the Mesaverde. The contact is picked at the base of the lowest marine shale. In a west-to-east direction from the vicinity of Hiawatha (T. 12 N., R. 101 W.) to North Craig field (T. 8 N., R. 90 W.), as shown on plates IV and V, the Lewis-Mesaverde contact drops stratigraphically about 750 feet. Bass, *et al.* (1955, pocket plate) show a west-to-east drop of the contact of about 650 feet from a surface section southeast of Craig (T. 6 N., R. 89 W.) to a core-hole section near Mount Harris (T. 6 N., R. 87 W.). At the Mount Harris section, the base of the Lewis is only about 130 feet above the Twentymile sandstone member of the Williams Fork formation (upper Mesaverde). Zapp and Cobban (1960) also show a similar thin nonmarine unit separating the base of the Lewis from the Twentymile in a section north of Oak Creek (T. 5 N., R. 96 W.).

In a northeasterly direction across the Sand Wash basin (plate VI) the Lewis-Mesaverde contact drops about 450 feet by facies change from upper Mesaverde to lower Lewis. Zapp and Cobban (1960, locality Z, fig. 112.3) show the base of the Lewis, in the approximate location of T. 11 N., R. 86 W., to be older than the Twentymile sandstone.

The Lewis shale is dark gray, sometimes described as bluish gray, and contains thin slabby sandstones, siltstones, and calcareous concretions. Isolated thin limestones have been reported from various parts of the Lewis, especially in the southeast part of the Sand Wash basin. Several bentonite beds occur in the lower part of the formation and were used as correlation points on plate V. In the subsurface, the middle part of the Lewis contains a thick sequence of sandstones and siltstones that are not present in most surface exposures. In several surface sections, this middle sandy member is present but has not been recognized as part of the Lewis shale. The regional extent of the middle sandy member is shown on plates I through VI. In the Spring Creek section, Elias (1959) placed the middle sandy member in the Lance formation. From a mapping standpoint, it may be logical to use the Lewis-Lance

[1]Associate Professor, Colorado School of Mines, Geologist, Barlow Hammond & Haun, Golden, Colorado.

