The Lincoln Creek Formation Grays Harbor Basin Southwestern Washington

By HELEN M. BEIKMAN, WELDON W. RAU, *and* HOLLY C. WAGNER

CONTRIBUTIONS TO STRATIGRAPHY

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CONTENTS

ILLUSTRATIONS

CONTRIBUTIONS TO STRATIGRAPHY

THE LINCOLN CREEK FORMATION, GRAYS HARBOR BASIN, SOUTHWESTERN WASHINGTON

By Helen M. Beikman, Weldon W. Rau,[1] and Holly C. Wagner

Abstract

The Lincoln Creek Formation, formerly called the Lincoln Formation, crops out in the Grays Harbor basin of southwestern Washington. It is principally an offshore marine deposit and consists of as much as 9,000 feet of tuffaceous siltstone and tuffaceous fine-grained sandstone. The formation is predominantly Oligocene in age but includes some rocks of late Eocene and early Miocene ages. Generally the Lincoln Creek Formation conformably overlies upper Eocene sedimentary rocks. However, in some places it overlaps older strata, and locally it rests unconformably on lower(?) and middle Eocene volcanic rocks. The formation is overlain by the Astoria(?) Formation of early to middle Miocene age.

The rocks in the Lincoln Creek Formation are included in three foraminiferal zones, which from oldest to youngest are the *Sigmomorphina schencki* zone, the *Cassidulina galvinensis* zone, and the *Pseudoglandulina* aff. *P. inflata* zone.

INTRODUCTION

The Lincoln Creek Formation consists of 2,000 to 9,000 feet of tuffaceous siltstone and fine-grained sandstone, predominantly Oligocene in age, that crops out within or underlies about 1,500 square miles in the Grays Harbor basin in southwestern Washington (figs. 1 and 2). The rocks here called the Lincoln Creek Formation were originally named the Lincoln Formation by Weaver in 1912. Because the name "Lincoln" was first used for the Lincoln Porphyry of Eocene age in Colorado (Emmons, 1882), its use for the rock sequence in Washington is preempted according to rules that govern stratigraphic nomenclature. To solve this nomenclatural problem and still retain nomenclatural similarity to a term in common usage, the name Lincoln

[1] Washington State Division of Mines and Geology.

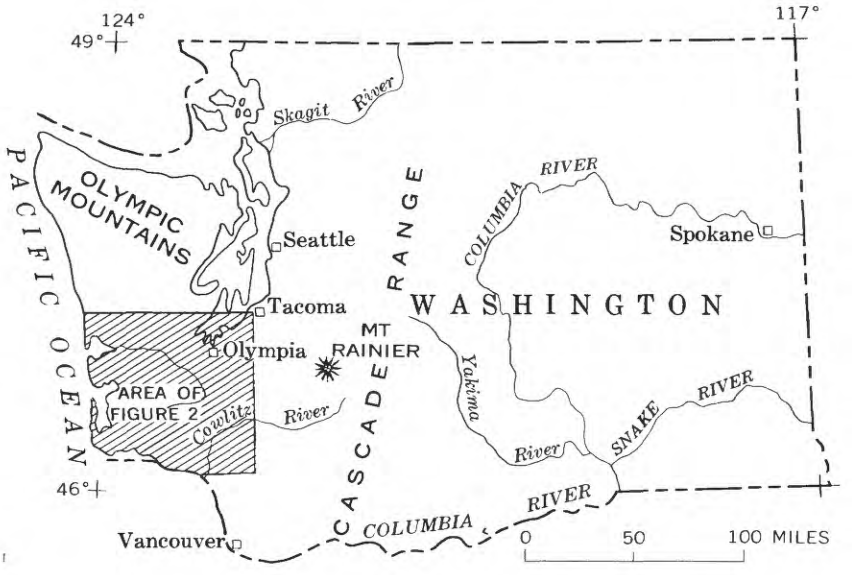

FIGURE 1.—Index map showing Grays Harbor basin area.

Creek Formation is here used to replace the name Lincoln Formation.

The definition and description of the Lincoln Creek Formation presented here are based on detailed geologic studies, mainly by the U.S. Geological Survey, in the Grays Harbor basin. The stratigraphy of the formation was worked out mostly during the mapping of the Centralia-Chehalis coal district between 1948 and 1951 by Snavely, Brown, Roberts, and Rau (1958). Additional information was obtained during later studies by Pease and Hoover (1957), Rau (1958, 1966), Gower and Pease (1965), and current work by H. C. Wagner.

