STRATIGRAPHY AND CORRELATION OF THE MARINE JURASSIC DEPOSITS OF CENTRAL OREGON

Thesis by

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CONTENTS

(Abstract)

Marine Jurassic rocks occupy an area of more than 200 square miles in the pre-Tertiary area of central Oregon. Eight formations are recognized in a series that ranges in age from the middle Lias to the Callovian of the upper Jura. The faunas are grouped into four chronologic divisions which are ~~not~~ ? characterized by groups of ammonoids coincident ~~with the stratigraphic divisions~~. The two sets of divisions may be compared in the following manner:

Group	Formation	Fauna	Age
Silvies	Lincoln	Gowericeratids	Proplanulitan (Callovian, upper Jura
	unconformity		
	Craddock	Stepheoceratids, Sonninids, and Sphaeroceratids	Ludwigian, Sonninian, and Stepheoceratan (Upper Aalenian and Bajocian)
	unconformity		
Ochoco	Warm Springs		
	Colpitts		
	unconformity?		
	Nicely	Hildoceratids, Harpoceratids, Amaltheid, and Dactyloid	Harpoceratan (Lower Toarcian, upper Lias)
	Freeman		
	Mowich		
	unconformity?		
	Donovan	Polymorphitids, Deroceratid, and Stepheoceratid	Polymorphitan (Charmouthian, middle Lias

STRATIGRAPHY AND CORRELATION OF THE MARINE JURASSIC DEPOSITS OF CENTRAL OREGON

INTRODUCTION

Location of the area

Marine Jurassic rocks constitute a considerable part of a large area of pre-Tertiary rocks recently discovered in central Oregon. The pre-Tertiary area, which covers approximately 800 square miles, is not more than 50 miles east of the exact center of the state. There are no towns in the area but only occasional ranch houses with an attached postoffice and name. Silvies, Seneca, Logdell, Izee, and Suplee are all towns of the ranch-house type and are located in the open valleys and basins of the major streams. Suplee is in the extreme eastern part of the area in the open country west of Beaver Creek and Izee is near the center of the deep upper South Fork valley. The other three postoffice stations are in the two broad basins of the upper Silvies River. Logdell is at the west end of Bear Valley, Seneca is on the south side, and Silvies is in the hills of the east side of Silvies Valley.

The nearest functioning railraad is thirty miles south of Silvies Valley at Burns, which is the western terminus of a branch of the Oregon Short Line. A logging railroad, recently constructed northward from Burns, crosses the Silvies basin and enters the south edge of Bear Valley. A new macadam highway is nearly complete between Burns and Canyon City. It follows the general course of the logging road from Burns and continues across Bear Valley to lower Canyon Creek. Another graded but otherwise unimproved road crosses the upper South Fork valley and connects the Bear Valley region with Suplee and Izee. A similar road lies between Suplee and Burns. In the open country "sage-brush" roads are as innumerable as the typically western wire gates, and the Forest Service maintains a network of serviceable roads within the forested areas.

A large part of the area is in the National Forest; that part lying west of Snow Mountain and the lower South Fork is in the Ochoco division and that to the east is in the Malheur division.

Previous work

An excellent record of the beginnings of geological knowledge in central Oregon is found in the biography and letters of Dr. Thomas Condon,[1] the pioneer Oregon geologist, minister, and professor, whose enthusiastic admirers sent him rocks, fossils, and geological information from numerous out-of-the-way places that he had not visited personally.

Apparently the first discovery of pre-Tertiary marine fossils in eastern Oregon was made in 1864 by a cavalry expedition under Captain John M. Drake. Mrs. McCornack states that these fossils were Trigonias and other Cretaceous shells, and this locality is doubtless the one that is known today as the Bernard ranch locality, which is of upper (Chico) Cretaceous age. It is about three miles northeast of Suplee.

Condon must have known of the existence of Paleozoic rocks in the same general ~~vicinity~~ region, for there are some Paleozoic fossils from Beaver Creek in the Condon Museum at the University of Oregon, and in his book on "The two islands" ~~Condon~~ he mentions "Rhynconella shells collected on Beaver Creek in Crook County, also of Paleozoic age"[2]

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1. McCornack, Ellen Condon, Thomas Condon, pioneer geologist of Oregon: University Press, Eugene, 1928
2. Condon, Thomas, Oregon Geology; a revision of "The two islands" Ed. by Ellen Condon McCornack, p. 148, Portland, Oregon, 1910

Other references to fossils from central Oregon are found in Mrs. McCornack's book. In 1894 there is some correspondence between Condon and J. S. Diller regarding some fossils found by Mr. Day at a pointwest of Canyon City in the Blue mountains.* In March of the same year Hyatt published a paper wherin he describes some Lias fossils received from Condon, through Diller, from "Beaver Creek, a tributary of the Crooked River, in the Blue Mountains of eastern Oregon" [2] Both of these localities are probably incorrect, for the fossils that Hyatt described surely must have come from the red sandstone of the Donovan locality which is 18 miles northwest of Burns. Condon's letters seem to indicate that the Donovan locality was discovered several years later, in 1900, by A. H. Huntington of Baker, Oregon. Nevertheless it seems certain that the only fossil localities of this region that were generally known prior to 1900 are the red Lias sandstone near the Donovan ranch, the Bernard ranch Cretaceous, and some of the Suplee Carboniferous.

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*"Blue Mountains" is a very general term. "Ochoco Range" is used in this paper for the range east and west of Canyon City.
1. Hyatt, A., Trias and Jura in the western states: Geol. Soc. America, Bull., vol, pp. 395-434, p. 401, 1894

Other geologists and collectors have visited the region since 1900. L. L. Davis, in 1900, while on a collecting expidition for von Zittel of Munich, visited the Bernard ranch and crossed the upper South Fork on his way to Canyon City. About the same time Lingren[1] was studying the mineral deposits of northeastern Oregon and noted the occurence of black shales west of Canyon Mountain, but again only the margin of the area was touched.

A year or two later Washburn collected at the Bernard ranch and followed the path of Davis across the head of the South Fork to Canyon City. His observations, recorded in a short paper,[2] gave the first indication of the extensive marine section that eventually was discovered there.

Nearly twenty years later Packard and Nelson visited the Donovan locality and subsequently presented a paper,[3] before the Geological Society, in which they gave a general description of the

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1 Lindgren, Waldemar; Gold belt of the Blue Mountains of Oregon: U. S. Geol. Survey, 22nd.Annual Rept., pt.2, 1900-1901.
2 Washburn, CChester W., Notes on the marine sediments of eastern Oregon: Jour. Geology, vol. 11, pp. 224-229, 1903.
3 Packard, E. L., and Nelson, R. N., Geologic occurence of the Hardgrave Jurassic fauna of Burns, Oregon (abstract): Geol. Soc. America, Bull., vol. 32, p. 148, 1921.

fauna and stratigraphy of this small but significant area. In 1929 a paper by J. P. Buwalda[1] mentions sedimentary Mesozoic strata in the forested plateau between the Ochoco Range and the Harney Basin.

Packard, Cunningham, Holdridge, and probably others have collected from Bernard ranch and vicinity and from the Donovan ranch, but it remained for Dr. E. L. Packard to begin geological explorations that resulted in bringing to light the remarkable sequence of fossiliferous pre-Tertiary marine sediments over a large area.

In 1926 Packard established the annual summer camp of the University of Oregon near the head of Beaver Creek, about eight miles above the Bernard ranch, and, by an unusual coincidence, that small area proved to be the most critical and most fossiliferous of the entire region. The ensuing days of exploration soon established the existence of the marine series in a broad band from upper Grindstone Creek southwest of Suplee across the upper South Fork valley to a point seven miles south of Canyon City, not far from the black shale area mentioned by Lindgren.

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1 Buwalda, J. P., Report on oil and gas possibilities of eastern Oregon: Oregon Bur. Mines and Geology; Min. Res. of Oregon, vol. 3, no. 2. 1921

Nature and purpose of this report

The writer was a member of the first central Oregon summer camp and soon became interested in a study of the Jurassic deposits and their faunas. The next three summers were spent in the field exploring for additional areas of pre-Tertiary rocks, studying the Jurassic sections, and collecting from the rich faunas.

Following a lead obtained by Dr. Packard several small patches of Jurassic and a large area of Triassic were found on the north side of Bear Valley, and continued exploration revealed large areas of sandstone and shale, entirely of Jurassic age, on the south side of Bear Valley, around the northern half of Silvies Valley, and in the canyon between the two valleys. Moreover, a large and unexpected portion of the pre-Tertiary beds proved to be of Jurassic age, so the problem of the central Oregon Jurassic has developed into such proportions that this paper can be little more than a reconnaissance report except the description of several small areas that have been studied in somewhat more detail.

Several major and minor divisions have been recognized in the central Oregon Jurassic, and faunal studies have been carried on in an attempt to determine their position in the standard European time scale.

This paper will be concerned principally with: (1) the areal distribution and stratigraphy of the Jurassic deposits, (2) the nature and succession of the faunas, and (3) their correlation with other Jurassic faunas.

Most correlations of North American Jurassic deposits must, in the present state of knowledge, be made with the better known and more complete European sections, and to achieve the greatest degree of accuracy it is necessary to employ sensitive, rapidly evolving organisms such as the Ammonoids. Fortunately the Ammonoids are well-represented in the central Oregon Jurassic. The faunas are somewhat closely related to those of Europe, but no species and but few genera have yet been recognized that are common to both areas. Therefore correlations must be made through a comparison of phylogenetic development and relationships.

S. S. Buckman's monumental works on the English Jura have been of great assistance because of his detailed faunal and stratigraphic subdivisions. The chronologic sequence of ages and hemerae, propo~~unded~~sed by Buckman, are used in this paper as a standard of comparison for the central Oregon Jura.

Acknowledgements

The writer is greatly indebted to Drs. J. P. Buwalda, E. L. Packard, and W. P. Woodring. The suggestions, criticisms, and support of these men have been helpful in so many ways that it is impossible to acknowledge each of them separately. The writer's interest was first drawn to a study of Mesozoic fossils while a student under Dr. Packard at the University of Oregon. Through the interest of Dr. Buwalda the Jurassic problem was carried to the California Institute of Technology where this thesis has been prepared under the guidance of Dr. Woodring. Dr. Packard has kindly loaned the University of Oregon and Condon collections of Jurassic fossils. Dr. Buwalda and Dr. Woodring ~~and Dr. Buwalda~~ have visited the area, and Dr. Packard has spent part of three summers in the region and his explorations have revealed many of the Jurassic exposures. The writer is especially indebted to his wife, Anna Woodward Lupher, for her assistance in the field and laboratory.

GEOGRAPHY

Topography

South of the upper John Day River are three diverse types of topography. They are, from north to south: (1) the Ochoco Range, a narrow east-west chain of heterogenous peaks and ridges; (2) a high, forested, dissected plateau, some 45 miles wide, adjacent and parallel to the south side of the range; (3) the lower semi-arid lake basin and sage-brush desert country of low relief, which merges farther to the south with the typical basin and range topography of the Great Basin. The marine Jurassic area to be discussed lies entirely within the high plateau division, but some of the other pre-Tertiary rocks make up a part of the Ochoco Range.

The Ochoco Range forms a sharp, narrow boundary between the high plateau and the broad valley of the upper John Day River. The northern slopes on the valley side are high and abrupt between Dayville and Prairie City, but the south slopes are much lower. The plateau dips gently southward and 35 miles south of the range it passes into the open sage-brush country--the High Desert on the southwest, the broad Harney Basin on the south, and the broken country of the Malheur drainage farther to the southeast.

The plateau division south of the mountains was once largely or entirely capped by Tertiary lavas. At the beginning of

Pliocene time it must have been a featureless plain that was similar to and continuous with the present day lava-capped surface west of Burns. However, even at its best development, or soon afterwards, the plateau had a high center that was due either to islands of the older rocks that was never covered by the lavas or to a structural uplift, for a radial drainage was developed. At the present time many of the major streams east of the Cascade Range have their headwaters in this former plateau surface. The Crooked River rises on the west near Suplee and flows far to the northwest, where it joins the Deschutes River near Redmond. The South Fork of the John Day and Canyon Creek are southern tributaries of the John Day River, which flows northwest to the Columbia River. On the east the large Malheur system flows south and then northeast to the Snake River. On the south Silver Creek and the broad drainage of the Silvies River empty into the southern lake basins and are within the Great Basin drainage.

The divide between the Pacific and Great Basin drainages winds eastward through Snow Mountain and around the head of the South Fork. Then it turns far to the north where it includes the upper Silvies River drainage basin and reaches some distance up the southern side of the Ochoco Range to the northernmost extension of the entire Great Basin area.

The plateau character of the country south of the mountains has been largely altered by stream degradation and by structural deformation, but ~~nevertheless~~ most of the land is not far above or below an altitude of 5,000 feet.

Almost without exception the principal streams have broad, branching headwaters in areas that are approaching maturity, but along their lower courses they are confined to deep, narrow canyons. The South Fork flows through a deep, rugged canyon from a point twenty miles south of its junction with the John Day River, cutting deeply into both the plateau surface and the Ochoco Range. South of and above the canyon the numerous tributary streams of the upper South Fork have carved out a broad area of deep canyons and high ridges--a deeply dissected mature valley system in the middle of the plateau. There are many open valleys on the upper Crooked River, especially near Suplee, but north of Paulina the river enters a narrow valley which, in places, narrows down to vertical-walled canyons.

The upper Silvies River and its tributaries lie in a long arc of nearly 180 degrees around the head of the South Fork. The Silvies drainage is at a much higher level than that of the South Fork and is nearer to the original plateau surface. The relationships of the two drainage systems show that the South Fork is advancing into the midst of the Silvies system.

The tributaries of the Silvies River are grouped into three clusters and between these clusters the river flows in narrow canyons that are unbroken by important tributary water courses. The most northern cluster centers around Bear Valley, a broad, shallow, nearly circular structural depression entirely surrounded by hills of the higher plateau level. The Silvies River rises in the hills southwest of Bear Valley and flows northeastward into the basin, where it meanders through elaborate oxbows as it turns south and enters the narrow upper canyon near Seneca. Six miles south of Seneca the river emerges from the canyon into Silvies Valley, a basin that closely resembles Bear Valley, so the Bear Valley drainage is duplicated here: the river meanders slowly across the broad valley, receiving a number of tributaries, then flows into another narrow canyon, the lower canyon of the Silvies River. South and southwest of the Silvies Valley the Tertiary lava plateau is least dissected and for 25 miles the Silvies River flows through a deep, narrow defile in the plateau until it again emerges into another structural depression, the enormous Harney Basin.

Climate and Vegetation

The climate and vegetation of this central Oregon region is very similar to that of the Rocky Mountains of Montana and Wyoming. The summers are hot in the lower country along the John Day River and in the southern desert and lake basin region, but the summer temperatures are more moderate on the intervening plateau and mountain areas. Frosts are common throughout the summer in Bear Valley and along the Ochoco Range. The winters are long and much colder than the latitude would indicate. Temperatures of more than 40 degrees below zero are not uncommon.

The summer precipitation comes almost entirely from sporadic thunder showers, but the fall and spring rains and winter snows furnish the principal supply of moisture. The moisture-bearing winds from the Pacific Ocean are relieved of a large part of their moisture by the ~~five thousand~~ 5000-foot Cascade barrier and therefore most of the areas that lie below that critical altitude do not receive sufficient rainfall to support a forest growth. The original plateau surface lies at an average elevation of 5,500 and consequently the larger part of the plateau division is covered by coniferous forests. The upper or cold timberline is apparently as low as 7000 feet south of the Ochoco Range. The higher peaks along the range are barren of timber and the top of Snow Mountain, 7,500 feet, is also barren.

The open country of the plateau division is confined principally to the large stream valleys. Bear Valley and Silvies Valley are open basins that are surrounded on all sides by broad areas of forests. The broad, deep valley of the upper South Fork is also without forests and an open strip north of Snow Mountain extends westward from the South Fork, includes Beaver Creek and the Upper Crooked River drainage, and broadens rapidly westward from Suplee. The southern margin of the forest is somewhat irregular because the lava surface dips at a very low angle ~~so gradually~~ beneath the open lake basins.

The plateau valleys support a heavy growth of sage-brush and grass. Rabbit-brush is very abundant along with the sage and the rocky ridges of the Suplee-South Fork region are dotted with juniper trees. Mountain mahogany is characteristic of the entire plateau. It grows in dense thickets on the higher rocky points of the open country and is especially abundant near the lower timber-line where it merges with the conifers and becomes less plentiful with increasing elevation. Quaking aspens prefer approximately the same elevation as the mahoganies, but the aspens are confined to the moist places and the mahoganies to the rocky ridges.

The timbered areas support extensive growths of yellow and black pines, which give rise to beautiful open forests with occasional thickets of mahogany, juniper, bull pines, wild currant and gooseberry as the only undergrowth. Tamaracks and firs often grow in the better watered canyons and north hillsides, and spruce appears near the upper timber-line.

PRE-TERTIARY ROCKS

General features and relation to Tertiary beds

The pre-Tertiary area is essentially a large erosional opening through the veneer of Tertiary lavas and other continental deposits. The shape of the opening is somewhat irregular, due to the protruding tongues and isolated remnants of the plateau surface, but most of the old rocks lie within a triangular area with a base, (see map in folder ~~opposite p.~~), on a line from Silvies north to Canyon City, and its altitude west from Silvies through Snow Mountain to an apex 7 miles southwest of Suplee. Thus the base of the triangle is ~~would be~~ 26 miles long, the altitude 44 miles, and the hypotenuese 52 miles. The resemblance of the northern corner to an acute angle is altered by a broad embayment that includes Fields Peak, McLellan Mountain, and Canyon Mountain. The southern side is also made irregular by the northward extension of the plateau lavas on Snow Mountain and on the Izee summit between the upper Silvies basin and the South Fork.

The structural break between the Mesozoic and Tertiary formations is as pronounced as the break between the Archaen and Paleozoic in the central interior of North America. The Paleozoic and Mesozoic beds of central Oregon dip very steeply and ~~some~~ at places are even overturned, but the oldest of the Tertiary lavas have very low dips in most places and the younger members are nearly horizontal.

The present plateau surface was formed when a single thin flow of glassy, pumiceous rhyolite flowed out after a prolonged period of erosion had developed a remarkably flat plain over thousands of square miles in central Oregon. No areas of old rocks are known ~~which~~ that escaped complete truncation by this erosion surface, but east of the Silvies River and north of Paulina the sea of rhyolite ends against hard Tertiary basalts.

The development of the opening through the lava plateau is not entirely the result of stream degradation, for orogenic forces played an important part in making the region accessible with a small amount of post-plateau erosion. This region, as pointed out on page 14, became a highland after the development of the final plateau, and the same forces must have acted in the past to keep it above the great floods of Columbia River lavas and of later lavas and tuffaceous accumulations. There is very little evidence to show that the Columbia River lavas were as extensively developed in southern and central Oregon as they were in northern Oregon. Large areas, probably larger than those of the Columbia River lavas, are now covered by younger Tertiary formations or are occupied by older rocks of both Tertiary and pre-Tertiary age. Furthermore, the present window of pre-Tertiary rocks in central Oregon was probably never covered by the basalts or by any other Tertiary formation until after the development of the Pliocene erosion surface. It is possible that the pre-Pliocene deposits did extend over this region, but if they did erosion has entirely removed them. Thus,the area of old rocks is partly a high positive area of Tertiary time,and partly a window that was carved out ~~near,~~ during and since the end of the Tertiary by the cutting through and stripping back of the thin lava veneer as a result of continued uplift of the positive area.

The pre-Tertiary formations are largely marine. The only igneous rocks are the deep-seated intrusions of the Ochoco Range. Though the marine beds have been subjected to severe epochs of mountain making and to igneous intrusion, ~~but nevertheless~~ they are remarkably free from metamorphism and ~~from~~ extreme crumpling and faulting. Probably the most striking geological features of the region ~~is~~ are the remarkable number of formations represented, the long time range they include, and the number of angular unconformities.

Carboniferous

The oldest rocks so far recognized in the pre-Tertiary section are the Carboniferous limestones and cherts recently mentioned by Packard[1]. These ~~occur~~ are found only in the western part of the ~~area~~ region where the main area occupies approximately 15 square miles, southwest of Suplee, at the westernmost tip of the triangle. Small, isolated outcrops, surrounded by Mesozoic beds, are found on Beaver Creek near the Bernard ranch and immediately north of Snow Mountain on upper Flat Creek. The Carboniferous beds dip very steeply and are probably overturned ~~in~~ at many places, but they seem to have no prevailing strike.

The limestones are not greatly altered and Packard has reported a typical Mississippian fauna, which includes Productus striatus Fisher and Productus giganteus Martin.

After the deposition of the limestones and cherts there was an epoch of folding and erosion sufficient to cause a marked nonconformity. The areas of Carboniferous rocks contributed large amounts of sediments ~~in~~to the later ~~advances of the~~ seas, for the Triassic and Jurassic grits and conglomerates contain much limestone and chert from the Carboniferous series.