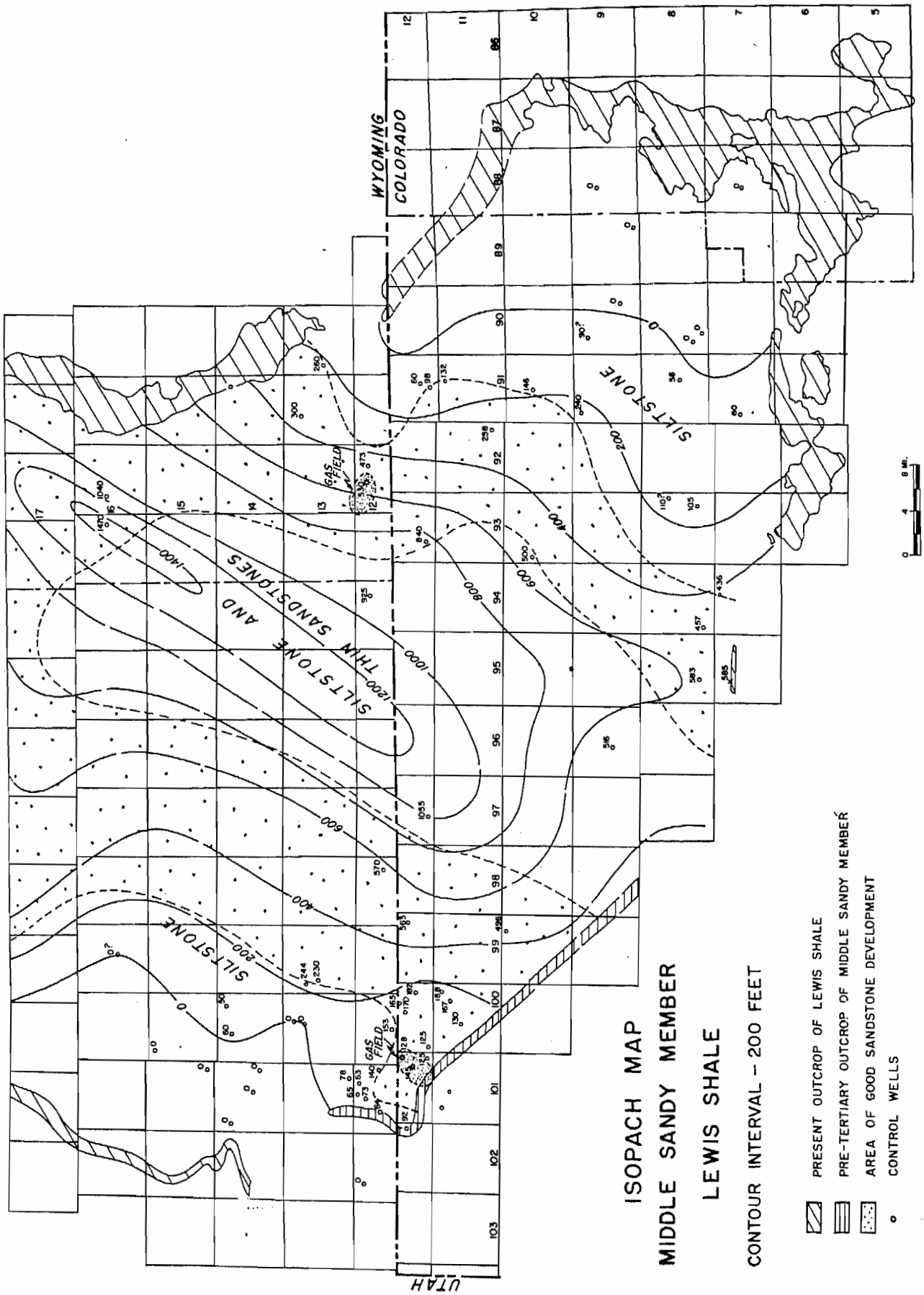

Figure 1. Deltaic deposits of the middle sandy member of the Lewis shale were deposited by a river that flowed from southwest to northeast. Gas production has been established in sandstones around the margin of the delta within the map area and just to the north of the map at Table Rock.

contact of Elias, but in order to understand the regional significance of this interval it is shown as a part of the Lewis on plate IV. In the outcrops east of Dad, Wyoming, the middle sandy member was mapped as part of the Lance formation. Ball and Stebinger (1910, p. 193) recognized that a problem existed at the Lewis-"Laramie" contact as they mapped it in the area north of Baggs. They report Montana fossils 400 feet above the top of the Lewis (footnote, p. 193). Correlation of nearby wells with the Sohio, Cow Creek No. 1 Unit well in sec. 12, T. 16 N., R. 92 W.,indicates that the well spudded in the lower part of the middle sandy member of the Lewis rather than in the lower part of the Lance as it is mapped on the Geologic Map of Wyoming (Love, Weitz, and Hose, 1955).

Figure 1 is an isopachous map of the middle sandy member of the Lewis. The member has a thick central section of over 1000 feet and thins to zero to the southeast and to the northwest. The thickest portion consists of siltstones and thin nonporous sandstones. Southeast and northwest of the thickest section there is an area containing well-developed sandstones. Between this area and the zero isopach, the member consists of marine shale, siltstone, and thin sandstones. The middle sandy member is interpreted as a delta that was deposited by a river that entered the sea from the southwest. The thick middle part of the delta resulted from the rapid deposition of clay, silt and sand. Wave action around the margins of the delta resulted in the clean-up of sand deposited as beaches and barrier bars. Silt-sized particles that were swept farther seaward account for the character of the outer margins of the middle sandy member. With the exception of the deltaic deposits, the main body of the Lewis shale was deposited in a neritic environment. The thickness and facies distribution indicates that early growth of Laramide structural features did not influence the depositional pattern. Existence of a delta in this area was recently verified by the work of J. F. Clement (paper read before the Rocky Mountain Association of Geoolgists, March 24, 1961), who used foraminifera as environmental indicators and outlined the areas of transitional and shallow neritic deposition that essentially conform to the distribution of the outer limits of the middle sandy member of figure 1 of this paper.

Sandstones near the upper and lower contacts of the Lewis shale and within the middle sandy member are remarkably similar. They are gray to brown or buff, very fine grained to medium grained, occasionally coarse grained, subangular to subrounded, medium sorted, contain dark chert grains that give a "salt and pepper" apearance, and occasionally contain glauconite. They are cemented with calcite and clay and contain a minor amount of feldspar. The large clay content probably formed from the alteration of feldspar deposited with the sand grains. Carbonaceous shale and coal beds are often found in association with the better-developed sandstones. Most of the sandstones have low porosity and permeability as a result of the high clay content. Many sandstones that were deposited in a high energy environment (zone of wave activity) should have good porosity, but have lost their porosity through feldspar alteration.

Thickness of the Lewis shale is depicted in figure 2. Isopachous maps of the Lewis shale and the Almond formation (uppermost member of the Mesaverde group) were made by Heppe (1960) in the area northwes· of the present study. The eastward increase in thickness is the result of facies changes at the base and top of the formation. Hancock (1925, p. 6) computed a thickness of 1600 feet for the Lewis shale southwest of Craig, but detailed thickness studies were not made by early workers. The thinning in the extreme west part of the area, however, is the result of pre-Tertiary erosion. If there had been no pre-Tertiary erosion, the zero isopach would have been 15 to 20 miles farther southwest.

In the Forest No. 1-15 Krause well, sec. 15, T. 4 N., R. 97 W., Moffat County, the Lewis shale is absent, but the middle sandy member is probably represented by the sandstones in the interval 2700-3500 feet. The upper part of the Mesaverde formation of the Sand Wash basin is represented by the sandstones in the interval 3900-4200 feet. Southeast of this well, in the southern Danforth Hills and Meeker area, Hancock and Eby (1930, p. 206) named the Lion Canyon sandstone member of the Williams Fork formation (upper Mesaverde group). They considered the Lion Canyon and associated beds equivalent to the Lewis shale in the region to the North. Brackish-water invertebrates were collected from this sequence. This would be in line with the pre-Tertiary zero isopach of the Lewis shale and was interpreted in this manner by Zapp and Cobban (1960, p. B-247). The interrelationship of the Sand Wash basin section and the Piceance basin section, advanced by Hancock and Eby, was discussed and diagrammed by Masters (1959). All of these observations, and the general aspect of the isopach map (Fig. 2), indicate that Laramide tectonic activity did not affect the depositional pattern of the Lewis shale and its nearby facies equivalents. Laramide folding did not become a factor in erosion or deposition in the Sand Wash or Washakie basins until after the deposition of the Lance formation.