PREVIOUS USAGE

Weaver (1912, p. 15–16) applied the name Lincoln Formation to a 1,000-foot-thick sequence of marine shale and sandy shale of Oligocene age exposed on Lincoln Creek near the boundary between Lewis and Thurston Counties. Later, Weaver (1937, p. 110–111) regarded the Lincoln Formation "as the equivalent of the entire middle Oligocene of Washington," and in 1944 he designated the type section of the formation as "a composite of numerous sections exposed in the banks of the Chehalis River between Centralia and Porter, Washington, and in the hills southwest of these towns" (Weaver and others, 1944, p. 592).

More recent work by Snavely, Brown, Roberts, and Rau (1958, p. 35–53) in the Centralia-Chehalis coal district on the east edge of the Grays Harbor basin and by Pease and Hoover (1957) in the

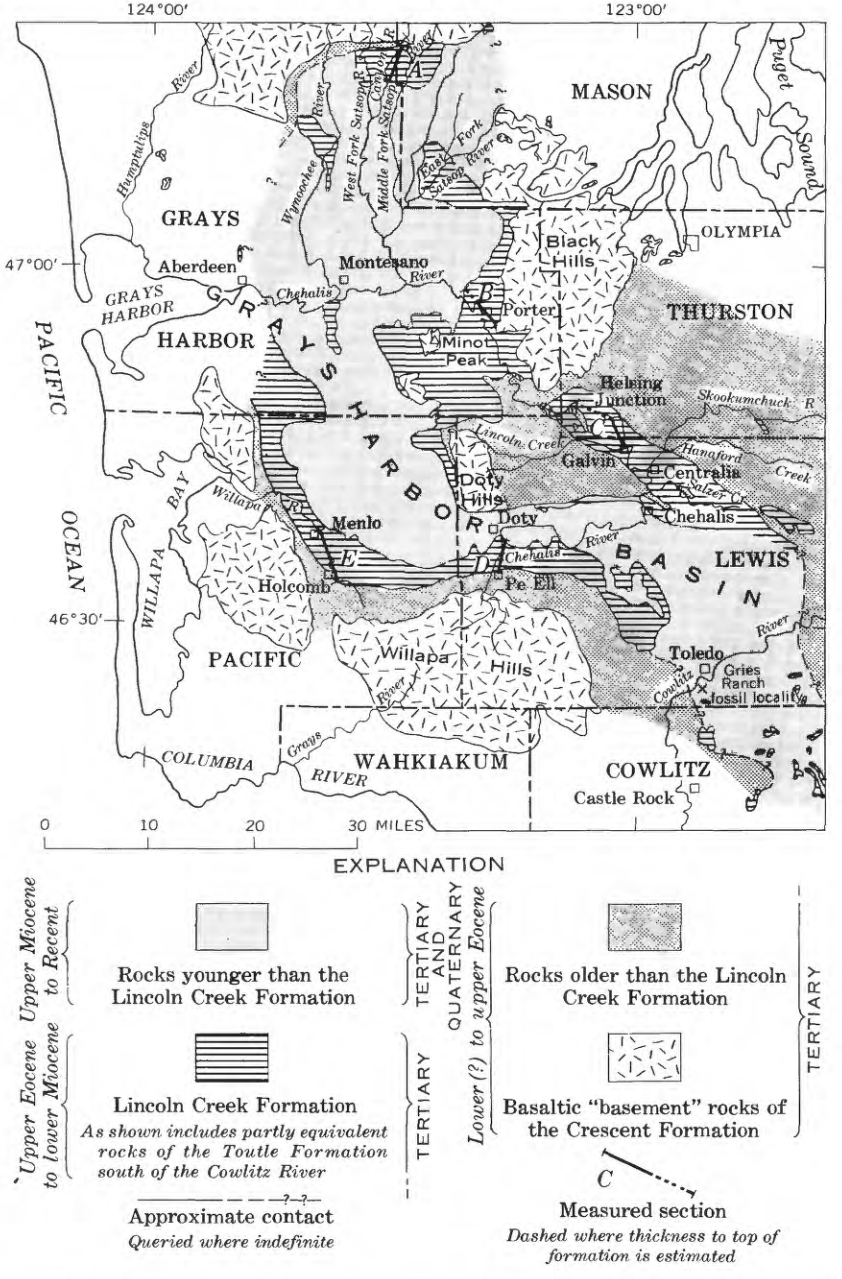

FIGURE 2.—Geologic map of area of outcrop and location of measured sections of the Lincoln Creek Formation in the Grays Harbor basin. Geology from Pease and Hoover (1957); Snavely, Brown, Roberts, and Rau (1958); Huntting, Bennett, Livingstone, and Moen (1961); Gower and Pease (1965); and H. C. Wagner (unpub. data, 1966).