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1 Packard, E.L., Discovery of the Baird Mississippian fauna of Central Oregon (abstract): Geol. Soc. America, Bull., vol. 40, p. 257, 1929.

Triassic

Marine rocks of Triassic age outcrop over considerable areas along the north and northwest side of the pre-Tertiary triangle. North of Bear Valley and west of Canyon Creek is a large area of Triassic shale and sandstone. It forms the northern rim of Bear Valley and the hills that descend abruptly to Canyon Creek as far north as Vance Creek. Packard[1] reports the same series farther west on the road that crosses the range to Mt. Vernon, and they probably extend as far west as McLellan Mountain. These Triassic beds ~~will be~~ are designated ~~as~~ the "Bear Gulch group" in another paper.[2] They are made up principally of hard black well-bedded shales with minor amounts of hard blue fine-grained sandstones. The total thickness is more than 15,000 feet, if some of the beds are not duplicated. Nearly everywhere the beds dip steeply northward, perhaps due to overturning from the north.

Pyroxenites, now largely altered to serpentine, were intruded into the Triassic sediments before Middle Lias time. The only younger Mesozoic rocks that have been found in contact with the Bear Gulch group are some patches of upper Lias limestone and shale on the north side of Bear Valley opposite Sencea.

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1 Packard, E.L., Oral communication
2 Lupher, R.L., A geological section across the Ochoco Range and Silvies Plateau south of Canyon City, Oregon: Mss. in preparation.

The total thickness of the western group is still unknown, but it is possibly greater than that of the Bear Gulch group. A sharp, angular unconformity separates the Triassic and Carboniferous group. It is best shown around the isolated area of Paleozoic on upper Flat Creek where both groups dip very steeply but strike at wide angles to each other. Boulder conglomerate and coarse grits of Paleozoic limestone and chert are found here at the base of the Triassic.

Typical Triassic fossils, including "Orthoceras", Belemnoids, Halobia or Daonella, and "Arcestes", have been found in the limestone near Suplee. Only a "Spiriferina" has yet come from the Bear Gulch group, but this ~~same~~ species is common to both Triassic areas.

The Triassic deposits ~~of~~ at the western end of the region are closely associated with overlying Jurassic formations, so their outcrops are mutually irregular and less ~~easily~~ readily defined. The principal outcrops of Triassic rocks lie in an area that abuts against the Paleozoic mass on the west between Snow Mountain and Suplee. It strikes about N. 55°E. across the South Fork and continues into unexplored country on upper Deer Creek and the head of Murderers Creek, perhaps connecting with the northern Triassic area near McLellan Mountain.

The sediments laid down in this western Triassic region are much coarser than those of the Bear Gulch series. Black shales still predominate but there are a number of sharply defined beds of fine conglomerate. This series has a very constant attitude; the strike usually lies within a few degrees of north and the dips are nearly vertical. No serpentines are associated with the Triassic sediments in this area but there are a number of sills of a green basalt porphyry of Tertiary age. Differential erosion of this series of hard layers of conglomerate and porphyry in thicker beds of soft shales has produced a coarse serrate topography that is characteristic of the Triassic exposures throughout this western region. The Triassic beds were steeply tilted before the Jurassic sea advanced over them and the hard and soft bands caused considerable lateral variations of lithology and environmental conditions in the Jurassic sea.

Jurassic

Jurassic rocks predominate over an area that is practically coextensive with the entire pre-Tertiary area. They appear to be absent only along the Ochoco Range. Several isolated Jurassic outcrops also are exposed beneath the plateau lavas southwest of Silvies Valley and one of these outcrops, in the Silvies canyon near the Donovan ranch house, is the oldest Jurassic deposit known in eastern Oregon. This section is made up of a variety of rock types from conglomerate to limestone, but it occupies a relatively small area of less than one square mile that is entirely surrounded by Tertiary lavas and intrusives.

Two distinct groups of Jurassic formations, separated by an angular unconformity, have been recognized in the main area. The lower group is best exposed throughout the western Triassic area discussed on pages 25-26. It is a relatively thin deposit not more than 700 feet thick, but it is very fossiliferous and contains five distinct formations and a number of faunal zones that show a long time range. This lower group is made up of a basal conglomerate, reef limestone, highly calcareous sandstone and grit, and black shale. The basal conglomerate bevels the steeply dipping Triassic beds with an angular unconformity that usually approaches 90 degrees, though the lower group of the Jurassic series is also thrown into a series of northeast trending folds that show dips as high as 70 degrees.

The isolated outcrops of limestone and shale on the north side of Bear Valley also belong to the lower group and, as in the Suplee region, they bevel steeply dipping Triassic beds. On the head of Flat Creek, north of Snow Mountain, the lower group truncates both Triassic and Paleozoic folds.

The upper group is best exposed in the southern half of the region, mostly south of the northeast trending area consisting of Triassic rocks and deposits lower group. On the headwaters of Beaver Creek, south of Suplee, the upper group is nearly horizontal and overlaps steeply dipping beds of the lower group; elsewhere it is considerably folded and even overturned. Less than a thousand feet of the upper group is exposed in the Beaver Creek country, but farther northeast, in the upper South Fork and upper Silvies region, ~~is~~ a much thicker section between Silvies and Seneca, apparently more than 15,000 feet, ~~are~~ is represented. The upper group is composed almost entirely of well-bedded black shales with occasional bands of massive, hard sandstone.

As in other places in the Pacific region of North America where Jurassic is known, the long period of marine sedimentation was brought to a final close by the intrusion of deep-seated magmas. These intrusions outcrop only in the Ochoco Range. Canyon Mountain and the high ridge on both sides of the peak are made up of medium to coarse-grained intrusives, probably of late Jurassic age. West of Canyon Mountain ~~are probably~~ there may be other granitic intrusions. Fortunately the intrusions were on such a small scale and sufficiently far removed that the Jurassic marine series were not greatly affected except by folding. Both the upper and lower series of the Silvies region may have been greatly disturbed by the intrusion or the presence of the granitoid masses to the north, but at anyrate the amount of metamorphism was very small. The Jurassic of the Suplee region, being much farther away from the intrusions, suffered even less.

Cretaceous

The Cretaceous of central Oregon is not extensive and has little bearing on the Jurassic problem. The principal area is the small outcrop of Chico sandstone and shale found by Captain Drake's expedition, in 1864, on the east side of Beaver Creek near the Bernard ranch house. Another small area is known on the Bernard ranch road a short distance northeast of Suplee. In both places the Cretaceous beds lie uncomformably upon Triassic, indicating that the Jurassic series was eroded away before Chico time. Both Jurassic groups are well developed only two miles south of the second Cretaceous locality and it is improbable that the absence of the Jurassic beds is due to thinning during deposition.

JURASSIC MARINE DEPOSITS

General Features

Most of the marine Jurassic rocks outcrop in an irregular area, approximately 10 miles wide and 40 miles long, which strikes N. 80°E. The western end lies between Suplee and Snow Mountain and ends against the Paleozoic mass of Iron Mountain. The east end extends across the Silvies River between Gold Hill and Seneca and ends about two miles northeast of Silvies. The Jurassic outcrops between Iron Mountain and the South Fork Valley are in the open country north of Snow Mountain and the southern Ochoco Forest. Eastward they cover a somewhat broader area in the deeply eroded valley of the upper South Fork where they include almost all the drainage basin above the Keerins Brothers ranch. Between the Keerins Brothers ranch and the head of the Silvies River is a northward extension of Jurassic and Triassic rocks that continues for an unknown distance into the Deer Creek and Murderers Creek drainage basins. Jurassic shales and sandstones have been found on some of the western tributaries of the uppermost Silvies River and they continue farther north around the west side of Bear Valley as far as the Bear Valley Ranger Station.

The continuity and regularity of the south side of the Jurassic area is somewhat obscured, as mentioned on page 31, by two peninsula-like extensions of the lava-capped plateau that reach northward on both sides of the upper South Fork valley. Snow

Mountain is the north brink of the southward-tilted western peninsula and the flat plateau on the upper parts of Camp Creek and Myrtle Creek is the eastern peninsula.

Of the several small outcrops isolated from the main area only four merit more than passing mention. Three are close together on the north side of Bear Valley; one is an area of 80 acres of limestone and shale on the ranch of Wm. Vancil; and the other two are less than a mile to the northwest on the Stratton ranch. The fourth is the Donovan ranch locality, which is in the lower Silvies Canyon 19 miles below the Silvies basin. All of these localities have yielded fossils and will be considered in the detailed section of this paper. Other isolated outcrops, exposed beneath the plateau lavas, have been found on Sawtooth Creek, a tributary of lower Emigrant Creek, on Sagehen Creek, a western tributary of the Silvies River, and even near the plateau surface on the Izee summit road. None of the latter localities has been carefully examined. Other areas doubtless exist in the numerous unexplored canyons of the plateau.

The small Donovan ranch area is of ~~e~~special significance, for it has yielded an abundant middle Lias fauna, which is older than any other known Jurassic fauna~~s~~ of eastern Oregon. This is the only locality of marine Jurassic that was generally known east of the Oregon Cascades prior to 1926, and it is probably the locality from which Condon obtained the "Beaver Creek" fossils described by Hyatt[1] in 1894. The fossils come from a dark red sandstone that is a conspicuous member of a sequence of sandstones and shale with a minor amount of limestone and conglomerate. The section is considerably folded and faulted, and Tertiary intrusives add to the compl~~ication~~exity. The total thickness of the section is probably not more than 1800 feet.

The structural relationship of these Liassic beds with the younger beds of the main Jurassic area is unknown, but the faunas show a~~n~~ long (appreciable) time interval between them. The younger series lie unconformably ~~up~~on Triassic many miles away, so it is evident that the Donovan section must be treated as a separate division, and it ~~is very~~ probabl~~e~~y ~~that it~~ is delimited by a structural unconformity somewhere beneath the plateau lavas. The Donovan sequence includes a variety of rock types and possibly an unconformity, but the stratigraphy is so imperfectly known that it seems best at present to designate these beds only as the Donovan formation.

The general distribution and relationships of the two groups represented in the main Jurassic area have been discussed on pages 27-28. The lower group can be subdivided into six well-marked stratigraphic units ~~which~~ that range in age from lowermost upper Lias to the middle Bajocian of the Middle Jurassic. These beds may be

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1 Hyatt, Alpheus, Trias and Jura in the western states: Geol. Soc. America, Bull., vol. 5, pp. 395-434, 1894

appropriately designated the Ochoco group, ~~because~~ as the best exposed and most complete section is found immediately north of the southern division of the Ochoco National Forest between the headwaters of Beaver Creek and Warm Springs Creek about eight miles south of Suplee. The type localities of all six stratigraphic units are within this small area and lie in secs. 19, 20, 28, 29, and 30, T. 18 S., R. 26 E. between the Colpitts ranch house on upper Warm Springs Creek and the junction of Freeman Creek and Beaver Creek.

The upper group includes several horizons in the middle Jura, beginning not far above the highest horizon in the Ochoco group. The faunal break between the two series seems relatively small in comparison to the erosional interval indicated by the marked unconformity.

The total thickness of the Ochoco group is not large. A composite column of maximum thicknesses would probably total not more than 700 feet. Nevertheless an appreciable time range is represented, for a number of well-defined faunal zones ~~as well as~~ and sharply defined lithologic divisions are present, and fossils are plentiful throughout. Thus the series is susceptible to detailed stratigraphic and faunal subdivision.

The lithologic succession varies considerably from place to place, but the series normally begins with a basal conglomerate that was derived from the truncated layers of Triassic grit. Above the conglomerate comes a lenticular reef limestone. The remaining part of the section may be divided roughly into a lower sandstone and limestone member succeeded by a lower black shale, then an upper sandstone can be further divided into several minor sandstone and shale units.

Fossils are unusually plentiful throughout the section. Lamellibranchs, cephalopods, and brachiopods are most abundant, but there are also a few corals and crinoid stems. Vertebrate remains, probably of marine reptiles, have been found at 5 localities which represent at least 4 horizons.

The dominant structure of the Ochoco group is a series of northeastward trending folds. The type area lies across the south limb of a broad major anticline in which are some minor folds, and north of this anticline is a corresponding syncline. The south~~ern~~ limb of the anticline dips under the Silvies series and the Snow Mountain lavas. The north~~ern~~ limb of the syncline comes up near Suplee and exposes Triassic and Paleozoic beds below and apparently does not come down again to form another anticline before it is covered by Tertiary beds. Farther to the east only the anticline is known, ~~this~~ it crosses the South Fork above the Keerins Brothers ranch house and continues northeastward into unexplored country. The isolated remnants of shale and limestone on the north side of Bear Valley are in a direct continuation of the trend of this anticline and it is possible that they are related to a major anticlinal uplift that extends nearly across the entire pre-Tertiary window.

The name Silvies group is proposed for the upper series of Jurassic deposits as exposed in the upper canyon of the Silvies River between Silvies Valley and Bear Valley. The Silvies group is present throughout most of the main area of Jurassic rocks. The exposures are relatively thin near Suplee where they wedge out between Tertiary lavas on the south and older rocks on the north, but the section thickens rapidly east of Snow Mountain. Probably not more than 1000 feet of the Silvies group is exposed at the Suplee end of the area, whereas the estimated thickness of the type section south of Seneca is at least 15,000 feet.

The Silvies section is complicated by extreme folding and by large igneous intrusions and ~~it now seems very probable that~~ a study of the South Fork area might have yielded much better results as the exposures are ~~much better~~ more satisfactory there, the beds appear less disturbed, and ~~there is~~ undoubtedly a large section is represented.

The Silvies group, in sharp contrast to the Ochoco group, is non-calcareous; even the shells of fossils have been almost entirely leached away. It is also made up of much finer sediments than is the lower group. Wherever the Silvies group has been found it is always a similar monotonous succession of thick beds of black and gray shale alternating with occasional thinner bands of fine blue and green sandstone. The shales are usually soft and well-bedded, but the sandstones are very hard, remarkably massive, and cut by numerous systems of joints.

The series begins with a black shale in the Suplee region, apparently without even a thin sandstone as a basal bed. The base of the series is not exposed in the Silvies section, but the lowest beds known are shales with a very minor proportion of sandstone. Bands of sandstone become more numerous higher up, though they are always subordinate to the shale members.

The attitude of the upper series differs greatly from place to place. South of Suplee the strike is variable, but the dip is usually less than 15 degrees. In the South Fork valley the strike is generally north, and the dip is very high and ~~often~~ at many places vertical. The strike usually ranges between west and northwest in the Silvies region and folding has been so intense as to overturn large sections.

Donovan Formation

Stratigraphy and Lithology

The Donovan beds outcrop in a small isolated area in the Silvies River canyon and are of considerable significance because they contain the oldest known Jurassic fauna in Oregon--the so-called "Hardgrave" fauna of the red sandstone.

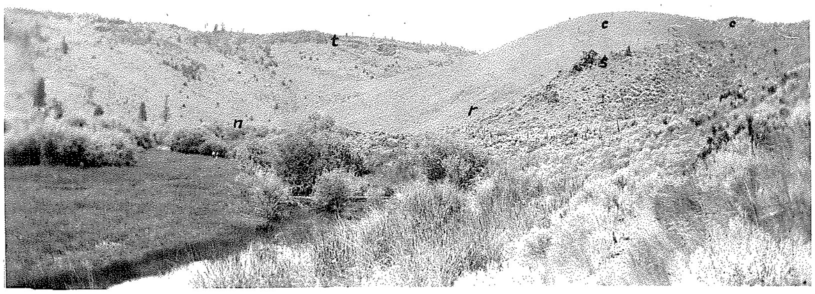
The writer first visited the locality in 1926 when he accompanied Dr. E. L. Packard on one of his trips of exploration. The party, which included Mr. Siemon Muller, spent three days at the Donovan locality. Most of the time was devoted to collecting from the red sandstone outcrops, but a short reconnaissance revealed that the area was by no means as small as formerly believed.

In 1927 the writer again visited the locality for a period of three days, made additional collections, and further extended the area of known outcrops. As before, the rich collecting ground attracted most attention and an attempt to work out the stratigraphic succession in the short time available at least showed more clearly than ever that the section is a very complicated one that is much disturbed by folding, faulting, and igneous intrusion. However, the lack of detailed stratigraphic knowledge is somewhat compensated by the fact that the fauna, with a single exception, shows so little variation in different parts of the section that it can probably be treated safely as a unit.

The Donovan beds are located, as near as can be determined from the Malheur National Forest map, in sections 7 and 8, T. 20 S., R. 30 E., about 18 miles northwest of Burns. The area is approximately one and one-fourth miles long and one-fourth mile wide, and trends northwest. The northwest end of the area is in a narrow part in the very bottom of the Silvies Canyon about one and one-half miles below and southwest of the mouth of Myrtle Creek, and one mile above Tim Donovan's ranch house. Southwest from the river bed most of the outcrops are on the south side of a high spur that comes down from the eastern rim of the canyon to the upper end of the Donovan meadows in the bottom of the canyon below the narrows. Beyond the high spur the outcrop crosses a deep north-south canyon and rises rapidly toward Red Butte which is a remnant of Tertiary rocks in an eastern embayment of the lava rim.

The Donovan outcrop was formed by the Silvies River cutting across a prominence of the pre-Tertiary basement beneath the plateau lavas. The Jurassic strata are partly or entirely surrounded by basalt that is probably a part of the widespread Calamity intrusive of the Silvies Valley. Within the mass of the Jurassic sediments are a number of older intrusions of a green basalt porphyry, probably of Clarno (Eocene) age. Above the basalt and sedimentary strata are several flows of rhyolitic lavas, of which the upper one forms the floor of the flat plateau surface. West of the river the lavas lie upon the Jurassic beds about 150 feet above the level of the stream channel, but on the spurs to the east the old rocks outcrop to an elevation of slightly more than 400 feet before they are covered by the lavas.

PLATE II



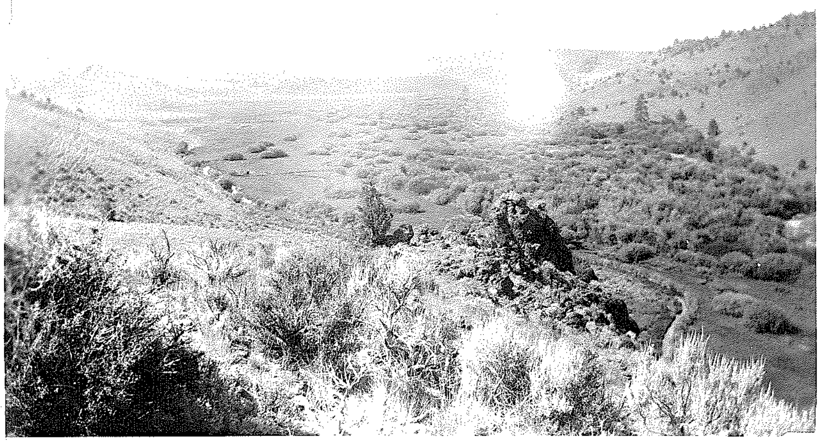
A. VIEW NORTHWESTWARD FROM THE EAST SIDE OF THE DONOVAN MEADOWS

t, Tertiary plateau lavas; n, narrows in the canyon between the red sandstone outcrops; 4, "third" red sandstone outcrop; c, Calamity basalt intruding and overlying Jurassic beds; s, sill of Soda porphyry at the base of section given on page 43.

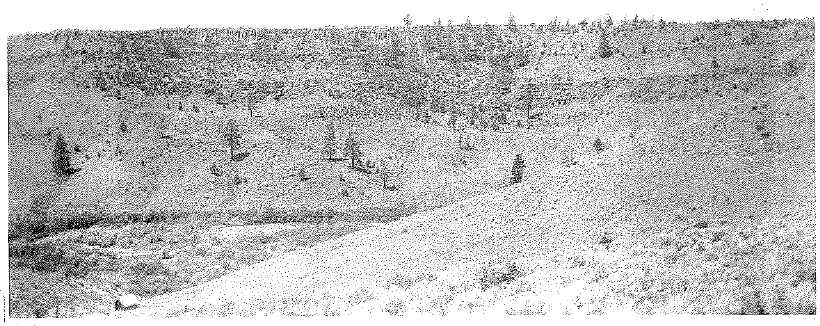
B. VIEW OF THE JURASSIC OUTCROPS SLIGHTLY FARTHER EAST THAN A.

l, limestone lens; other symbols as in A.

PLATE III



A. VIEW OF THE DONOVAN MEADOWS FROM THE JURASSIC AREA



B. RIM OF THE SILVIES CANYON WEST OF THE NARROWS

The Jurassic rocks are principally sandstones with a minor amount of shale, two small lenses of limestone, and a thick bed of coarse conglomerate.

The fossiliferous red sandstone is the most conspicuous member of the section. It is highly calcareous, very fine-grained, usually a deep, rich red color on both the fresh and weathered surfaces, and on the weathered surfaces it usually shows an even, glossy lustre. Bedding is not well-defined, and joints and fracture planes are numerous.