Age of the Lewis Shale

The regional relationships of the Lewis shale and associated formations of northwest Colorado were described by Weimer (1959 and 1960) and Haun and

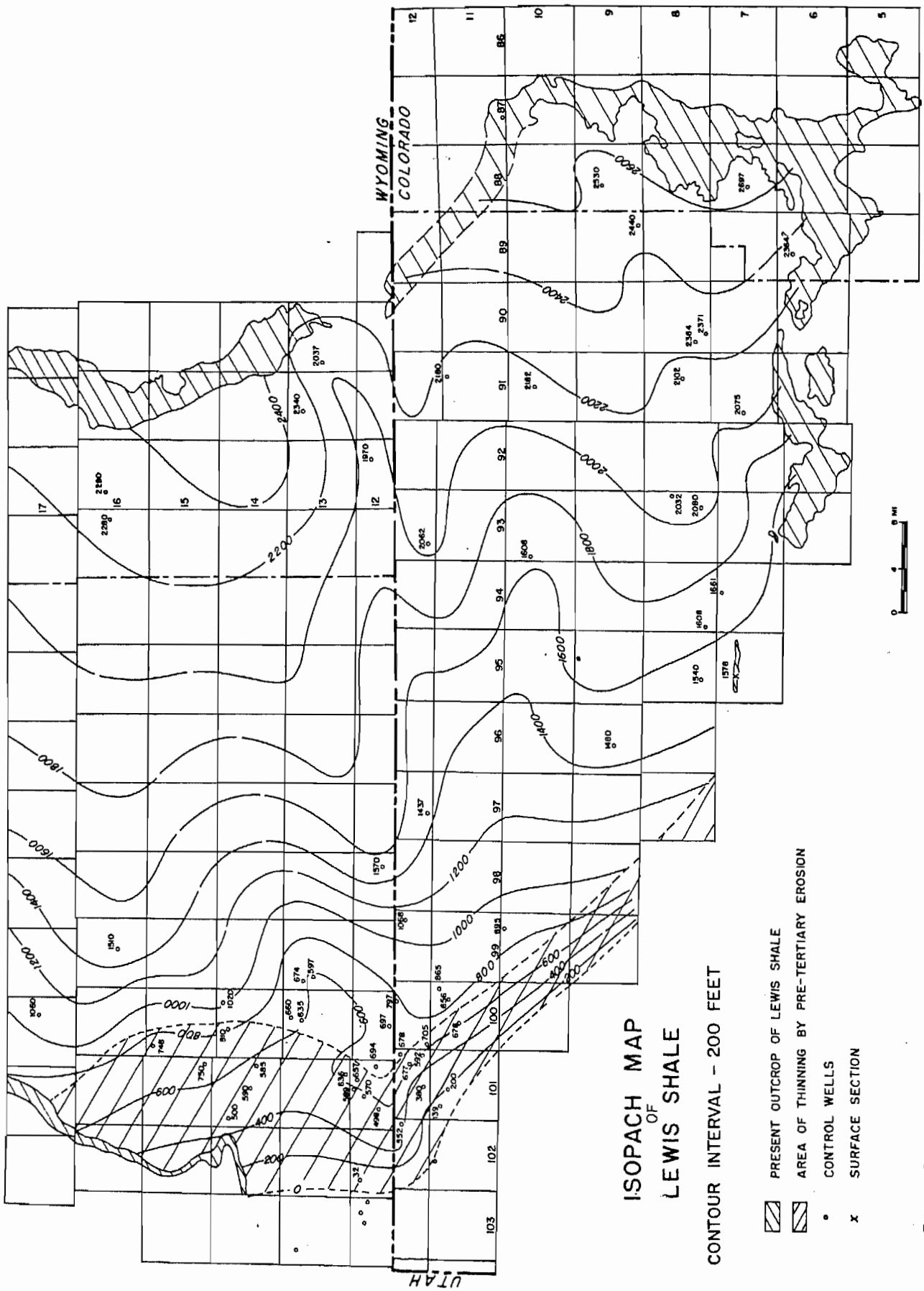

FIGURE 2

Figure 2. Thickness of the Lewis shale in the Sand Wash and southern Washakie basins. The thickness is related to formation contact relationships as interpreted in the cross sections.

Weimer (1960). It was pointed out that the Lewis shale of the type area in southwest Colorado is the time and lithologic equivalent of the upper part of the Mancos shale of northwest Colorado. Change in age of a formation from one area to another is common and should not be used as evidence for change in name, but the formation should be a lithogenetic entity. The "Mesaverde" and "Lewis" of northwest Colorado are not related lithogenetically to the formations with the same names in the type area. The names are probably so deeply ingrained in present usage that changes would not be feasible.