Doty-Minot Peak area in the central part of the basin has extended the age range of Weaver's Lincoln Formation to late Eocene to early Miocene. The mapping in the Centralia-Chehalis coal district also demonstrated that the formation consists of a lower basaltic sandstone member representing continental or near-shore deposition and an upper tuffaceous silty sandstone and siltstone unit representing shallow-water offshore marine deposition.

GENERAL FEATURES

Throughout most of the Grays Harbor basin the Lincoln Creek Formation consists predominantly of tuffaceous siltstone and tuffaceous very fine to fine-grained sandstone strata which in places contain thin units of basaltic or glauconitic sandstone and beds or zones of calcareous concretions. Along the east edge of the basin, however, the Lincoln Creek consists mainly of the basaltic sandstone member with interbeds of pyroclastic rocks (Snavely and others, 1958, p. 38). This basaltic sandstone member is about 1,500 feet thick in the area east of Chehalis (fig. 2) but thins to the south and west. Equivalent rocks of the Toutle Formation, consisting of basaltic conglomerate, sandstone, siltstone, clay, and lignite beds, are about 600 feet thick south of the Cowlitz River (Roberts, 1958).

The thickness of the Lincoln Creek Formation increases from east to west and from south to north in the Gray Harbor basin. The formation is about 2,000 feet thick immediately west of Chehalis, about 3,500 feet thick west of the Doty Hills, about 4,500 feet thick south of Raymond, and 8,500 feet thick along the Canyon River at the north edge of the basin. The formation thins locally where it onlaps highs of older rocks that now form the Doty Hills, the Black Hills, and Minot Peak (Pease and Hoover, 1957). The thickness and extent of the formation to the west of its outcrop area (fig. 2) are not known because of the thick cover of younger rocks.

Throughout most of the Grays Harbor basin, the Lincoln Creek Formation conformably overlies sedimentary rocks of late Eocene age. In the eastern part, these older rocks are fine- to medium-grained marine and continental clastic rocks of the Skookumchuck Formation. In the western part, they are lateral equivalents of the Skookumchuck and consist of marine siltstone and sandstone strata. In areas of pre-Oligocene relief, the Lincoln Creek overlaps older sedimentary rocks and locally rests unconformably on volcanic rocks of the Crescent Formation of early(?) and middle Eocene age.

The Lincoln Creek Formation is overlain by brackish-water and marine sedimentary rocks of the Astoria(?) Formation of early to middle Miocene age except in the eastern and southern parts of the basin where it is overlain by nonmarine sedimentary rocks of the

Miocene and Pliocene(?) age. The contact between the Lincoln Creek and the overlying rocks is unconformable in the eastern two-thirds of the basin and conformable in most of the western third.

TYPE SECTION

The name Lincoln Creek Formation is taken from Lincoln Creek in Lewis County, Wash. Weathered outcrops of strata typical of the greater part of the formation are easily accessible in the south half of T. 15 N., R. 3 W. along State Road 1N, which is parallel to and north of Lincoln Creek (Snavely and others, 1958, pl. 1). However, because only a small part of the rock sequence is exposed along Lincoln Creek, the type section is designated as the rocks exposed along the Chehalis River from Galvin to Helsing Junction. This section is shown as *C* on figures 2 and 3 and consists of approximately 1,200 feet of offshore marine strata. The exposed rocks are generally massive greenish-gray to olive-gray tuffaceous siltstone and fine-grained sandstone, a few thin tuff beds (fig. 3), and some calcareous beds that form persistent ledges (fig. 4).

The total thickness of the Lincoln Creek Formation in the type section is estimated to be about 2,500 feet. As determined from cores and cuttings from a nearby test hole, the lowermost 400 feet is composed predominantly of tuffaceous siltstone and sandy siltstone which conformably overlies the Skookumchuck Formation of late Eocene age (Snavely and others, 1958, pl. 3). The formation is disconformably overlain by the Astoria(?) Formation of early to middle Miocene age.