The red sandstone is known to outcrop in six places along the band of Jurassic rocks, and the lithology and fossil content is always so characteristic that it would seem improbable that the six outcrops could be anything but repetitions of the same bed. But such is not the case unless the structure is far more complicated than is apparent at present, for the red sandstone is not always found in the same sequence. The relationships of three of the red sandstone localities are obscured by intrusions and talus slopes, but in the other localities other beds are present.

The sequence of the Donovan beds is shown best in two localities, one in the bottom of the canyon at the extreme northwestern end of the area and the other on the south side of the high spur one-fourth mile southeast of the river.

On the west side of the stream bed is a low cliff showing about 15 feet of gray and green unfossiliferous sandstone beneath less than 50 feet of red sandstone. These beds dip uniformly northwest at an angle of about 25 degrees. Above the red sandstone cliff, outcropping beneath the lava debris from the west rim of the canyon, is a small patch of unfossiliferous gray limestone which dips toward the upper surface of the sandstone beds. Only the red sandstone member of this sequence is found on the other side of the stream channel where it outcrops under talus on the south side of the western tip of the high spur. These two localities by the stream bed are nearly surrounded by Tertiary igneous rocks--intruded on the north and east by the Soda porphyry and dense Calamity basalt, and overlain on the south and west by alluvium and debris from the later plateau lavas.

The high spur rises rapidly east of the river bed outcrops. Its western end is formed of the Soda porphyry and Calamity basalt, whose talus obscures the red sandstone outcrop ~~by~~ along the east side of the river. The best and most complete sequence of Jurassic beds outcrops along the southwest side of the high spur, beginning about 100 yards east of the eastern river bed locality. With the exception of occasional sills and dikes of the Soda porphyry, the sedimentary outcrops are continuous throughout the remaining part of the area.

The beds dip steeply southeast and away from the river, and strike transverse to the main spur but parallel to the auxilliary spurs that come down from the south side of the main spur to the

Donovan meadows.

At the base of the sequence is some of the typical red sandstone. It extends up the steep side of the spur perhaps 200 feet above the level of the meadow before it is covered by basalt talus. This outcrop is separated from the red sandstone immediately east of the river channel only by some intrusive Calamity basalt, so the two were perhaps once continuous. This third red sandstone outcrop is apparently overlain by a sequence of strata, which also includes, higher up in the series, another bed of red sandstone lying above green and gray sandstone as it does on the west side of the river bed. Therefore if the red sandstone in the river bed and that of the upper beds of the southeastward-dipping sequence are to be correlated, as it seems that they should be, then it is necessary to conclude either that the typical red sandstone is represented at more than one horizon, or that the third red sandstone outcrop at the base of the sequence has been brought to that position by a fault. The former supposition seems most reasonable. A summary of the probable stratigraphic succession, based upon this supposition is given below.

The attitude of the red sandstone at the base of the sequence could not be determined, but it is separated from the higher beds by a sill of green porphyry that dips with the rest of the section. This intrusion forms the backbone of one of the minor spurs and the top of the sequence ends with green and brown sandstone on the next minor spur to the southeast. The section may be tabulated, from top to bottom, as follows:

	Feet
1. Green sandstone above brown, fine-grained sandstone, both unfossiliferous ------------------	300
2. Coarse, yellowish-brown sandstone with the fauna of the red sandstone------------------------	100
3. Red sandstone, typically developed and very fossiliferous--------------------------------	120
4. Coarse green and gray sandstone with two sills of green porphyry----------------------	300
5. Brown, green, and yellow calcareous sandstone containing brachiopods--------------------------	50
6. Well-bedded black and brown shale-------------------	5
7. Green porphyry sill--------------------------------	?
8. Thick bed of green sandstone and conglomerate--------	?
9. Sill of green porphyry----------------------------	10
10. Red sandstone of "third locality"------------------	?
	1000 ±

The section might be considerably extended upward above the tabulated section, for there are more beds to the east~~,~~ including a heavy bed of green sandstone and conglomerate, more red sandstone, a coral-bearing sandstone, and about 200 feet of black shale. These beds are steeply inclined and their relationships with the enumerated sequence is still unknown. Their chief interest at present is that they show the red sandstone in still another association.

High up on the top of the main spur, above the base of the section just enumerated, is a lens of gray limestone similar to that west of the river bed. The lens is about 500 feet long and its maximum thickness is about 20 feet. It is nearly vertical and strikes about N. 70 E., nearly parallel to the sandstone series. The apparent relations are that the limestone lenses out into the basal beds of the arenaceous series and is succeeded by the brachiopod sandstone (no. 5 on page 43). The limestone, however, lies immediately beneath the brachiopod sandstone some distance up in the sequence, but the general trend of the outcrop is across the strike of the beds below the brachiopod sandstone; in fact, the relations are the same as the limestone and red sandstone beds across the river--an angular discordance similar to an ~~inverted~~ overturned unconformity. Both the limestone outcrops are very similar lithologically to the reef limestone near the base of the Ochoco group.

Northwest of the limestone lens, on the north side of the spur, is another outcrop of fossiliferous red sandstone that may be a continuation of the red sandstone beneath the enumerated sequence on the south side of the spur. The stratigraphic relations of this sandstone is also unknown because it is surrounded by lavas and intrusives.

Conclusions regarding the stratigraphy of the Donovan formation may now be summarized, using the tabulated sequence on page 43 as a standard of comparison. The green, gray, and red sandstones west of the river channel may be correlated with the similar beds numbered 3 and 4 in the table. The stratigraphic positions of the two limestones and the "third red sandstone" are still uncertain. The third red sandstone on the south side of the ridge and the red sandstone on the north side of the ridge probably belong to the same bed which is continuous through the ridge beneath the basalt intrusive. This red sandstone is apparently beneath the tabulated section, but that position may be due to faulting.

The limestone west of the river probably does not belong above the red sandstone, where it now appears, because (1) it dips into the upper surface of the red sandstone below, and (2) the limestone is not repeated in the sequence on the south side of the spur as the red sandstone seems to be. The limestone on the ridge is apparently a lens near the base of the standard sequence, but its attitude, as well as that of the limestone on the other side of the river, can best be explained as inverted unconformities due to overturning of the section.

Aside from the single continuous sequence tabulated on page 43, the stratigraphy and structure seems extremely confused and uncertain--beds apparently dip into one another in the manner of inverted nonconformities and the limestone near the base of the section could best be explained if it were the highest bed. In fact, the entire section could best be explained by overturning of a large part of the section, and such may prove to be the case, for much younger beds are overturned in the Silvies Valley not far to the northeast.

Fossils

Most of the Donovan fossils, as mentioned before come from the calcareous red sandstone. A few brachiopods have been found in a calcareous sandstone, (see no. 5 on page 43) and a coralliferous sandstone contains numerous heads of colonial corals, but the remainder of the fauna seems to be a very homogeneous assemblage that is characteristic of the red sandstone at all localities ~~horizons~~. Therefore the succeeding discussion will be devoted entirely to the red sandstone fauna.

The first published mention of the red sandstone fossils came in 1893~~,~~ from J. S. Diller[1] who had received a small collection from Thomas Condon. These fossils were subsequently described by Hyatt[2] and later returned to Condon. The fossils were stated to have come from "Beaver Creek, a tributary of the Crooked River", but this locality is apparently incorrect because (1) the Beaver Creek country has been explored more carefully than any other part of the pre-Tertiary area~~,~~ and no red sandstone or even a similar fauna has been found there; (2) three of the fossils mentioned by Hyatt were found in the Condon collection at the

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1 Diller, J.S., Cretaceous and early Tertiary of northern California and Oregon: Geol. Soc. Am., Bull., Vol. 4, pp. 205-224, P. 221, 1893.

2 Hyatt, Alpheus, Trias and Jura in the western states: Geol. Soc. America, Bull., Vol. 5, pp. 395-434, pp. 401, 418-420, 1894.

University of Oregon with Hyatt's identification labels still upon them, and these three fossils, as well as a number of others in the same collection, are typical species of the Donovan beds; (3) the matrix is apparently identical with the characteristic red sandstone of that locality. Such a mistake could easily be made because Condon did not collect the fossils himself, in spite of the statements of Diller and Hyatt to the contrary. The fossils were sent to Condon by a "Mr. Day"[1] perhaps ~~it was~~ John Day, the pioneer trapper.

The Donovan locality was apparently rediscovered in 1900, by A. H. Huntington[2] of Baker, Oregon. Condon soon came into possession of Huntington's collection and thought that he recognized a new locality of Oregon Jurassic. The locality given by Huntington is near Donovan's ranch, but it is slightly east of the area known to the writer.

It is possible that the fossils came from a canyon west of the Donovan area for a northern tributary of lower Emigrant Creek, now known as Hay Creek, runs nearly parallel to the Silvies River canyon less than two miles west of the Donovan ranch, and the name of this creek appears on the General Land Office map as "Beaver Creek."

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1 Condon, Thomas, Oregon Geology; a revision of "The two islands": Ed. by Ellen Condon McCornack, Portland, Oregon, p. 47, (1902), 1910.
2 McCornack, Ellen Condon, Thomas Condon, pioneer geologist of Oregon, p. 334 ,University press, Eugene, Oregon, 1929

It is impossible to say, at present, that Hyatt's "Beaver Creek" fossils actually came from the Donovan area but this much is evident: (1) that the fossils are specifically identical with the Donovan species, (2) their matrix is also similar, and (3) if other localities were known to Condon they have since remained unknown to later workers as well as to the present inhabitants of the region.

The "Beaver Creek" collection studied by Hyatt[1] included six species; four species were referred to known Jurassic species and one was described as new. They are:

Pecten acutiplicatus Meek
Pholadomya nevadana Gabb
Pholadomya multilineata Gabb
Pleuromya concentrica Hyatt
Cardinia gibbosum (?) (Meek)
Rhynconella sp. (?)

The descriptions were not accompanied by figures but all the species have been identified, as far as possible from the meagre descriptions, in the red sandstone fauna of the Donovan group.

So far as known, the only other reference to the red sandstone fauna that is based upon a first-hand study of the fossils

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1 Hyatt, A., *op. cit.* pp. 418-420

is found in Hertlein's[1] description of a single species of ammonite from the Stanford University collections. The ammonite is described as a new species, Uptonia silviesi Hertlein, and some of the lamellibranchs are listed as:

Anatina sp.

Gervillia sp

Pecten acutiplicatus Meek

Pleuromya concentrica Meek*

Pleuromya depressa Meek**

Pholadomya multilineata Gabb

Pholadomya cf. nevadana Gabb

Pholadomya sp.

The red sandstone and its fauna may now be considered in greater detail from the observations upon which this paper is based.

The shelly material of the fossils has been almost entirely removed from the rock, but ~~nevertheless~~ the fossils are well-preserved due to some curious circumstance that has permitted delicate features of external ornamentation to be impressed on the interior mold--features such as the fine ribbing on thick-shelled Protocardias are perfectly reproduced on the molds ~~of~~ on which ~~there is~~

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1 Hertlein, L.G., New species of marine fossil Mollusca from western North America: Bull. So. Cal. Acd. Sci., vol. 24, pt. 2, pp. 39-40, 1925.

* Probably Pleuromya concentrica Hyatt

** Probably Pleuromya depressa (Meek)

no vestige of shell remaining. The sandstone is hard and shattered by numerous fractures, but the fractures seldom cross the fossils so that they ~~only~~ facilitate their removal. Many of the shells are distorted, though never crushed and broken. Separate lamillibranch valves are very rare and therefore the fossils must be autocthonous.

Lamellibranchs make up nearly 85 per cent of the species and perhaps 98 per cent of the number of individuals. A conservative estimate of the number of lamellibranch species already collected from the red sandstone ~~would~~ not be less than 65, and they would include a variety of genera. Several species of gastropods and ammonites, a nautiloid, a brachiopod, a compound coral, and a crinoid stem constitute the remainder of the fauna.

The lamellibranchs have not been studied in sufficient detail to attempt a detailed comparison with described Jurassic species, but several groups and species of especial interest may be noted. The most conspicuous and characteristic fossil is a ~~single species of a~~ large, coarsely-ribbed Pecten that Hyatt referred to Pecten acutiplicatus Meek. This species often attains a length of   inches, and the big corrugated hemispheres are to be expected wherever the red sandstone outcrops. Another group, perhaps more abundant than the large Pecten, is a series of Pholadomyas that shows a wide variation of ornament and proportions. The variations are so gradual that it is difficult to assign specific limits within the series, but there are several species represented in specimens that do not fall within the series. Moreover, there are other large groups that show the same sort of variation. This cannot be accounted for by mechanical distortion, for variations of ornament are just as marked as variations of proportion. Some of the other variable groups, which are also conspicuous elements in the fauna, are: *Mytilus**, *Modiolus*, and *Pleuromya*. Other well-represented genera are *Protocardia*, *Pinna*, *Lima*, and *Camptonectes*. Less abundant species belong to the genera *Gervillea*, *Oxytoma*, *Trigonia*, *Goniomya*, and *Anatina*.

The ammonites are not numerous, but ~~there are~~ at least three genera and perhaps six species are represented. The correlation is based almost entirely upon these few ammonite species, so they are discussed more fully below.

The remainder of the fauna is poorly preserved and has received very little attention. There are several species of small gastropods; the brachiopod is probably Hyatt's *Rhynconella* sp. (?); and the crinoid stem is the characteristic star-like Mesozoic type, probably *Pentacrinus*.

The fauna of the brown sandstone, which succeeds the red sandstone in the sequence of page 43 , is apparently the same as that of the red sandstone except that the large *Pecten* is found in even greater abundance than below and the other lamellibranchs are fewer in number.

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* Time-honored Jurassic lamellibranch names are used in this paper with the full realization that many of them are inapplicable to Jurassic genera.

The corals from the Coraliferous band near the eastern end of the area are all of a colonial, fasciculate type resembling Calamophyllia Blainville.

Age and Correlation

The fossils from "Beaver Creek" were assigned, by Hyatt, to the upper Lias.[1] This determination resulted from his conviction that both the Oregon fauna and one from the Volcano district, in southwestern Nevada, were the same as that of the Hardgrave formation[2] of Taylorsville, California.

Hyatt did not find Pholadomya multilineata at Taylorsville; in fact, the entire correlation of the three supposed Hardgrave faunas was based upon the presumed occurrence of Pecten acutiplicatus and Pholadomya nevadana at all three places and the occurence of Pholadomya multilineata only at "Beaver Creek", Oregon, and Volcano, Nevada. But the large Pecten from "Beaver Creek" is surely not P. acutiplicatus, even though Hyatt did regard it as "an almost unmistakable form."

The use of Pecten acutiplicatus as a means of correlating the Donovan group with the Hardgrave sandstone must be disregarded for the present, because of the uncertainty of identification. Thus the correlation rests only upon Pholadomya nevadana and the similar lithology. The correlation between the Donovan

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1 Hyatt, Alpheus, Trias and Jura in the western states: Geol. Soc. America, Bull., vol. 5, pp. 395-434, 1894.

2 Hyatt, Alpheus, Jura and Trias at Taylorville, California: Geol. Soc. America, Bull., vol. 3, pp. 395-412, 1892.

fauna and that of Volcano, Nevada rests upon Pholadomya multilineata and P. nevadana, and between the Volcano locality and the Hardgrave sandstone there is again only Pholadomya nevadana.

In connection with these two species of Pholadomya it will be of interest to note again the variable series of Pholadomyas in the Donovan fauna. P. multilineata is characterized principally, as the name signifies, by a number of fine radiating ribs, about thirty in number; P. nevadana has only eight to ten ribs, so it was formerly regarded as very distinct from Pholadomya multilineata. But such is not the case with the variable Pholadomyas in the Donovan formation; one end of the series is represented by multilineata and near the other end is nevadana. Between the two there is a gradual sequence of variations.

The multilineata and nevadana stages of the Pholadomya sequence are very similar to the species described by Gabb, but considering the great variation of the Oregon specimens the writer would hesitate to follow Hyatt in referring them to Gabb's species, for it seems that many Pholadomya species, some of them perhaps distantly related, might be closely duplicated, in ribbing and general form, in this Donovan series.

Hyatt seems to have been somewhat impressed by the lithologic similarity of the "Beaver Creek" and Hardgrave sandstones, and the similarity may have some significance. Moreover, the Hardgrave genera listed by Hyatt are very suggestive of the genera found in the Donovan beds. Nevertheless, it seems that a correlation of these two faunas is based upon such very insufficient evidence that any determination of age of one can have but little application to the age of the other. This applies also to the more recent inference of the age of the Hardgrave fauna derived by Hertlein[1] from a study of one ammonite from the Donovan beds.

Hertlein placed the "Hardgrave fauna", implying both the Donovan and true Hardgrave faunas, in the middle Lias, a time that is perhaps lower than Hyatt's "upper Lias".* This resulted from the generic determination of an ammonite, in the Stanford University collections, as Uptonia, a characteristic Charmouthian genus of Europe.

The writer cannot agree with Hertlein's generic determination, or with the correlation of the Hardgrave sandstone and Donovan formation as stated before. A number of specimens, belonging to the same genus as Hertlein's species but including some additional species, have been collected from the Donovan beds. All of them show a stage of development that is distinctly removed from the adult stage of Uptonia. This genus as originally defined by Buckman, included

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1 Hertlein, L.G., New species of marine fossil Mollusca from western North America: Bull. So. Cal. Acad. Sciences, vol. 24, pt. 2 pp. 39-40, pl. 3, 1925.

* Hyatt seems to have accepted the upper Lias-Inferior Oolite division set forth by Buckman in his "Monograph of the Inferior Oolite Ammonites." Here the Jurense zone is taken as the lowermost member of the Inferior Oolite, and the Jurense zone corresponds approximately to the Haugian age which is far below the dividing line usually accepted by other authorities as well as below that later adopted by Buckman. So Hyatt's "upper Lias" may very well have included the Charmouthian and therefore would be equivalent to Hertlein's "Middle Lias."

species in which "the spinous stage is never strongly developed, but that it only takes the form of small knobs upon the costae; and that earlier or later, according to the degree of development, these knobs disappear, giving place to a strong costate stage."[1] The species silviesi and its allies bear strong nodes or spines that are not lost in later stages, even to a diameter of 38 centimeters. The ribbing and septation of the Oregon genus does seem to show a connection with Uptonia, but this connection was through some distant ancestral form, such as Ammonites bronni Roemer. No genus showing the stage of development of the Oregon specimens is known to the writer and they may prove to belong to a new genus. However, they seem to be fully as advanced from the ancestral type as is Uptonia, and are probably not far removed in time from the Uptonia jamesoni horizon on Polymorphitan age*.

The best evidence of the age of the red sandstone is afforded by another ammonite--a species of Coeloceras Hyatt that is very close to Coeloceras pettos (Quenstedt). The group that Quenstedt included under Ammonites pettos occurs along with Ammonites jamesoni, or Uptonia, not far above the middle of his Lias Gamma, and both species continue upward into the davoei zone. Buckman, dealing with much finer specific and chronologic differences than the

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1. Buckman, S.S., On the grouping of some divisions of so-called "Jurassic" time: Quart. Jour. Geol. Soc., vol. 54, p. 453, 1898.
* See correlation chart in folder.

broad divisions of Quenstedt, placed the pettos hemera next above the jamesoni hemera, in the upper Polymorphitan age, but the davoei hemera comes somewhat later in the next, or Liparoceratan age.

Buckman does not figure or describe a specimen of pettos in the restricted sense in which he would have used the name, so it is impossible to tie up the horizon of the Oregon species with Buckman's pettos hemera because the species must be compared with the broader divisions of Hyatt and Quenstedt.

Another Ammonoid from the red sandstone indicates that the horizon of the earlier forms of Quenstedt's pettos, which probably correspond in age to Buckman's pettos hemera, is more nearly the correlative of the Donovan representative of C. pettos. This ammonite is a Deroceratid, a group that is found at much lower horizons in Europe than Uptonia and Coeloceras pettos. The Donovan specimen is very small in comparison to true Deroceras species, so it must be either an immature specimen or a dwarf species. In either case it should be much later than Deroceras in Europe, for it shows adult characters of such species as Deroceras impavidum Buckman and D. hastatum (Young and Bird) at a diameter of no more than four centimeters. It would not be at all improbable to find such a form associated with a species such as Coeloceras pettos, and it would be more likely to be with early types of pettos than with advanced types. Therefore this ammonite seem to place the age of the Donovan fauna in the upper Ploymorphitan age.

It might be suspected that the association of a Deroceratid and a *Coeloceras pettos* type is due to actual age difference, and that the two forms were colledted from beds of different ages, but all three Ammonoid genera, along with most of the lamellibranchs, were collected in the red sandstone outcrop on the west side of the river channel. Fossils are distributed throughout the thickness of the bed, but the homogeneous character of the entire bed and the lack of bedding planes indicates that deposition was short and continuous.