According to faunal evidence accumulated by many workers (summarized by Katich, 1959) and recent data presented by Zapp and Cobban (1960), the Lewis shale ranges in age from latest Campanian to late Maestrichtian in northwest Colorado. The faunal collections from the Lewis include representatives of the following zones: *Baculites eliasi, Baculites grandis, Baculites clinolobatus,* and from the Fox Hills, south of Craig, questionable *Sphenodiscus* cf. *S. lenticularis*. The occurrence of *Baculites grandis* at the base of the Lewis, northwest of Oak Creek, Colorado, indicates that the time division between the Campanian and Maestrichtian in the Craig area should be below the top of the Mesaverde formation rather than above as indicated on some previous diagrams. The exact division between Campanian and Maestrichtian based on fauna of the Western Interior is subject to question, however, because of uncertainties regarding faunal correlations and ranges of European species (Jeletzky, *in* Cobban and Reeside, 1952, p. 1026-1028).

FOX HILLS SANDSTONE

The upper contact of the Lewis shale with the Fox Hills sandstone shows an interfingering relationship similar to the Lewis-Mesaverde contact. The Fox Hills sandstone was deposited during the final withdrawal of the Cretaceous sea from the Sand Wash basin area. The sandstones were deposited in the transitional environments between the marine environment to the east and the nonmarine environment to the west and southwest. The eastward and northeastward stratigraphic rise of the Lewis-Fox Hills contact is more erratic and much more pronounced than the corresponding drop of the Lewis-Mesaverde contact. From the vicinity of Shell Creek (T. 11 N., R. 100 W.) eastward to North Craig field (T. 8 N., R. 90 W.) the stratigraphic rise of the contact is about 1150 feet (plates IV and V). The resultant thickening of the Lewis by facies change at the upper and lower contacts is partially compensated, however, by thinning of various parts of the Lewis shale in offshore areas. In a northeasterly direction, the stratigraphic rise of the Lewis-Fox Hills contact is about 150 to 200 feet (plate VI). An eastward stratigraphic drop of the top of the Lewis shale in the area east of Craig, described by Bass, *et al.* (1955, p. 160), was not observed in the present study. The thickest and best-developed sandstones in the Fox Hills were deposited in areas where the shoreline remained relatively stable for a period of time. Several thick areas of sandstone may be seen on the cross sections.

Gale (1910, pp. 89-94) discussed in detail the problems of Cretaceous stratigraphic nomenclature and age and, among other comments (p. 91), stated that "It is likely that the use of the term Fox Hills to define any particular formation representing a specific time interval in the Cretaceous history of the Rocky Mountain region will now be abandoned." Dorf (1938, pp. 4-21) extended the name Fox Hills into the Craig region. He recommended the use of the names Fox Hills and Medicine Bow for the post-Lewis Cretaceous formations of northwest Colorado and southern Wyoming. The Fox Hills, as Dorf and other workers defined it, has been adopted in the present study. The Medicine Bow, as defined by Dorf in northwest Colorado, is the same stratigraphic unit as the Lance formation of this paper. From a lithogenetic standpoint, Fox Hills is a legitimate formation name (a mappable unit) in northwestern Colorado and southern Wyoming, where it represents the transitional and marine sandstones associated with the final withdrawal of the Cretaceous sea. It occupies this same stratigraphic position in eastern Colorado and Wyoming. The age, however, as indicated on the plates in this paper, varies considerably from place to place. Dobban and Reeside (1930) described the transitional contact between the Fox Hills and Lance throughout the Rocky Mountain region.

LANCE FORMATION

The Lance formation was named by Hatcher (1903, pp. 369-375) in the vicinity of Lance Creek, Niobrara County, Wyoming. The formation formerly mapped as "Laramie" in northwest Colorado, was depicted as Lance on the Geologic Map of Colorado (Burbank, et al., 1935), but it was considered Tertiary rather than Cretaceous. The formation mapped as "Laramie" by Schultz (1920) was changed to Lance on the Geologic Map of Wyoming (Love, et al., 1955).

The Lance formation, from zero to over 2000 feet thick in the Sand Wash and southern Washakie basins, is a nonmarine sequence of carbonaceous shale, sandstone, and siltstone with occasional coal beds. Coal beds often lie immediately above the Fox Hills sandstone. Regional southwest thinning is the result of pre-Fort Union erosion.

Dorf (1938, pp. 18-21) made two plant collections in the Lance just east of Craig, but he measured the

