Stratigraphy of the Cretaceous Hornbrook Formation, Southern Oregon and Northern California

U.S. GEOLOGICAL SURVEY PROFESSIONAL PAPER 1521

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By TOR H. NILSEN

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A stratigraphic division of the Hornbrook Formation into five nonmarine and marine members

UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON : 1993

U.S. DEPARTMENT OF THE INTERIOR

BRUCE BABBITT, ***Secretary***

U.S. GEOLOGICAL SURVEY

DALLAS L. PECK, ***Director***

Illustrations edited by Dale Russell and prepared by Michelle Coveau

Library of Congress Cataloging in Publication Data

Nilsen, Tor Helge.
Stratigraphy of the Cretaceous Hornbrook Formation, southern Oregon and northern California / by Tor H. Nilsen.
p. cm. — (U.S. Geological Survey professional paper ; 1521)
Includes bibliographical references.
Supt. of Docs. no.: I 19.16:1521
1. Geology, Stratigraphic—Cretaceous. 2. Geology—California. 3. Geology—Oregon. 4. Hornbrook Formation (Calif. and Or.)
I. Title. II. Series.
QE685.N55 1993
551.7'7'097952—dc20 93-3585
CIP

For sale by Book and Open-File Report Sales, U.S. Geological Survey,
Federal Center, Box 25286, Denver, CO 80225

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By Tor H. Nilsen

ABSTRACT

The Cretaceous Hornbrook Formation crops out continuously for a distance of about 80 km from the Medford Valley in southwestern Oregon to the Shasta Valley in north-central California; it also crops out as an outlier in the Grave Creek area of Oregon, about 39 km northwest of the northernmost outcrops in the Medford Valley. In its main outcrop belt, which is the area of concern in this paper, the Hornbrook Formation forms a northwest-striking and northeast-dipping homoclinal sequence of nonmarine and marine sedimentary rocks. The Hornbrook Formation rests unconformably on Paleozoic, Triassic, and Jurassic igneous, metasedimentary, and metavolcanic rocks of the core of the Klamath Mountains; these rocks form the southwestern margin of the outcrop belt. To the northeast, the Hornbrook Formation is unconformably overlain by Tertiary volcanic and sedimentary rocks of the Western Cascade Series. Although no continuous section of the Hornbrook Formation has been measured, a composite section made up of measured type sections of its various members indicates a total thickness of 1,235.7 meters for the formation in its type area located adjacent to Hornbrook, California. The Hornbrook Formation contains abundant megafossils and microfossils within its marine units that are indicative of an age of late Albian(?) to early Maestrichtian for the rocks of its main outcrop belt.

The Hornbrook Formation is subdivided into five members, each of which, except for the lowest member, is present over most of its outcrop length. The members are, in ascending order, (1) the Klamath River Conglomerate Member (36.5 m thick), consisting of basal nonmarine breccia, grus, debris-flow and streamflow conglomerate, sandstone, siltstone, and mudstone, with interbedded paleosols; (2) the Osburger Gulch Sandstone Member (116.5 m thick), consisting of shallow-marine sandstone with some interbedded conglomerate and thin shale partings in its upper part (containing abundant megafossils); (3) the Ditch Creek Siltstone Member (61.6 m thick), consisting of massive, nonmarine to deep-marine, bioturbated, muddy siltstone and silty mudstone, with locally abundant sandstone interbeds, thin coals, and megafossils; (4) the Rocky Gulch Sandstone Member (171.2 m thick), consisting of deep-marine thin- to thick-bedded turbidite sandstone and siltstone with shale interbeds, and locally abundant conglomerate in its upper part; and (5) the Blue Gulch Mudstone Member (849.9 m thick), consisting of shallow- to deep-marine mudstone with thinly interbedded turbidite sandstone. Within the Blue Gulch Mudstone Member, two additional subunits have been differentiated: (1) the Rancheria Gulch Sandstone Beds (85.8 m thick), consisting of shallow-marine sandstone, with locally abundant megafossils, that forms a lens in the lower part of the Blue Gulch Mudstone Member in the Hornbrook area; and (2) the Hilt Bed (as thick as 4.71 m), a compound turbidite sandstone bed about 410 m above the base of the Blue Gulch Mudstone that forms a mappable horizon from the Shasta Valley area to the Ashland area. The members of the Hornbrook Formation appear to form an essentially conformable sequence, although previous workers have suggested the presence of an unconformity between the Ditch Creek Siltstone Member and the Rocky Gulch Sandstone Member.

Manuscript approved for publication, January 17, 1991.

INTRODUCTION

Lower and Upper Cretaceous sedimentary strata that crop out in Siskiyou County, California, and Jackson County, Oregon, were named the Hornbrook Formation by Peck and others (1956). These rocks had previously been assigned by various authors to the Chico Formation (Diller, 1906) or "Chico Group" (Gabb, 1869), which crops out on the northeastern margin of the Sacramento Valley in California. Peck and others (1956) measured a composite type section of the Hornbrook Formation that is 2,673 ft (815 m) thick in the vicinity of Hornbrook, California. On the basis of extensive mapping and detailed measurement of stratigraphic sections of the Hornbrook Formation over the entire extent of its outcrop area, which ranges far to the south and northwest of the Hornbrook area, Nilsen (1984a) subdivided the Hornbrook Formation into the following members, in ascending stratigraphic order: Klamath River Conglomerate Member, Osburger Gulch Sandstone Member, Ditch Creek Siltstone Member, Rocky Gulch Sandstone Member, and Blue Gulch Mudstone Member (including the Rancheria Gulch Sandstone Beds and the Hilt Bed). These members are discussed herein, and their areal extents, type sections, lithologies, stratigraphic relations, thicknesses, depositional environments, ages, and correlations are summarized. Other aspects of the Hornbrook Formation, such as sedimentology, petrography, paleogeography, and tectonic framework, are treated elsewhere (Nilsen, 1984a, c, d).

The Hornbrook Formation rests unconformably on older Paleozoic, Triassic, and Jurassic accreted terranes and plutons that form the core of the Klamath Mountains (fig. 1; Irwin, 1960, 1966, 1981, 1984, 1985, 1989; Harper and Wright, 1984; Wright and Fahan, 1988). It underlies a generally low-lying group of valleys on the northeast flank of the Klamath Mountains (fig. 2), where it forms a northwest-striking and northeast-dipping homoclinal sequence (Elliott, 1984; pl. 1). It is overlain unconformably to the northeast by Tertiary sedimentary and volcanic rocks of the Cascade Range (figs. 3, 4; McKnight, 1971, 1984; Hammond, 1983; Vance, 1984; Chesterman and Saucedo, 1984; Bestland, 1987).

The Hornbrook Formation crops out northward from the areas southwest and southeast of Yreka,

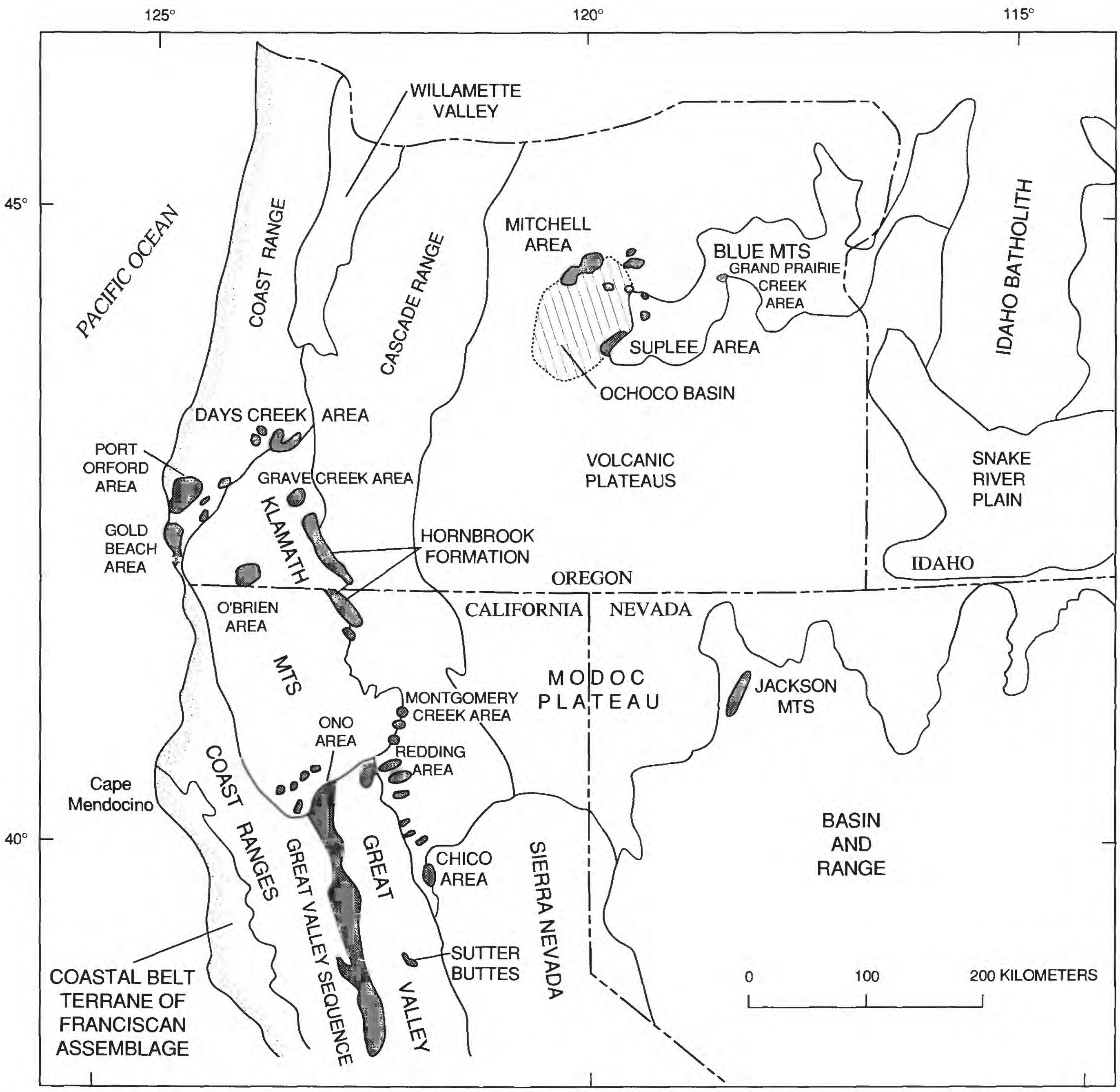


FIGURE 1.—Outcrop locations of the Hornbrook Formation, major physiographic provinces, and adjacent outcrop areas of Cretaceous strata (shown by dark pattern).

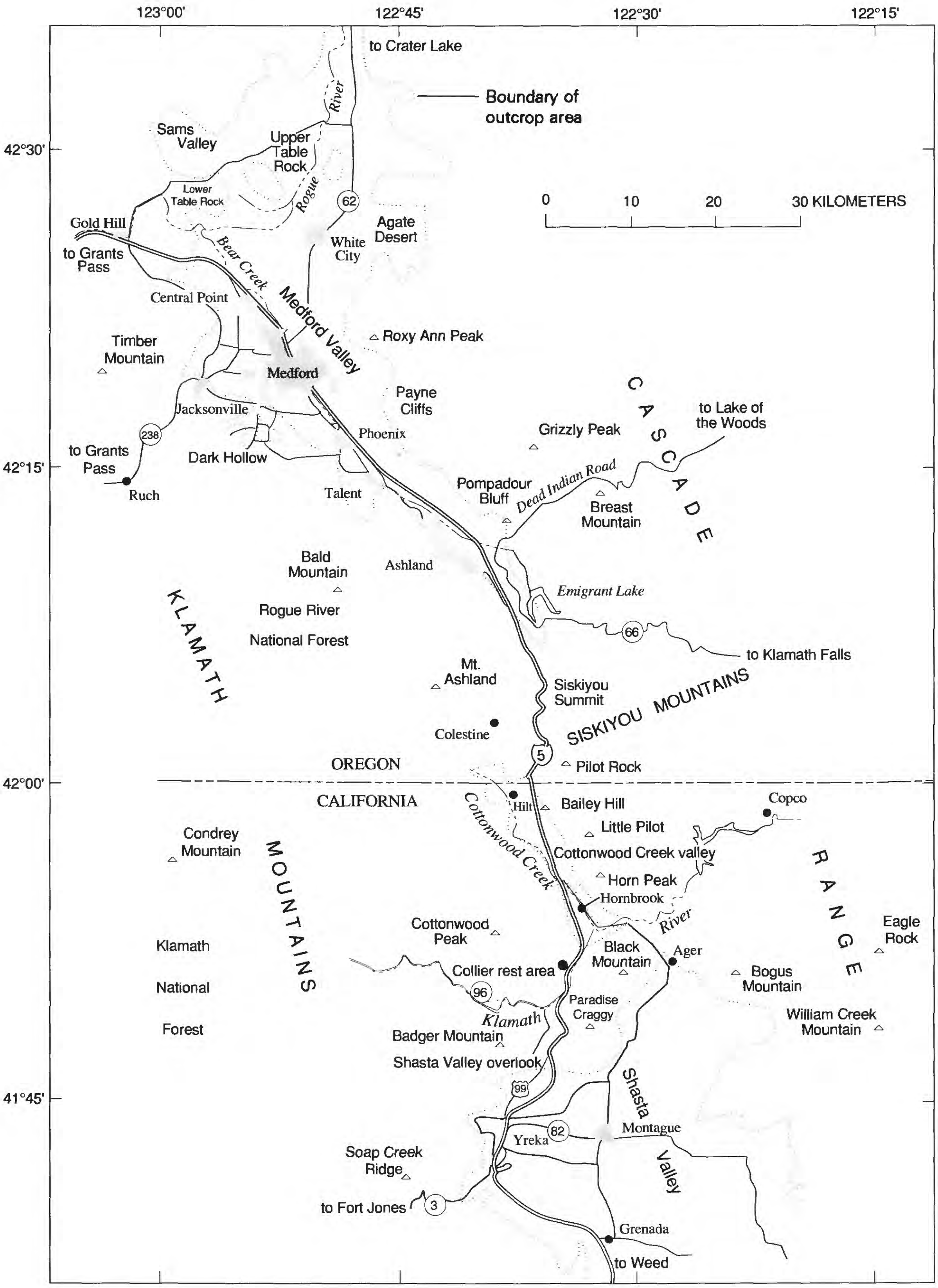


FIGURE 2.—Index map of outcrop area of the Hornbrook Formation (modified from Nilsen, 1984c).