The lamellibranchs are of little assistance, either to verify or refute the evidence furnished by the ammonites. One species is perhaps specifically identical with *Lima recticostata* Meek; *Pholadomya nevadana* and *Pholadomya multilineata* have already been mentioned; and "*Pleuromya depressa* Meek", (probably *Pleuromya depressa* (Meek) = *Myacites depressus* Meek), is listed by Hertlein from the Donovan beds but could not be located in the collections available to the writer. All these species involve a comparison with either the California or Nevada faunas, and the chronologic position of these faunas are so imperfectly known at present that such comparisons have little age significance.

Conclusions regarding the age and correlations of the Donovan formation may now be summarized: (1) the age determination is based upon three genera of ammonites--one Deroceratid, several species of an unknown genus, and especially upon a close ~~relative~~ ally of *Coeloceras pettos* (Quenstedt); (2) these fossils indicate that the red sandstone fauna is of upper Polymorphitan age, which falls in the Charmouthian period, or middle Lias, of Europe; (3) the red sandstone is possibly a correlative of the Hardgrave sandstone, and of the Jurassic beds of Volcano, Nevada, but these correlations cannot be established until the latter deposits are more accurately dated.

Ochoco Group

Type locality on upper Beaver Creek

The general features of the Ochoco group have been summarized on page 27 . The type area will now be considered in detail so that it can be used as a standard of comparison for the other less complete sections.

The Ochoco group of the type locality and the northward continuation of these beds lie in a peculiar broad depression consisting of a series of broad valleys, in some places more than two miles wide, which are separated by low divides. This depression may, for convenience, be termed the Suplee trough. Beaver Creek rises in the upper end of this trough immediately below the northward-facing brink of Snow Mountain. Just below the mouth of Freeman Creek it turns from west to north and enters a deep, narrow canyon. The trough continues westward and turns down Warm Springs Creek toward Suplee, but Beaver Creek, the master stream of the region, flows in a narrow canyon that is separated from the trough by a high flat-topped narrow ridge, which is much less than one mile wide in most places. Western tributaries of Beaver Creek rise in the broad depression and at intervals ~~they~~ cut across the ridge in narrow canyons to join the main stream.

The Ochoco type area, as stated before, extends along the south side of a complex anticlinal uplift from Colpitt's ranch house, and the type area extends across the divide from one stream to the other. The stream divide trends north about one mile east of Warm Springs Creek and two miles west of Beaver Creek and Freeman Creek. The Suplee-Izee road comes down Beaver Creek from the east, crosses lower Freeman Creek, and continues westward across the divide to Warm Springs Creek; where there it turns north toward Suplee.

Nearly all the lithologic and faunal divisions of the Ochoco group are found in the type area and these divisions are remarkably constant for many miles. There are some minor lateral changes of lithology and fossil content, but most fossil species have a definite stratigraphic position in a definite lithologic sequence.

The sequence begins, in the type area, with a basal conglomerate and the conglomerate is overlain by a lenticular reef limestone. The limestone is a lithologic and faunal unit that can be recognized in many places outside the type locality. It is designated as the Mowich limestone as it is typically exposed for several miles west of Mowich Mountain, especially in the type locality of the Ochoco group. The remaining part of the sequence is made up of limestone, calcareous sandstone, and black shale. A lower limestone and sandstone member is well-developed west of Mowich Mountain from Freeman's ranch westward across Freeman Creek to the Beaver Creek-Warm Springs Creek divide, so it can be appropriately named the Freeman formation. A black shale overlying the Freeman formation is designated the Nicely shale, for it is also typically exposed west of Freeman Creek, especially on the Nicely Homestead one-half mile west of the Beaver Creek-Warm Springs Creek divide. Another limestone--sandstone member, which also includes several bands of shale, is best developed slightly farther west than the lower members of the Ochoco group. It is very fossiliferous and well-exposed on the divide, on both sides of the Suplee-Izee road, and continues northwestward down into the Warm Springs valley immediately above the Colpitts ranch house. This area is taken as the type area of the Colpitts formation which includes the calcareous sandstone, sandy limestone, limestone, and shale between the Nicely shale and the uppermost shale member of the Ochoco group.

The upper or Warm Springs shale is well-exposed in both the South Fork and Suplee regions, but it is best known at its type locality on upper Warm Springs Creek where it lies conformably upon the type Colpitts formation. Erosion has stripped away most of the shale from the harder sandstones of the Colpitts formation and therefore the shale is best exposed near the bottom of the valley, whereas the Colpitts formation continues on up to the divide.

The thickness of the Ochoco group, in the type area, is about 750 feet, and a composite column showing the maximum thicknesses of the several members, as shown in other localities, would total about 1700 feet.

The southeastern part of the section, for one and one-half miles west of the junction of Freeman Creek and Beaver Creek, ~~is~~ strik~~ing~~es N. 75°- 85° E. and dip~~ping~~s steeply southward. Therefore it outcrops as a narrow band that is continuous with the south limb of the major anticline that can be traced for some distance to the northeast where it crosses the South Fork of the John Day River and continues into unexplored country beyond.

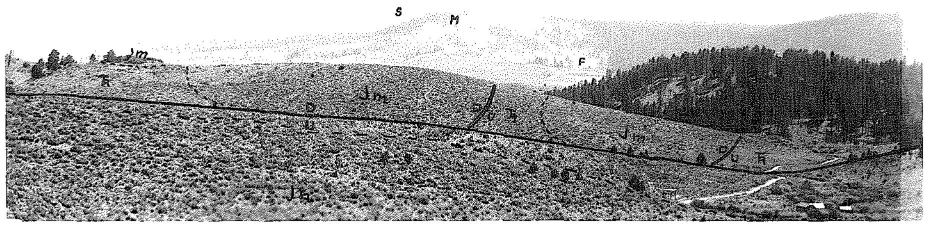
One and one-half miles west of lower Freeman Creek the regularity of the narrow outcrop is interrupted by several faults. One of the major faults, transverse to the anticlinal limb, ~~has~~ offset the west side of the area about one-quarter mile to the south. West of the fault the strike changes to N. 35°-40°W. so that the series trends obliquely across the Beaver Creek-Warm Springs Creek divide. South of the place where the road crosses the divide the beds dip 35 degrees southwest, but north of the road they dip only 14 degrees southwest and consequently cover a broad area on both sides of the divide and dip gently into and under Warm Springs Valley. The dip of the series is so near the dip of the valley side that many of the beds and faunal zones can be traced in somewhat intricate patterns around the hills and gullies of the east side of the valley. It is in this area of gently inclined beds, on both sides of the divide, that the most complete section of the Ochoco group is exposed. The Mowich limestone is the only absent member in this section, but it is found only a few hundred feet south of the road.

The south limb of the Ochoco anticline dips beneath the Silvies group and the Tertiary lavas. Freeman Creek and its tributaries rise south of the anticline and they have stripped back the lava capping more than a mile and exposed several hundred feet of of the lower beds of the Silvies series. In this region the Ochoco group dips as steeply as 60 degrees southward and the Silvies group dips gently across the upturned edges of the lower series. North and below the steeply dipping Ochoco group are the nearly vertical Triassic beds striking northward nearly at right angles to the Jurassic series.

West of the Freeman Creek drainage basin as far as the divide the Tertiary lavas overlap the upper series of Jurassic beds and part of the lower series in some places, and remnants of lava are found even farther north within the Triassic area. West of the divide the lava margin again turns southward and the Silvies series is exposed as on Freeman Creek.

One and one-half miles west of Freeman Creek a major east-west fault parallel to the anticlinal limb, with downthrow to the north, ~~has~~ repeat~~ed~~s some of the lower beds of the Warm Springs series about 400 feet north of the main outcrop, and other faults have blocked out a mosaic in this displaced block. Parts of the main east-west fault, a minor one parallel to it, and a much larger cross-fault are shown in plate IV. The cross-fault in the foreground ~~has~~ drop~~ped~~s the base of the series about 150 feet, so that the lower beds, which were once continuous with the Jurassic beds in the immediate foreground, are repeated again on the rounded hill east of the fault. This cross-fault has also moved the east block some distance northward relative to the west block and consequently has offset the south limb of the anticline.

PLATE IV



VIEW EASTWARD FROM THE TYPE LOCALITY
OF THE COLPITTS FORMATION.

$\frac{D}{U}$ fault; Tr, Triassic outcrops; Jm, Mowich limestone; Jb, basal conglomerate of the Ochoco group; S. Snow Mountain; M, Mowich Mountain; F, Freeman Creek drainage basin

The major east-west fault, later than the cross-fault, continues westward and offsets the Warm Springs weries on the divide just south of the road. The fault is the dividing line between the steeply dipping beds south of the road and the gently dipping beds on and north of the road. In the northern or downthrown block the base of the upper or Warm Springs shale has been dropped against the lower or Nicely shale on the other side of the fault,--a displacement of about 250 feet.

The stratigraphic succession differs somewhat even within the small type area. Part of this difference is caused by variation of lithologic and faunal facies and part by stratigraphic overlap to the north and west.

Stratigraphy and Lithology

Basal Conglomerate

The upturned Triassic beds, with occasional layers of hard grit and conglomerate alternating with thick beds of shale determine, to a considerable extent, the lithology of the lower beds of the Ochoco group. A basal conglomerate is developed where the Jurassic beds overlie layers of hard Triassic grit, but above the intervening shale areas the basal conglomerate thins or disappears.

The thickest section of basal conglomerate in the type area is in the area most distrubed by the minor faults mentioned on page 64 . Here the conglomerate is nearly 100 feet thick and forms distinct bluffs on both sides of the Suplee-Izee road.

The material in the conglomerate is poorly sorted. It contains much fine material and only a few pebbles or boulders. The Triassic and Jurassic conglomerates are very similar and the latter were doubtless derived entirely from the Triassic beds.

Mowich Limestone

The basal conglomerate is overlain in most places by a reef limestone that is largely made up of a single species of a gregarious Rudistid. Most of the Rudistids still remain upright just as they grew, and in some places dip surfaces of the limestone show innumerable oval cross-sections of this peculiar fossil. The lithologic character of the matrix in which the fossils are imbedded ranges from a pure limestone to ~~little more than~~ a calcareous sandstone, and in some places it is highly siliceous or cherty. The matrix is so hard that the fossils can be broken away only in a few favorable localities. The greatest thickness of Mowich limestone exposed in the type area is about 150 feet--a very moderate thickness in comparison to some other localities.

The hard and soft layers in the underlying Triassic series have determined the development of the Mowich limestone as well as the basal conglomerate. The Rudistid is a gregarious, reef-building species that flourished in the surf around rocky promontories of Triassic conglomerate. The limestone is best developed above thick basal conglomerates of the Jurassic which, in turn, lie upon the truncated edges of Triassic conglomerate. The Mowich limestone is, therefore, a Jurassic reef limestone that was formed under special conditions and these conditions explain the absence of the limestone above the Triassic shale areas.

The dependence of both the basal conglomerate and Mowich limestone upon the type of substratum is clearly demonstrated in the type area. West of Freeman Creek, as far as the Beaver Creek-Warm Springs Creek divide, the conglomerate and limestone are well-developed. One and one-half miles west of Freeman Creek, on both sides of the Suplee-Izee road in the area blocked out by faults, are the thickest sections of conglomerate and limestone, and below them are several thick beds of Triassic conglomerate. West of the faulted area are some thick beds of Triassic shale and the Jurassic conglomerate and limestone thin out and are entirely lacking in the west end of the type area.

Freeman Formation

The Freeman formation is only 25 to 57 feet thick in the type locality and ~~it~~ is one of the thinnest members of the Ochoco group. Its fauna and lithology are so characteristic that the bed can be traced eastward for many miles, but it thins out and is lacking in the west end of the Ochoco type area and in other localities to the north.

The Freeman beds have the general appearance of brown sandstones, but some of them are really brown limestones with various amounts of sand and shell fragments. The sandstones are mostly calcareous, fine or medium-grained, brown or yellowish buff, and much softer than the sandy phases of the Mowich limestone. They show a coarse though distinct stratification that is characteristic of nearly all the sandstones in the Ochoco group.

Nicely Shale

Overlying the Freeman formation is about 50 feet of the Nicely shale which is also a persistent member outside the type area. It is soft, black, well-bedded, and not very calcareous. Fossils have been found only in occasional large extremely hard calcareous concretions. The Nicely shale appears to have the same distribution in the type Ochoco area as the Freeman formation--both are well-developed east of the divide, but where the base of the series appears again nearer Warm Springs Creek both members are absent and the series begins with the Colpitts formation. Neither the Freeman formation nor the Nicely shale are as hard as the adjoining members of the series, so they normally outcrop in a depression between ridges formed by the conglomerate and limestone below and the Colpitts formation above.

Colpitts Formation

The Colpitts formation includes the most fossiliferous beds of the entire central Oregon pre-Tertiary area, but it is fossiliferous only within a small area. The sandstones are well-exposed on the top and west side of the Beaver Creek-Warm Springs Creek divide for two miles northwest of the Ochoco National Forest boundary and here fossils are plentiful. But farther north and east fossils are less abundant and the apparent correlative in the South Fork region, only 12 miles away, is almost barren of fossils.

The best section of the Colpitts formation is on the top of the divide one-half mile north of the forest boundary and immediately north of the Suplee-Izee road. A section was measured here, and a thickness of 212 feet was recorded for the upper sandstones. Another measured section one mile northwest of the type section showed 156 feet. The first figure probably represents the maximum thickness for this member.

Most of the beds in the Colpitts formation have the appearance of sandstones, but many of them are so highly clacareous that they are really sandy limestones, and others are almost pure limestone. The sandy beds are fine to coarse-grained, mostly poorly sorted, with sub-angular sand grains or grit imbedded in a matrix of gray calcite. The fresh surfaces are light brown, buff, or gray, and the weathered surfaces are slightly darker. Stratification planes are distinct but not numerous, and joints normal to the stratification planes are widely spaced so that the layers break away in angular polygons several inches in diameter. The lower part of the sequence is made up almost entirely of sandy and calcareous beds and the shale bands are confined to the upper half. At the top is a dark-colored fine-grained tough sandstone that is apparently non-calcareous and unfossiliferous.

The entire sequence of beds in the Ochoco group seems to be conformable, but there is some evidence that a disconformity exists at the base of the Colpitts formation. North of the type locality the first fossiliferous bed, almost at the base of the group, is a zone that comes at least 88 feet above the base in the type locality. East of the type locality the opposite is true; as the Mowich limestone, Freeman sandstone, and Nicely shale are well represented, but the fauna of the Colpitts formation is absent. Perhaps the most convincing evidence is the long interval of time, shown by the fossils, between the Nicely shale and the base of the Colpitts formation.

The presence of this possible stratigraphic break~~s~~ is made uncertain by two other lines of reasoning: (1) the lower members north of the type locality could be accounted for by progressive overlap, ~~and this~~ a view that is substantiated by the disappearance, first, of the Mowich limestone, then the Freeman sandstone and Nicely shale, and finally the lower part of the Colpitts formation;

(2) though the Colpitts fauna is absent in the South Fork region there is, nevertheless, a thick unfossiliferous sandstone member lying between the Nicely shale and the Warm Springs shale, so it is the same kind of lithologic sequence that is shown in the type locality.

Warm Springs Shale

The Colpitts formation is conformably overlain by the Warm Springs shale, which is also present far to the east and north of the type area. It is largely overlapped by the Silvies group and Tertiary lavas in the eastern two-thirds of the Ochoco type area, but it is well exposed on the west side of the divide. The series dips toward Warm Springs valley at a steeper angle than the slope of the valley side, so the Warm Springs shale is exposed between the higher hills of the Colpitts formation and the bottom of the valley.

The Warm Springs shale is a well-bedded black shale that is rather calcareous and in some places somewhat sandy and hard. The measured sections do not give the total thickness of the shale and it is difficult to make a reliable estimate. In the type area as well as in other localities, the shale is overlapped by Tertiary lavas or by the Silvies group. Moreover, the base of the Silvies group begins with a black shale that is very similar to the Warm Springs shale, so the contact almost everywhere lies in a soil covered depression. On the east side of Warm Springs valley there is at least 300 feet of Warm Springs shale exposed, but on lower Warm Springs Creek the structural relations of the Warm Springs and Silvies series seem to require that the shale be more than twice as thick.

Measured section

A section has been measured across the most typical and best exposed sequence of the Ochoco group in the type area. It trends westward across the strike of the beds that lie on top of the divide immediately north of the Suplee-Izee road. It shows the basal conglomerate, Freeman sandstone, and Nicely shale on the east side of the broad divide and the Colpitts formation on top of the divide, but most of the Warm Springs shale has been stripped away from the higher part of the ridge and is consequently better developed nearer the bottom of the Warm Springs valley.

Section of the Ochoco group in the type locality of the Colpitts formation

	Ft.	in.	Ft.	in.
WARM SPRINGS SHALE				
(Absent at this locality because of removal by erosion)				
COLPITTS FORMATION				
Sonninid zone------------------------------------			88	8
1. Tough, flinty fine-grained dark-colored sandstone----------------------------------	10			
2. Light gray gritty sandstone, highly calcareous------------------------------------	7	7		

	Ft.	in.	Ft.	in.
3. Very light-gray sandy limestone with some shaly layers; contains Sonninids----	26	6		
4. Dark poorly-bedded sandy shale-----------	18	9		
5. Highly calcareous gray sandstone with Sonninids-------------------------------	2			
6. Dark poorly-bedded sandy shale-----------	9	4		
7. Dark-gray fine-grained calcareous sandstone and sandy limestone---------------	13	6		
8. Tan-colored fine-grained calcareous sandstone with Sonninids---------------------	1			
Ichthyosaur zone-----------------------------			26	6
1. Terebratuloid bed. Fine grained calcareous sandstone and sandy limestone--------	2	6		
2. Ichthyosaur bed. Dark-gray fine-grained flinty sandstone--------------------------				
3. Oppelid bed. Dark-gray and gray sandy limestone weathering brownish-buff-------	3			
4. Inoceramus bed. Dark non-calcareous sandy shale, calcareous gray sandstone and grit, and sandy and gritty limestone-----	21			
Rhynconellid zone----------------------------			17	
1. Upper Rhynconellid bed. Gray sandy limestone----------------------------------	2			

	Ft. In.	Ft. in.
Pecten zone		
Very fine-grained calcareous and non-calcareous brown and gray soft sandstone--------		15 8
Total of Freeman formation		57'
MOWICH LIMESTONE		
(Absent at this locality because of stratigraphic failure)		
BASAL CONGLOMERATE		
Fine and poorly sorted; small, rounded pebbles of chert and limestone in a sandy groundmass-----------		50 +
Total of Ochoco group		325 +

Fossils

Well-preserved fossils are found in all the main divisions of the Ochoco group except the basal conglomerate. The Freeman and Colpitts formations are especially fossiliferous and contain a great number of species as well as individuals. The two shale members contain a very small number of species in comparison to those of the sandstone and limestone faunas, but some species are locally abundant. Lamellibranchs, cephalopods, and brachiopods are most abundant in all formations. There are also some species of solitary corals and occasional gastropods and crinoid stems in the sandstones. Two of the five marine vertebrate localities are within the type area--one in the Colpitts formation and one in the Warm Springs shale.

The fossils are distributed through the series in several distinct faunal zones. Most of these zones are not merely the result of variation of facies and ecologic conditions. They seem to represent a lapse of time marked by faunal evolution or by an invasion of the region by new forms that replace all or nearly all the autochthonous species and genera. The zones of the lower part of the series have been recognized in the South Fork region as well as in the type area and in both places their stratigraphic sequence is the same. The faunal lists of a certain zone in several localities are not exactly the same. Some species not found elsewhere appear at each locality, but a composite faunal list of a given zone does not contain very many species that are found in other zones. A few species of lamellibranchs and one brachiopod are the most persistent species in several zones, but the ammonites have a very restricted range.

The greatest number of zones are found in the Colpitts formation but this member apparently becomes unfossiliferous a short distance from the type area and none of the zones have been recognized over a distance of more than eight miles.

Only a few fragments of oyster and Rhynconellid shells have been found in the basal conglomerate, or in beds corresponding to the conglomerate.

The Mowich limestone is made up largely of innumerable specimens of a large gregarious aberrant lamellibranch which became adapted to the same sort of habitat that was occupied by the late Jurassic and Cretaceous Rudistids. A large triplicate Nerinea is associated with the Rudistid in most places, but only one locality has been found in which the Nerineas are more abundant than the Rudistids. These two forms dominate the limestone almost to the total exclusion of other organisms. A small gastropod is the only other fossil found in this member. The most calcareous parts of the Mowich limestone contain the greatest number of Rudistids and the least number of Nerineas, and conversely, the Nerineas increase in numbers in the sandy parts of the bed and even exceed the number of

Rudistids. Evidently the Nerineas favored the more sandy parts of the littoral around the Rudistid reefs.