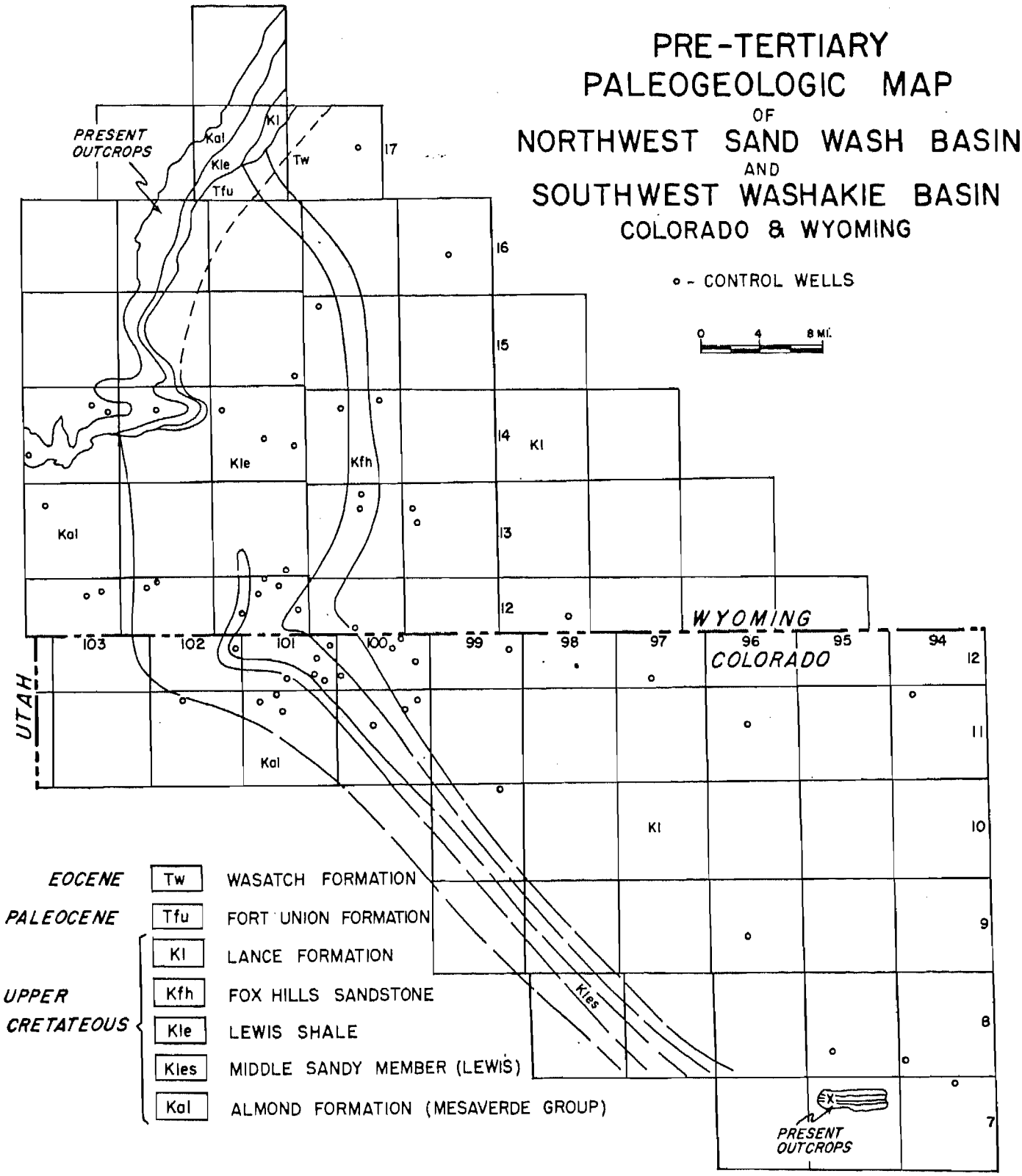

FIGURE 3

Figure 3. Pre-Tertiary paleogeologic map of northwest Sand Wash and southwest Washakie basins. The map indicates the presence of the Uinta uplift (to the southwest) and, to a much less degree, it indicates the initial rise of the Rock Springs uplift (to the northwest).

Fox Hills and lower Lance section at Spring Creek, 24 miles west of Craig. With minor changes in designations of sandy shales, shaly sandstones, etc., the section he measured is the same as that of Elias (1959). The lower two coal beds in the Lance of Elias, 500 feet apart, are the same two coal beds in the section of Dorf. Dorf correlated the Craig section with the Spring Creek section on the basis of two massive sandstones, with a coal bed between, in the lower part of the Fox Hills sandstone. He then related his plant collections, and the invertebrate collections of Hancock (1925, p. 22) from the Craig area, to the Spring Creek measured section. As is demonstrated on plates IV and V of this paper, the section at Spring Creek is a part of the middle sandy member of the Lewis shale and is about 1000 feet stratigraphically below the Fox Hills of the Craig area. In other words, the section illustrated by Dorf bears no relationship to the section from which the fossils were collected.

The Lance-Fort Union contact is easily distinguished around the southern and eastern margins of the Sand Wash Basin, but toward the center of the basin the contact is more difficult to locate. The Lance formation records the last known deposition of Cretaceous rocks in this area.

FORT UNION FORMATION (PALEOCENE)

The Fort Union formation of early workers in the northern Rocky Mountain region was extended into northwest Colorado as a substitute for the post-"Laramie" of former maps and was depicted as such on the Geologic Map of Colorado (Burbank, et al., 1935). As a result of the work of Brown (1949), the Fort Union was split from the base of the former Wasatch formation along the east flank of the Rock Springs uplift and the east flank of the Washakie basin.

The Fort Union formation, in the eastern and southern part of the Sand Wash basin, contains a basal conglomerate in some areas and in other areas it is marked by a medium- to coarse-grained sandstone that is usually arkosic and contains small isolated chert pebbles. To the west, the grain size of the lower sandstone diminishes. As indicated on the cross sections, the lower 200 to 500 feet of the Fort Union throughout the basin contains thick beds of sandstone that facilitate the location of the Lance-Fort Union contact. Conglomerates are not always indicative of the base of the Fort Union, however, and can be found at various intervals higher in the formation. The lithologies (carbonaceous shale, coal, and sandstone) are similar to those of the Lance formation and similar environments of deposition are indicated. The sandstones of the Fort Union, however, tend to be coarser grained than those of the Lance. Coal beds occur above the basal conglomerate in some areas, but the better coal development is usually higher is the formation.