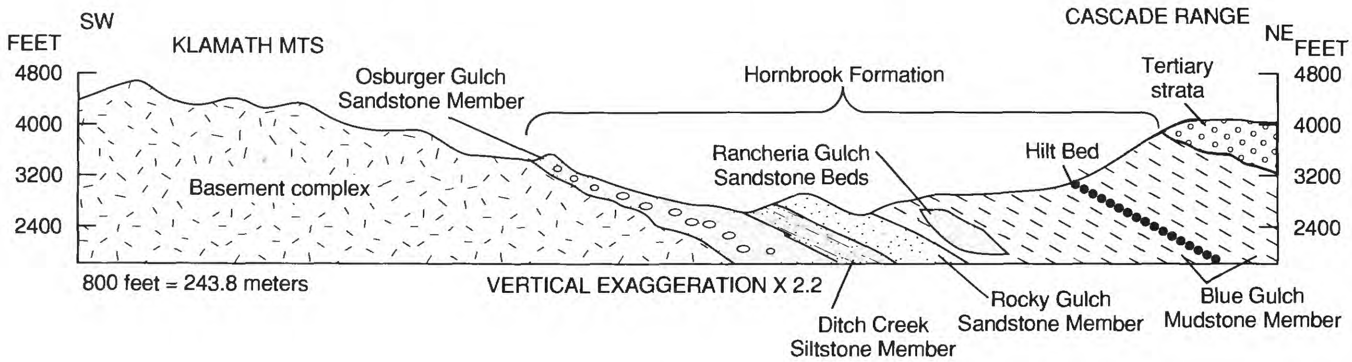


FIGURE 3.—Northeast-southwest cross section in Cottonwood Creek valley area. Topography and stratigraphic boundaries of geologic units shown are modified from Elliott (1971). The basal member of the Hornbrook Formation, the Klamath River Conglomerate Member, is not shown.

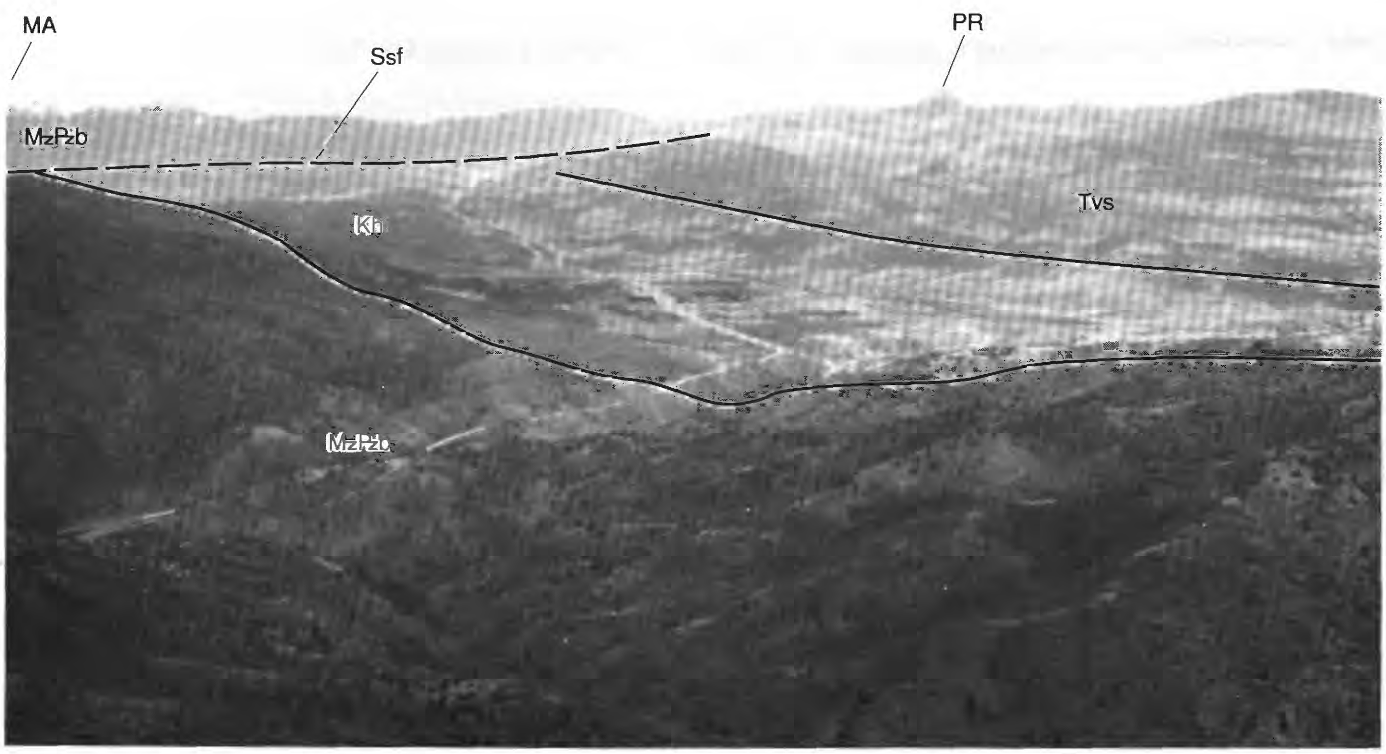


FIGURE 4.—View northwest from Paradise Craggy toward Cottonwood Creek valley, showing northeast-dipping strata of the Hornbrook Formation and related geologic features. Kh, Cretaceous Hornbrook Formation, MA, Mount Ashland; MzPzb, Paleozoic and Mesozoic basement complex; Ssf, Siskiyou Summit fault; PR, Pilot Rock; Tvs, Tertiary volcanic and sedimentary rocks. Large highway in center of valley is Interstate Highway 5; valley is approximately 4 km wide at highway. Contacts are approximately located.

adjacent to the Shasta Valley, through the Cottonwood Creek valley to about 6 km north of the Oregon-California border. Here the Hornbrook Formation is offset along the Siskiyou Summit fault to the Bear Creek valley area. From the Bear Creek valley area, exposures extend northwestward into the Medford Valley and to the Dark Hollow and Jacksonville areas (fig. 5). Cretaceous strata in the Grave Creek area of southwestern Oregon, located about 35 km northwest of the northernmost outcrops in the Medford Valley, were also included in the Hornbrook Formation by Wells (1955) and Peck and others (1956); these strata are not discussed in this report because a more detailed discussion is being prepared for publication elsewhere. The members of the Hornbrook Formation, except for the lowermost member, the Klamath River Conglomerate Member, are mapped almost continuously over its entire outcrop extent.

Upper Cretaceous sedimentary rocks that are, at least, partly correlative with the Hornbrook Formation are present in the northern Sacramento Valley (Great Valley sequence) of California (Popenoe, 1943; Matsumoto, 1960; Trujillo, 1960; Murphy and others, 1969; Ingersoll, 1979; Haggart and Ward, 1984; Haggart, 1986a; Russell and others, 1986; Verosub and others, 1989), the Gold Beach area of southwestern Oregon (Diller, 1907; Imlay and others, 1959; Dott, 1971; Blake, 1984a; Blake and others, 1985a; Bourgeois and Dott, 1987), and the Mitchell and adjacent areas (McKnight, 1964; Dickinson and Vigrass, 1965; Wilkinson and Oles, 1968; Oles, 1969; Oles and Enlows, 1971; Kleinhans and others, 1984; Thompson and others, 1984) of central Oregon (fig. 1). In addition, parts of the Franciscan assemblage and related rocks of the northern California Coast Ranges include strata of Late Cretaceous and younger age (Evitt and Pierce, 1975; Blake and Jones, 1981; McLaughlin and others, 1982, 1988; Blake, 1984b; Blake and others, 1985b, 1988, 1989). Nonmarine strata that crop out in the Klamath Mountains between the southernmost outcrops of the Hornbrook Formation and northernmost outcrops of the Great Valley sequence along the northern edge of the Sacramento Valley have been assigned to the Montgomery Creek Formation; Higinbotham (1987) has suggested that the basal conglomerate of this unit is of Late Cretaceous age, based partly on analyses of fossil pollen, which would make this unit partly correlative with the Hornbrook Formation.

PREVIOUS WORK

The name "Hornbrook Formation" was applied to outcropping clastic sedimentary rocks in Siskiyou County, California, and Jackson County, Oregon, by Peck and others (1956). They proposed and measured a composite type section near Hornbrook, California, based on suggestions by F.G. Wells of the U.S. Geological Survey, that included conglomerate, sandstone, siltstone, and mudstone. Their composite type section is at least 2,673±50 ft (815±15 m) thick and is subdivided into six informal members denoted by Roman numerals I–VI (fig. 6). They inferred, on the basis of collected megafossil assemblages, an age of Cenomanian, Turonian, and Campanian for the Hornbrook Formation, with an unconformity between members II and III that spanned chiefly the Coniacian to early Campanian interval of the Late Cretaceous.

The strata of the Hornbrook Formation had previously been referred to as the Chico Group, the name applied to Upper Cretaceous clastic sedimentary rocks around the northern margins of the Sacramento basin of California, about 140 km south of Hornbrook. It was chiefly because of the great distance separating the two outcrop areas that Wells proposed that the strata of the northern outcrops be named the Hornbrook Formation, a suggestion followed by Peck and others (1956).

Gabb (1869) applied the name "Chico Group" to Cretaceous strata in northern California and all of Oregon. He established type sections on the east side of the Sacramento Valley adjacent to Chico Creek. Diller (1893) described strata of "Chico age" near Yreka, California, and along Grave Creek in Oregon. Dunn (1894) and Turner (1903) described auriferous conglomerate at the base of the Chico Group in the Cottonwood Creek valley area.

Anderson (1895) described some Cretaceous rocks in the Bear Creek valley and subsequently (Anderson, 1902) described the stratigraphy and megafossils of the Chico Group in the Cottonwood Creek valley and Bear Creek valley. Anderson (1931) described the Chico Group near Hornbrook as consisting of about 2,000 ft (610 m) of lower fossiliferous sandstone with a basal conglomerate and 1,000 ft (305 m) of upper clay shale; he inferred an age of middle Turonian for the lower part of the sandstone unit and an age of late Turonian and early Senonian for the upper part of the sandstone unit. Anderson (1943) made the Chico Group on the Pacific coast a series, dividing it into three groups that spanned the Cenomanian to Danian time interval, but he did not define a type section for it.

Diller (1909) reported the presence of coal in shale and shaly sandstone along the east side of Bear Creek valley and near Ager, California. Diller and Kay (1924) described the thickness and lithology of

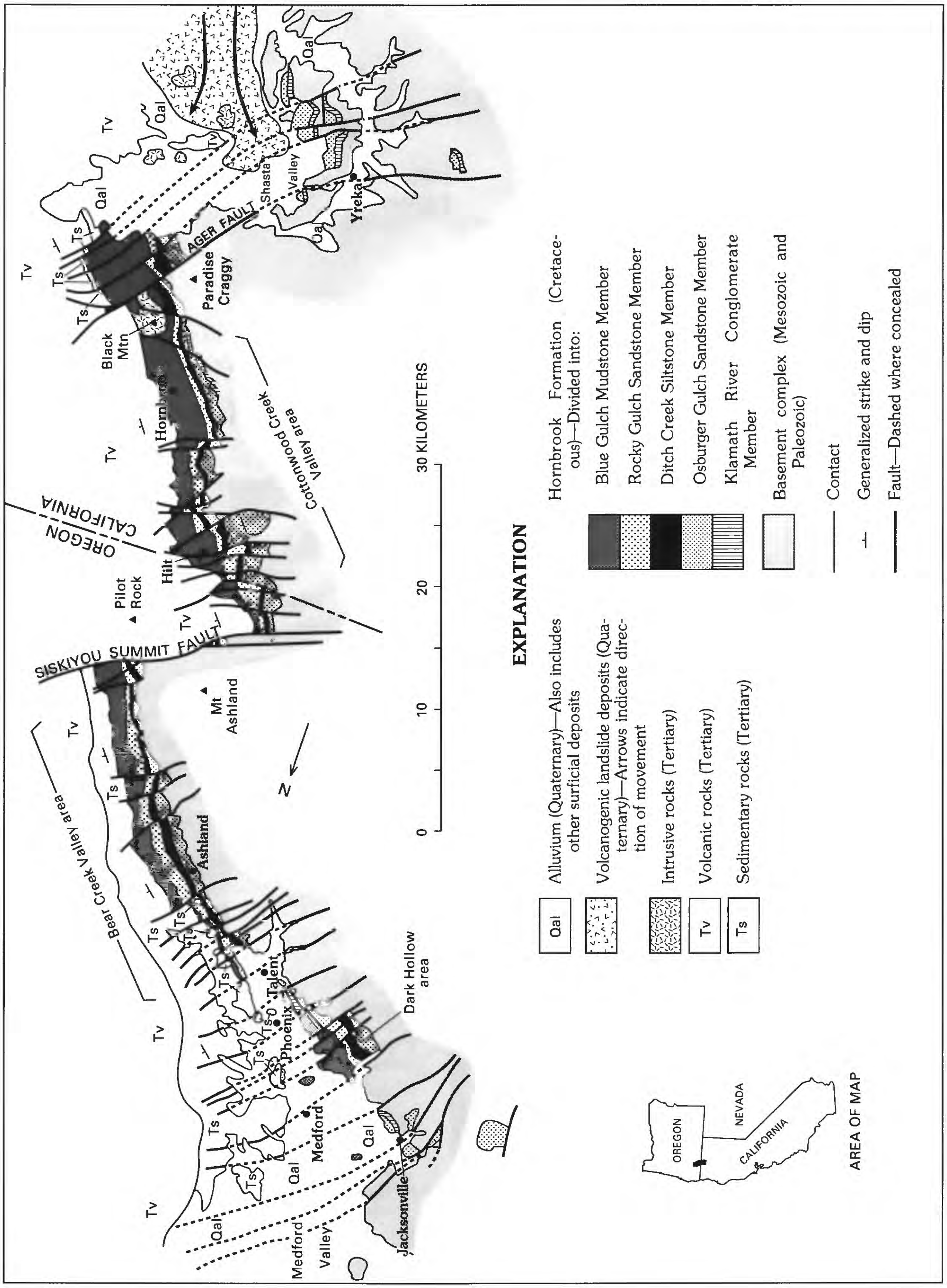


FIGURE 5.—Simplified geologic map of the Hornbrook Formation, showing distribution of major stratigraphic units (modified from Nilsen and others, 1983).

the Upper Cretaceous strata along Grave Creek. Wells (1939) mapped the Chico Group in the Medford 30-minute quadrangle, Oregon, and subsequently called the Upper Cretaceous rocks the Hornbrook Formation when he republished the Medford 30-minute quadrangle in 1956. Williams (1949, p. 16-18, pl. 4) described Upper Cretaceous strata of the Chico Formation in the Yreka area west of the MacDoel 30-minute quadrangle in northern California.

Subsequent to the naming of the Hornbrook Formation by Peck and others (1956), F.M. Anderson's detailed faunal lists, locations, and regional correlations for the Upper Cretaceous strata on the Pacific coast were posthumously published (Anderson, 1958). Mack (1959) mapped Cretaceous strata around the margins of the Shasta Valley as the Chico Formation and indicated a thickness of about 1,100 ft (330 m) near Black Mountain and only several hundred feet (100 m) east of Yreka, where only the lower part of the formation is exposed. Mack (1959) mapped several conglomerate bodies exposed about 16 km to the south of Yreka, principally in the Pythian Cave area (NW¼ sec. 7, T. 43 N., R. 6 W., Yreka 15-minute quadrangle), as Cretaceous in age and correlative with the Hornbrook Formation to the north.