The Freeman formation contains at least two faunal zones. In some places these zones are only a few inches apart, but they are distinctly separate wherever they have been found. The lower zone is characterized by a large angular-ribbed *Pecten* that resembles *P. acutiplicatus* Meek much more closely than does the Donovan *Pecten* mentioned on page 53. The upper zone is characterized by a peculiar small Rhynconelloid brachiopod ~~which~~ that has two pronounced ribs on the elevated median area of the pedicle valve and only one rib on the median sinus. These zones are referred to as the *Pecten* zone and the brachiopod zone.

The *Pecten* zone is very fossiliferous in one small locality in the type area, but the brachiopod zone contains only innumerable specimens of the fossil for which it is named.

The *Pecten* zone has not been found in the eastern part of the type area, though the Freeman sandstone is well-represented there. The section on the hill above the old Wooley ranch house, one-half mile west of lower Freeman Creek, shows about 133 feet of the sandstone in which the brachiopod zone is present, but the *Pecten* and associated fossils are apparently absent. These two zones are absent in the westernmost part of the area, as both the Freeman formation and succeeding Warm Springs shale are overlapped by the upper sandstone.

The two zones are exposed for more than a mile along the east side of the divide and especially in the faulted area farther to the east. At this latter locality, which is about 200 feet south of the Suplee-Izee road in a bend of the old road to Howard valley, both zones are well-developed. The zones lie in contact with one another and the combined thickness of the fossiliferous beds is not more than three feet. The Freeman formation is about 25 feet thick here and the fossiliferous zones are not more than 10 feet from the top.

The fauna of the *Pecten* zone includes a variety of organisms. Lamellibranchs constitute perhaps 90 per cent of the number of species. Next in order of abundance are corals and cephalopods, then only one or two species each of bryozoa, gastropods, and crinoid stems. The most abundant species are a small concentrically ribbed lamellibranch and a cup-shaped solitary coral. The *Pecten*, which characterizes the zone elsewhere, is well-represented but not nearly as plentiful as some of the other lamellibranchs. The most striking member of the fauna is a large, highly ornamented and well preserved *Trigonia* of the *davellata* group. Two types of *Pholadomya* are present and one can be closely duplicated in the *Pholadomya* series of the Donovan group. The lamellibranchs have received little attention so far, and only the following ~~a few other~~ well-known genera have been recognized: ~~They are:~~ *Pinna*, *Ostrea*, *Gryphaea*, *Camptonectes*, *Lima*, Modiolus, Anatina (?), and Lucina (?). In addition to the cup-shaped corals there are occasional specimens of another conical solitary coral. The Cephalopods include two or three species of Harpoceratid ammonites and one Nautiloid. The gastropod is small, poorly preserved, and indeterminate. The crinoid stems belong to the Pentacrinus group.

Perhaps 50 species are represented in this one thin bed in a distance of 75 feet along the strike, but, with the exception of the Pecten and brachiopod zone markers, the cup-shaped coral is the only fossil that has been found beyond the 75 foot outcrop. This peculiar feature is probably due to ecologic conditions. The matrix in which the fossils are imbedded has the appearance of a fine-grained sandstone, but really is a soft arenaceous limestone. It contains many poorly-sorted sand grains and fragments of organic material. In other localities, where only the zone markers are present, the matrix is well-sorted brown sandstone. This seems to indicate that the highly fossiliferous part of the zone was deposited in warm quiet water, perhaps in a lagoon between the shore and a barrier reef of Rudistids and Nerineas where conditions were favorable for a variety of sea life. The fossil zone markers in the well-sorted sandstone probably lived outside the supposed lagoon in the more agitated water of the littoral, and, as would be expected both the zone markers seem to be types that would flourish in such a habitat.

The Nicely shale is not highly fossiliferous and fossils have been found only in hard, flinty black concretions. Ammonites are most abundant and the only other fossils recorded are two small species of lamellibranchs and one large heavily ribbed Rhynconellid. The Hildoceratid group of ammonites is represented by a number of specimens of a single species. Next in abundance is a Dactyloid, and finally a single small specimen of a late Amaltheid.

A very characteristic fauna is found in the lowermost part of the Colpitts formation. This fauna is well-represented in the section measured on the divide north of the east-west fault, and especially near the forest boundary on both sides of the old road to Howard Valley. These beds are also present in both the extreme eastern and western parts of the area but are less fossiliferous than at the other localities. There is probably more than one zone in these beds, but they have not been differentiated, so they will be treated as a single zone in this paper, principally as a matter of convenience, because the fauna can be recognized at several places some distance away from the type locality.

It is difficult to decide which fossil is most characteristic of this zone at the base of the Colpitts formation. Several species of *Gresslya* and *Astarte* (?), and one Belemnoid are most numerous, but they are not confined to this zone. One species of the *Trigonia costata* group and one of the *Trigonia clavellata* group are apparently confined to this zone and have been found at nearly all localities, so it seems best to designate this division as the Trigonia zone.

Lamellibranchs are most numerous in the Trigonia zone. Most of them belong to the genera Gresslya, Astarte, Pecten, Camptonectes, Pinna, Lima, and Ostrea. Gastropods are represented only by a small Naticoid shell. The only cephalopod found in the Trigonia zone of the type locality of the Colpitts formation ~~in~~ is the previously mentioned Belemnoid. A Sphaeroderatid Ammonoid was collected in the Trigonia zone on the ridge 150 feet north of the point where the old road to Howard valley passes through the National Forest boundary, and a Tmetoceras is associated with the same fauna six miles northeast of the type locality on the hillside 100 feet east of the Bill Harris ranch house.

The remaining part of the Colpitts formation is locally very fossiliferous and can be divided into several zones, but perhaps all these zones do not have equal a significance to that of the lower zones already enumerated because they cannot be traced more than five miles along the strike and some of them not more than two miles. ~~It is very probable that~~ most of them ~~will~~ may prove to have a recognizable chronologic significance and ~~will~~ may be found in the same sequence if other localities are found in the future. These upper zones are best exposed along the Beaver Creek-Warm Springs Creek divide on both sides of the road and the measured section, given on page 43, crosses the most fossiliferous localities. Therefore, a description of the zones as they appear in the measured section will furnish practically all that is known of them. These zones may be tabulated, in ascending order, as follows:

Rhynconellid zone. This zone is made up of three divisions, each of which may prove to be a distinct zone. It begins with a three-foot bed ~~which~~ that contains innumerable specimens of a single species of Rhynconellid and a minor number of oysters. This bed is succeeded by 12 feet of calcareous grit and sandstone called the Lamellibranch bed, which carries Goniomya, Camptonedtes, Modiolus, Asta~~t~~rte (?), and Gresslya. Cephalopods are represented only by a Belemnoid, a Sonninid, and a Sphaeroceratid. The last two species mark the first appearance of the two groups that are so abundant in the higher beds of the Colpitts formation. The Rhynconellid zone ends with another Rhynconellid and oyster bed.

Ichthyosaur zone. About 15 feet above the Rhynconellid zone is a fossiliferous grit and sandstone ~~which~~ contains ~~a~~ many small fine-ribbed Pecten, a large Inoceramus, and other lamellibranchs. A few feet above the Pecten-Inoceramus bed is the Ichthyosaur bed, so named because it has yielded a number of supposed Ichthyosaur bones. The bed is not more than three feet thick, but ~~it~~ is very fossiliferous and can be ~~easily~~ readily traced along the outcrop. Several species of Ammonoids of the Sonninid group and two early Oppelid are found in a thin stratum near the base of the Ichthyosaur bed. The Ichthyosaur remains seem to come from a slightly higher stratum though some Sonninid fragments, apparently the same as the others, were found with the Ichthyosaur bones. A few inches above the Ichthyosaur horizon is another thin bed that is characterized by a large, globose Terebratuloid and a giant Camptonectes. In addition, there are several lamellibranchs, among which Trigonia, Modiolus, Pinna, Gresslya, Astarte (?), Lima, and Ostrea have been recognized. This generic list is somewhat the same as that of the Rhynconellid zone, but only two species have been found common to both beds, and they are the Astarte (?), and Gresslya which are so abundant in the Trigonia zone.

Sonninid zone: The remaining part of the Colpitts formation constitutes a rather broad zone that is probably capable of further subdivision, but the whole zone is characterized by the same general groups of Ammonoids and no distinguishing characteristics of minor divisions were recognized at the time the field work was done. There are at least three thin Ammonoid-bearing sandstone strata which, in the type locality, occur at intervals in the upper shaley part of the Colpitts formation.

The Ammonoids of the sonninid zone include a large number of species and several families. The most conspicuous members are the Sonninids. They show an extraordinary variety of species and genera in all the fossiliferous beds of the zone. Some are apparently referable ~~directly~~ to the genus *Euhoploceras* Buckman, but most of them are very advanced types derived from *Euhoploceras* and should be placed under new genera. These species of *Euhoploceras* and related genera are mostly large specimens; some attaining a diameter of 38 centimeters and large fragments of these specimens are found at almost all localities where the zone outcrops. Other Sonninids are smaller and possibly were derived from some other Sonnininae stocks. Other Ammonoid groups are represented only by two or three species of Sphaeroceratids that are not far removed from *Docidoceras*, one species of a *Zemistephanus*-like Stepheoceratid, one Strigoceratid, one Phylloceratid, and one Belemnoid. Most of the lamellibranchs belong to the genera *Gresslya*, *Cardium*, *Modiolus*, *Lucina*, *Pecten*, and *Camptonectes*.

Fossilis are not abundant in the Warm Springs shale. Sonninids are still predominant and are represented by beautiful specimens of a number of species that are allied to *Dorsetensia* S. Buckman. The only other fossils are two ammonoids, one a "*Stephanoceras humphriesianum*" type and the other a Phylloceratid, one *Inoceramus*, and one Ichthyosaur.

Age and Correlation

The American Jurassic succession and faunas are so imperfectly and incompletely known that it is necessary to base most of the correlations upon the Jurassic record of Europe. Therefore, before detailing the results of correlation studies of the Ochoco group, it is necessary to arrive at some conclusion regarding the exactitude and limitations of such long-range correlations.

S. S. Buckman[1] has recognized more than 300 chronologic divisions or hemerae in the English Jurassic alone, and a large number of unknown hemerae are represented by unfossiliferous beds and by breaks in the records. Most of these hemerae are characterized by short-ranging ammonite genera and species, and, as the ammonites are such ideal fossils for long-range correlation, it might be supposed that ammonite-bearing strata of western North America could be closely tied in with the British deposits, providing that there was a free interchange of faunas during the deposition of contemporaneous beds.

Buckman does not hesitate to correlate Mexican, South American, and Indian horizons with English hemerae. The upper Jurassic faunas of Mexico, for example, have been described in some detail by Burckhardt[2], and Buckman[3] has attempted to correlate them

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1 Buckman, S.S., Type ammonites: vol. I-VII, 1909-1928
2 Burckhardt, Carlos, Inst. Geol. de Mexico, vols. 23 (1906), 29 (1912), and 33 (1919).
3 Buckman, S.S., Type ammonites: vol. 4, p. 45

with the European hemeral sequence and makes as many as four hemeral correlations in one age.

Crickmay and McLearn are the only workers in western North America who have made intensive studies of Jurassic Ammonoids and used Buckman's system of ages and hemerae as a basis of correlation. Niether of these writers attempt to correlate American species with any definite hemerae in Europe. They wisely point out the chronologic position of English species that show affinities with their species and make their correlations only with the broader "age" divisions. McLearn[1] goes so far as to designate such correlations as "late Sonninian age" and "early Proplanulitan age", and such close correlations seem justified because of that authors prolonged and careful studies of genetic affinities. It may be possible to establish similar close correlations in other parts of North America providing there is either a sufficient fauna of Ammonoids or some species represented that are also present elsewhere in beds of known date. If, as often happens neither of these conditions are met, then the correlations become somewhat uncertain.

The very few ~~occurence of~~ species are found in ~~common to~~ both western North America and Europe ~~is seldom found~~, according to ~~judging from~~ published reports. McLearn has described a number of Ammonoids from the Canadian Jurassic, but has referred only two to European species. Hyatt's conception of a species was ~~apparently~~ very broad in comparison to present day

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1 McLearn, F.H., Some Canadian Jurassic faunas: Trans. Roy. Soc. Canada, ser., vol. 21, sec. IV, pp. 61-73, 1927.

standards, but in his report on the Taylorsville fauna[1], he assigns not even a single species of lamellibranch to a European species. So it seems that North American Jurassic faunas contain mostly new species, and comparisons must be made with more or less closely related European species.

Buckman's findings on the phylogeny of the Oppelacea[2] are particularly significant in this respect. He shows that the biologically earliest species may be the geologically latest species because the primitive stocks remain, for a considerable length of time, in some unknown region, perhaps in the deeper water bordering the continental masses, where evolution is retarded and the species remain in primitive stages. Immigrants from the stable, primitive stock reach the shallow epicontinental seas from time to time and evolution speeds up, giving rise to a series of modifications that may nearly or entirely crowd out the primitive ancestral characters. In the meantime the primitive species in the center of dispersal are but slightly modified and at some later date they may advance upon the present land areas and so be found, retaining their primitive characters, in later deposits than the highly modified, related groups below.

This principle seems to have a very direct bearing on the

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1 Hyatt, Alpheus, Jura and Trias at Taylorville, California: Geol. Soc. America, Bull., vol. 3, pp. 395-412, 1892.
2 Buckman, S.S., Type ammonites: vol. V, pp. 7-10, 1924.

exactitude of long-range correlations based upon species that are apparently closely related but not identical. If evolution progressed at a known, unchanging velocity, then it would not be difficult to determine how much later or earlier a certain species lived than some related species, but if the Buckman's views are accepted, the assignment of an American species to a definite European horizon because it is closely related to some European species would become rather uncertain. Thus, if it is found that the ontogeny of an American species shows that it is slightly less or more advanced than the corresponding stage of an English species, then it might be assumed that the two are not greatly separated in time. But what would happen if, in the course of migration the species passes through a habitat that results in a stagnation of evolution? An example of something of this sort may be found in the Deroceratid in the Donovan formation, which, if found alone, would doubtless have been recognized as an advanced Deroceratid and assigned to a slightly higher horizon than its related species, but the writer would never have suspected that it could occur so far up as the <u>Coeloceras pettos</u> zone if it were not for other fossils.

Now it may seem that a fauna containing a number of Ammonoid species might nevertheless be correlated closely with European horizons by finding several immediate descendants of European species associated with immediate ancestors of slightly later European species. This criterion is surely one of the best that can be applied when no cosmopolitan species are found. But what are the chances of applying it? Buckman states "........that not more than about 25 per cent of the once living species of Ammonoids are known to us." One-third of the unknown species, or another 25 per cent of the total, is supposedly buried in inaccesible strata, including the deep-water deposits. This percentage, of course, applies only to the "well-known" faunas of the European Jurassic. The deep-water species do not enter into this comparison because the American species probably lived in shallow seas, so the chances of finding an American species directly related to a British species is automatically decreased by the percentage of species that were able to ~~i~~migrate from one area to another. Certainly a very small percentage of English species would give rise to descendants in America. Buckman and Ulrich believe that primitive deep-water forms give rise to successive invasions of new species upon the continental regions. If this is true, the American species are more likely to come from such primitive forms than from the European continental species, so it becomes necessary to multiply the ratio a few more time. Now consider the number of known European species that are accurately and closely dated and multiply again the ration of chances of correlation.

Therefore, it seems that the possibility of an Ammonoid species in a North American horizon being directly related to an accurately dated European species is very small--perhaps no more than one chance in fifty or even less, so in a restricted faunal zone containing a half-dozen Ammonoid species the chances would be increased to only one in eight or ten.

When attempts are made at long range correlations of restricted zones containing only a few species of Ammonoids it seems that the best one can ordinarily do is to trace the genesis of a species to an unknown "lowest common denominator" that is ancestral to both the American species and its European relative. When this is done ~~the estimations~~ of time estimates are necessarily more uncertain than when a directly related European species is concerned because the date of the common ancestor is unknown, and attempts to date an unknown common ancestor would meet with many additional difficulties and uncertainties.

The preceeding discussion has a direct bearing upon the correlation of faunal zones in the Ochoco group. It is certainly impossible to correlate Oregon horizons with such fine divisions as hemerae at a distance of 5,000 miles from a region with accurately dated fossils, and it seems impossible to assign even "age" determinations in some cases. The best that can be done at present is to point out the European affinities of the faunas, establish correlations subject to the limitations set forth above as well as to the limitations of present knowledge, and set forth the stratigraphic succession of the faunas as they appear in the Ochoco group.

The Mowich limestone can be dated only by the large *Nerinea* and by the overlying faunas. The Rudistid, *Plicatostylus gregarius*

Lupher and Packard, has been made the type of a new genus and family[1], and it is so far advanced from any known ancestral lamellibranch that its relationships are unknown. Consequently it has no age significance in the present correlation. The Nerinea belongs to the triplicate Nerinea parva, oolitica, attenuata, and expansa group[2] which appears first in the Opalinus zone of the English Jura. This Opalinus zone, as Huddleston used it, is a rather broad division and was intended to include beds whose ages apparently range from Dumortierian through the Canavarinan and into theLudwigian, but Cossman's[3] designation of this Nerinea group as Bajocian evidently limits the horizon to the Ludwigian age, a division that is referred to the uppermost Lias by some authors and to the Inferior Oolite by others.

The four species mentioned above form such a homogeneous group that Huddleston considers them as possibly only varieties of the same species, and, according to Cossman[4], this group marks the first appearance of Nerinea, sensu stricto,so it would seem that the close resemblance of the Mowich species would show that the Mowich limestone is not earlier than uppermost Lias. But such is not the case, for overlying faunas show that the Mowich Nerinea occurs well down in the upper Lias far below the earliest European Nerineas.

Hyatt notes the presence, in the Thompson limestone of

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1 Lupher and Packard, The Jurassic and Cretaceous Rudistids of Oregon: Univ. of Oregon Pub., Geology series, Vol. 1, no. 3, 1930.
2 Huddleston, W. H., Gasteropoda of the Inferior Oolite: Pal. Soc. Monographs, vol. 43, 1889.
3. Cossman, M. , Essais de Pal. Comp., pt. 2, p. 27
4. Cossman, M. , Loc. cit. p. 27

Taylorsville, California, of "a large form of Nerinea with the columella, showing the typical ridges of the normal forms of this group"[1]. In Diller's second Taylorsville paper is another significant statement: "The Thompson limestone is gray and somewhat shaly, and on its weathered surface in places are round, oblong, or irregular patches of darker more or less granular calcite, which at once suggest fossils, though their specific determination is a matter of difficulty[2]".

These two statements raise the ~~interesting~~ speculation as to whether the Thompson limestone may not be the correlative of the Mowich limestone of central Oregon. Hyatt's statement that the Thompson limestone Nerineas show the typical ridges of the normal form of this group indicates that he is dealing with a tri-plicate species of the same type as the Oregon species, and Diller's description of the "round, oblong, or irregular patches of darker more or less granular calcite" is as good a description as could be applied to the Mowich Rudistid. The fact that the Thompson limestone apparently lies above the Hardgrave sandstone, which Hyatt assigned to the "upper Lias", need not stand in the way of a possible correlation of Mowich and Thompson limestones, for Hyatt's upper Lias extended no higher than

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1 Hyatt, Alpheus, Jura and Trias at Taylorville, California: Geol. Soc. America, Bull., vol. 3, p. 402, 1892.
2 Diller, J.S., Geology of the Tayloxsville region of California: U.S. Geol. Survey, Bull. 353, p. 41, 1908.

the Hildoceratan age, and furthermore it may very well be, as several writers believe, that the Hardgrave horizon is near that of the Donovan fauna, though this is based upon slight evidence.

More faunal contradictions are encountered in the Freeman fauna. The Montlivaultia of the Pecten zone is a characteristic Lias type, but the highly ornamented species of the Trigonia clavellata group is one that should not be older than the Inferior Oolite. The few Ammonoids are poorly preserved. One is evidently a Harpoceratid that should belong in the Harpoceratan age of the lower upper Lias. Apparently none of the species in this fauna, even of the lamellibranchs, can be identified with fossils in the Donovan beds.

The relationships of the Rhynconellid in the brachiopod bed are unknown, so the basis of separation of the brachiopod and Pecten zones must, at present, rest only upon their distinctive and separate character wherever they have been found and not upon any known measurable time interval.

The several Ammonoids in the Nicely shale are better preserved than those of the Pecten zone and so can be more accurately determined. The most abundant species is a small Hildoceratid which evidently belongs in or close to the group that Buckman included in the genus Hildoceras in 1898.[1] This genus has since undergone considerable division and the name of Hildoceras is now restricted to the type of Hildoceras bifrons Bruguière--a group that is very different from the Nicely species. None of Buckmans more recent subdivisions of the old genus Hildoceras nor any of the Hildoceratid

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1 Buckman, S.S., Monograph of the Inferior Oolite ammonites: Pal. Soc. monographs, vol. 42, pp. 111-112, 1888.

species known to the writer may be closely compared with the Nicely shale species, but the suture line clearly shows that the species is not far removed from the early Hildoceratid species of Hildoceratan age.