An unconformity at the base of the Fort Union has long been recognized. Schultz (1909, p. 259) showed an unconformity at the base of the Wasatch, the lower part of which he believed to be Fort Union, in the northern Rock Springs uplift and (Schultz, 1910, p. 223) at the base of the "Upper Laramie" formation of the southern Rock Springs uplift. Gale (1909, p. 286) recognized an unconformity at the base of what he called the "post-Laramie" in the Craig area. In 1910, Gale (opposite p. 90) used Fort Union (?) in his manuscript, but mapped the formation as "post-Laramie" in the Craig area and mapped it as part of the Wasatch in other areas of western Colorado. Along the east flank of the Rock Springs uplift the north-to-south truncation of successively older Cretaceous formations below the Wasatch was mapped by Schultz (1920). This map became a part of the Geologic Map of Wyoming (Love, et al., 1955) except that the lower part of the Wasatch of Schultz was changed to Fort Union. Along the east flank of the Washakie basin, north of Baggs, Ball and Stebinger (1910, pp. 193-196) also recognized an unconformity at the base of the basal conglomerate in the "Upper Laramie" formation.

Gale (1910, pp. 75-76) examined in detail the pebbles in the conglomerate at the base of the Tertiary in the Grand Hogback, Danforth Hills, and Yampa areas and listed the following rock types: "Red quartzite (evidently formed from the "Uinta" quartzite); white quartzite and hard sandstone (in less amount than the red, probably also from the "Uinta"); conglomeratic quartzite (still more rare, evidently also from the "Uinta"); vein quartz; chert of various colors, especially in irregularly rounded lumps, weathering yellow, many containing impressions of fossils (pebbles of a jet-black chert are especially noticeable); a feldspathic porphyry, with small phenocrysts in a fine red or gray groundmass; gneissoid granitic or felsitic rocks; silicified wood in waterworn fragments." The fossils were thought to be from the Carboniferous.

Ritzma (1955a) considered the source of the conglomerate (including Paleozoic chert and limestone) to be the Park Range, despite the fact that Triassic and Jurassic rocks rest on the Precambrian over much of the range and the upper Paleozoic rocks are dominantly clastics. Paleozoic carbonates may have been available, however, to the south or to the north in Wyoming. If Uinta quartzites are present, this would indicate that considerable uplift and erosion of the Uinta Mountains had taken place.

Hale (1955) has shown something of the regional extent of the unconformity at the base of the Tertiary. Ritzma (1955b, p. 136) presented a diagram of the unconformable relationship of the Fort Union formation

to the underlying Cretaceous formations along the southeast flank of the Rock Springs uplift. The position of the pre-Fort Union unconformity was also defined by Reese and Gras (1959, p. 94). Plates I through VI illustrate the position of the unconformity in the area of this study. Although the discordance of dip between formations above and below the unconformity appears on the cross sections to be considerable, this is the result of the vertical exaggeration, and the actual discordance, in all cases, is less than one degree. It can be seen that the magnitude of deformation prior to the deposition of the Fort Union, within the present outcrop area, was very gentle. This explains why most surface mapping has failed to reveal any dip discordance. It is probable that the dip of Cretaceous formations, even in the vicinity of the rising Park and Uinta ranges, was less than ten degrees. This amount of dip would be sufficient to allow erosion down to Precambrian rocks in the central parts of the ranges. The unconformity is of regional extent, and is not confined to the rims of present structural basins.

By using outcrop information along the southeast part of the Rock Springs uplift and subsurface control, it was possible to make a pre-Tertiary paleogeologic map of the northwest Sand Wash basin and the southwest Washakie basin (Fig. 3). The Wasatch formation overlaps the Fort Union formation in a southwesterly direction and in the western part of the map the Wasatch rests on the lower part of the Lewis shale and the upper part of the Almond formation (upper Mesaverde). The outcrop pattern of the Cretaceous formations prior to Fort Union and Wasatch deposition indicates the presence of the Uinta uplift and, to a much less degree, it indicates the initial rise of the Rock Springs uplift. This is diametrically opposed to the theory advanced by Ritzma (1955b) that there was an early "Douglas Creek Arch-Rock Springs Uplift structural element" and that the Uintas did not begin to rise until the beginning of deposition of the Wasatch formation.

GAS PRODUCTION

Post-Mesaverde Cretaceous gas pools (mostly shut-in) have been discovered in six fields around the margins of the Sand Wash basin and the southern Washakie basin. The middle sandy member of the Lewis shale contains gas at South Baggs (Fig. 1 and Plate VI), West Hiawatha (Fig. 1 and Plate II), Table Rock and South Table Rock (Haun and Barlow, 1959). It is notable that all of these fields are in the area of better sandstone development around the margin of the delta outlined on Figure 1 (the Table Rock area is just off the map to the north). It should be possible to develop more production of gas and possibly oil within this band of sandstones. The West Hiawatha production, in addition to the sand development, is controlled by the pre-Fort Union unconformity (Plate II) which forms a barrier to migration across a plunging anticline.