Jones (1959) remapped the Hornbrook area and proposed a stratigraphic subdivision of the Hornbrook Formation into three mappable units—in ascending order, units A, B, and C (fig. 6*A*); in addition, he mapped a major fossiliferous sandstone lens in the lower part of unit C, equivalent to the Rancheria Gulch Sandstone Beds of this paper. Jones determined a total thickness of about 4,880 ft (1,490 m) for the Hornbrook Formation. He collected late Turonian to early Coniacian megafossils from unit A and middle Campanian to Maestrichtian(?) ammonites from unit C. Jones (1960a) described *Pterotrigonia* pelecypods, which range in age from Turonian to Campanian, from the Hornbrook Formation in the Yreka-Hornbrook area and also from the Grave Creek area. Jones (1960b) described Albian (Early Cretaceous) fossils from the Grave Creek area of Oregon. Popenoe and others (1960) reported the presence of Cenomanian megafossils at Dark Hollow, east of Jacksonville, Oregon.

Elliott (1971) completed a Ph.D. thesis on the stratigraphy of the Upper Cretaceous rocks near Hilt and Hornbrook, California (fig. 6). He divided the Cretaceous strata into two units: (1) his lower Hornbrook Formation, 1,002 ft (305 m) thick, of late Turonian to early Coniacian age, subdivided into an unnamed lower arenaceous member (principally conglomerate and sandstone) and his overlying Henley mudstone unit (principally siltstone); and (2) his Hilt unit, 3,059 ft (932 m) thick, of middle Campanian to Maestrichtian age, subdivided into an unnamed lower arenaceous member (principally sandstone) and his overlying Bailey Hill mudstone unit (principally mudstone). M.A. Elliott (unpub. data, 1980) subsequently prepared a revised geologic map of the Cottonwood Creek valley area between Hilt and Hornbrook; on this map, he revised his previously proposed nomenclature, including all the Cretaceous strata within his expanded Hornbrook Formation and dropped his formal names in favor of four informal units, A to D, in ascending order (fig. 6). He also recognized the presence of a local nonmarine unit at the base of the Hornbrook Formation (the Klamath River Conglomerate Member of this paper) and included it within the Hornbrook Formation. Elliott (1971; unpub. data, 1980) embraced the concept of a major unconformity within the Hornbrook Formation between his units B and C that he thought represented much or all of the late Coniacian to middle Campanian interval.

McKnight (1971) mapped and described the Hornbrook Formation and overlying Tertiary strata in the Medford-Ashland region. He recognized a thickness of more than 3,000 ft (910 m) of the Hornbrook Formation in the Ashland area and recovered fossils of Turonian, Campanian, and Maestrichtian age from it. McKnight subdivided the Hornbrook Formation into four units—three lower sandstone units and an upper mudstone unit (fig. 6). The basal sandstone unit, 360 ft (110 m) thick, is fossiliferous, locally conglomeratic and coquinoid, and rests unconformably on the basement complex. His second sandstone unit, 75 ft (23 m) thick, consists of interbedded sandstone, siltstone, mudstone, and shale. The uppermost sandstone unit, about 660 ft (200 m) thick, consists of thin- to thick-bedded sandstone that is generally unfossiliferous. McKnight's (1971) upper mudstone unit, about 1,900 ft (580 m) thick, consists of mudstone with locally abundant thin interbeds of fine-grained sandstone.

Hotz (1977) mapped the Yreka 15-minute quadrangle and showed the distribution of discontinuous remnants of the Hornbrook Formation in the Shasta Valley area to the south of the Cottonwood Creek valley. He did not subdivide the Hornbrook Formation of this area into subunits and suggested that only the lower part of the formation, about 250 m of sandstone with some conglomerate, was exposed. Hotz (1977) also estimated a thickness of about 40 m for the outlying exposures of the Hornbrook Formation on Soap Creek Ridge to the west of the Shasta Valley. He suggested an age of late Turonian and early Coniacian for the Hornbrook Formation in the Yreka area, but he did not present any new fossil data. Hotz (1977) mapped several conglomerate units in the southern part of the Yreka quadrangle, particularly the extensive beds of conglomerate at Pythian Caves (NW¼ sec. 7, T. 43 N., R. 6 W., Yreka 15-minute quadrangle), as being of Tertiary(?) age, principally because of their abundant suite of volcanic clasts that resembled volcanic rocks of the western Cascade Range.

Page and others (1977) mapped the outcrops of Lower Cretaceous strata along Grave Creek in the Wimer 7½-minute quadrangle, referring to them as the "Grave Creek strata." Ramp and Peterson (1979) mapped a small outlier of the Lower Cretaceous rocks of Grave Creek in the Glendale 15-minute quadrangle, Josephine County, Oregon, that had not been mapped by Page and others (1978). Beaulieu and Hughes (1977) mapped rocks in Jackson County, Oregon, including the Hornbrook Formation and the Cretaceous strata at Grave Creek, as an undivided unit of Cretaceous sedimentary rocks. Smith and others (1982) mapped the Medford 1° × 2° quadrangle and showed the distribution of the Hornbrook Formation in the Grave Creek area. Black and others (1983) mapped the Hornbrook Formation in the Ashland area but did not divide it into subunits. Wagner and Saucedo (1987) mapped the distribution of the Hornbrook Formation in the Weed 1:250,000-scale map sheet covering northwestern California, and Wagner (1988) described the geology of the map sheet.

Schultz and Levi (1981) reported on paleomagnetic studies of the Hornbrook Formation. They initially reported a post-Late Cretaceous 50° clockwise rotation of the Hornbrook Formation in their abstract, but verbally they retracted this conclusion. Mankinen and Irwin (1982) and Mankinen and others (1984, 1988) reported the possibility of 11.5°±15.8° and 14.4°±6.9° of post-Cretaceous clockwise rotation of the Hornbrook Formation, far less than that reported for the Oregon Coast Range to the north (Beck and Plumley, 1980), but similar to that reported from lower Tertiary volcanic rocks of the southern Cascade Range to the east (Beck and others, 1986).

Nilsen and others (1983) mapped the entire outcrop length of the Hornbrook Formation, subdividing it into nine informal units (fig. 6). Nilsen and Barats (1983) discussed the general sedimentology of the Hornbrook Formation, and Nilsen (1983) the sedimentology of the "Hilt bed." Bourgeois and Leithold (1983) described and measured two sections in the lower part of the Hornbrook Formation, interpreting these sections as high-energy, storm wave-dominated transgressive sequences. Nilsen (1984a) discussed the

A

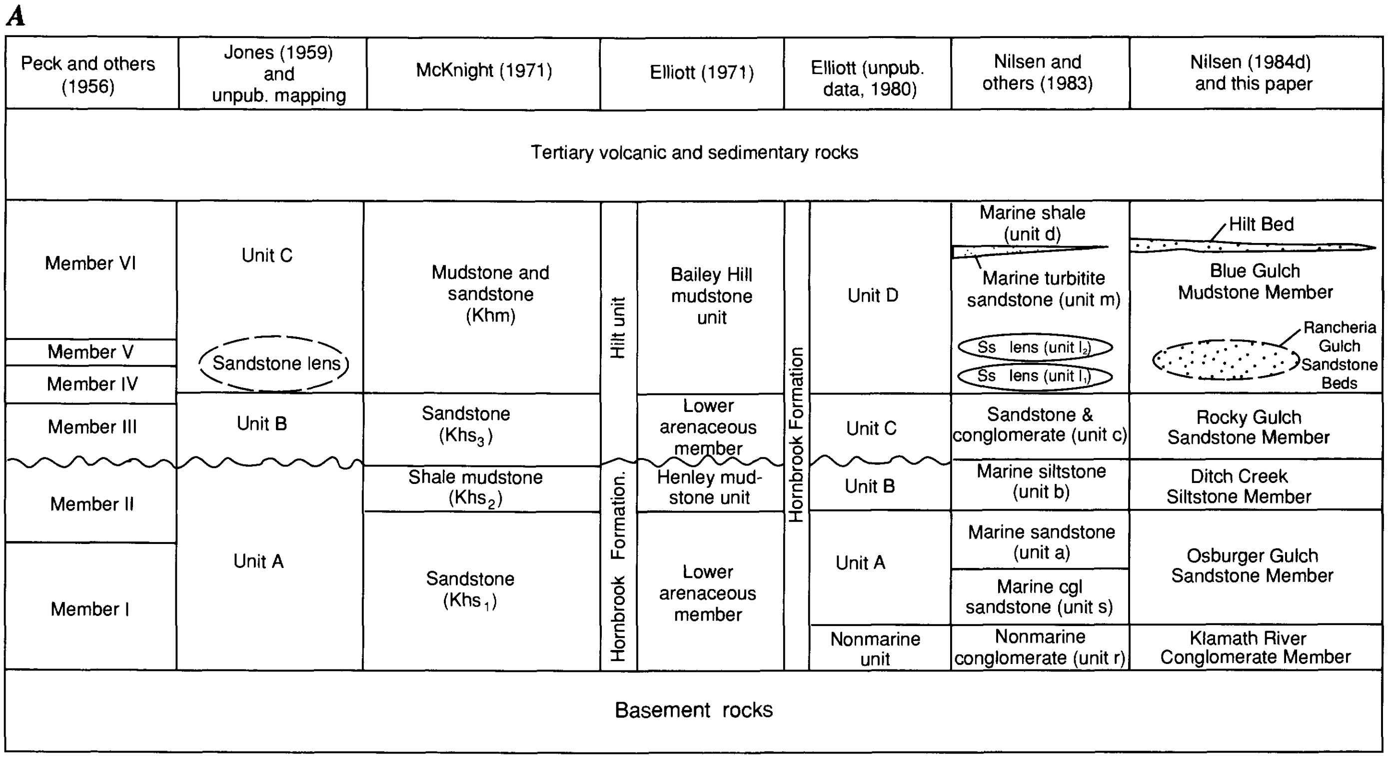


FIGURE 6.—Stratigraphic and age relations of the Hornbrook Formation. *A*, Development of stratigraphic nomenclature and correlation of units within the Hornbrook Formation. *B*, Subdivisions of Late Cretaceous time proposed by various workers.

tectonic framework of sedimentation of the Hornbrook Formation, and Nilsen (1984b) discussed a depositional model for member III of the Hornbrook Formation of Peck and others (1956; the Rocky Gulch Sandstone Member of this paper).

A wealth of new information about the Hornbrook Formation was presented in a field trip guidebook edited by Nilsen (1984c). This volume includes (1) a description of field trip stops and a roadlog to the outcrop areas of the Hornbrook Formation (Nilsen and others, 1984); (2) a synthesis of the stratigraphy, sedimentology, and tectonic framework of the Hornbrook Formation (Nilsen, 1984d); (3) a summary of paleontologic data from the Hornbrook Formation (Sliter and others, 1984); (4) a summary of the sandstone petrography of the Hornbrook Formation (Golia and Nilsen, 1984); (5) a summary of the conglomerate clast composition of the Hornbrook Formation (Barats and others, 1984); (6) a description of coal samples from the Hornbrook Formation in the Shasta Valley area (Zigler and Nilsen, 1984); (7) results from analyses of both the porosity and permeability, as well as a discussion of the diagenetic history of surface samples of the Hornbrook Formation (Kreighin and Law, 1984); (8) a discussion of the petroleum source-rock potential of the Hornbrook Formation (Law and others, 1984); and (9) discussions of the stratigraphy and sedimentology of the marine Osburger Gulch Sandstone Member of the Hornbrook Formation (Gaona, 1984; Bourgeois, 1984). In addition to these papers on the outcrop geology of the Hornbrook Formation, papers by Fuis and Zucca

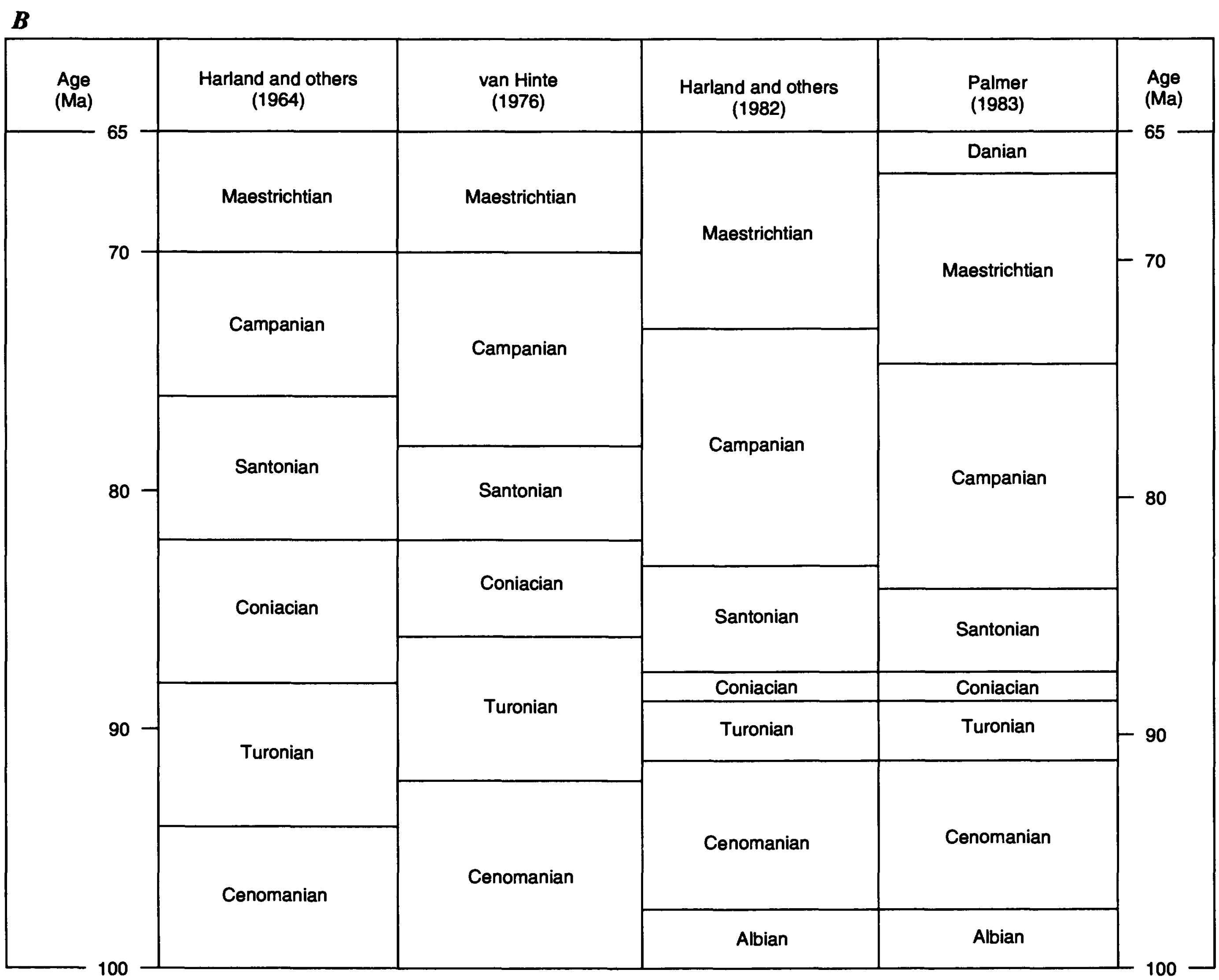


FIGURE 6.—Continued.

(1984) and Erskine and others (1984) discussed the subsurface extent of the Hornbrook Formation from geophysical studies.