The resemblance of the Nicely species to the adolescent stages of the forms that Buckman included under Grammoceras toarcense (d'Orbigny)[1] is very striking. A distinctive feature of Grammoceras, according to Buckman, is "the shape of its ribbing--subarcuate with a long ventral projection meeting the carina at an acute angle." The ribs are usually much more numerous than in true Hildoceratids and run continuously from the inner margin to the ventral carina. In the earliest species of Grammoceras this stage is preceded by an "Arietan" stage in which the ribs are separated from the carina by a flattened or sulcate area and in some species, such as G. toarcense, the ribs are also inconspicuous on the inner third of the lateral area. Judging from Buckman's figures, the ribs of the Arietan stage do not have the long ventral projections of the Hildoceratids and Grammoceratids.

It is to this Arietan stage of the Grammoceratids, especially of G. toarcense, that the Nicely species bears most resemblance-- the ribs are lacking on the inner third of the lateral area, the ventral projection is very slight, and the ribs are separated from a high, solid carina by a broad sulcus. The carinate, bisulcate venter is better developed than in the Arietan stage of toarcense, and it

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1 Buckman, S.S. loc. cit., vol. 43, p. 169-173, 1889

evidently points to an Arietan or Hildoceratid ancestor. Buckman[1] once derived the Grammoceratids and Hildoceratids from a common ancestor which came from the carinate, bisulcate Echioceratids of the Lower Lias, but later he seems somewhat doubtful of that derivation. But it does not matter, at present, whether the carinate, bisulcate stage of the Grammoceratids came from the Arietids, from the Echioceratids, or whether it was an independent development in the forerunner of the Hildoceratids, Grammoceratids, Harpoceratids, etc. The significant point is that the Grammoceratids and Hildoceratids probably came from the same carinate, bisulcate ancestor. Now the Oregon species has a typical Hildoceratid suture line, but ~~nevertheless~~ it shows some Grammoceratid tendencies in the slight narrowing of the siphonal saddle, a tendency toward trifurcation of the first lateral lobe, and a beginning of elaboration of the inner part of the siphonal saddle and the auxillary lobes. The ribbing is distinctive of neither the Hildoceratids or Grammoceratids; it belongs to the more primitive Arietid or Echioceratid stages and the sulcate, carinate keel is found only in the early stage of early Grammoceratids, in adult Hildoceratids, and in the older Arietid and Echioceratid groups. So it seems evident that the Oregon species fills in some of the gap between the Grammoceratid and the Hildoceratid groups--it is near the hypothetical common ancestor because it has a pronounced Arietid or

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1 Buckman, S.S., On the grouping of some divisions of so-called "Jurassic" time: Quart. Jour. Geol. Soc., vol. 54, pp. 442-462, table II, 1898.

Echioceratid ribbing, the Arietid, Echioceratid, and Hildoceratid venter, and a Hildoceratid suture line that has commenced to assume the Grammoceratid characteristics.

Here again some of the factors mentioned at the beginning of this section come into play. The fact that the Oregon species is in an earlier stage of development than either the Hildoceratid or Grammoceratid groups leads to the probable but unproved assumption that it is geologically earlier than either group. It is the representative of the "lowest common denominator" of the two groups, but the exact range of forms bearing these characteristics is unknown--perhaps this primitive stock continued to exhibit these "lowest common denominator" characteristics long after it had given rise to true Hildoceratid and true Grammoceratid characteristics. It must be remembered, in this connection, that this species is stratigraphically above beds containing species of *Nerinea* and *Trigonia* that should belong to the uppermost Lias or middle Jurassic, while *Grammoceras toarcense* and the true *Hildoceras* are far below in the lower or middle upper Lias.

The next lower shale species to be considered is a single small specimen of an Amaltheid. It is much smaller than the normal species of this group and ~~it~~ is evidently an immature specimen, but it shows the typical *Amaltheus* shape and the beginning of fine longitudinal lineation and prorsiradiate ribs, similar to the adult stage of _Amaltheus reticularis_ (Simpson). No estimate of its possible relationships can be made at present, but the European Amaltheids are earlier than the Hildoceratids and Grammoceritids and are confined to a short period in the lower upper or upper middle Lias, so the Oregon species at least furnishes another indication that the age of the Nicely shale is pre-Hildoceratan and pre-Grammoceratan.

The third species supports the evidence of the other Nicely shale and _Pecten_ zone Ammonoids. It is evidently a Dactyloid, but it differs from all other Dactyloids known to the writer in that only occasional ribs are bifurcated as they pass over the venter and the lateral areas are rounded rather than flattened. The European Dactyloids are apparently confined to the Harpoceratid and Hildoceratid ages.

It is evident that the age indications of the several species mentioned from the lower Ochoco group do not agree very closely. Apparently the youngest fauna is in the Mowich limestone and is overlain by successively younger species. No hypothesis of overturning can be called to the rescue here, for Triassic beds lie unconformably below. The difference is principally between the evidence of the Ammonoids and that of the lamellibranchs and gastropods. As the Ammonoids are most diagnostic, it seems best to accept the lower age indications of the Ammonoids. The disagreement of the Ammonoids is only a matter of less than two of Buckman's ages and these ages are rather fine divisions in comparison to standards of the past. One might expect that this apparent disagreement of the Ammonoids, in both the Donovan and lower Ochoco fauna, is really caused by age difference and that species from several horizons have been lumped together. This may be true for the Donovan group, but the homogeneous nature of the red sandstone and the scarcity of bedding planes are rather against such a conclusion. The Ammonoids of the lower Ochoco group, however, are surely not susceptible to such a criticism as the apparently youngest forms occur stratigraphically below the apparently oldest, and the Hildoceratids, Dactyloids, and the Amaltheids were all collected from the same concretion.

The evidence of the Ammonoids in the lower shale and Pecten zone may be summed up as follows: (1) the Harpoceratid type in the Pecten zone indicates Harpoceratan age; (2) the Hildoceratid from the upper shale indicates pre-Hildoceratan, and is most probably of Harpoceratan age; (3) the Dactyloid may be either Harpoceratan or Hildoceratan age; (4) the Amaltheid indicates Amaltheian age or later.

Therefore, it is evident that the assignment of the Nicely shale fauna to the Harpoceratan age meets with the least conflict and that conflict is not serious, for the Amaltheid is such a small specimen that the adult stage may show extremely advanced Amaltheid characteristics that would place it later than the Amaltheian age. It may be concluded, then, that the Nicely shale, Freeman sandstone, and Mowich limestone of the lower Ochoco group are most probably of

Harpoceratan age, a time that corresponds to the base of the Toarcian stage in the lowermost part of the upper Lias of England.

The possibility of the Mowich limestone of central Oregon being the correlative of the Thompson limestone of the Taylorsville region has already been mentioned on page 96 , and it is of interest to note that the analogy is continued in the higher beds of both regions. Hyatt lists three species of Ammonoids from the Mormon sandstone and one of these he also compares to "Grammoceras toarcense" as figured by Buckman"[1], so this raises the speculation that the Mormon sandstone may be nearly the equivalent of the Nicely shale or the Freeman formation. Hyatt referred the Mormon sandstone to the upper Inferior Oolite, but his Inferior Oolite included everything from Haugian to Zigzagiceratan, so "upper Inferior Oolite" may be nothing higher than upper Lias under the present terminology.

Very little evidence of the age of the Trigonia zone has been obtained from the type locality of the Colpitts formation. The Trigonias should not be older than the Bajocian, but, judging from the age of the Trigonia in the Freeman formation, the Trigonias cannot be relied upon. The Tmetoceras, from the Bill Harris ranch locality six miles northeast of the type locality, affords the best age indication, as it is very closely related to Tmetoceras scissum (Benecke) of the Ludwigian age in the uppermost Lias, of England.

The other Ammonoid is the Sphaeroceratid from the old Howard Valley road locality. It indicates a slightly later date, but this discrepancy is not serious, at present, because there is some uncertainty regarding the stratigraphic position of the Sphaeroceratid and it probably comes from a higher horizon than the Tmetoceras of the Harris locality. The affinities of the Sphaeroceratid are still unknown. The coiling and septation are typical of the thick-whorled Sphaeroceratids, but the ribbing differs from most genera known to the writer in the marked forward curvature of the primary and secondary ribs and in the great size of the bullate primary ribs which give rise to as many as six secondary ribs. The Sphaeroceratids are mostly confined to the Sonninian and Stepheoceratan ages of the Bajocian period, so they are generally associated with Sonninids and Stepheoceratids, such as those found higher up in the Colpitts formation. This indicates that the Trigonia zone includes an appreciable time range, perhaps from lower Ludwigian age well into the Sonninian age. More detailed and careful collecting will probably show that there are two or more zones in what is now placed in the Trigonia zone, the lower beds with Tmetoceras belonging in the upper Lias, and the upper beds with the Sphaeroceratid in the lower Bajocian along with the higher zones of the Colpitts formation.

The fauna in the remaining part of the Colpitts formation does not seem to show a very long time range. This is probably because the central Oregon region was separated from the European seas near the beginning of the middle Jurassic and the faunas developed independently and free from European invasions.

The first Sonninids and Sphaeroceratids appear in the Rhynconellid zone and the same groups predominate among the Ammonoids throughout the remaining part of the Colpitts formation. The Sonninid group appeared in England near the end of the Ludwigian age, in the uppermost Lias. They were a cryptogenic group that had passed through progressive stages in some unknown region and were mostly retrogressive at the time they invaded the European seas. These earliest European Sonninids are mostly large specimens which show large costae, coarse spines or nodes, and quadrate, evolute whorls, all in various stages of retrogression toward a smooth involute stage with sharpened venters and flattened lateral areas. A few rare species passed beyond this period of retrogression into a second costate-spinous stage.

The early quadrate-whorled Sonninids, which have been set apart in the genus Euhoploceras Buckman, are surely the ancestors of most or all of the Sonninids in the Colpitts formation. Some of the Colpitts specimens seem to ~~be referable directly~~ fall under ~~to~~ Euhoploceras; others have passed far beyond the catagenetic stages shown by Euhoploceras, for they bear secondary progressive stages in which coarse ribs and spines are acquired for the second time. This renewal of anagenesis in the Colpitts Sonninids is a most remarkable development in the phylogeny of the Euhoploceras group. Apparently only a few English and South American species bear this interesting feature and it is shown only by the development of a few nodes during a costate stage. Many of the Colpitts species, however, reached an advanced stage of catagenesis before anagenesis again set in and consequently show, on the innermost whorls, a costate-spinous stage followed successively by costate and smooth stages, then acquire costae, nodes, and finally spines. A few show two costate or spinous stages well out on the later whorls and it seems most probable that the spinous stage of Euhoploceras is on the innermost whorls, thus making the last spinous stage a third or tertiary cycle of anagenesis and catagenesis.

Such diversity of form and extreme development of progressive and retrogressive stages, whose incipient stages are found in a few English species, indicates that the Colpitts Sonninids are of a later date than the genus Euhoploceras. This indication is supported by several small specimens which are remarkably similar to Euhoploceras, and these small specimens seem to be immature specimens, or inner whorls, of some of the giant species in the same beds. Despite all these advanced stages and diversity of form, the Colpitts Sonninids should not be far removed in time from Euhoploceras because of the very close similarity of some of the forms to Euhoploceras, and because even some of the advanced species have preserved and repeated Euhoploceras characters to a remarkable degree. It is a significant fact that the most advanced, secondarily progressive Sonninids have been found only in the Sonninid zone. The lower Sonninid-bearing beds, which include the Ichthyosaur and Rhynconellid zones, contain species in which secondary progression is not developed and consequently not far removed from Euhoploceras. This would indicate that the deposition of the upper part of the Ochoco group progressed during a length of time that was sufficient for marked faunal evolution.

McLearn[1] has described and reported several species of Sonninids from the Hazelton group of British Columbia. Four species are referred to the late Sonninian genera, Sonninites and Sonninia, of Europe. Another is described as the type of the new genus Guhsania McLearn, which is allied to the Dorsetensia stock of even later date. None of McLearn's species have yet been identified among the Colpitts Ammonoids.

The close relationship of the Canadian and European Sonninids is not at all in keeping with the apparent divergence of the Oregon group from the European stock. The British Columbia locality is not far from central Oregon and it would be expected that the two faunas would be more closely related to one another than to European species, but such is evidently not the case. The explanation is surely to be found in age differences, for the Canadian fauna is probably of a slightly later date and so could contain new European immigrants that are unrecorded in the Colpitts formation.

The date of Euhoploceras is uppermost Ludwigian and the Colpitts Sonninids might well be of lower and middle Sonninian age. This dating is supported by most of the other Ammonoid groups.

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1 McLearn, F.H., New Jurassic species from the Hazelton group of British Columbia: Geol. Surv. Canada, Bull., no. 44, pp. 89-99, 1926.

The Stepheoceratids are not numerous but they are found throughout the Sonninid-bearing beds. The stratigraphically lowest species is associated with the lowest Sonninid in the lamellibranch bed of the Rhynconellid zone. Its septation shows a close connection with Docidoceras cylindroides S. Buckman, but the primary and secondary ribs develop a marked forward curvature on the outer whorls--a character that is not found in Docidoceras. Whether this form came directly from Docidoceras or from an unknown common ancestor is impossible to say at present, but at any rate, it is probably not far removed in time from the Docidoceras horizon in the Sonninian age.

In the upper part of the Sonninid zone, lying above most of the Sonninids, are two other Docidoceras--like species which show the typical coiling, whorl shape, mouth borders, and septation of the planulate Sphaeroceratids. One species is very similar to Docidoceras planulatum S. Buckman and the other is similar in outward form but distantly related to D. perfectum S. Buckman. The ribs of both species are slightly inclined forward but to a much lesser degree than in the species of the Trigonia and Rhynconellid zone species.

A fifth Sphaeroceratid species was collected from the Colpitts formation on the ridge immediately southwest of the old Wooley ranch house, but its exact stratigraphic position is unknown. It has the general form and ornamentation of the heterogenous forms once included under "*Stephanoceras humphriesianum*", but the septation shows clearly that it is another serpenticonic derivitive from the *Docidoceras* stock.

Probably none of the Sphaeroceratid species can be referred directly to the genus *Docidoceras* because they show a divergence from the *Docidoceras* stock that is manifested principally by the prosiradiate costation. This inference of independent development is supported by the Sonninids, which clearly show that there was probably no free interchange of faunas between the European and Oregon seas during all or nearly all of the Colpitts deposition. Since *Docidoceras* comes well down in the Sonninian age it seems probable that the Oregon species is of lower or middle Sonninian age.

The two Oppelids from the Ichthyosaur zone are of little assistance, for they are known only from a few imperfect fragments. One species shows a typical *Oppelia* suture line, so there is, at least, no objection to the evidence furnished by the other Ammonoids.

The affinities of the Strigoceratid from the Sonninid zone are also difficult to determine because the costae are not well-preserved. The septation, whorl shape, mode of coiling, and all that can be seen of the costation approaches nearest to *Leptostrigites* S. Buckman. The Strigoceratids have a considerable geologic range--from Ludwigian to Parkinsonian--but the geologically earliest species do not show longitudional limeation. As the Colpitts species also lacks this character it should also be an early Strigoceratid, so it probably is no younger than *Leptostrigites* of the Upper Sonninian age.

The single Stepheoceratid in the Sonninid zone is known only from a few poorly preserved fragments. It is stringly similar to Zemistephanus McLearn, a genus that is found at the base of the Yakoun formation of British Columbia[1], but it lacks the umbilical enlargement and whorl contraction of the Canadian genus. Though the two forms may be closely related there is nothing to indicate that they are of the same age. In fact, the sudden acquisition of the serpenticonic contracticone stage in Zemistephanus is a later stage than that shown by the Oregon species, and therefore Zemistephanus is most probably also geologically later.

Perhaps the best age indication given by the Stepheoceratids is their almost total absence from the Ochoco group. In other parts of the world almost all the late Sonninian faunas contain an abundance of Stepheoceratids, and the lack of them in the Colpitts fauna, seems to be good evidence even though it is negative, that the Colpitts formation was deposited before the appearance of complex ramifications in the Stepheoceratid group. This line of evidence, however, is rendered somewhat uncertain by the provincial character of the fauna which seems to have had its origin from uppermost Lias types, but as will be shown later, the upper Sonninian Stepheoceratids do appear associated with late Sonninids, in the base of the Silvies group.

Several Sonninian faunas are known in North America, especially in British Columbia and Alaska, but all that have been

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1 McLearn, F.H., Some Canadian Jurassic faunas: Trans. Roy. Soc., Canada, 3rd ser., vol. 21, sec. IV, p. 72, 1927.

closely dated are apparently of upper Sonninian age, and in sharp contrast to the Colpitts fauna, they contain abundant Stepheoceratids and Sonninids that are closely related to European species.

Conclusions regarding the age and correlation of the Colpitts formation may be summarized as follows:

(1) The _Tmetoceras_ of the _Trigonia_ zone indicates that deposition of the Colpitts formation began in the lower Ludwigian age of the uppermost Lias.

(2) The various Ammonoids of the higher beds indicate a lower and middle Sonninian age in the lower Bajocian or Inferior Oolite.

(3) The time between the lower Ludwigian and lower Sonninian ages may be accounted for by the upper beds of the _Trigonia_ zone.

(4) The Sonninid group shows that the deposition of the upper beds covered an appreciable length of time that was accompanied by recognizable faunal evolution.

(5) The divergent evolution of the Sonninid and Sphaeroceratid groups show that the central Oregon region was not in free communication with the European seas during the lower and middle Sonninian age.

(6) The Colpitts faunas are apparently without known correlatives in North America.

The identification of the Ammonoids in the Warm Springs shale is somewhat more difficult than in the lower zones of the Ochoco group. Apparently the same faunal divergence that began in the lower Colpitts formation was continued and accentuated in the Warm Springs shale.

Most of the Ammonoids belong to a single genus possibly related to Dorsetensia, S. Buckman 1892. A smooth coronate stage on the innermost whorls of the Warm Springs species shows a Sonninid deviation, and the coiling, whorl shape, costation, and the hollow heel are strikingly similar to the Dorsetensia group. The ontogeny of most of the species is rather complex--in some ~~there are~~ two or three stages of progression and retrogression of ornament from smooth or striate to costate can be recognized. Therefore, if the Dorsetensia-like features of the Warm Springs species are due to an actual close relationship with Dorsetensia and not to accidental homeomorphy, then their phylogeny becomes extremely complicated, because the Warm Springs species seem to be geologically earlier and biologically later than known Dorsetensia species. The retrogressive species of Dorsetensia are principally of Stephoceratan age, though some doubtful specimens are of late Sonninian age. The retrogressive Stephoceratan species still preserve an ancestral coronate stage on their inner whorls. The Warm Springs species should not be later than middle Sonninian age, yet many of them have eliminated the coronate stage and have also passed through more than one period of retrogression. Therefore it would be necessary to connect the Warm Springs species with Dorsetensia through an unknown common ancestor of middle Sonninian or earlier date, and a relationship through such a circuitous route can give no accurate age indication for the Warm Springs shale.

The Stephoceratid species is likewise of little assistance. It has the costation of the "humphriesianum" types but the suture lines are not preserved and therefore it is impossible to make an estimate of its possible relationships. The Phylloceratid and Inoceramus species have not been studied.

The Dorsetensia-like group and the "Stephanoceras humphriesianum" type are both indicative of Stephoceratan age, and if it were not for the fauna in the base of the overlying Silvies series, the Warm Springs shale would have been assigned to the Stephoceratan age. But the base of the Silvies series is surely of upper Sonninian age and, moreover, there is a marked angular unconformity at its base.

The principal conclusions regarding the age, correlation, and faunal relationships of the Ochoco group may now be listed in a short summary:

(1) The Ochoco group was deposited during the upper Lias and lowermost middle Jurassic, between and including the Harpoceratan and middle Sonninian ages.

(2) A noticeable time interval, therefore, intervenes between the Ochoco and Donovan groups, but there is no marked time interval between the Ochoco and Silvies group even though they are

delimited by an angular unconformity.

(3) The ages of the Mowich limestones, Freeman formation, and Nicely shale are close together in the Harpoceratan age.

(4) The lowermost beds of the Colpitts formation seem to be of lower Ludwigian age or uppermost Lias.

(5) The remaining part of the Colpitts and also the Warm Springs shale are of lower and middle Sonninian age and the lower and middle Ludwigian age may be represented by non-ammonitiferous beds.

(6) There is not a very close relationship between the Ochoco fauna and those of Europe. Faunal divergence, probably due to very indirect paleogeographic connections, is especially noticeable in the Colpitts and Warm Springs faunas.

(7) The Mowich limestone, Freeman formation, and Nicely shale faunas may perhaps be correlated with some of the very imperfectly known upper Lias faunas of North America, but most of these possible correlations are based upon apparent correspondence of geologic age, rather than upon close relationships of faunas.