REFERENCE SECTIONS

Inasmuch as the Lincoln Creek Formation is not completely exposed in its type section, four reference sections—Canyon River (Rau, 1966); Porter (Rau, 1958); Pe Ell-Doty (Chehalis River of Rau, 1958); and Willapa River (Rau, 1951 and H. C. Wagner, unpub. data, 1966)—in other parts of the basin are shown as *A*, *B*, *D*, and *E* respectively, in figures 2 and 3.

Canyon River section.—The Lincoln Creek Formation is thickest in the northern part of the Grays Harbor basin. Along the Canyon River, the formation consists of about 8,500 feet of siltstone, sandstone, conglomerate, and mudstone which is tuffaceous and contains some concretions. The basal part of the formation, a basaltic sandstone about 100 feet thick, rests with apparent conformity on micaceous well-bedded siltstone and sandstone of late Eocene age. The basaltic sandstone is overlain by 1,600 feet of massive tuffaceous siltstone containing scattered concretions and concretionary beds. Above the siltstone is 1,350 feet of poorly sorted, very tuffaceous, thick-bedded sandstone and conglomerate interbedded with siltstone. The sandstone and conglomerate beds are composed largely of altered glass shards or

256-760 O - 67 - 2

fragments of pumice, together with grit-sized particles of basalt and sedimentary clasts. The next higher 4,400 feet of strata is primarily fine-grained silty sandstone, siltstone, and mudstone, which is tuffaceous. Much of this part of the formation is massive, but in some places the strata are rudely bedded, and in a few places thin beds of tuffaceous sandstone are present in the massive siltstone. Several glauconite and a few concretionary beds occur in this part of the section. The uppermost 1,000 feet of the formation is massive

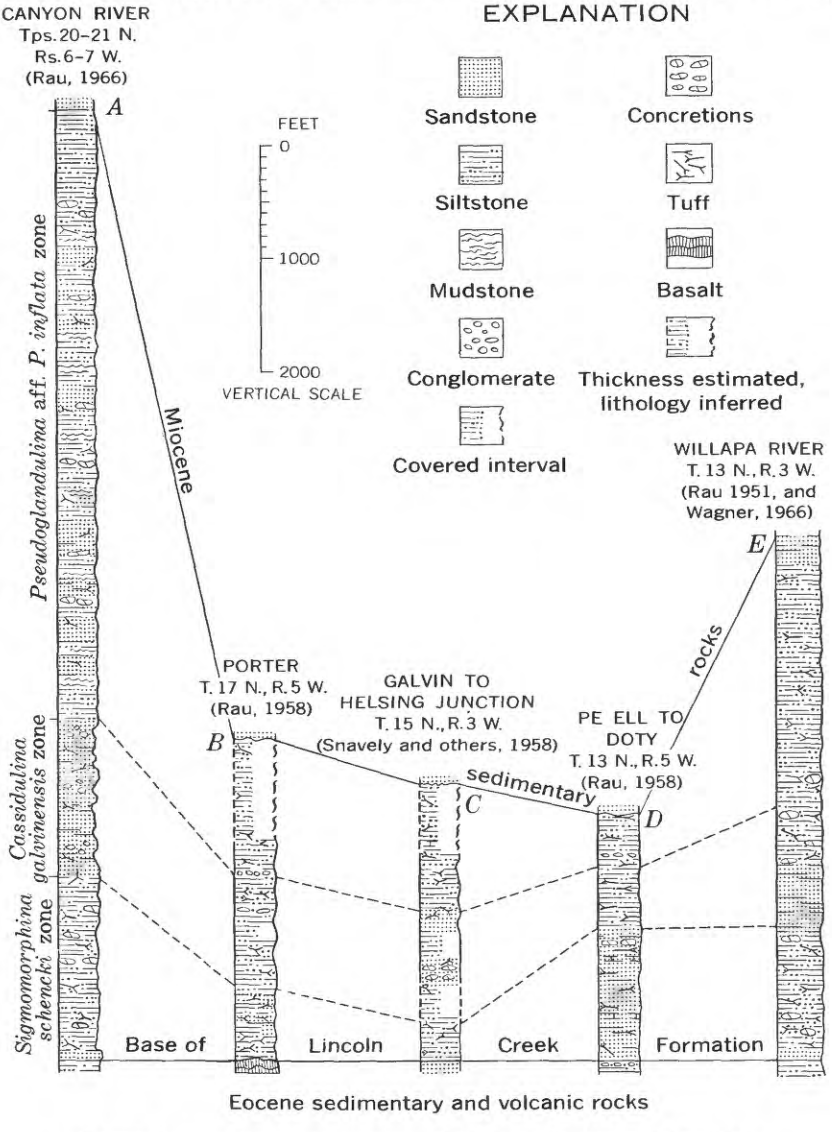

FIGURE 3.—Stratigraphic sections of the Lincoln Creek Formation.

tuffaceous siltstone with scattered concretions. The formation is overlain with apparent conformity by carbonaceous and micaceous siltstone and fine-grained sandstone of the Astoria(?) Formation.