Ages previously presented for the members of the Hornbrook Formation by Nilsen (1984a, d) have been revised in the present paper. Initial paleontologic age determinations from benthic and planktonic foraminifers for the members were incorrect for various reasons; the ages reported herein are more correct, and the data are presented in appendices I and II and summarized by Sliter and others (1984).

Subsequent work on the conglomeratic bodies of the Pythian Cave area to the south of Yreka, previously mapped as Cretaceous by Mack (1959), as Tertiary(?) by Hotz (1977), and not considered to be part of the Hornbrook Formation by Nilsen and others (1983) and Nilsen (1984a, d), has yielded mid-Cretaceous (Albian and Cenomanian) ages (Jameossanaie and others, 1986; Wetzstein and others, 1986; Wetzstein, 1986; Nancy Lindsley-Griffin, written commun., May 12, 1987). These ages were obtained from angiosperm pollen and trilete spores in the lower part of the main conglomeratic unit.

HORNBROOK FORMATION

The stratigraphic divisions of the Hornbrook Formation proposed by Nilsen (1984a, d) (figs. 6, 7) were based on previous stratigraphic studies by Peck and others (1956), Jones (1959), Elliott (1971; unpub. data, 1980), McKnight (1971), and Nilsen and others (1983). The previous nomenclatural subdivisions utilized Roman-numeral or letter systems and were clearly suitable for informal stratigraphic usage. The basal nonmarine member, the Klamath River Conglomerate Member, is the only discontinuous member, cropping out in thicknesses sufficient to be mapped in the Shasta Valley, southern Cottonwood Creek valley, northern Bear Creek valley, and Jacksonville areas (pl. 1). The other members, which are marine except for possibly a coal-rich interval in the Ditch Creek Siltstone Member in the Shasta Valley, are continuous except for the Rocky Gulch Sandstone Member, which is locally absent on the south flank of Black Mountain. The Rancheria Gulch Sandstone Beds of the Blue Gulch Mudstone Member, distinguished in the measured type section of the Hornbrook Formation by Peck and others (1956) and mapped by D.L. Jones (unpub. data, 1960), is present only in the type area of the Hornbrook Formation near the town of Hornbrook. The Hilt Bed of the Blue Gulch Mudstone Member was first recognized and mapped but not named by Nilsen and others (1983); it crops out more or less continuously from the northern Shasta Valley to the Ashland area, although locally it has been eroded off by the unconformity at the top of the Hornbrook Formation or has not been recognized because of poor exposures or Quaternary cover.

The Hornbrook Formation was defined by Peck and others (1956) for exposures of clastic sedimentary rocks near Hornbrook, California, where they measured their composite type section. The type sections of Nilsen (1984a, d) for the stratigraphic units of the Hornbrook Formation are nearly all in the Hornbrook area, so that they are relatively close to each other and within the type area (fig. 8). All stratigraphic names were taken from place names in the type area except for that of the Hilt Bed, which was named for the abandoned town of Hilt, located about 9 km northwest of Hornbrook, where the bed is thickest and best developed.

The thickness of the Hornbrook Formation varies considerably along the length of its outcrop, partly as a result of variable depths of erosive downcutting along the pre-Tertiary unconformity. Peck and others (1956) determined an incomplete thickness of 815±15 m for the Hornbrook Formation in the type area. Jones (1959) found a total thickness of about 1,490 m for the Hornbrook Formation in its type area, and Elliott (1971) a thickness of 1,237 m in the northern part of the Cottonwood Creek valley area. McKnight (1971) determined a thickness of more than 910 m for the Hornbrook Formation in the Bear Creek valley area. The thickness of the Hornbrook Formation in the type area presented herein, which is based on adding up the separate thicknesses of individual measured type sections of the members and subunits (rather than the measurement of a continuous section), is 1,236 m.

Previous workers (Peck and others, 1956; Jones, 1959; Elliott; 1971: unpub. data, 1980) concluded that there is a major unconformity within the lower part of the Hornbrook Formation. The unconformity was thought to be located at the contact between strata equivalent to the Ditch Creek Siltstone Member and the Rocky Gulch Sandstone Member; an erosive contact can be observed locally in outcrops between these members in the Hornbrook area, and Elliott (1971) concluded that there is a 3°–4° angular discordance between the members. The unconformity was thought to span Coniacian and Santonian time; however, no megafossils or microfossils had been obtained from strata equivalent to the Rocky Gulch Sandstone Member or the lower part of the Blue Gulch Mudstone Member below the Rancheria Gulch Sandstone Beds. Megafossils from strata equivalent to the

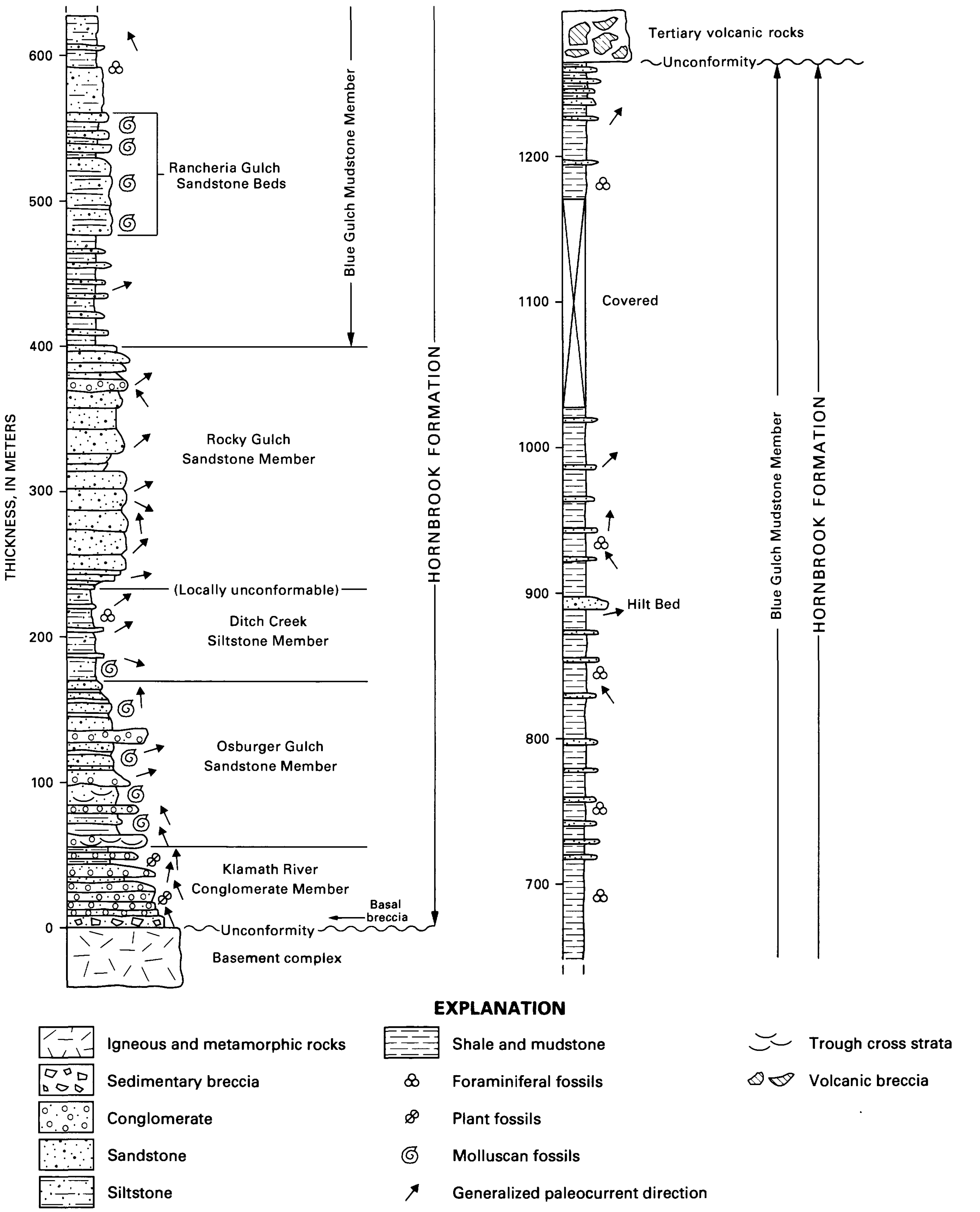
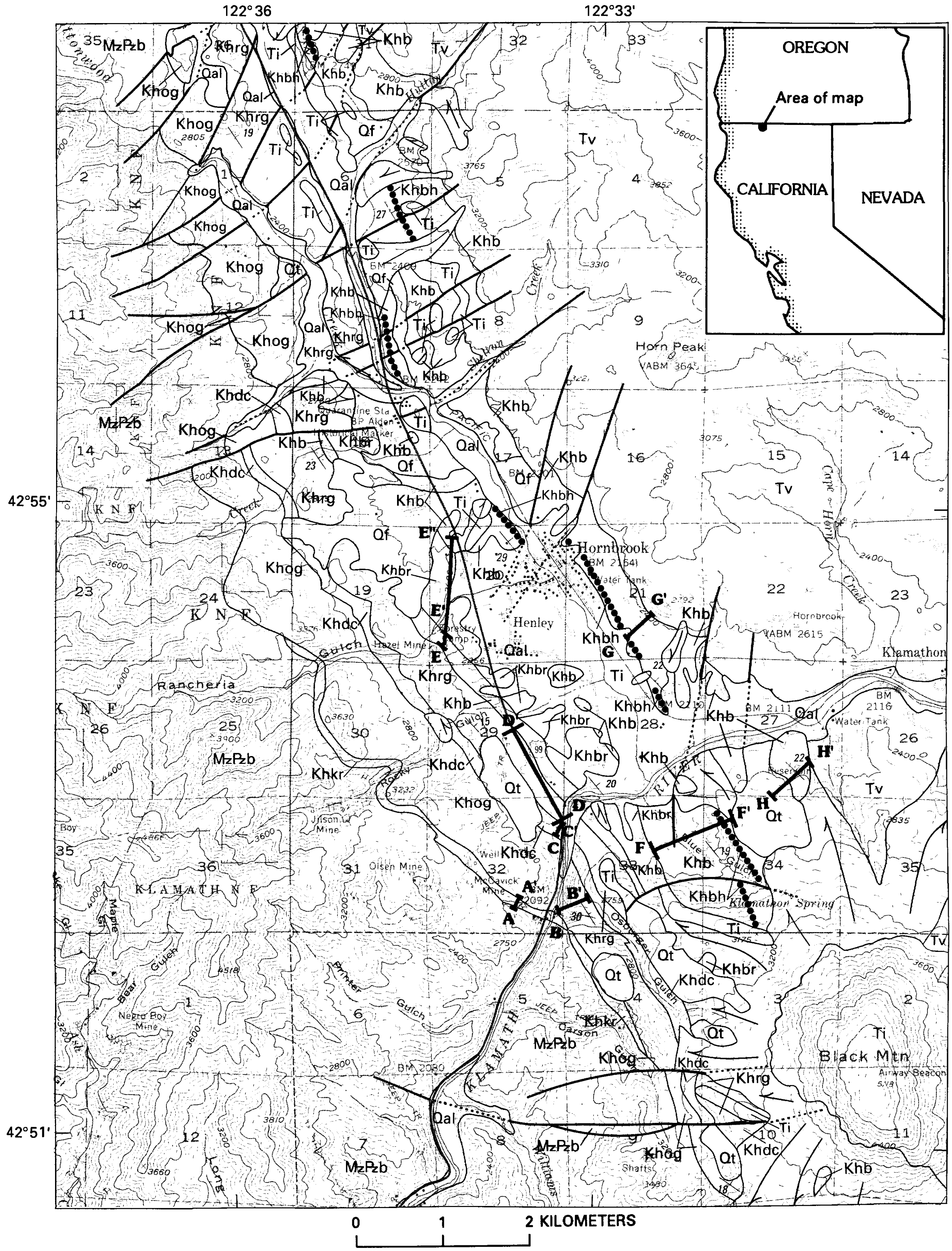


FIGURE 7.—Composite measured section of the Hornbrook Formation.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122°33'
42°55'
42°51'
OREGON
Area of map
CALIFORNIA
NEVADA
Hornbrook
Henley
Horn Peak
Klamathon
Black Mtn
Klamathon Spring
KLAMATH N F
Rancheria
Hazel Mine
Olsen Mine
McGavick Mine
Negro Boy Mine
Quarantine Sta
Forestry Camp
Water Tank
Airway Beacon
Khog
Khrg
Khb
Khbh
Khbr
Khdc
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1
2 KILOMETERS

underlying Osburger Gulch Sandstone Member and Ditch Creek Siltstone Member in the type area had been indicative of Turonian to possibly early Coniacian ages, and megafossils from strata equivalent to the middle and upper parts of the Blue Gulch Mudstone Member were indicative of middle Campanian to Maestrichtian(?) ages.

EXPLANATION

Qal	Alluvium (Quaternary)
Qf	Alluvial fan deposits (Quaternary)
Qt	Alluvial terrace deposits (Quaternary)
Tv	Volcanic rocks (Tertiary)
Ti	Intrusive rocks (Tertiary)
	Hornbrook Formation (Cretaceous)—Divided into:
Khb	Blue Gulch Mudstone Member—Includes:
Khbh	Hilt Bed
Khbr	Rancheria Gulch Sandstone Beds
Khrg	Rocky Gulch Sandstone Member
Khdc	Ditch Creek Siltstone Member
Khog	Osburger Gulch Sandstone Member
Khkr	Klamath River Conglomerate Member
MzPzb	Basement complex of Klamath Mountains (Mesozoic and Paleozoic)
	Contact
	Fault—Dotted where concealed
A A'	Measured section location
	Landslide deposit—Arrow indicates direction of movement
20	Strike and dip of beds

FIGURE 8.—Geologic map of Cottonwood Creek valley area, showing location of type sections of stratigraphic units of the Hornbrook Formation. Type sections: (1) *A–A'*, Klamath River Conglomerate Member; (2) *B–B'*, Osburger Gulch Sandstone Member; (3) *C-C'*, Ditch Creek Siltstone Member; (4) *D–D'*, Rocky Gulch Sandstone Member; (5) *E–E'*, lower part of the Blue Gulch Mudstone Member; (6) *E'–E"*, Rancheria Gulch Sandstone Beds; (7) *F–F'*, middle part of the Blue Gulch Mudstone Member, including the Hilt Bed; (8) *G–G'*, upper part of the Blue Gulch Mudstone Member above the Hilt Bed; and (9) *H–H'*, uppermost part of the Blue Gulch Mudstone Member. Although the basement complex is shown here as being composed of Paleozoic and Mesozoic rocks, the area shown by this map is probably underlain wholly by rocks of Mesozoic age (W.P. Irwin, oral commun., 1984). Base map from U.S. Geological Survey 1:62,000-scale Hornbrook, Calif. quadrangle.