(8) The lower and middle Sonninian faunas of the Colpitts formation and Warm Springs shale are apparently without known correlatives in North America.

Areas near the Type Locality

Lower Warm Springs Creek

Outcrops of the Ochoco group continue northward from the type locality for a distance of four miles. They lie upon the east side of Warm Springs valley for a distance of one and one half miles below the Colpitts ranch house, but in this distance Warm Springs Creek runs north obliquely across the Jurassic outcrops and joins Beaver Creek through a narrow canyon in the Tertiary lavas and tuffs.

Northwest of lower Warm Springs Creek the Mesozoic beds, including Triassic, both groups of Jurassic, and Cretaceous, continue to outcrop in the broad structural depression. The Ochoco group strikes northeastward normal to the length of the depression and consequently its exposures are marked by narrow strike ridges which on the west, continue up over the high western side of the depression, and on the east, are overlain by the plateau lavas of the narrow ridge between Beaver Creek and the Suplee trough.

The dominant structure of the Ochoco group, as stated before, is a series of northeastward trending folds. The type locality lies across the south limb of the major anticline, but in the western end of the type area, east of the Colpitts ranch house, the continuity of the steeply dipping south limb is broken by the northwestward striking beds with gentle dip. This feature is largely due to faulting, but it gives the appearance of a flat-topped anticline which plunges to the southwest.

About three-fourths of a mile north of the Colpitts ranch house the gently-dipping beds are interrupted by two minor folds in the flat top of the anticline. These folds are essentially elongate domes that approximately parallel the strike of the major anticline. They are each about one-fourth mile in width and show dips of more than 35 degrees. Warm Springs Creek cuts across both folds and exposes Triassic beds beneath. The north limb of the northern-most minor anticline is coincident with the north limb of the major anticline which dips steeply beneath beds of the Silvies group east and west of the Weberg ranch house. Two and one-half miles farther north the Ochoco beds rise to the surface again to join the north limb of a syncline. Both synclinal limbs are marked by prominent stride ridges transverse to the Suplee trough.

Only 200 to 300 feet of the Ochoco group is exposed on the north limb of the syncline partly because it is largely overlapped by the Silvies group. Consequently structural relations are clearer here than elsewhere. A section only 100 yards long on the east side of the trough would show three of the five major divisions of the central Oregon Mesozoic: north of the strike ridge is the Triassic, with an altitude of N. 10°E., 85°S., then comes the Ochoco group, N. 60°E., 50°S., then the Silvies group, N. 25°E., 35°S.

The basal conglomerate, Mowich limestone, Freeman formation, and Nicely shale, as stated before, are overlapped by the Colpitts formation in the western end of the type locality. Farther north some of the lower zones of the Colpitts formation also disappear. The sequence on the north limb of the major anticline, which is also the south limb of the major syncline, begins with conglomeratic and gritty beds that are probably equivalent to the Ichthyosaur zone and these are followed by the Sonninid zone and Warm Springs shale. The conditions are essentially the same on the north limb of the syncline--the Sonninid zone and possibly the Ichthyosaur zone outcrops as a narrow hogback between underlying Triassic beds and overlying Silvies group. The Colpitts formation is consequently much thinner than in the type locality, and the Warm Springs shale is largely or entirely overlapped by the shallow syncline of Silvies shales and sandstones.

Fossils are not as plentiful in the lower Warm Springs Creek region as in the type locality of the Ochoco group. Some collections were made in the Colpitts sandstones and Warm Springs shale along the south limb of the syncline west of Warm Springs Creek, but they show nothing new except a large ammonite, of unknown affinities, in the Warm Springs shale.

Pine Creek Area

The Ochoco group is exposed in several places northeast of lower Warm Springs Creek along the strike of the syncline which trends toward Morgan Mountain on the east side of the South Fork valley. One of these localities, located on the bluffs immediately southeast of the Bill Harris ranch house on a southwestern tributary of Pine Creek, is worthy of note because of the great development of the Mowich limestone and basal conglomerate. The conglomerate on the high ridge above the ranch house, is at least 500 feet thick and the limestone is considerably more than 100 feet thick. These beds continue eastward along the high ridge, north and below the ridge is a series of fossiliferous beds of the Colpitts formation. The <u>Trigonia</u> zone is especially well-developed on the low spur east of the Harris ranch house. It is from this locality that the <u>Tmetoceras</u> was obtained.

Neither of the Ochoco shale formations nor the Freeman snadstone were noted at this locality, but ~~it is very probable that~~ ~~some or~~ all probably are represented because the locality is known only from a single short reconnaissance.

About two miles northeast of the Harris ranch are other exposures of Mowich limestone and conglomerate, which parallel the north side of Pine Creek between the upper and lower forks of the drainage basin. These beds dip steeply northward and in some places are almost vertical. The Mowich limestone reaches its maximum development, of fully 500 feet, in this area, but a large part of this thickness is accounted for by unfossiliferous coarse green massive sandstones and conglomerates.

The structure of the Pine Creek region seems to have very little of the simplicity of the synclinal area in the Suplee trough. The limbs of the syncline trend across the Suplee trough from one rim to the other and are interrupted only by minor fault offsets, but the continuation of this structure is very irregular and much more complicated. The Pine Creek outcrops are between and in line with the south limb of the syncline on lower Warm Springs Creek and the Ochoco group of Morgan Mountain in the South Fork region. The beds dip north in all these areas and it seems probable that they are all part of the same major fold. The present evidence seems to show that northeastward continuation of the Ochoco structures in the Suplee trough are interrupted at intervals by transverse faults--a theory that finds considerable verification in the next two areas to be discussed.

Beaver Creek Canyon Area

In the narrow canyon of Beaver Creek, about one-half mile above its junction with Warm Springs Creek, is another isolated area of the Ochoco group that has been exposed beneath the Tertiary plateau lavas by the down-cutting of the creek. The best exposures are on the northeast side of the creek. The beds strike obliquely across the canyon with an attitude of N. 10°E. 20°N. The dip and geographic location of these beds indicates that they are part of the north anticlinal limb of the lower Warm Springs area, but the outcrop cannot be traced from one area to the other because of the flat lava-covered ridge that lies between Beaver Creek and the Suplee trough. However, the continuity of the structure is interrupted beneath the lava ridge, either by pre-lava faulting or cross folding, for the anticlinal limb, on the Warm Springs side, strikes almost directly east beneath the lava but does not appear in the canyon on the opposite side of the ridge~~—instead there are~~ where only Triassic beds ~~there and~~ are found, the Jurassic beds are found again more than one-half mile north of this point at the canyon locality where the strike has changed to N. 10°E. It is an interesting and probably very significant fact that this offset of the north limb is directly north and in line with the prolongation of the north-south fault ~~which~~ that offsets the south limb of the anticline east of the Beaver Creek-Warm Springs divide, as mentioned on page 64 . The offset is in the same direction in both places and it ~~seems probable that~~ the same fault ~~is~~ may be responsible for both offsets.

The stratigraphic sequence of the Beaver Creek canyon locality begins with approximately 500 feet of basal conglomerate, a thickness that is comparable to that of the Harris locality conglomerate. The Mowich limestone is absent in this sequence, probably because the sedimentation was too rapid for even the vigorous Rudistids. Apparently the Nicely shale is also absent, a condition that should not be at all unexpected in an area that gave rise to such a thickness of conglomerate.

The Colpitts formation and Warm Springs shale are well represented in the canyon locality. The Colpitts formation is more than 300 feet thick. It is very fossiliferous and all the zones of the type locality are present. In lithology and fossil content it is very similar to the type locality, and therefore it needs no detailed description.

The only additional information on the Warm Springs shale that was gained from this locality was the finding of the characteristic small Warm Springs *Inoceramus* in the uppermost beds of the Sonninid zone--a fact that corroborates the supposition that the Warm Springs shale is not of a greatly later date than the Colpitts formation.

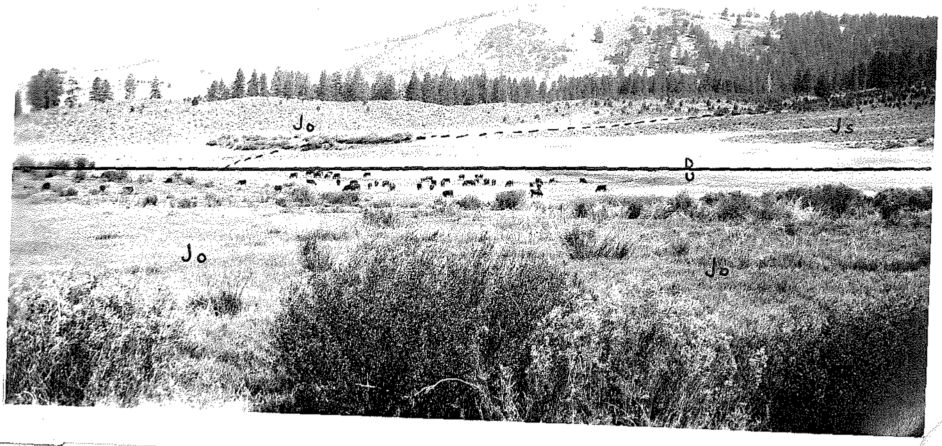
Freeman Creek Area

The Freeman Creek area is the eastward continuation of the south limb of the anticline from the type locality of the Ochoco group. It lies in a nearly circular drainage basin, about one mile in diameter, which has been carved out south of the hogback formed by the southward-dipping anticlinal limb. The area was once covered by nearly flat-lying beds of the Silvies group and by Tertiary lavas, but erosion has reduced the cover to less than 200 feet of Silvies shale and sandstone. A mosaic of ancient post-Jurrassic faults has caused the Ochoco beds to protrude through the silvies cover at several places in the basin.

The basal conglomerate and Mowich limestone, typically developed upon nearly vertical beds of Triassic conglomerate and shale, form a conspicuous hogback along the anticlinal limb from the Wooley ranch house eastward to the north face of Mowich mountain. There they are cut off by cross-faults and the Triassic beds pass under the lavas of Mowich Mountain without interruption. Immediately south of the Hogback the higher beds of the Ochoco group are largely overlapped by the Silvies group.

The strike of the anticlinal limb is N. 75°-80°E. across the mouth of Freeman creek and almost due east nearer Mowich mountain. The Silvies group, west of Freeman creek, strikes N. 20-40 W. and dip 10-20S., and east of the creek, which marks a N-S fault, the

PLATE V



VIEW OF MOWICH MOUNTAIN FROM THE WEST SIDE OF THE FREEMAN CREEK DRAINAGE BASIN

D
U fault; Jo, Ochoco group; Js, Silvies group;
contact of Ochoco and Silvies group. The branch fault up Freeman Creek lies in the depression marked by the long line of trees.

Silvies group strikes N. 60° W., and dip 10° S. Because of the divergent strike of the two Jurassic groups east of Freeman Creek, successively younger beds of the Ochoco group are revealed near Mowich Mountain, but they are not well exposed and only a few fossils were found in them.

A north-south fault of slightly more than 100 feet vertical displacement with downthrow to the east, cuts across the anticlinal limb at the mouth of Freeman creek and continues southward up the south branch of Freeman creek. The marshy meadow along this fault is only a few feet below the base of the nearly flat-lying upper series west of the fault and therefore a narrow band of the Ochoco beds, apparently the Warm Springs shales, outcrops along the base of the hills west of the creek. The north-south fault gives rise to two or more southeastward trending branch faults which have brough up the Ochoco group on the southern or upthrown blocks. One of these faults lies beneath the main branch of Freeman Creek, which comes down from the west face of Mowich Mountain. The Colpitts formation, as far down as the Trigonia zone, is exposed on the upthrown block south of the creek, (see Plate V). The Warm Springs shale is overlapped by the nearly flat-lying beds of the Silvies group as it is north and east of Freeman Creek. About one-half mile south of this fault the Colpitts formation is again exposed by another fault whose exact position has hot been determined.

South Fork of the John Day River Area

The south limb of the Ochoco anticline emerges from beneath the lavas on the northeast side of Snow Mountain, continues northeastward across upper Flat Creek, and crosses the John Day River at the junction of the Suplee-Izee and lower South Fork roads. The Suplee-Izee road lies ~~upon~~ in the area of Triassic and Paleozoic beds as it enters upper Flat Creek and crosses Big Flat under the northern rim of Snow Mountain. On the east side of Big Flat the road crosses the strike ridge of the Ochoco group and descends into the South Fork valley ~~upon~~ on slopes formed by the Warm Springs shale.

The bottom of the valley narrows to a rocky canyon where the river passes through the southward-dipping Ochoco group, and broadens again in the Triassic area beyond. A typical section of the Ochoco group is exposed on the high hill northwest of the river. The section shows:

(1) Warm Springs shale: Fossiliferous soft black shale with flinty concretions and well-bedded flinty and sandy layers.

(2) Colpitts formation (?): Thick beds of hard blue sandstone and conglomerate, almost barren of fossils.

(3) Nicely shale: Black shales as in the type locality.

(4) Freeman formation: Brownish-yellow calcareous sandstones with the Pecten of the Pecten zone and other fossils.

(5) Shales, and calcareous and cherty layers which are the equivalents of the basal conglomerate and Mowich limestone of the type area.

The assignment of the green sandstone and conglomerate to the Colpitts formation is somewhat doubtful because of the lack of fossils and extremely different lithology. However, its position, between the Nicely and Warm Springs shales, is perhaps good ~~incontrovertible~~ evidence.

The opposite or north limb of the anticline has been found in the steep southeastern face of Morgan Mountain, which rises abruptly from the north side of the South Fork River about three miles below the cross-roads section. The base and greater part of the mountain is made up of Triassic beds and the top is capped by Tertiary basalts, so the Ochoco group outcrops as a narrow band between the lavas and the Triassic basement. The Jurassic beds dip steeply to the northeast and are apparently a continuation of the Pine Creek area. The section shows:

	Ft.	in.
(1) Nicely shale		
Well-bedded black shale with lamellibranchs and Hildoceratid ammonites--------------------	15-20	
Calcareous gray sandstone with numerous small Rhynconellids----------------------------------		6
Black well-bedded shale with numerous big flinty concretions containing Hildoceratid ammonites--	50	
(2) Freeman formation:		
Pecten zone: Calcareous gray-brown sandstone with very large Pectens-----------------------	175	
Brachiopod zone: Calcareous gray sandstone with innumerable small Rhynconellids as in the type locality-------------------------------	1	

	Ft.	in.
(3) Tough poorly beeded shale-------------------	50	
(4) Mowich limestone:		
Unfossiliferous white sandy limestone with chert pebbles----------------------------	75	

Bear Valley area

The Ochoco group is represented in the Silvies drainage only by three small remnants, which lie ~~upon~~ the Triassic basement on the north side of Bear Valley opposite Seneca. Only the upper Lias portion of the group is represented in the 200-300 feet of shale and limestone, and a very minor amount of sandstone. The sizes and locations of these outcrops are best shown on a map of the Crow Flat-Canyon City region which is now in preparation.[1]

The largest area is found immediately east of the old Canyon city stage road on the ranch of William Vancil, where it covers more than 80 acres in the low foothills of the north rim of Bear Valley. The sequence begins with about 50 feet of black well-bedded shale and continues with more than 150 feet of Rudistid-bearing Mowich limestone. Some of the limestone beds are very pure limestone, but others contain a considerable amount of silica. The Freeman formation is represented by less than 15 feet of calcareous brown and gray sandstone in the eastern end of the area.

The section is greatly disturbed by folding and faulting in the eastern end of the area, but near the road the beds lie in a gently dipping anticline whose axis plunges to the southeast.

Large Ichthyosaur bones and several ammonites have been

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1 Lupher, R.L., a Geological section across the Ochoco Range and Silvies plateau south of Canyon City, Oregon: Mss. in preparation.

found in the lower shale, and the limestone has yielded a number of brachiopods, a few lamellibranchs and gastropods, including the large triplicate *Nerinea* of the Suplee region. The *Pecten* zone of the Freeman sandstone contains, in addition to its characteristic zone marker, two species of *Pholadomya* and two of small *Pectens*, one species each of *Ostrea*, *Pinna*, *Trigonia* (?), and *Camptonectes*, two species of Terebratuloids, one large solitary coral, and several Ammonoid fragments. Field notes mention a shaley sandstone about six feet above the *Pecten* fauna which contains two or three species of Rhynconellids, so it seems probable that the brachiopod zone is also represented, though none of the Rhynconellids could be found in the collections.

The other two Bear Valley outcrops cover only a few acres on the west side of a northward-trending ridge about seven-tenths of a mile northwest of the Vancil outcrop. They are close together and have been faulted down against the Triassic sediments and serpentines ~~which~~ form the ridge above. The base of the sequence is not well-exposed because of a mantle of waste. The lowest known beds are part of the Mowich limestone and contain Rudistids, Nerineas, and brachiopods. The upper part of the sequence is the Freeman formation which is made up of calcareous sandstones. They contain some very large specimens of the *Pecten* and *Trigonia* of the *Pecten* zone. In addition there are several species of *Camptonectes* and Terebratuloids.

SILVIES GROUP

General features of the type locality

The Silvies group seems to be so similar in its wide distribution throughout the pre-Tertiary area that a discussion of the single sequence of the type locality will probably give the essential features of the group wherever it may be found.

The type locality lies in and near the upper canyon of the Silvies River between the alluviated basins of Bear and Silvies Valleys. The basins are structural downwarps in the plateau surface and the Silvies River, in maintaining its course across the undisturbed surface between the basins, has stripped back the Tertiary lavas and exposed the Jurassic basement beneath. Similar degradation by tributary streams entering the basins have exposed the basement between the high flat-lying plateau and the broad alluviated valley floors. Consequently the Silvies group is well-exposed around the northern half of Silvies Valley and on the south side of Bear Valley. The outcrops on the south side of Bear Valley extend far to the west where they are continuous with the large area of these rocks that lie west of Bear Valley and in the South Fork of the John Day River.

The upper Silvies canyon area is chosen for the type locality because (1) the stratigraphic sequence is least in doubt there; (2) it has yielded both the youngest and oldest known faunas;

and (3) it can also be made the type locality of both minor divisions of the group.

The beds strike eastward normal to the canyon and dip steeply northward throughout the region except where they have been locally disturbed by intrusions of Tertiary age. The distance between Silvies and Bear Valley is more than four miles, and the faunas are successively younger from soth to north, so a thickness of at least 15,000 feet must be represented in the Silvies Group unless there is repetition of beds by unknown faulting.

The Jurassic area on the west side of Silvies Valley is almost directly south of the canyon area, so the continuation of the structure should be found here, either as successively older beds or as an opposite anticlinal limb. However, the monotonous nature of the sequence makes the stratigraphic succession somewhat doubtful. The northward dip predominates in this area as it does in the canyon, but it seems certain that the northward dip is caused by overturning and not by a continuation of successively lower beds.

The structures in the canyon area are somewhat complicated by crumpling around large intrusions of Eocene basalt porphyry and Miocene basalt. The largest Eocene intrusion, which is 400-3,000 feet thick, trends southwestward across the canyon from Soda Mountain. Another smaller Eocene intrusion is found immediately west of the Craddock ranch house where it is associated with a large intrusion of Miocene basalt.

No unconformities have been definitely distinguished on a purely stratigraphic basis, therefore the subdivision of the Silvies group into two formations is dependent upon lithologic and faunal evidence.

Both faunas are of Bajocian age, but the distance between them is three and three-tenths miles and the steep northward dip of the section indicates that they are approximately 12,000 feet apart stratigraphically.

Approximately 150 feet above the highest Middle Jurassic fauna in the upper part of the canyon is an ammonite fauna of lower upper Jurassic age. Therefore, a time interval equal to most of the Middle Jurassic must be accounted for by a disconformity somewhere in this 150 feet of sandstone and shale. So it becomes necessary to recognize, in the Silvies Group a lower and upper division, the Craddock and Lincoln formations, which are appropriately named from the old-time ranches at each end of the canyon.

The fossils of the Silvies group are not well-preserved because of crushing and removal of all the shelly material. A few favorable localities have yielded molds and casts which have preserved delicate features of ornamentation and even suture line. The predominance of Ammonoids throughout the entire group is remarkable. There are only a few rare lamellibranchs and other fossils are unknown.

Craddock Formation

Stratigraphy and Lithology

The Craddock formation cannot be readily subdivided at present because it is a rather monotonous alternation of thick beds of black shale and thin beds of hard blue sandstone. The shales are many times thicker than the sandstones and if it were not for the Tertiary intrusions the canyon would have been widened into a sizeable valley in the part that lies below the Lincoln formation.

Sandstones are most noticeable in the middle part of the section and shales predominate in the upper and lower parts. The river leaves Bear Valley through a narrow canyon in the Lincoln sandstones and continues in a canyon until it passes through a conglomerate and two sills of green porphyry in the uppermost part of the Craddock formation. Immediately below the two sills the canyon opens into Soda Valley, which is an erosional basin one mile in diameter in the upper Craddock shales. At the lower end of Soda Valley the river passes abruptly into another canyon that is determined by several heavy beds of sandstone in the middle part of the section. The canyon does not widen again in the lower shale area beyond because it cuts across large intrusions of the Eocene porphyry.