The Fox Hills sandstone is productive at Four Mile Creek (Ts. 11 and 12 N., R. 91 W.). The productive interval was considered by Parker (1959, p. 85) to be in the Lewis shale, but, as defined in this paper, it is part of the Fox Hills. The North Craig field, described by Greer (1959) and Parker (1959) produces from a sandstone sequence in the upper part of the Lewis shale that, although related to the Fox Hills (Plate V), appears to be an offshore bar development. Additional gas fields may be discovered in the sandstones of the upper Lewis and Fox Hills, but their occurrence will probably not be as predictable as the potentially productive interval in the middle sandy member of the Lewis.

Gas was reported from the upper part of the Lance formation at North Lay Creek (Plate V). Several gas-producing intervals in the lower part of the Fort Union formation are shown on the cross sections. These productive sandstones are very lenticular and probably represent stream channel deposits. Further discussion of Fort Union gas production is beyond the scope of this paper.

SUMMARY

The base of the Lewis shale interfingers with Mesaverde sandstones and the top interfingers with Fox Hills sandstones. This change of facies at the contacts of the Lewis accounts for the increase in thickness in an easterly direction. The thickening is partially compensated by thinning of parts of the shale facies in areas distant from the shore. The middle sandy member of the Lewis is interpreted as a delta deposited by a river that entered the Lewis sea from the southwest. The best-developed sandstones are associated with the margins of the delta. The middle sandy member was mapped as part of the Lance-Fox Hills section in some surface work. Deposition of the Lewis shale and its facies equivalents in the Sand Wash and Washakie basins was not affected by Laramide tectonism.

The Lewis shale of northwestern Colorado and southern Wyoming is not related lithogenetically to the Lewis of the type area in southwest Colorado. Age of the Lewis in the area of study is latest Campanian to late Maestrichtian.

The Fox Hills sandstone represents the transitional and marine sandstones associated with the final withdrawal of the Cretaceous sea. The Lance formation is a nonmarine sequence that interfingers with the Fox Hills.

The nonmarine Fort Union formation was deposited unconformably on the Lance, Fox Hills, Lewis, and

Mesaverde. Gentle Laramide folding accompanied the pre-Fort Union erosion and the Uinta and Park ranges were probably eroded to the Precambrian basement.

Gas fields have been discovered in the middle sandy member of the Lewis shale, the upper Lewis and Fox Hills sandstones, and possibly in the Lance formation. It should be possible to predict the regional trend of future gas discoveries in the middle sandy member of the Lewis, but in the upper Lewis and Fox Hills, the occurrence will probably be much less predictable.

ACKNOWLEDGMENTS

Much of the data and most of the conclusions in this paper have been discussed at length with James A. Barlow, Jr., Robert J. Weimer, and Charles D. Masters. Their critical review of the correlations and conclusions is appreciated. Masters permitted me to read his unpublished manuscript concerning the gas occurrences in the Sand Wash basin. Although some of the conclusions of my paper differ from those of Masters (position and extent of the Fort Union-Lance contact, etc.), specific reference to his paper has been reserved until after it has been published.

REFERENCES

BALL, M. W., and STEBINGER, EUGENE, 1910, "The Eastern Part of the Little Snake River Coal Field, Wyoming," *U. S. Geolog. Survey Bull.* 381, pp. 186-213.

BASS, N. W., EBY, J. B., and CAMPBELL, M. R., 1955, "Geology and Mineral Fuels of Parts of Routt and Moffat Counties, Colorado," *U. S. Geol. Survey Bull.* 1027-D, 250 pp.

BROWN, R. W., 1949, "Paleocene Deposits of the Rocky Mountains and Plains," *U. S. Geol. Survey Prelim. Map.*

BURBANK, W. S., LOVERING, T. S., GODDARD, E. N., and ECKEL, E. B., 1935, "Geologic Map of Colorado," *U. S. Geol. Survey.*

COBBAN, W. A., and REESIDE, J. B., JR., 1952, "Correlation of the Cretaceous Formations of the Western Interior of the United States," *Bull. Geol. Soc. America,* Vol. 63, No. 10, pp. 1011-1044.

CROSS, WHITMAN, and PURINGTON, C. W., 1899, "Description of the Telluride Quadrangle," *U. S. Geol. Survey Geol. Atlas Folio* 57, 19 pp.

----------, SPENCER, A. C., and PURINGTON, C. W., 1899, "Description of the La Plata Quadrangle," *U. S. Geol. Survey Geol. Atlas Folio* 60, 14 pp.

DOBBAN, C. E., and REESIDE, J. B., JR., 1930, "The Contact of the Fox Hills and Lance Formations," *U. S. Geol. Survey Prof. Paper* 158, pp. 9-25.

DORF, ERLING, 1938, "Upper Cretaceous Floras of the Rocky Mountain Region," *Carnegie Inst., Wash., Pub. No.* 508, pp. 1-78.

ELIAS, D. W., 1959, "Cretaceous Section Exposed in the Spring Creek Area, Moffat County, Colorado," *Rocky Mountain Assoc. Geol. 11th Field Conf. Guidebook,* pp. 74-75.

FENNEMAN, N. M., and GALE, H. S., 1906, "The Yampa Coal Field, Routt County, Colorado," *U. S. Geol. Survey Bull.* 297, 96 pp.

GALE, H. S., 1909, "Coal Fields of Northwestern Colorado and Northeastern Utah," *U. S. Geol. Survey Bull.* 341, pp. 283-315.