In this paper, new paleontological data, chiefly benthic and planktonic foraminiferal collections and some megafossil collections, are presented that place further constraints on the proposed unconformity. Megafossils from the basal part of the Osburger Gulch Sandstone Member in the area south of Hornbrook are indicative of a Turonian age, and one collection of megafossils from the Ditch Creek Siltstone Member is indicative of a Turonian age (app. I). Two collections (Mf6580 and Mf6581) of benthic foraminifers from the Ditch Creek Siltstone Member in the Cottonwood Creek valley area are indicative of a late Turonian to Coniacian age. Megafossils from the Rancheria Gulch Sandstone Beds are indicative of a late Campanian age (Sliter and others, 1984), and foraminifers from the middle and upper parts of the Blue Gulch Mudstone Member in the Cottonwood Creek valley area and its type section are indicative of ages that range generally from Campanian to Maestrichtian (app. I). Thus, in the type area and in the Cottonwood Creek valley area, a local unconformity that represents Santonian time could possibly be present between the Ditch Creek Siltstone Member and the Rocky Gulch Sandstone Member; alternatively, and more likely, in my opinion, the Santonian interval, which represents only about 2.5 m.y (fig. 6*B*), is present within the unfossiliferous Rocky Gulch Sandstone Member and lower part of the Blue Gulch Mudstone Member below the Rancheria Gulch Sandstone Beds.

To the north in the Bear Creek valley, Medford Valley, and Dark Hollow areas, strata mapped herein as the Rocky Gulch Sandstone Member and the Blue Gulch Mudstone Member are considered to be middle and late Turonian in age (app. II). Thus, the proposed unconformity in the type area and in the Cottonwood Creek valley area would be present stratigraphically above the youngest strata farther north. As a result of these new age determinations, it is not clear whether the proposed unconformity can be substantiated. In this paper, the contact is considered gradational and conformable, except in the type area and in parts of the northern Cottonwood Creek valley, where it is erosive and possibly locally unconformable.

The Hornbrook Formation undoubtedly extends northeastward in the subsurface beneath the Cascade Range, as inferred from gravity, magnetic, and seismic data (Leaver and others, 1984; Erskine and others, 1984; Fuis and Zucca, 1984; Blakely and others 1985; Fuis and others, 1987). However, it has been penetrated by only one well drilled for petroleum, the

Kuck No. 1 (sec. 26, T. 46 N., R. 5 W., Copco 15-minute quadrangle) at the northeastern edge of the Shasta Valley south of Bogus Mountain (Alldredge and Meigs, 1984; Montgomery, 1988, p. 32-35); even though about 1,405 m (4,500 ft) of Hornbrook Formation was penetrated in this well, it is difficult to regionally project possible facies changes or changes in thickness beneath the volcanic cover.

To the southeast and northwest, the Hornbrook Formation probably originally extended as a continuous sheet of marine conglomerate, sandstone, and shale with local nonmarine deposits at its base. However, it is covered by Quaternary alluvium in the Medford Valley and Shasta Valley. At the southeast end of the Shasta Valley, volcanogenic landslide deposits partly overlap it (Chesterman and Saucedo, 1984; Crandell and others, 1984). In the Pythian Cave area, nonmarine conglomeratic bodies along the western flank of Shasta Valley and west of the landslide deposits are considered to be mid-Cretaceous in age; these conglomerates may be correlative with the Klamath River Conglomerate Member of the Hornbrook Formation and indicate southward continuation of the basal fluvial deposits. Farther to the northwest and southeast, Tertiary volcanic rocks rest directly on the Klamath Mountains basement complex, either as a result of complete overlap of the Hornbrook Formation by virtue of the angular unconformity between the Cretaceous and Tertiary strata (Elliott, 1971, p. 17–18) or owing to complete erosion of the Cretaceous strata beneath the post-Cretaceous unconformity. The lateral continuity of the members of the Hornbrook Formation over its entire outcrop extent suggests that the Hornbrook Formation originally extended much farther to the southeast and northwest. To the southeast, it may have connected with Cretaceous strata of the Great Valley sequence in the Redding area (Nilsen, 1984a), although this idea has been opposed by other workers (Haggart, 1986b); the deposits in the Redding area also rest unconformably on basement rocks of the Klamath Mountains and are at least partly coeval with the Hornbrook Formation. To the northwest, in the Grave Creek area, Cretaceous strata rest on basement rocks of the Klamath Mountains in two downfaulted blocks; here the lowest marine strata are of Albian age, older than the Cenomanian strata in the Dark Hollow area, and facies-equivalent strata of the Rocky Gulch Sandstone Member are absent.

To the west, a downfaulted block of Cretaceous strata within the basement rocks of the Klamath Mountains near O'Brien, Oregon, contains similar nonmarine deposits at its base and overlying transgressive shallow-marine conglomerate, sandstone, and siltstone (Shenon, 1933). Megafossils from this area, however, are indicative of Early Cretaceous ages (Shenon, 1933), although the uppermost part of the sequence has been eroded off, so that any Upper Cretaceous deposits that might have originally been present were subsequently removed. Upper Cretaceous (Campanian and Maestrichtian) shallow-marine deposits of the Cape Sebastian Sandstone of Dott (1971) and deep-marine deposits of the Hunters Cove Formation of Dott (1971) in the Gold Beach area of coastal southwestern Oregon (fig. 1) are correlative with the upper part of the Hornbrook Formation. However, these strata are fault bounded and may have accreted to southwestern Oregon in post-middle Eocene time (Blake, 1984a; Blake and others, 1985a, 1989; Bourgeois and Dott, 1987).

STRATIGRAPHIC SUBDIVISIONS OF THE HORNBROOK FORMATION

KLAMATH RIVER CONGLOMERATE MEMBER

DEFINITION

The name "Klamath River Conglomerate Member" was applied by Nilsen (1984a) to discontinuous nonmarine conglomeratic strata that form the basal part of the Hornbrook Formation. The member was named for exposures west of the Klamath River, about 4 km south of Hornbrook, California (figs. 8, 9). The type section was measured in the Blue Gravel Mine directly west of the southbound lane of Interstate Highway 5, about 0.4 km west of the Klamath River and about 0.7 km southeast of the McCavick Mine (fig. 9).

The Klamath River Conglomerate Member is the lowest member of the Hornbrook Formation. It had previously been mapped by M.A. Elliott (unpub. data, 1980) as his nonmarine unit and by Nilsen and others (1983) as their unit r (of Hornbrook Formation), a nonmarine conglomerate, sandstone, pebbly mudstone, mudstone, and siltstone that contains plant fossils, paleosols, and a basal breccia. Peck and others (1956) did not separate this unit from member I in their stratigraphic subdivision of the Hornbrook Formation. The member rests unconformably on Paleozoic and Mesozoic igneous and metamorphic basement rocks and is overlain conformably by the Osburger Gulch Sandstone Member of the Hornbrook Formation.

The lower boundary of the Klamath River Conglomerate Member is defined by the unconformable depositional contact on the basement rocks. Paleosols that are as thick as several meters are locally present

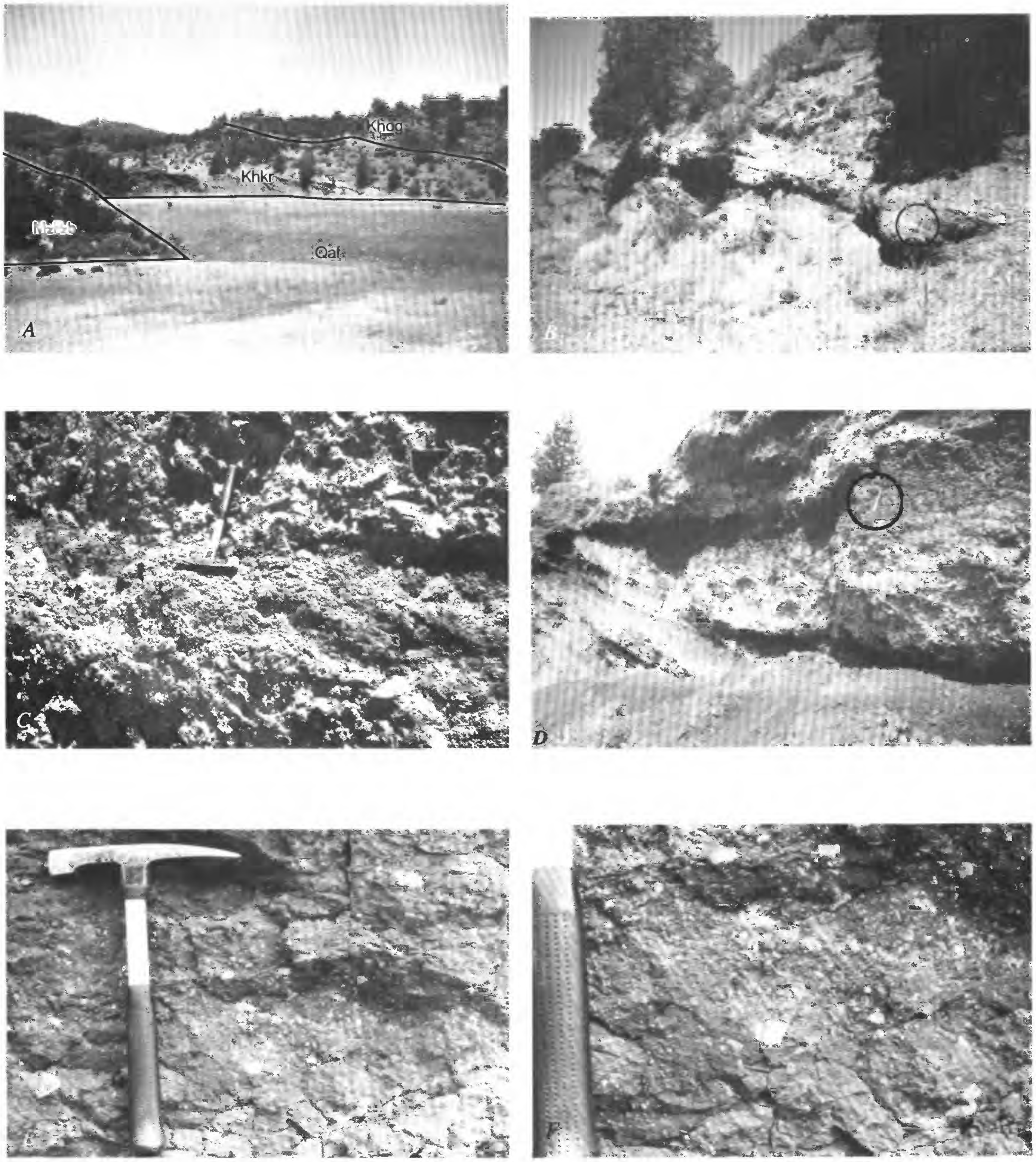


FIGURE 9.—Type section of the Klamath River Conglomerate Member of the Hornbrook Formation. *A*, View northwestward of Blue Gravel Mine, showing northeast-dipping strata; massive bluffs above underlain by Osburger Gulch Sandstone Member (Khog) of the Hornbrook Formation. Qaf, artificial fill; KhKr, Klamath River Conglomerate Member (of Hornbrook Formation); MzPzb, basement complex of Klamath Mountains. *B–D*, Interbedded light-colored conglomerate and dark-colored, less resistant pebbly mudstone. Rock hammer (circled in *B* and *D*) is 35 cm long. *E* and *F*, Basal breccia consisting of matrix-supported angular clasts of metavolcanic rocks in pebbly mudstone.

on the top of the basement rocks, but in other places the sedimentary strata rest directly on unweathered basement rocks. A basal breccia (composed wholly of angular blocks of basement rocks that directly underlie the breccia) or a conglomeratic grus (consisting mostly of untransported granitic detritus derived from underlying granitic rocks) can form the basal part of the Klamath River Conglomerate Member.

The upper boundary of the Klamath River Conglomerate Member is placed at the base of the first bed of massive, well-sorted, calcareous sandstone or conglomeratic sandstone. This massive sandstone, which may locally be trough cross-bedded or thinly laminated, may contain marine molluscan fossils and marine burrows. It is more resistant than the underlying nonmarine deposits of the Klamath River Conglomerate Member because of its well-developed carbonate cement. The calcareous sandstone is typically medium gray (N5) where fresh, in contrast to the grayish red (5R 4/2) and grayish brown (5YR 3/2) colors of the underlying nonmarine rocks. The basal beds of sandstone of the Osburger Gulch Sandstone Member in the type area and in its type section consist of siltstone and platy, very fine grained sandstone that contains some local marine mollusks and evidence of marine bioturbation.

AREAL EXTENT

The Klamath River Conglomerate Member extends discontinuously across almost the entire outcrop extent of the Hornbrook Formation. It is commonly present as a veneer of nonmarine conglomeratic strata as thick as several meters between the basement rocks and the Osburger Gulch Sandstone Member. However, it has been mapped only where it is much thicker (pl. 1). The northernmost mapped outcrops of the Klamath River Conglomerate Member are present about 1 km east of the city of Jacksonville, Oregon, along the southwestern flank of Bellinger Hill (secs. 90, 91, 92, and 95, T. 37 S., R. 2 W., Medford 15-minute quadrangle). In addition, there are loose blocks of red-weathering conglomerate present near a school on a small hill on the east side of Jacksonville (NE¼ sec. 37, T. 37 S., R. 2 W., Medford 15-minute quadrangle). These blocks are composed of conglomerate and contain angular, poorly sorted, matrix-supported clasts as long as 10 cm that resemble clasts present in the Klamath River Conglomerate Member. The Klamath River Conglomerate Member also forms prominent outcrops in foothills east of Coleman Creek (N½ sec. 21, T. 38 S., R. 1 W., Medford 15-minute quadrangle), where conglomerate containing clasts as long as 25 cm is present.

In most of the Bear Creek valley and Cottonwood Creek valley areas, the Klamath River Conglomerate Member is either very thin or absent. Adjacent to Ashland, fossiliferous conglomerate that forms a coquina locally rests directly on basement. Near the Siskiyou Summit fault, as much as 5 m of the Klamath River Conglomerate Member was measured at the base of a section of the Osburger Gulch Sandstone Member along Interstate Highway 5 (NW¼ sec. 21, T. 40 S., R. 2 E., Ashland 15-minute quadrangle).

The Klamath River Conglomerate Member is thickest and best exposed southwest of Hornbrook, California, in the following areas: the southeast end of the Cottonwood Creek valley, west of the Klamath River; along the northwest and southwest margin of the Shasta Valley; and in the Soap Creek Ridge outlier of the Hornbrook Formation southwest of Yreka. The member extends more or less continuously from the Hornbrook area southward to the southernmost outcrops of the Hornbrook Formation in secs. 5 and 6, T. 44 N., R. 6 W., sec. 1, T. 44 N., R. 7 W., and sec. 1, T. 44 N., R. 8 W., Yreka 15-minute quadrangle. The conglomeratic bodies at Pythian Cave and adjacent areas, located about 10 km south of the southernmost outcrops of the Hornbrook Formation as mapped herein, have recently yielded Albian and Cenomanian pollen and spores (Wetzstein, 1986; Wetzstein and other, 1986). These conglomeratic bodies could be correlative with the Klamath River Conglomerate Member. However, because of their dissimilar clast compositions, sandstone compositions, and paleocurrent orientations, these bodies will not be considered to be part of the Hornbrook Formation until additional data are published. The widespread outcrops of the Klamath River Conglomerate Member in the Shasta Valley area result from the abundant faulting of the Cretaceous section and low angles of dip (pl. 1).