Porter section.—The Lincoln Creek Formation is estimated to be about 3,000 feet thick along Highway 9 in the vicinity of Porter. The lower 1,900 feet consists of tuffaceous siltstone and sandstone, some of which is calcareous and concretionary. The base of the formation rests unconformably on the Crescent Formation. The upper third of the formation is poorly exposed, but the contact with the overlying Astoria(?) Formation is probably unconformable (Pease and Hoover, 1957).

Pe Ell-Doty section.—More than 2,000 feet of tuffaceous and concretionary siltstone and sandstone constitutes the Lincoln Creek Formation along the Chehalis River, between Pe Ell and Doty, near the south margin of the Grays Harbor basin. The basal part of the formation is basaltic tuffaceous sandstone, about 60 feet thick, that rests on concretionary sandstone and siltstone of the upper Eocene Skookumchuck Formation. The uppermost part of the formation is unconformably overlain by sandstone of the Astoria(?) Formation.

FIGURE 4.—Massive tuffaceous siltstone and fine-grained sandstone of the Lincoln Creek Formation as exposed along the Chehalis River, half a mile north of Galvin, Wash. Height of cliff is about 125 feet. Photograph by Parke D. Snavely, Jr.

Willapa River section.—The Lincoln Creek Formation is well exposed in the bed and banks of the Willapa River from Holcomb to the town of Menlo, a distance along the river course of nearly 5 miles. The formation which overlies a laminated to finely crossbedded sandy siltstone sequence of late Eocene age is about 4,500 feet thick and is mainly tuffaceous siltstone that contains several thin units of basaltic or glauconitic sandstone and micaceous silty sandstone in its lower and upper parts. The foraminiferal fauna throughout the area was studied by Rau in 1951, but only general notes on the lithology were taken. More detailed lithologic data are embodied in the following description by H. C. Wagner.

The basal part of the formation is basaltic, glauconitic granule sandstone as much as 50 feet thick and is overlain by predominantly tuffaceous siltstone about 1,200 feet thick in which bedding is generally well developed. Calcareous concretions, many of which contain megafossils, occur sporadically in beds and zones throughout this siltstone. Between this bedded siltstone and the upper part of the formation is a unit that is as much as 500 feet thick and is composed of very fine to fine-grained fossiliferous slightly micaceous lenticular silty sandstone and sandy siltstone. The upper 3,000 feet of the formation is massive tuffaceous siltstone. Discontinuous beds of glauconite and zones of calcareous concretions occur throughout much of the lower part of this massive siltstone. The content of volcanic ash decreases in the upper part, and the uppermost few hundred feet contains much sand-sized material and is mainly a slightly micaceous tuffaceous sandy siltstone and silty sandstone. The formation is conformably(?) overlain by the basal member of the Astoria(?) Formation, a dark-medium-gray carbonaceous siltstone that generally has a thin glauconitic sandstone bed at its base.

AGE AND CORRELATIONS

Molluscan and foraminiferal collections indicate that the Lincoln Creek Formation ranges in age from late Eocene to early Miocene. The formation correlates in part with the Toutle Formation to the south in Cowlitz County and in part with the Twin River Formation to the north on the Olympic Peninsula (fig. 5).

Age determinations made on molluscan faunas collected from the Lincoln Creek strata indicate that the formation in the Centralia-Chehalis area includes rocks of late Eocene and Oligocene age. These age determinations were made by H. E. Vokes (in Snavely and others, 1958, p. 51–54) and are as follows: (1) A fauna from the lower part of the basaltic sandstone member is late (or latest) Eocene in age, (2) faunas from the middle part of the formation collected at scattered localities are middle Oligocene in age, and (3) a fauna collected