----------, 1910, "Coal Fields of Northwestern Colorado and Northeastern Utah," *U. S. Geol. Survey Bull.* 415, 265 pp.

GREER, W. J. 1959, "North Craig Field, Moffat County, Colorado," *Rocky Mountain Assoc. Geol. 11th Field Conf. Guidebook,* pp. 81-84.

HALE, L. A., 1955, "Stratigraphy and Facies Relationship of the Montana Group in South Central Wyoming, Northeastern Utah and Northwestern Colorado," *Wyoming Geol. Assoc. 10th Ann. Field Conf. Guidebook,* pp. 89-94.

HANCOCK, E. T., 1925, "Geology and Coal Resources of the Axial and Monument Butte Quadrangles, Moffat County, Colorado," *U. S. Geol. Survey Bull.* 757, 134 pp.

----------, and Eby, J. B., 1930, "Geology and Coal Resources of the Meeker Quadrangle, Moffat and Rio Blanco Counties, Colorado," *U. S. Geol. Survey Bull.* 812-C, pp. 191-242.

HATCHER, J. G., 1903, "Relative Age of the Lance Creek (Ceratops) Beds of Converse County, Wyoming, the Judith River Beds of Montana, and the Belly River Beds of Canada," *Amer. Geologist,* Vol. 31, pp. 369-375.

HAUN, J. D., and BARLOW, J. A., JR., 1959, "Structure Contour Map of Green River Basin, Wyoming, and Colorado," *Petroleum Ownership Map Company,* Casper, Wyoming.

----------, and WEIMER, R. J., 1960, "Cretaceous Stratigraphy of Colorado," *Geol. Soc. America, Rocky Mountain Assoc. Geol., and Colorado Sci. Soc.,* Guide to the Geology of Colorado, pp. 58-65.

HEPPE, W. C., 1960, "A Brief Summary of the Stratigraphy of the Almond and Lewis Formations of the Washakie Basin, Sweetwater County, Wyoming," *Wyoming Geol. Assoc. 15th Ann. Field Conf. Guidebook,* pp. 147-151.

KATICH, P. J., 1959, "Late Cretaceous Faunal Zones, Western Colorado," *Rocky Mountain Assoc. Geol. 11th Field Conf. Guidebook,* pp. 26-29.

LOVE, J. D., WEITZ, J. L., and HOSE, R. K., 1955, "Geologic Map of Wyoming," *U. S. Geol. Survey.*

MASTERS, C. D., 1959, "Correlation of the Post-Mancos Upper Cretaceous Sediments of the Sand Wash and Piceance Basins," *Rocky Mountain Assoc. Geol. 11th Field Conf. Guidebook,* pp. 78-80.

PARKER, J. M., 1959, "Lewis Formation Gas Sands, Eastern Sand Wash Basin," *Rocky Mountain Assoc. Geol. 11th Field Conf. Guidebook,* pp. 85-88.

REESE, D. L., and GRAS, V. B., 1959, "Cretaceous Production of the Vermillion Basin," *Rocky Mountain Assoc. Geol. 11th Field Conf. Guidebook,* pp. 92-94.

RITZMA, H. R., 1955a, "Early Cenozoic History of the Sand Wash Basin, Northwestern Colorado," *Rocky Mountain Assoc. Geol. and Intermountain Assoc. Petrol. Geol. Guidebook to the Geology of Northwest Colorado,* pp. 36-40.

----------, 1955b, "Late Cretaceous and Early Cenozoic Structural Pattern, Southern Rock Springs Uplift, Wyoming," *Wyoming Geol. Assoc. 10th Ann. Field Conf. Guidebook,* pp. 135-137.

SCHULTZ, A. R., 1909, "The Northern Part of the Rock Springs Coal Field, Sweetwater County, Wyoming," *U. S. Geol. Survey Bull.* 341, pp. 256-282.

----------, 1910, "The Southern Part of the Rock Springs Coal Field, Sweetwater County, Wyoming," *U. S. Geol. Survey Bull.* 381, pp. 214-281.

----------, 1920, "Oil Possibilities in and Around Baxter Basin, in the Rock Springs Uplift, Sweetwater County, Wyoming," *U. S. Geol. Survey Bull.* 702, 107 pp.

WEIMER, R. J., 1959, "Upper Cretaceous Stratigraphy, Colorado," *Rocky Mountain Assoc. Geol. 11th Field Conf. Guidebook,* pp. 9-16.

----------, 1960, "Upper Cretaceous Stratigraphy, Rocky Mountain Area," *Bull. Amer. Assoc. Petrol. Geol.,* Vol. 44, No. 1, pp. 1-20.

----------, 1961, "Upper Cretaceous Delta on the Tectonic Foreland, Northern Colorado and Southern Wyoming," (Abstract), *Bull. Amer. Assoc. Petrol. Geol.,* Vol. 45, No. 3, p. 417.

----------, and HAUN, J. D., 1960, Cretaceous "Stratigraphy, Rocky Mountain Region, U. S. A.," *International Geol. Cong., XXI Session, Norden, Part XII, Regional Paleogeography,* pp. 178-184.

ZAPP, A. D., and COBBAN, W. A., 1960, "Some Late Cretaceous Strand Lines in Northwestern Colorado and Northeastern Utah," *U. S. Geol. Survey Prof. Paper* 400-B, pp. B246-B249.