TYPE SECTION

The type section of the Klamath River Conglomerate Member of the Hornbrook Formation was measured along the northern margin of an area of artificial fill within old mine workings west of Interstate Highway 5 in the S½SE¼ sec. 32, T. 47 N., R. 6 W., Hornbrook 15-minute quadrangle (fig. 10).

The section is about 36.5 m thick and is almost completely exposed.

	Thickness (in meters)
Hornbrook Formation (lower part):	
Osburger Gulch Sandstone Member (lower part):	
Sandstone, medium- to coarse-grained; pebble stringers, trough cross-stratified; minor amounts of bioturbation; calcareous cement; medium gray (N5) where fresh, moderate yellowish brown (10YR 5/4) where weathered	10.00
Covered interval (float of siltstone)	12.05
Siltstone, massive to laminated; plant fragments	3.05
Sandstone, fine-grained, massive to laminated; plant fragments on bedding surfaces; some scattered molluscan fossils	.22
Siltstone, massive to laminated	.22
Conformable contact.	
Klamath River Conglomerate Member:	
Conglomerate, reverse-graded, matrix-supported; mudstone matrix; clasts subangular to subrounded; maximum clast size 4 cm	.35
Pebbly mudstone, massive; clasts subangular to subrounded, matrix-supported; maximum clast size 1 cm	.80
Conglomerate, reverse-graded, matrix-supported; mudstone matrix; clasts subangular to subrounded; maximum clast size 5 cm	.30
Pebbly mudstone, massive; clasts subangular to subrounded, matrix-supported; maximum clast size 1 cm	.10
Conglomerate, reverse-graded, matrix-supported; mudstone matrix; clasts subangular to subrounded; maximum clast size 2 cm	.12
Pebbly siltstone, laminated, carbonaceous with coaly laminae; plant fossils in growth position; scattered pebbles of maximum clast size 0.5 cm	.42
Conglomerate, reverse-graded, matrix-supported; mudstone matrix; clasts subangular to subrounded; maximum clast size 5 cm	.42
Siltstone, massive to laminated, laterally discontinuous; abundant plant fossils, some possibly in growth position	.10
Conglomerate, reverse-graded, matrix-supported; mudstone matrix; clasts subangular to subrounded; maximum clast size 3 cm	.18
Conglomerate, reverse-graded, matrix-supported; mudstone matrix; clasts subangular to subrounded; maximum clast size 8 cm	.60
Pebbly mudstone, massive; clasts subangular to subrounded, matrix-supported; maximum clast size 2 cm	.90
Conglomerate, reverse-graded, matrix-supported; mudstone matrix; clasts subangular to subrounded; maximum clast size 3 cm	.15
Pebbly mudstone, massive; clasts subangular to subrounded; matrix-supported; maximum clast size 2 cm	.95
Conglomerate, reverse-graded, matrix-supported; mudstone matrix; clasts subangular to subrounded; maximum clast size 5 cm	.12
Pebbly mudstone, massive; clasts subangular to subrounded, matrix-supported; maximum clast size 1 cm	.30

	Thickness *(in meters)*
Klamath River Conglomerate Member—*Continued*:	
Conglomerate, reverse-graded, matrix-supported; mudstone matrix; clasts subangular to subrounded; maximum clast size 3 cm	.11
Pebbly mudstone, massive; clasts subangular to subrounded, matrix-supported; maximum clast size 2 cm	.62
Conglomerate, reverse-graded, matrix-supported; mudstone matrix; clasts subangular to subrounded; maximum clast size 7 cm	.38
Pebbly mudstone, massive; clasts subangular to subrounded, matrix-supported; maximum clast size 2 cm	.55
Conglomerate, reverse-graded, matrix-supported; mudstone matrix; clasts subangular to subrounded; maximum clast size 8 cm	.63
Pebbly mudstone, massive; clasts subangular to subrounded, matrix-supported; maximum clast size 2 cm	.35
Conglomerate, reverse-graded, matrix-supported; mudstone matrix; clasts subangular to subrounded; maximum clast size 4 cm	.07
Pebbly mudstone, massive; clasts subangular to subrounded, matrix-supported; maximum clast size 1 cm; partly laminated	.12
Conglomerate, reverse-graded, matrix-supported; mudstone matrix; clasts subangular to subrounded; maximum clast size 8 cm	.55
Pebbly mudstone, massive; clasts subangular to subrounded, matrix-supported; maximum clast size 3 cm	.12
Conglomerate, reverse-graded, matrix-supported; mudstone matrix; clasts subangular to subrounded; maximum clast size 8 cm	.20
Pebbly mudstone, massive; clasts subangular to subrounded, matrix-supported, partly laminated, conglomeratic at base; maximum clast size 2 cm	.42
Pebbly mudstone, massive; clasts subangular to subrounded, matrix-supported, partly laminated in upper part; maximum clast size 2 cm	.60
Conglomerate, partly stratified, moderately sorted, matrix- supported; slightly imbricated clasts, not graded; clasts subangular to subrounded; maximum clast size 17 cm	.80
Pebbly mudstone, massive; clasts subangular to subrounded, matrix-supported; maximum clast size 0.5 cm	.80
Pebbly mudstone, massive; clasts subangular to subrounded, matrix-supported; maximum clast size 0.5 cm	.90
Pebbly mudstone, massive; clasts subangular to subrounded, matrix-supported; maximum clast size 2 cm	.45
Conglomerate, reverse-graded, matrix-supported; mudstone matrix; clasts subangular to subrounded; bed thickens laterally to 150 cm; maximum clast size 15 cm	.28
Pebbly mudstone, massive; clasts subangular to subrounded, matrix-supported; maximum clast size 2 cm	.60

Klamath River Conglomerate Member—*Continued*:	*Thickness (in meters)*
Conglomerate, reverse-graded, matrix-supported; mudstone matrix; clasts subangular to subrounded; maximum clast size 8 cm	.10
Pebbly mudstone, massive; clasts subangular to subrounded, matrix-supported; maximum clast size 2 cm	.42
Conglomerate, reverse-graded, matrix-supported; mudstone matrix; clasts subangular to subrounded; maximum clast size 8 cm	.24
Conglomerate, reverse-graded, matrix-supported; mudstone matrix; clasts subangular to subrounded; maximum clast size 8 cm	.18
Pebbly mudstone, massive; clasts subangular to subrounded, matrix-supported; maximum clast size 0.5 cm	.08
Conglomerate, reverse-graded, matrix-supported; mudstone matrix; clasts subangular to subrounded; channelized base; maximum clast size 8 cm	.30
Pebbly mudstone, massive; clasts subangular to subrounded, matrix-supported; maximum clast size 3 cm	.38
Conglomerate, reverse-graded, matrix-supported; mudstone matrix; clasts subangular to subrounded; maximum clast size 5 cm	.10
Pebbly mudstone, massive; clasts subangular to subrounded, matrix-supported; maximum clast size 2 cm	.30
Conglomerate, reverse-graded, matrix-supported; mudstone matrix; clasts subangular to subrounded; maximum clast size 10 cm	.45
Pebbly mudstone, massive; clasts subangular to subrounded, matrix-supported; maximum clast size 5 cm	.80
Conglomerate, reverse-graded, matrix-supported; mudstone matrix; clasts subangular to subrounded; maximum clast size 2 cm	.07
Pebbly mudstone, massive; clasts subangular to subrounded, matrix-supported; maximum clast size 0.5 cm	.05
Conglomerate, reverse-graded, matrix-supported; mudstone matrix; clasts subangular to subrounded; maximum clast size 2 cm	.12
Pebbly mudstone, massive; clasts subangular to subrounded, matrix-supported; maximum clast size 2 cm	.10
Conglomerate, reverse-graded, matrix-supported; mudstone matrix; clasts subangular to subrounded; maximum clast size 10 cm	.52
Conglomerate, reverse-graded, matrix-supported; mudstone matrix; clasts subangular to subrounded; maximum clast size 11 cm	.58
Conglomerate, reverse-graded, matrix-supported; mudstone matrix; clasts subangular to subrounded; erosional base; maximum clast size 4 cm	.11
Pebbly mudstone, massive; clasts subangular to subrounded, matrix-supported; maximum clast size 2 cm	.38
Pebbly mudstone, massive; clasts subangular to subrounded, matrix-supported; maximum clast size 5 cm	.27

Klamath River Conglomerate Member—*Continued*:	*Thickness (in meters)*
Conglomerate, reverse-graded, matrix-supported; mudstone matrix; clasts subangular to subrounded; maximum clast size 10 cm	.55
Conglomerate, reverse-graded, matrix-supported; mudstone matrix; clasts subangular to subrounded; maximum clast size 18 cm	.80
Pebbly mudstone, massive; clasts subangular to subrounded, matrix-supported; maximum clast size 1 cm	.12
Conglomerate, reverse-graded, matrix-supported; mudstone matrix; clasts subangular to subrounded; erosional base; maximum clast size 10 cm	.62
Pebbly mudstone, massive; clasts subangular to subrounded, matrix-supported; maximum clast size 4 cm	.33
Conglomerate, reverse-graded, matrix-supported; mudstone matrix; clasts subangular to subrounded; maximum clast size 11 cm	.20
Conglomerate, reverse-graded, matrix-supported; mudstone matrix; clasts subangular to subrounded; maximum clast size 1 cm	.08
Conglomerate, reverse-graded, matrix-supported; mudstone matrix; clasts subangular to subrounded; erosional base; maximum clast size 3 cm	.10
Pebbly mudstone, massive; clasts subangular to subrounded, matrix-supported; maximum clast size 8 cm	.30
Conglomerate, reverse-graded, matrix-supported; mudstone matrix; clasts subangular to subrounded; maximum clast size 13 cm	.47
Conglomerate, reverse-graded, matrix-supported; mudstone matrix; clasts subangular to subrounded; maximum clast size 3 cm	.15
Conglomerate, reverse-graded, matrix-supported; mudstone matrix; clasts subangular to subrounded; maximum clast size 3 cm	.15
Conglomerate, reverse-graded, matrix-supported; mudstone matrix; clasts subangular to subrounded; maximum clast size 18 cm	.20
Conglomerate, reverse-graded, matrix-supported; mudstone matrix; clasts subangular to subrounded; maximum clast size 13 cm	.22
Conglomerate, reverse-graded, matrix-supported; mudstone matrix; clasts subangular to subrounded; maximum clast size 18 cm	.75
Conglomerate, reverse-graded, matrix-supported; mudstone matrix; clasts subangular to subrounded; maximum clast size 15 cm	.60
Conglomerate, reverse-graded, matrix-supported; mudstone matrix; clasts subangular to subrounded; maximum clast size 20 cm	1.35
Conglomerate, reverse-graded, matrix-supported; mudstone matrix; clasts subangular to subrounded; erosional base; maximum clast size 15 cm	.81
Pebbly mudstone, massive; clasts subangular to subrounded, matrix-supported; maximum clast size 2 cm	.20
Conglomerate, reverse-graded, matrix-supported; mudstone matrix; clasts subangular to subrounded; erosional base; maximum clast size 22 cm	.70

	Thickness (in meters)
Klamath River Conglomerate Member—*Continued*:	
Pebbly mudstone, massive; clasts subangular to subrounded, matrix-supported; laterally dis continuous; maximum clast size 1 cm	.12
Conglomerate, reverse-graded, matrix-supported; mudstone matrix; clasts subangular to subrounded; erosional base; maximum clast size 22 cm	1.25
Pebbly mudstone, massive; clasts subangular to subrounded, matrix-supported; maximum clast size 10 cm	.90
Conglomerate, reverse-graded, matrix-supported; mudstone matrix; clasts subangular to subrounded; maximum clast size 20 cm	.65
Siltstone, sandy, massive, laterally discontinuous	.10
Conglomerate, reverse-graded, matrix-supported; mudstone matrix; clasts subangular to subrounded; maximum clast size 18 cm	.60
Siltstone, sandy, massive, laterally discontinuous	.80
Conglomerate, reverse-graded, matrix-supported; mudstone matrix; clasts subangular to subrounded; maximum clast size 21 cm	.67
Conglomerate, massive; appears to be ungraded, matrix-supported, poorly exposed; clasts angular to subrounded; maximum clast size 22 cm	2.30
Breccia and conglomerate, partly residual and partly transported; about 95 percent larger angular clasts of underlying metavolcanic basement rocks and about 5 percent smaller subrounded clasts of quartzite, chert, and quartz, which increase in abundance upward; maximum clast size 62 cm	.50
Total thickness of the Klamath River Conglomerate Member	36.50

Unconformable contact.
Applegate Group (basement complex):
Metavolcanic rocks of Triassic age

The colors of the Klamath River Conglomerate Member vary considerably. The basal breccia and conglomerate, 0.50 m thick, are dark gray (N3) and grayish black (N2) on fresh, unweathered surfaces and light brown (5YR 5/6) on weathered surfaces. The overlying conglomerate beds are medium dark gray (N4) on fresh, unweathered surfaces and pale yellowish brown (10YR 6/2) on weathered surfaces. The pebbly mudstone beds are generally grayish red (5R 4/2) and grayish brown (5YR 3/2) on fresh, unweathered surfaces and very dusky red (10R 2/2) and dark reddish brown (10R 3/4) on weathered surfaces. In general, the entire unit has a reddish appearance from a distance, with the color probably reflecting the abundance of hematite and other oxidized iron minerals in the mudstone matrix of the pebbly mudstone, siltstone, and conglomerate units.

LITHOLOGY

The Klamath River Conglomerate Member consists mostly of conglomerate. In the type section, it consists of alternating beds of conglomerate and pebbly mudstone, with the distinction based chiefly on the abundance and size of clasts. Some interbedded siltstone with dispersed sand-sized grains is present, particularly in the upper part of the section; some of these siltstone beds contain plant fossils, a few of which appear to be in growth position. No bioturbation has been noted in the unit. At the base of the type section, the Klamath River Conglomerate Member contains a coarse sedimentary breccia that grades locally into conglomerate.

The conglomerate clasts in the type section of the Klamath River Conglomerate Member consist mostly of metavolcanic rocks derived from the underlying Applegate Group, with subordinate amounts of resistant quartzose clasts (table 1). Near the top of the unit are small amounts of sandstone clasts that may possibly represent reworking of eroded fragments of the Klamath River Conglomerate Member itself, or of fragments of a previously deposited Mesozoic sandstone no longer preserved because of erosion on the basal unconformity. The uniformity of clast composition and the relative angularity of the clasts indicate that the sedimentary material was derived chiefly from the underlying basement, without long distances of transport.

Adjacent to its type section, in roadcuts along the northbound lane of Interstate Highway 5, a thinner section of the Klamath River Conglomerate Member is exposed. Here, the basal unconformity and contact with the overlying Osburger Gulch Sandstone Member are well exposed. The Klamath River Conglomerate Member here is lithologically similar to the type section, consisting of interbedded matrix-supported conglomerate and pebbly mudstone; however, it contains finer conglomerate and thinner beds of conglomerate than in the type section. The base of the member here consists of a red, nodular, nonpebbly mudstone that grades upward from a whitish-weathering paleosol that caps the underlying metavolcanic rocks. This red mudstone, which is about 2 m thick, may also partly consist of paleosol materials.