Only a single bed of conglomerate has been found in the Craddock formation of the type locality, and this is at the very top of the section nine-tenths of a mile below the head of the canyon. The conglomerate is mostly fine-grained and includes a considerable amount of sandstone. In it are numerous pebbles and even some fairly large boulders from the harder beds of the underlying shale. The shales are well-bedded, noncalcareous, soft, and unaltered except near large Tertiary intrusives where they are changed from black to gray and even white. Almost everywhere they are fine-grained and the transition to sandstone is very sharply defined. The sandstones are strikingly similar throughout the formation. They are mostly fine-grained, dense, evenly sorted, and extremely hard. All of them show a characteristic blue color. The beds are cut by several systems of joints, but bedding planes are rarely defined except by intercalation of thin, remarkably even bands of shale which, in some places, are only a few millimetres in thickness.

Fossils

The most fossiliferous localities of the Craddock formation have been found near the supposed base and at the very top of the formation. Two localities are stratigraphically close together near the lower end of the canyon and represent the oldest known fauna of the Silvies group. One locality is in an excavation for road material in the hillside about six-tenths of a mile northeast of the Jack Craddock ranch house; the other is slightly more than one mile northwest of the Craddock ranch house in a railway cut in the bottom of the Silvies Canyon. Both localities are in shales which have been greatly disturbed and whitened by nearby Tertiary intrusives.

The fauna from the easternmost locality is noteworthy for the remarkable abundance and variety of Stepheoceratids—a feature that contrasts sharply with the scarcity of Stepheoceratids in the canyon locality where there are a variety of Sonninids and only two Stepheoceratids. Some of the species from the eastern locality also appear to be Sonninids, but their identification is somewhat uncertain because the specimens are not sufficiently well preserved to show the spines which should be on the inner whorls. The general form and ornamentation of the body chambers suggest a retrogressive Sonninid stage.

Aptychi, presumably from the Sonninids, are very abundant in the canyon locality. They belong to three very different types; one is a coarsely ribbed imbricate type similar in shape to two opposed *Donax* shells; another is fused along the median line and is otherwise very similar to the coalescent aptychi of *Scaphites*; and a third, which is oval in outline and bears a high longitudional median ridge, is apparently another kind of a coalescent aptychus, or perhaps ~~is~~ an anaptychus.

The best fossil localities of the upper Craddock formation are in the previously mentioned conglomerate bed near the head of the canyon and in a thick shale bed immediately below the conglomerate. Stepheoceratids are as predominant in the conglomerate as they were in the shale at the lower end of the canyon, but they belong to different and later types. The only other fossils are a Phylloceratid and a small oyster. The fossils in the underlying shale are very poorly preserved, but they appear to be mostly Sphaeroceratids and *Dorsetensia*-like Sonninids.

Age and Correlation

The lowermost fauna in the Craddock formation can be correlated with the fauna in the base of the Craddock formation near Suplee by means of a Stepheoceratid that is common to both areas. This means that the Sonninid fauna of the Craddock formation is separated from the Ochoco Sonninids by a marked angular unconformity as shown in the Suplee region. It is very surprising to find two faunas so nearly of the same age according to the European time scale yet separated by such an angular discordance of beds, but the conclusion is inevitable.

The Craddock Sonninids are distinctly different from the Ochoco species. They are more closely allied to the post-*Euhoploceras* Sonninid genera. They fall principally into two distinct groups—one is single ribbed and tuberculate retrograding to smooth as in *Papilliceras* S. Buckman; the other shows bifurcating tuberculate ribs retrograding to simple costate. Secondary progression is found only in one species of the latter type.

The Stepheoceratids of the eastern locality contain a number of genera whose exact affinities are still unknown, but it is evident that they are all closely related to the serpenticonic, highly ornamented European Stepheoceratids of upper Sonninian age. *Skirroceras*-like types are especially abundant and another is very similar to *Rhytostephanus* S. Buckman.

It seems that the presence of these late Sonninids and early Stepheoceratids, which are stratigraphically close together and associated, to some extent, with one another, dates the lower Craddock formation as of upper Sonnian age.

The fauna in the topmost Craddock beds indicates a Stepheoceratan age. The Stepheoceratids, in contrast to the serpenticonic species of the lower beds, are mostly thick-whorled, deeply unbilicate, and not so acutely ribbed. One species is very close to _Epalixites_ _formosus_ S. Buckman, of the _blagdeni_ hemera. This short time range between the upper and lower faunas is rather unexpected in view of their great stratigraphic separation, or perhaps it is better to say that such a thickness of beds is not indicated by the upper Sonninian and Stepheoceratan succession of Europe.

The Craddock faunas find many close correlatives in western North America, for late Sonninian and Stepheoceratan faunas have been reported near the Pacific Coast from Oaxaca to Alaska* and as far inland as Sheep River, Alberta. The British Columbian and Albertan faunas are being carefully recorded by McLearn and Crickmay, and when the Craddock fauna is better known the two regions will doubtless prove to have a great deal in common.

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* See correlation chart at the end of this report.

Lincoln Formation

Stratigraphy and Lithology

The basal beds of the Lincoln formation are apparently shales and fine-grained sandstones, and the top of the Epalixites-bearing conglomerate of the Craddock formation is taken as the dividing line between the two formations. It seems very peculiar to find one formation ending with a conglomerate and the overlying formation beginning with shales and fine-grained sandstones, especially since the conglomerate contains boulders from the underlying beds, but the conglomerate fossils show that the conglomerate is much older than the shales. The conglomerate fossils are mostly broken fragments, so it might seem that the conglomerate is the basal bed of the Lincoln formation in which fossils have been reworked from the older Craddock beds. But it is impossible to adopt such an hypothesis, however attractive it may be, because the matrix inside the fossils, even in the septal chambers of the smallest Ammonoids, is the same as the matrix of the conglomerate. It does not seem possible that lower middle Jurassic fossils could be reworked in the upper Jurassic in such a way as to remove all the original matrix, even from the inner chambers of small Ammonoids.

The Lincoln sequence differs from the Craddock formation principally in the relative amounts of sandstone and shale. Thick beds of shale are very subordinate to the hard blue sandstone.

The lithologic description of the Craddock sandstones and shales applies in every way to those of the Lincoln formation. No criteria are known which would serve to distinguish hand specimens from the two formations.

The total thickness of the Lincoln formation is nearly two thousand feet in the type locality and an unknown thickness of these beds lie beneath the Tertiary beds and Quaternary alluvium of Bear Valley.

Age and Correlation

Most of the Lincoln fossils come from the previously mentioned locality in the upper Silvies canyon, which is about 150 feet above the base of the formation. They are mostly Gowericeratids which show many resemblances to Canadian genera. Some belong to the genus Seymourites Kilian and Reboul and are probably referable directly to some of the species described by McLearn from the Yakoun and Fernie formations of British Columbia and Alberta. The date of the Seymourites fauna is late Proplanulitan, a time that comes near the middle of the Callovian stage of the early upper Jurassic. This fauna shows that the central Oregon region was flooded by the same Callovian sea that spread so widely over British Columbia and Alberta.

The Chinitna shale of Cook Inlet, Alaska, has been assigned to the Callovian by Stanton[1], and McLearn[2] has pointed out the possibility of correlating a part of its fauna with the Seymourites fauna of Canada upon the basis of "Kepplerites (?) cf. K. loganianus (Whiteaves)"[3] which has been reported from the Chinitna shale. Burckhardt[4] reports another Callovian fauna from Mexico, but it is referred to the "zone of Macrocephalites macrocephalus" so it probably has nothing in common with the Lincoln fauna.

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1 Stanton, T.W., & Martin, G.C., Mesozoic section on Cook Inlet and Alaskan Peninsula: Geol. Soc. Amer. Bull., vol. 17, p. 401, 1905

2 McLearn, F.H., Contributions to the paleontology of Skidegate Inlet, Queen Charlotte Islands, B.C.: Nat. Mus. Canada, Bull. 54, p. 2, 1929

3 Martin, G.C., The Mesozoic Stratigraphy of Alaska: U.S. Geol. Survey, Bull. 776, p. 65, 1926

4 Burckhardt, Carlos, Cefalopodos del Jurasico medio de Oaxaca y Guerrero: Inst. Geol. Mexico, Bol. 47, 1927.

Silvies Group outside the Type Locality

Silvies Valley

The Jurassic exposures on the west side of the Silvies Valley are continuous with those of the type locality. They lie between Gold Hill and the canyon in an area that is six miles long from north to south, and four to five miles wide. The strata strike northwest in most places and the streams entering the Silvies basin from the west are superimposed upon the Jurassic beds at a very acute angle.

Some heavy sandstone beds are exposed on the ridge north of the Miranda ranch on Jump Creek and these seem to correspond to the heavy sandstone beds near the middle of the Craddock formation of the upper canyon area. This would place the base of the formation about one mile south of, and perhaps 3,000-4,000 feet below the Sonninian and Stepheoceratan faunas. Between Jump Creek and Flat Creek are mostly shales ~~which~~ that would correspond to the Soda Valley shales of the upper Craddock formation. This is substantiated by the occurence in the shales of a Stepheoceratid of the subcoronatum type. A conglomerate, which is very similar to the Epalixites conglomerate at the top of the Craddock formation, outcrops at the edge of the Flat Creek meadows near the Smith ranch house, and ~~it~~ is surely the correlative of the upper Craddock conglomerate.

The parallelism between the upper canyon and west Silvies sections is carried still farther on the south side of Flat Creek where there are some thick beds of sandstone ~~which~~ that should be the correlative of the Lincoln formation, ~~and~~ this appearance is verified by a Macrocephalitid species ~~which comes~~ from a grit and sandstone member overlying the supposed Craddock conglomerate. Sandstones and shale outcrop for more than a mile south of Flat Creek and these are doubtless higher beds of the Lincoln formation that are unrecorded in the two thousand foot section of the type locality.

It seems inevitable to conclude that the west Silvies section is the south limb of the same fold whose north limb is shown in the northward-dipping canyon sequence. The prevailing steep northward dip in the west Silvies area, therefore, must be due to overturning.

Very little is known about the Silvies group on the east and northeast sides of Silvies Valley. Fossils have been found only in one locality and they have not been identified. The group is exposed as far south as Poison Creek, which joins the river between Jump and Flat Creeks. The exposures continue for an unknown distance east of the upper Silvies basin. The northward dip prevails as in other localities.

Probably only the Craddock formation is represented in this eastern area, for no marked development of sandstones was noted and the Lincoln formation south of Flat Creek strikes across the valley toward the country south of Poison Creek which is overlain by Tertiary deposits.

West Bear Valley--South Fork Area

The Silvies beds west of Bear Valley and in the South Fork valley cover a much larger area than in the Silvies region, but they are very incompletely known and only a few fragmentary fossils have been found in them. The known exposures are all on the south side of the Ochoco anticline in the South Fork valley, but west of Bear Valley only the Silvies group is known and the contact with the Ochoco group or older rocks lies somewhere to the west of Bear Valley in the unexplored country around the headwaters of Deer Creek and Murderers Creek.

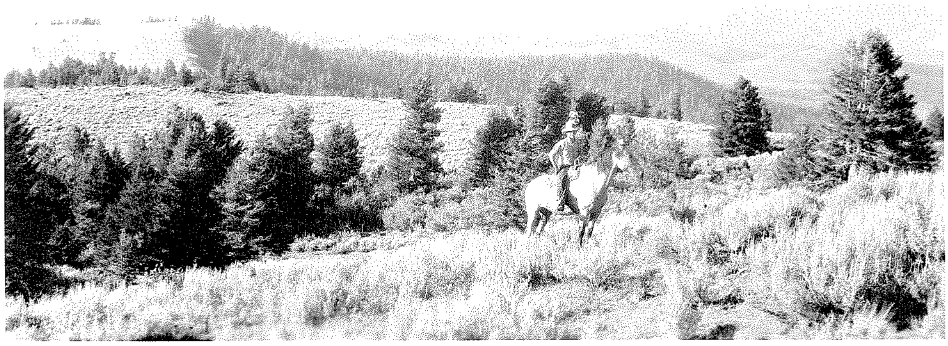
The great valley of the South Fork River, shown in the photographs on plates VI & VII, holds great possibilities of a wonderful section of the Ochoco group. More than 100 square miles of sandstones and shales are exposed in this single valley, and other outcrops, surrounded by the plateau lavas, are found farther to the south and east. Most or all of this large area is surely made up of Silvies beds. Their strike is nearer north than in the Silvies region, but the lithology is very similar in both regions.

PLATE VI

VIEW NORTHWARD ACROSS THE UPPER SOUTH FORK VALLEY FROM THE NORTH RIM OF SNOW MOUNTAIN

The river crosses the picture from right to left in the distance at the edge of the timber.

PLATE VII



VIEW OF THE SOUTH FORK VALLEY WEST OF THE PRECEDING PHOTOGRAPH

The flat surfaces in the left foreground are denuded surfaces of the Snow Mountain lavas.

Suplee Region

Southeast of the South Fork valley the Silvies outcrops continue south of the Ochoco anticline except on upper Flat Creek and upper Beaver Creek, where it is overlapped by the Snow Mountain lavas. West of Snow Mountain the Silvies outcrops are relatively small. They are found in the Freeman Creek drainage as described on pages 122-123, and from there they continue southward over the Great Basin divide and cover several square miles in Howard Valley and in the hills south of Mowich Mountain. Another small area is found on upper Warm Springs Creek and a third in the Ochoco syncline north of lower Warm Springs Creek as described on page 116.

The total thickness of the Craddock formation in the Suplee region is about 600 feet. The sequence begins with 20 feet of black shale, which is overlain by approximately 150 feet of yellowish-green and tan shales. Above the shales is more than 400 feet of hard bluish-green sandstone and grit.

Two localities are known where an apparently unfossiliferous conglomerate of unknown age overlaps the Craddock formation and Ochoco group, and it seems ~~very~~ probable that this conglomerate is the base of the Lincoln formation. The unconformable relationships is best shown on the western rim of the Freeman Creek drainage basin and in the canyon beyond. Here the conglomerate lies above the Craddock formation which, in turn, lies across the upper Ochoco beds.

The Craddock sandstones are separated from the Ochoco beds by the lower Craddock shales, but the unknown conglomerate continues across the Craddock shales and lies directly upon the Nicely shale and Freeman formation of the Ochoco group.

The other locality is on the strike ridge three-fourths of a mile west of Weberg's ranch house on lower Warm Springs Creek. The strike ridge is the eastward striking north limb of the Ochoco anticline. North of the ridge is the shallow syncline of the Craddock formation in which the sandstones overlie the black and tan shales as on Freeman Creek. The conglomerate in question lies directly on the upturned edges of the Ochoco beds and therefore it overlaps the Craddock formation.

The age of the conglomerate has been in doubt for some time. It seems that it is the basal bed of the Lincoln formation, but the possibility of a Cretaceous age must not be overlooked, for undoubted Cretaceous deposits are found only a few miles north of the Weberg locality and there they overlap both Jurassic groups and lie directly upon the upturned Triassic strata. The conglomerate, therefore, may represent outlines of the Cretaceous, but it would be very interesting if it proves to be the base of the Lincoln formation, for it would show the upper Jurassic deposits overlapping more than 12,000 feet of middle Jurassic strata.

Fossils are found at several localities in the Craddock formation but they have not been studied sufficiently to date the formation closer than was done for the type locality. Stepheoceratids and Sonninids are most abundant, as in the Silvies region, and so they agree with the Silvies canyon fossils in placing the lower Craddock formation in the upper Sonninian age.

General summary of the Silvies group

The principal conclusions regarding the stratigraphy and correlation of the Silvies formation are:

(1) The Silvies group is made up almost entirely of sandstones and shales that ~~which~~ are subdivided into two formations.

(2) The upper or Lincoln formation is of Proplanulitan age, which is in the Callovian stage of the lower Upper Jura.

(3) The lower or Craddock formation is of late Sonninian age, which is in the Bajocian stage of the lower Middle Jura.

(4) The formations are separated by a great time interval, ~~which is~~ represented by a disconformity in the type section and possibly by a nonconformity in the Suplee region.

(5) Stepheoceratids and Sonninids predominate in the Craddock formation, but ~~they~~ are replaced by Gowericeratids in the Lincoln formation.

(6) The Craddock formation is probably more than 14,000 feet thick and 12,000 feet of these beds are represented in a time that is equivalent to a few supposedly short hemerae in the English time scale.

(7) Less than 2,000 feet of the Lincoln formation is represented in the type area, but it is apparently nearly twice as thick on the west side of Silvies Valley.

(8) The Silvies group is regarded as the correlative of the Hazelton group, the upper and middle Yakoun, and the middle and lower Fernie

formations of British Columbia and Alberta. Similar correlatives may possibly be found in the Tuxedni sandstone and Chinitna shale of Alaska, and in the upper Bajocian of Oaxaca.

The correlation of the Silvies fauna with the middle and upper Jurassic faunas of Canada leads to some significant comparisons of the two regions and a discussion of some interesting questions that are brought up by McLearn in his summary of the Canadian faunas wherein he states:

> "It is difficult to explain why the Fernie formation carries faunas of different age or composition at almost every locality. Two faunas that can be dated have not so far been found in any one section and locality. Was the Fernie a shifting sea or a sea in which the site of deposition shifted from one place to another, i.e., do the Fernie strata represent different ranges of time in different localities; or have the strata of all localities approximately the same, and a long, time range, and is it by chance that a fauna of only one horizon and age has been preserved or found at any locality? This problem will be more easily solved when the exact stratigraphic ranges of the known faunas in the Fernie are better known and when more faunas are found and their horizons determined. To establish the second hypothesis it will be necessary to find two or more dateable faunas at each locality."[1]

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1 McLearn, F.H., Some Canadian Jurassic faunas: Trans. Roy. Soc. Canada, 3rd. ser., vol. 21, sec. IV, pp. 70-71, 1927.

"Fernie formation" is a very general term which was intended for all the middle and upper Jurassic deposits of the Rocky Mountain region of British Columbian and Alberta. The Fernie formation, therefore, is the equivalent of the Craddock and Lincoln formations of the Silvies region, the Sundance formation of the western interior, and the Mariposa slates of California. It seems impossible to regard these Fernie deposits as a single formation whose deposition continued throughout most of middle and part of upper Jurassic time because (1) the Oregon correlatives of the lower and middle Fernie faunas are separated by a disconformity--a break in the record that is equal to the entire difference between the lower and middle Fernie faunas, and (2) Bathonian deposits are noticeably lacking in other parts of North America--they have been reported only in southern Mexico.

The fact that all the known Fernie faunas are of different age or composition is apparently explained by the Silvies section where almost exactly the same conditions are found. Fossils have been found at a number of localities in the Silvies group, and with the exception of the lower Craddock fauna, all are of different age or composition. The great thickness of the Craddock formation shows that the second possibility mentioned by McLearn is probably correct--that the strata of all localities are approximately the same, and a long, time range, and that it is only by chance that one horizon and age has been recorded in each locality, for when it is known that a few supposedly short hemerae of the English time scale are represented in North America by 12,000 feet of fine-grained deposits, then it is not at all surprising to find many different faunas in such a series.

The contrast of the thick Silvies deposits with the apparently short corresponding part of the European time scale brings up an interesting conjecture in regard to the supposed abundance of life in the Bajocian seas of Europe. Fossils, especially Ammonoids, appear in great profusion and diversity of form in this stage and this has led to the belief that Ammonoids reached their greatest development at that time. Consequently several highly fossiliferous subdivisions have been recognized in the Bajocian and it was supposed that each one represents a very short time in a very fossiliferous stage. In Oregon, however, several hundred feet of Ochoco beds, a marked angular unconformity, and perhaps 12,000 feet or more of the Craddock formation all come within this period. This seems to indicate that the Bajocian seas did not carry a much greater number and kinds of Ammonoids than other Jurassic seas, but that the abundance of Ammonoids is due to very slow deposition during a long time and a consequent concentration of fossils in a few thin beds. So perhaps many other apparent decreases and expansions of fossil groups is only due to acceleration and retardation of deposition.

McLearn[1] also remarks about the common occurence of faunas of Stepheoceratan and Sonninian age in the Canadian Jurassic, but "it is noted, in passing, that to date no ammonoids of the subfamily Sonnininae have been found associated with those of the families Stepheoceratidae and Sphaeroceratidae in the Canadian Middle Inferior Oolite faunas."[2]

So it is very interesting to find all three groups associated in the Ochoco group and Sonninids and Stepheoceratids associated in the base of the Craddock formation.

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1 McLearn, F.H., op. cit. , p. 71, 1927
2 McLearn, F.H., Contributions to the stratigraphy and paleontology of Skidegate Inlet, Queen Charlotte Islands, B.C., Nat. Mus. Canada, Bull. 54, p. 3, 1929