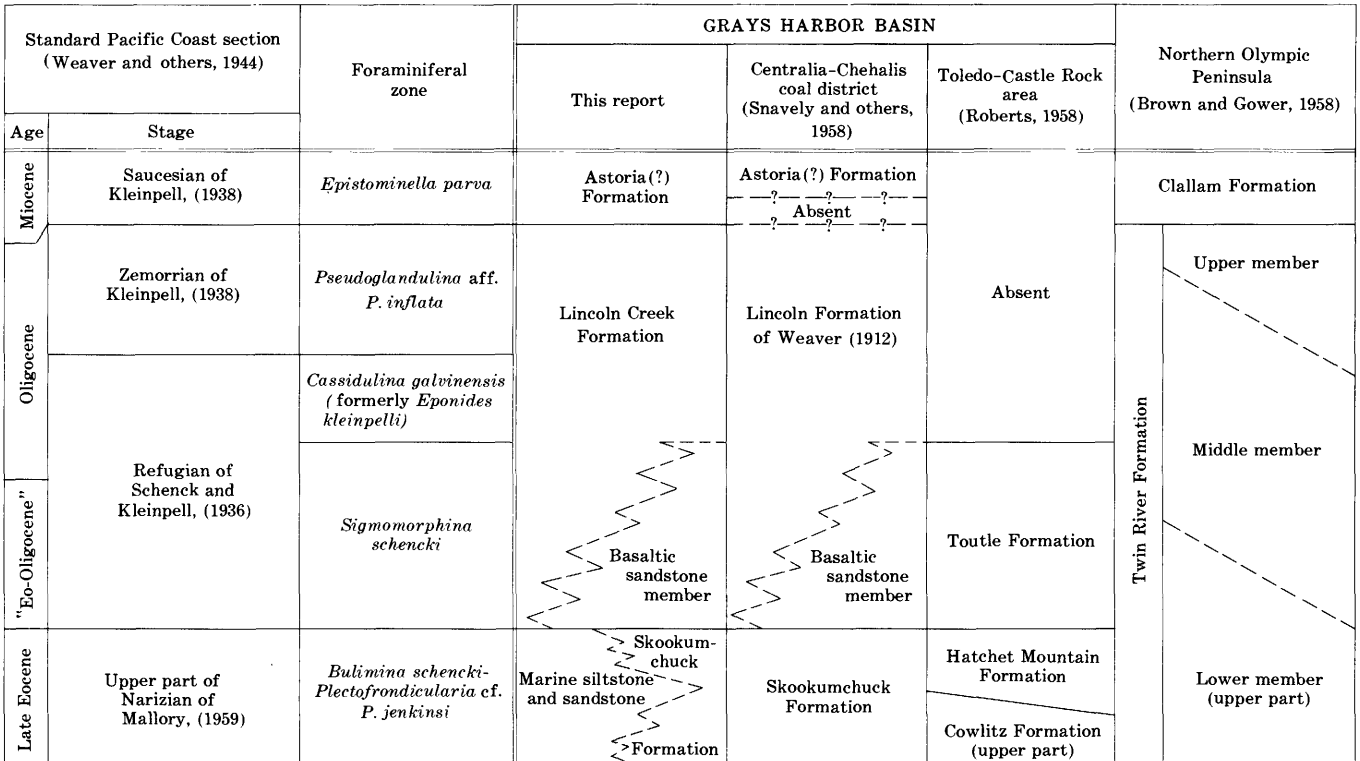

FIGURE 5.—Correlation chart of the Lincoln Creek Formation.

from the uppermost part of the formation southeast of Helsing Junction is late Oligocene in age, and the rocks there correlate with a fauna from the type Blakeley Formation of Weaver (1912).

To the west in the Doty-Minot Peak area well-preserved megafossils, collected in the SW¼ sec. 34, T. 17 N., R. 5 W. from strata equivalent to the tuffaceous siltstone member in the Centralia-Chehalis area, were tentatively correlated by Vokes (in Snavely and others, 1958, p. 52–53) with fauna from beds (Toutle Formation) at the Gries Ranch fossil locality (fig. 2). Megafossils collected from the upper part of the Lincoln Creek Formation were correlated with a fauna from the type Blakeley by Ellen J. Trumbull (in Pease and Hoover, 1957). who asigned an early Miocene age to the assemblage.

In the Willapa River exposures, a varied and abundant marine megafauna occurs in the basal part of the formation. Warren Addicott (written commun., December 1964 and March 1966) places the fauna in the *Turcicula columbiana* zone [= the Keasey Stage of Weaver and others (1944)] of late Eocene or early Oligocene age. In the Centralia-Chehalis district, also, *T. columbiana* has been reported from the basaltic sandstone in the lower part of the Lincoln Creek Formation (Snavely and others, 1958, p. 51–52).