The Klamath River Conglomerate Member south of its type section consists of reddish-weathering conglomerate with subordinate amounts of sandstone, siltstone, and mudstone. It generally contains a basal breccia or a paleosol at its base, overlain by conglomerate. In most areas adjacent to the Shasta Valley and Yreka, it consists of clast-supported, well-rounded, imbricated, polymict conglomerate with interbedded cross-stratified to parallel-stratified medium- and coarse-grained sandstone, ripple-marked fine-grained sandstone and siltstone, and massive silty mudstone that contains thin paleosols and very thin coal seams. Plant fossils are common in these southern exposures, both as larger fragments of leaves, branches, and trunks in the coarser-grained strata and as roots of plants in growth position in the finer-grained strata. Conglomerate clasts in the southern exposures include major amounts of metavolcanic rocks, metasedimentary rocks, quartzite, chert, and (locally) granitic rocks and possibly peridotite.

The best exposures of the Klamath River Conglomerate Member in the Yreka-Shasta Valley area are roadcuts along Oberlin Road east of Yreka, in the NE corner of sec. 35, T. 45 N., R. 7 W., Yreka 15-minute quadrangle. This section is a good reference section, one that could be adopted if the type section were ever destroyed. The basal contact is not exposed, but the upper contact with the Osburger Gulch Sandstone Member is well exposed. About 75 m of the Klamath River Conglomerate Member is exposed here. The lowermost 22 m consists of interbedded conglomerate, conglomeratic sandstone, and medium- to coarse-grained sandstone. These units form lens-shaped beds characterized by abundant channeling, medium- to large-scale crossbedding, and fining-upward couplets of channel conglomerate and sandstone. In this outcrop, all of the conglomerate is clast supported, in contrast to the type section. The overlying approximately 50 m consists of conglomerate, sandstone, and mudstone that are organized into fining-upward cycles with channelized bases. These cycles range from less than 2 m to almost 10 m in thickness. Paleosols, coal seams, and fossil plant roots are present in the mudstone strata at the top of the cycles.

North of its type area, the Klamath River Conglomerate Member is commonly not present or consists of a thin unit of basal conglomerate or conglomeratic grus at the contact of the Hornbrook Formation with basement rocks. In a roadcut exposure adjacent to the southbound lanes of Interstate Highway 5 near the Siskiyou Summit (NW¼NW¼ sec. 21, T. 40 S., R. 2 E., Ashland 15-minute quadrangle), the basal layers of the Hornbrook Formation on the Mount Ashland plutonic complex of Wells (1956) consist of 5.12 m of conglomeratic grus with some interbedded coarse-grained sandstone (Nilsen and others, 1984, stop 1). The basal 4.10 m consist of a massive to poorly stratified mixture of granitic or quartz dioritic grus, derived from the underlying plutonic rocks, and scattered angular to well-rounded clasts of quartzite, chert, and metavolcanic rocks that are as long as 10 cm. The overlying 1.02 m consist of two massive beds of conglomeratic, very coarse-grained sandstone that grade reversely upward into conglomerate that contains clasts as long as 10 cm. The sandstone and conglomerate matrix consists almost wholly of grus-like sediment derived from the underlying plutonic rocks. No molluscan or plant fossils or paleosols are present in this exposure of the Klamath River Conglomerate Member.

Farther north, in the Dark Hollow and Jacksonville areas, the Klamath River Conglomerate Member consists

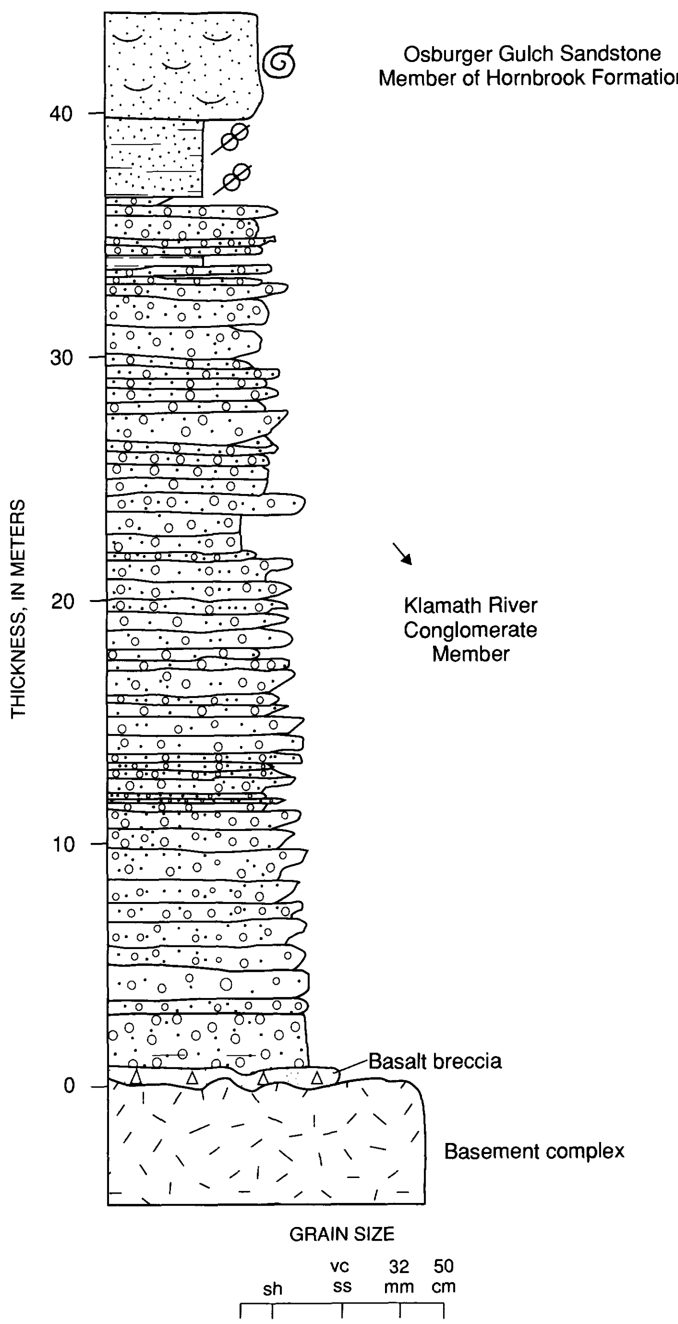


FIGURE 10.—Type section of the Klamath River Conglomerate Member (including basal breccia) of the Hornbrook Formation. sh, shale; vc, very coarse grained; ss, sandstone.

mostly of polymict conglomerate resting directly on the basement complex. The best exposure of the unit is in a quarry west of Talent (SW¼NE¼ sec. 21, T. 38 S., R. 1 W., Medford 15-minute quadrangle), where conglomerate consisting of metavolcanic rocks, metasedimentary rocks, granitic rocks, quartzite, and chert is exposed. This conglomerate contains clasts that are as long as 25 cm and are well rounded to angular. The conglomerate beds are reverse graded and matrix supported, similar to those in the type section. Other reverse-graded, matrix-supported, poorly sorted conglomeratic beds of the Klamath River Conglomerate Member crop out in the Jacksonville area.

STRATIGRAPHIC RELATIONS

The Klamath River Conglomerate Member rests directly on either the pre-Cretaceous basement rocks of the Klamath Mountains or a paleosol developed on those rocks. It generally rests with profound angular unconformity on metasedimentary or metavolcanic rocks, but locally it rests nonconformably on Jurassic plutonic rocks. Where it is not present, the Osburger Gulch Sandstone Member rests directly on the various basement rocks.

The Klamath River Conglomerate Member is conformably overlain everywhere by the Osburger Gulch Sandstone Member. This contact is generally marked by the abrupt upward lithologic change from conglomeratic beds with some interbedded sandstone and mudstone to resistant, cross-stratified, massive bluffs of calcareous sandstone that contain some fine conglomerate in crossbed troughs. The lower beds of sandstone of the Osburger Gulch Sandstone Member typically form steep bluffs capped by large outcrops of sandstone that contrast strongly with the less resistant beds of the Klamath River Conglomerate Member.

In the Hornbrook area, the basal part of the Osburger Gulch Sandstone Member consists of a less resistant siltstone unit that is 3–15 m thick (see description of the type section of the Klamath River Conglomerate Member). This siltstone contains marine

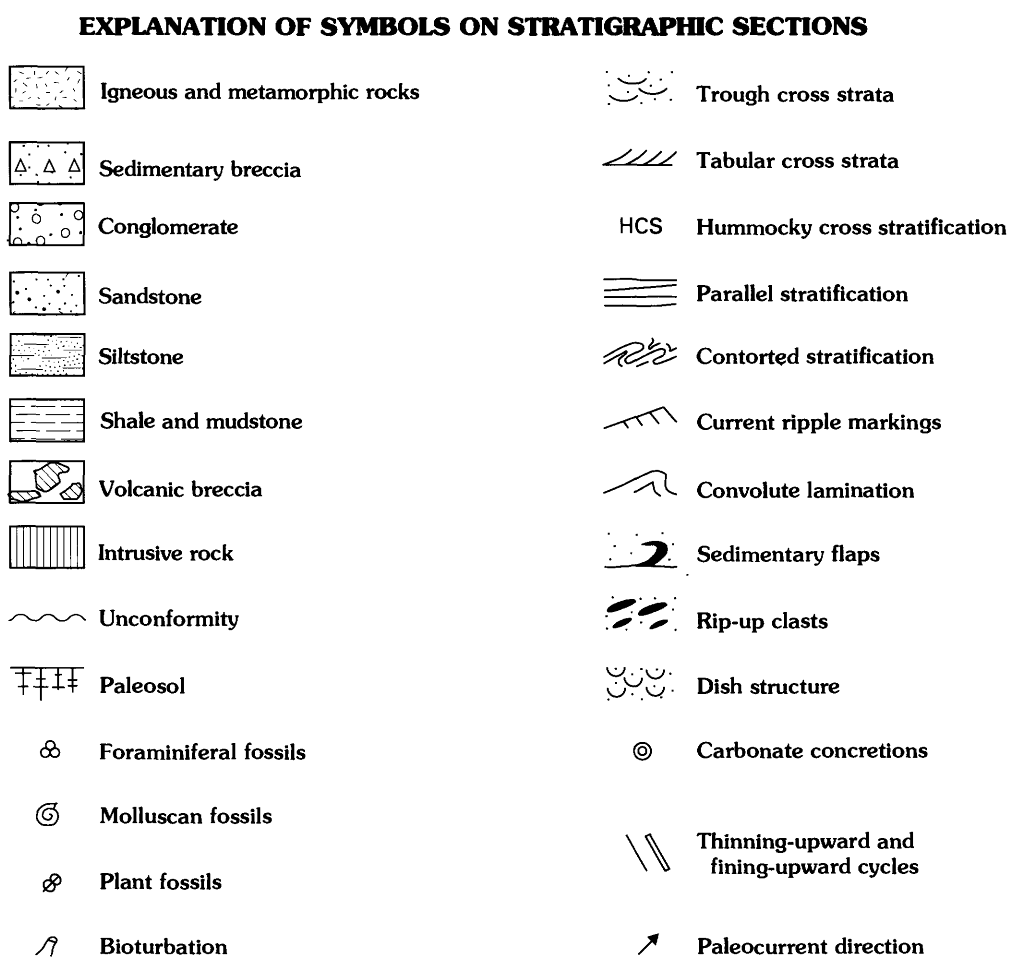


FIGURE 10.—Continued.

TABLE 1.—*Composition of conglomerate clasts in the type section of the Klamath River Conglomerate Member*

[Data are from Barats and others (1984, table 1) and are based on three random samples of 100 clasts larger than 2 cm in longest dimension]

	Location of pebble count		
	At contact with basement	3.8 m above basal contact	35.3 m above basal contact
Metavolcanic rocks	91	95	93
Metasedimentary rocks	0	1	1
Quartzite	1	0	—
Chert (including jasper)	8	4	3
Sandstone	0	0	3
Total	100	100	100

megafossils and marine burrows, which are not present in the underlying Klamath River Conglomerate Member. This siltstone unit was recognized by Peck and others (1956, p. 1978) as unit 1 of their member I. They described it as 8.7 m thick, sandy, soft, poorly sorted, and nonbedded, with minor amounts of granules and pebbles. At the type section of the Osburger Gulch Sandstone Member along Osburger Gulch east of the Klamath River (SW¼ sec. 33, T. 47 N., R. 6 W., Hornbrook 15-minute quadrangle), it underlies most of the covered interval between the first massive sandstone beds of the Osburger Gulch Sandstone Member and the metavolcanic basement rocks.

The upper contact of the Klamath River Conglomerate Member with the Osburger Gulch Sandstone Member thus is generally abrupt, apparently marking the change from nonmarine to marine conditions of sedimentation. However, locally there is some intermixing of the units over a thickness of a few meters, or the presence of sedimentary rocks that are transitional between the two units.

Lateral contacts of the Klamath River Conglomerate Member cannot be seen in outcrop. Prior to the stripping away of much of the Hornbrook Formation from the Klamath Mountains to the southwest, it probably persisted in all directions as a laterally discontinuous, thin conglomeratic unit resting directly on the basement and forming the basal part of the Hornbrook Formation.

THICKNESS

The Klamath River Conglomerate Member ranges in thickness from 0 to possibly as much as 90 m. At its type section, it is 36.50 m thick (fig. 10), but several hundred meters to the east it is about 11 m thick, and several hundred meters farther east, near Osburger Gulch, it may be only a few meters thick. At the reference section along Oberlin Road east of Yreka, it is about 49 m thick, but because its lower part is not exposed, it might be 5–10 m thicker. Along the southbound lane of Interstate Highway 5 near the Siskiyou Summit, where it consists mostly of grus and conglomerate resting directly on the Mount Ashland plutonic complex, it is 5.12 m thick. In many areas along the northern Cottonwood Creek valley and southern Bear Creek valley areas, it appears to be either absent or very thin, because marine sandstone of the Osburger Gulch Sandstone Member rests directly on basement. In the Dark Hollow area, it is generally 0–15 m thick.

DEPOSITIONAL ENVIRONMENT

The Klamath River Conglomerate Member, as defined herein, is wholly nonmarine in origin and was deposited in at least three different depositional environments: (1) debris-flow and mudflow-dominated alluvial fans, (2) braided to meandering fluvial systems, and (3) residuum in the form of either weathered blocks of basement rocks derived from the directly underlying basement or granitic grus, mixed with some rounded and transported pebbles. In addition, paleosols developed within the Klamath River Conglomerate Member form an important part of some sections.

At its type section, the Klamath River Conglomerate Member was probably deposited as a small alluvial fan (Nilsen and others, 1984, stop 2). It consists almost wholly of matrix-supported debris-flow conglomerate and pebbly mudstone; these deposits were probably formed by subaerial debris flows and mudflows, most likely on a small alluvial fan within the uplifted Klamath Mountains block. The fan was subsequently overlapped by the transgressing Cretaceous sea. Bourgeois and Leithold (1983, p. 11) and Bourgeois (1984), who also infer an alluvial-fan origin for these red beds in the type section, note the presence of thin beds of tuffaceous silty sandstone in the red beds; I have not observed any tuffaceous material in the Klamath River Conglomerate Member, despite a careful search for it.