Age determinations based on Foraminifera place the strata of the Lincoln Creek Formation entirely in the Oligocene Series. Three foraminiferal zones were recognized by Rau in the Lincoln Creek Formation as a result of study of Foraminifera collected during the mapping of the Centralia-Chehalis area (Snavely and others, 1958, p. 43–51; Rau, 1958). From oldest to youngest, these zones were: the *Sigmomorphina schencki* zone, the *Eponides kleinpelli* zone, and the *Pseudoglandulina* aff. *P. inflata* zone. A fourth zone, the *Epistominella parva* zone, was thought to be represented in the upper part of the Lincoln Creek Formation in the Willapa River section (Rau, 1951; 1958). However, detailed mapping by Wagner along the Willapa River has shown that the section is repeated by faulting and that the strata containing *E. parva* forms are in the overlying Astoria(?) Formation. Based on recent determinative work, Rau redesignated the *E. kleinpelli* zone the *Cassidulina galvinensis* zone (fig. 5) and also slightly revised the lists of representative forms in the different zones.

The *Sigmomorphina schencki* zone ranges in thickness from 700 to 1,700 feet and includes the basal basaltic sandstone of the Lincoln Creek Formation, where this sandstone is present, as well as tuffaceous siltstone and silty sandstone. The foraminiferal fauna of the basaltic sandstone corresponds closely with the fauna found in rocks of the Toutle Formation at the Gries Ranch locality (fig. 2). The basaltic sandstone and Toutle Formation are paleontologic and

lithologic equivalents (Roberts, 1958, p. 24). Foraminifera from the *S. schencki* zone also compare favorably with those from the Keasey Formation and the Bastendorff Shale (latest Eocene or earliest Oligocene) of western Oregon (Rau, in Snavely and others, 1958, p. 50) and with some from part of the Twin River Formation on the north flank of the Olympic Mountains (Rau, 1964). However, rocks of the Twin River Formation are nontuffaceous and do not correspond lithologically to the predominantly tuffaceous strata of the Lincoln Creek Formation (Brown and Gower, 1958, p. 2497). The zone represents a large part of the Refugian Stage and in accordance with the Standard Pacific Coast section is regarded as "Eo-Oligocene" in age (fig. 5).

Forms typical of the *Sigmomorphina schencki* zone include:

Cancris joaquinensis Smith
Ceratobulimina washburni Cushman and Schenck
Cibicides elmaensis Rau
hodgei Cushman and Schenck
Dentalina dusenburyi Beck
Nonion halkyardi Cushman
Plectofrondicularia packardi Cushman and Schenck
Robulus spp. (large in size)
Sigmomorphina schencki Cushman and Ozawa
Uvigerina atwilli Cushman and Simonson
cocoaensis Cushman

The *Cassidulina galvinensis* zone includes the beds in the middle part of the Lincoln Creek Formation. It was first called the *Eponides kleinpelli* zone (Snavely and others, 1958, p. 49–50) but *E. kleinpelli* has been found to have a limited geographic distribution. Therefore the zone is here renamed after *C. galvinensis,* a more widespread and useful species. The *C. galvinensis* zone is approximately 1,000 feet thick in most of the Grays Harbor basin but is more than 2,000 feet thick along the Middle Fork of the Satsop River in the northern part. The rocks included in the zone are lithologically uniform, consisting largely of tuffaceous sandy siltstone and silty sandstone. In the northern part of the basin, thick beds of coarse-grained tuff and other pyroclastic debris are common.

The *Cassidulina galvinensis* zone is believed to be represented in the middle part of the Twin River Formation of the northern part of the Olympic Peninsula (fig. 5). In Oregon an approximate equivalent of this zone is known in a part of the Toledo Formation. It may also be represented in the upper part of the Keasey Formation of Oregon. The zone represents the upper part of the Refugian Stage of Schenck and Kleinpell (1936) and is Oligocene in age.

A typical assemblage from the *Cassidulina galvinensis* zone contains:
Cassidulina galvinensis Cushman and Frizzell
Ceratobulimina washburni Cushman and Schenck
Epistomina eocenica (Cushman and Hanna)
Eponides kleinpelli Cushman and Frizzell
Guttulina hantkeni Cushman and Ozawa
Karreriella washingtonensis Rau
Quinqueloculina imperialis Hanna and Hanna

The *Pseudoglandulina* aff. *P. inflata* zone includes more than 5,000 feet of strata where it is complete. Two general subdivisions of the zone can be recognized and are informally referred to as lower and upper parts. Foraminiferal assemblages most nearly like those of this zone are known from beds correlated with a part of the Twin River Formation and all the Blakeley Formation of Weaver (1912). In Oregon, similar assemblages are known from an upper part of the Toledo Formation. The *Pseudoglandulina* aff. *P. inflata* zone is referred to Kleinpell's Zemorrian Stage which he has regarded as Oligocene in age (Kleinpell and Weaver, 1963).

Combinations of foraminiferal species typical of the lower and upper parts of the *Pseudoglandulina* aff. *P. inflata* zone are:

Upper part:
Bulimina alligata Cushman and Laiming
subfusiformis Cushman
Cassidulina crassipunctata Cushman and Hobson
Elphidium? cf. *E. minutum* Cushman
Eponides mansfieldi oregonensis Cushman and R. E. and K. C. Stewart
Pseudoglandulina aff. *P. inflata* (Bornemann)
Robulus brevispinosus (Nuttall)
Siphogenerina nodifera Cushman and Kleinpell
Uvigerina gallowayi Cushman

Lower part:
Bolivina marginata adelaidana Cushman and Kleinpell
Cassidulina crassipunctata Cushman and Hobson
Elphidium? cf. *E. minutum* Cushman
Eponides duprei Cushman and Schenck
mansfieldi oregonensis Cushman and R. E. and K. C. Stewart
Plectofrondicularia packardi multilineata Cushman and Simonson
Pseudoglandulina aff. *P. inflata* (Bornemann)
Quinqueloculina weaveri Rau
Uvigerina gallowayi Cushman

GEOLOGIC SUMMARY

The present area of the Grays Harbor basin was a part of a eugeosyncline that occupied western Washington and Oregon throughout much of the Tertiary Period (Snavely and Wagner, 1963). At the beginning of late Eocene time, before deposition of the Lincoln Creek sediments began, active uplift and volcanism formed land areas on the

north, south, and east of the present Grays Harbor and made a separate basin within the eugeosyncline. Basaltic rocks of the Crescent Formation of early(?) and middle Eocene age were exposed as islands and as sea cliffs along the north margin of the basin. In the southern part, basaltic fragmental debris resulting from late Eocene volcanism as well as basaltic material of the Crescent Formation was exposed to local erosion. Basaltic and andesitic rocks of the Northcraft and Hatchet Mountain Formations of late Eocene age formed the northward-trending east margin.

At the beginning of Lincoln Creek time, a great quantity of detritus was rapidly eroded from the volcanic highlands along the east margin and deposited in the adjacent part of the Grays Harbor basin. The eastern part of the basin fluctuated near sea level, and the resulting continental and near-shore strata constitute the lower basaltic sandstone unit of the Lincoln Creek Formation. Concurrent with deposition of this sandstone, coal-bearing strata of the Toutle Formation were being laid down on a swampy coastal plain at the southeast margin of the basin.

In the deeper parts of the basin to the west and north no major break occurred between deposition of older sedimentary rocks and the Lincoln Creek strata. However, a much greater quantity of air- and water-transported volcanic ash which originated from subaqueous and subaerial explosions to the east in the area of the present Cascade Range was carried into the basin. The type of sediments deposited changed from essentially nontuffaceous siltstone and sandstone to the tuffaceous strata that characterize the Lincoln Creek. As the basin subsided, Lincoln Creek strata overlapped upper Eocene sedimentary rocks. Along the margins of the basin and adjacent to volcanic islands, Lincoln Creek sediments were deposited unconformably on the Crescent Formation. In most places where this overlap occurred, a basal basaltic sandstone derived from the underlying rocks was deposited.

Early in the middle Oligocene time, accelerated erosion due to uplift or greater transporting capacity of streams resulted in an incursion of very fine to fine sand-sized detritus into the southwestern part of the basin. Volcanic ash that continued to be supplied to the Lincoln Creek depositional environment forms a considerable part of the detritus and indicates that eruptive activity persisted throughout this part of Lincoln Creek time.

Deposition in middle and late Oligocene time possibly reflects a return to lowland conditions adjacent to the basin area. Continuous deposition of silt- and clay-sized debris in the marine environment formed a massive ash-filled clayey silt. Toward the end of Oligocene

time, somewhat coarser detritus was carried into the basin, and by the end of Oligocene time volcanic activity had apparently ceased and the basin was nearly filled. In early Miocene time the nearby low-lying land area was presumably covered with vegetation and supplied much silt, clay, and carbonaceous material to the near-shore marine environment of early Astoria time.

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