At its reference section east of Yreka, the massive conglomerate and cross-stratified conglomeratic sandstone in the lower part of the Klamath River Conglomerate Member were probably deposited by braided streams (Nilsen and others, 1984, stop 3). The fining-upward cycles of conglomerate, sandstone, and mudstone in the upper part of the section were probably deposited by more sinuous, possibly meandering streams. The mudstone units, which contain plants in growth position and interstratified paleosols, were probably deposited on flood plains.

At the base of most sections of the Klamath River Conglomerate Member are weathered angular blocks of the basement complex that probably formed largely by weathering of the basement with little or no transport. Where plutonic rocks form the basement, a conglomeratic grus forms the base of the Klamath River Conglomerate Member. Paleosols are locally thick and well developed on the basement directly beneath the conglomerate.

AGE AND CORRELATION

No fossil or radiometric ages have been determined from the Klamath River Conglomerate Member. The youngest rocks that it rests on are felsic plutons in the northern Klamath Mountains. The Mount Ashland pluton has yielded potassium-argon ages of 146, 147, 151, 152, 164, and 167 Ma, and the Jacksonville pluton has yielded potassium-argon ages of 137±4.1 and 141±4.2 Ma (Lanphere and others, 1968; Hotz, 1971; Fiebelkorn and others, 1983; M. A. Lanphere, oral commun., September 2, 1983; Irwin, 1984, and oral commun., February 11, 1984). Since the Jurassic-Cretaceous boundary is generally placed at 144 Ma (Harland and others, 1982; Palmer, 1983), these ages suggest that the Klamath River Conglomerate Member must be post-Jurassic in age.

The youngest possible age of the member is constrained by paleontologic dating of the overlying marine Osburger Gulch Sandstone Member, which is locally fossiliferous in its basal parts. The oldest ages reported from basal marine strata of the Hornbrook Formation (listed from northwest to southeast) are Albian in the Grave Creek area (Jones, 1960b); late Albian(?) to early Cenomanian in the Dark Hollow area (Peck and others, 1956); middle Turonian in the Bear Creek valley area, the type area, parts of the Shasta Valley area, and the outlier west of Yreka along Soap Creek Ridge (app. I); and possibly early Coniacian in part of the Black Mountain area (Sliter and others, 1984). From these ages, the Osburger Gulch Sandstone Member is clearly time-transgressive from northwest to southeast.

Thus, although the Klamath River Conglomerate Member could possibly range in age from earliest Cretaceous (or even latest Jurassic, locally) to early Coniacian, it is most likely Albian, Cenomanian, and Turonian in age because it conformably underlies the basal marine strata of the Hornbrook Formation. There is no way to determine (because of the lack of age-diagnostic fossils within it) if the Klamath River Conglomerate Member is also time-transgressive or if it has significant variations areally in its age.

The Klamath River Conglomerate Member is probably correlative with marine sedimentary rocks of the Hudspeth and Gable Creek Formations in central Oregon near Mitchell (Wilkinson and Oles, 1968; Kleinhans and others, 1984), with the Bernard Formation (Dickinson and Vigrass, 1965) in the Suplee area, and with rocks in the subsurface Ochoco basin (Thompson and others, 1984). Because the oldest possible age of the Klamath River Conglomerate Member is so poorly constrained, it is possible that the member is partly correlative with Lower Cretaceous marine sedimentary rocks of the Days Creek Formation in the Days Creek and Riddle areas (Imlay and others, 1959; Popenoe and others, 1960). It could possibly partly correlate with Lower Cretaceous sedimentary rocks along the coast of southwestern Oregon, with the Humbug Mountain Conglomerate and the Rocky Point Formation of Koch (1966), and possibly with some other poorly dated Cretaceous units discussed by Dott (1971, p. 26). To the south, in California, it is correlative with parts of the Great Valley sequence on the west side of the Sacramento Valley (Ingersoll, 1979), the Budden Canyon Formation of Murphy and others (1969) at the northwestern edge of the Sacramento Valley, and possibly older parts of the Chico Formation on the east side of the Sacramento Valley.

OSBURGER GULCH SANDSTONE MEMBER

DEFINITION

The name "Osburger Gulch Sandstone Member" was applied by Nilsen (1984a) to continuous outcrops of marine sandstone strata in the lower part of the

Hornbrook Formation. The member was named for exposures in Osburger Gulch, located about 3.5 km south of Hornbrook, California (figs. 8, 11). The type section was measured near the mouth of and along the north flank of Osburger Gulch, which is located east of and across the Klamath River from the type section of the Klamath River Conglomerate Member (fig. 8).

The Osburger Gulch Sandstone Member is, in ascending stratigraphic order, the second lowest member of the Hornbrook Formation. It is equivalent to the upper part of member I (units 2–6) and the lower part of member II (unit 7) (of Hornbrook Formation) as mapped by Peck and others (1956) (fig. 6). The Osburger Gulch Sandstone Member is also equivalent to the lower part of unit A (of Hornbrook Formation) of Jones (1959), the upper part of the unnamed lower arenaceous member (of Hornbrook Formation) of Elliott (1971), the upper part of unit Khs_1 (of Hornbrook Formation) of McKnight (1971), unit A (of Hornbrook Formation) of M.A. Elliott (unpub. data, 1980), and units a and s (of Hornbrook Formation) as mapped by Nilsen and others (1983).

The Osburger Gulch Sandstone Member rests either conformably on the Klamath River Conglomerate Member of the Hornbrook Formation or unconformably on Paleozoic and Mesozoic igneous and metamorphic rocks where the Klamath River Conglomerate Member is absent. It is overlain conformably by the Ditch Creek Siltstone Member of the Hornbrook Formation.

The lower boundary of the Osburger Gulch Sandstone Member is defined either by the first fossiliferous beds of sandstone, siltstone, or conglomerate, or by the unconformable depositional contact on the basement rocks. Several meters of paleosol, thin residual breccia, or conglomeratic grus derived from weathering of the basement rocks may be present locally on the top of the basement rocks; the breccia and conglomeratic grus form part of the underlying Klamath River Conglomerate Member, but they are commonly too thin to map at a scale of 1:62,500. The lower boundary is generally marked by massive beds of trough cross-stratified, well-sorted, conglomeratic sandstone with rare molluscan megafossils and trace fossils. The massive beds underlie ridge crests, particularly in the Shasta Valley area.

The lower boundary of the Osburger Gulch Sandstone Member in its type area, however, is marked by beds of siltstone and very fine-grained sandstone that contain sparse molluscan megafossils and rest directly on the subaerial debris-flow and mudflow deposits of the Klamath River Conglomerate Member. In most of the outcrop area of the Hornbrook Formation, this basal siltstone unit is absent.

The upper boundary of the Osburger Gulch Sandstone Member is marked by an abrupt to gradational change from dominantly resistant sandstone to less resistant siltstone of the Ditch Creek Siltstone Member. This contact, like the lower one, is typically marked by a major topographic bench. The upper boundary is arbitrarily placed at the top of the highest bed of well-sorted, resistant fine-grained sandstone.

AREAL EXTENT

The Osburger Gulch Sandstone Member extends continuously along the entire outcrop extent of the Hornbrook Formation as a ridge-forming unit (fig. 5; pl. 1). It appears to always be present in the lower part of the Hornbrook Formation. It is also present in each of the outliers of the Hornbrook Formation west of the main outcrop belt, such as those west of Jacksonville and west of Yreka.

The northernmost outcrops of the Osburger Gulch Sandstone Member are almost 3 km north-northwest of Jacksonville in secs. 19, 20, 29, 38, and 39, T. 37 S., R. 2 W., Medford 15-minute quadrangle. Wells (1956), Beaulieu and Hughes (1977), and Smith and others (1982) show the Hornbrook Formation, which in this area probably consists of the Osburger Gulch Sandstone Member, extending farther to the north of Jacksonville. On the map of Beaulieu and Hughes (1977) of Jackson County, Oregon, it is shown as far north as secs. 61, 62, and 63, T. 36 S., R. 2 W., Medford 15-minute quadrangle, about 4.5 km south of the Rogue River. However, none of these maps show any strikes and dips measured from the Hornbrook Formation. Detailed examination of this area failed to reveal any outcrops or rubble of the Osburger Gulch Sandstone Member (Nilsen and others, 1983), although it probably does extend farther north in subsurface beneath the Bear Creek valley, resting on either basement rocks or on the Klamath River Conglomerate Member.

The southernmost outcrops of the Osburger Gulch Sandstone Member are located southeast and southwest of Yreka, at the southern limit of the Hornbrook Formation, in secs. 5 and 6, T. 44 N., R. 6 W., sec. 1, T. 44 N., R. 7 W., and sec. 1, T. 44 N., R. 8 W., Yreka 15-minute quadrangle. The outcrops of the Osburger Gulch Sandstone Member are discontinuous in the Shasta Valley-Yreka area as a result of extensive faulting.

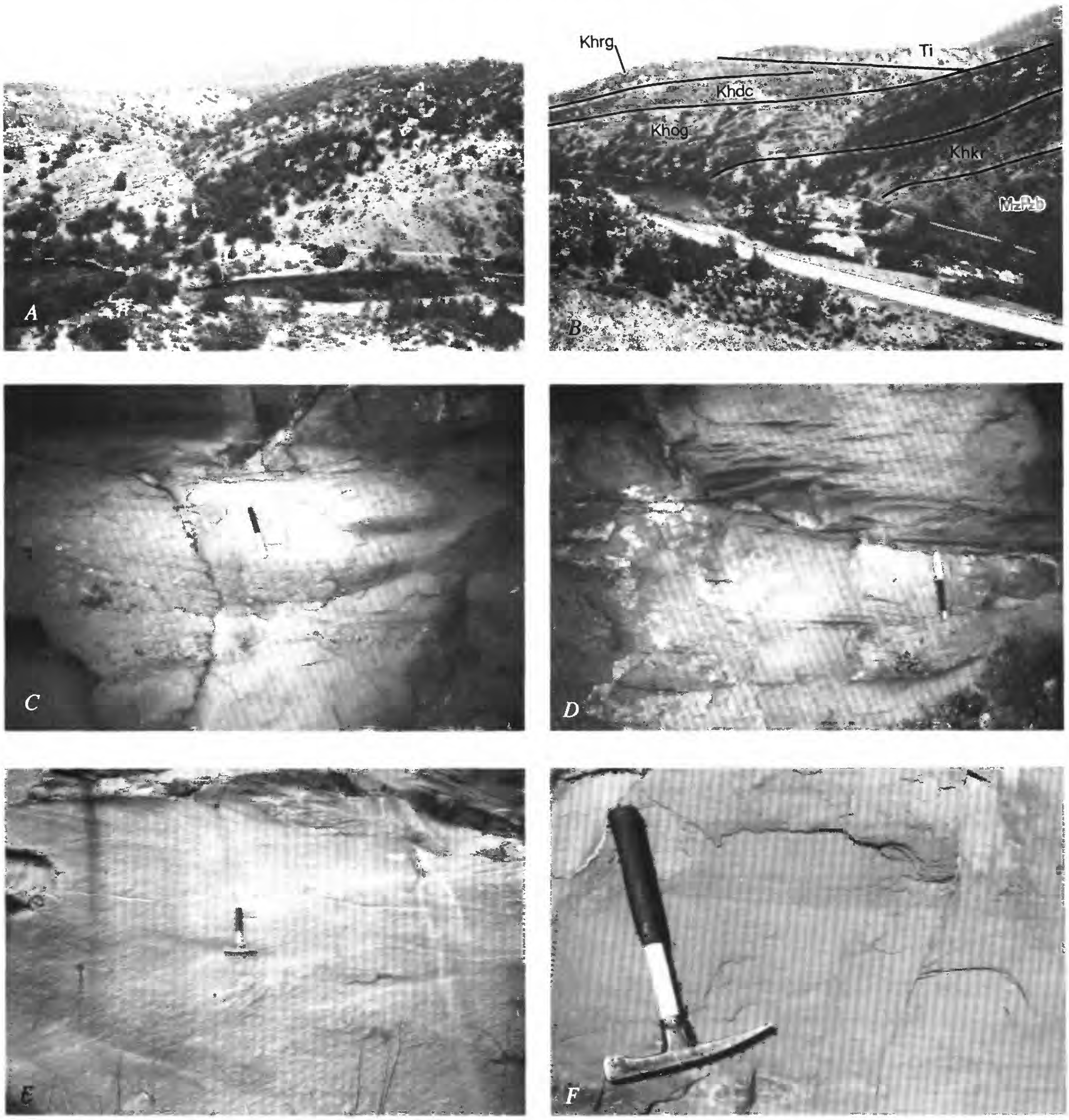


FIGURE 11.—Type section of the Osburger Gulch Sandstone Member of the Hornbrook Formation. *A* and *B*, View northeast across Klamath River of type section adjacent to Osburger Gulch. MzPzb, Paleozoic and Mesozoic basement complex; Khkr, Cretaceous Klamath River Conglomerate Member (of Hornbrook Formation); Khog, Cretaceous Osburger Gulch Sandstone Member (of Hornbrook Formation); Khdc, Cretaceous Ditch Creek Siltstone Member (of Hornbrook Formation); Khrg, Cretaceous Rocky Gulch Sandstone Member (of Hornbrook Formation); Ti, Tertiary intrusive rocks. Northbound lanes of Interstate Highway 5 in foreground. *C* and *D*, Trough cross-stratified sandstone, Osburger Gulch. *E* and *F*, Parallel-laminated and hummocky cross-stratified sandstone, Osburger Gulch. Note megafossils in carbonate concretions below hammer (*F*). Pen (in *C* and *D*) is 14 cm long; rock hammer (in *E* and *F*) is 35 cm long.

TYPE SECTION

The type section of the Osburger Gulch Sandstone Member of the Hornbrook Formation was measured along the northern margin of Osburger Gulch near its confluence with the Klamath River in SW¼ sec. 33, T. 47 N., R. 6 W., Hornbrook 15-minute quadrangle. The section is about 116.5 m thick (fig. 12). It is almost completely exposed except for the basal siltstone and very fine grained platy sandstone unit at its base, which is covered, as is the basal contact with the Klamath River Conglomerate Member. However, the basal siltstone unit was measured at the type section of the Klamath River Conglomerate Member, and the thickness of that unit (15.5 m) is used in this type section.

	Thickness (in meters)
Hornbrook Formation (lower part):	
Ditch Creek Siltstone Member (lower part):	
Siltstone, massive, bioturbated, poorly exposed	5.00
Conformable contact.	
Osburger Gulch Sandstone Member:	
Sandstone, fine-grained, massive	1.00
Sandstone, very fine grained, silty, thoroughly bioturbated	.70
Covered interval (float of sandstone, very fine grained, silty, bioturbated)	.50
Sandstone, fine-grained, laminated to trough cross-stratified	.70
Covered interval (float of sandstone, very fine grained, silty, bioturbated)	.70
Sandstone, fine-grained, laminated to massive	1.10
Sandstone, very fine grained, silty, bioturbated, partly covered	1.60
Sandstone, fine-grained, massive, thoroughly bioturbated; some molluscan fossils	1.20
Sandstone, fine- to medium-grained, massive, thoroughly bioturbated; some molluscan fossils	.60
Covered interval (float of sandstone, very fine grained, silty, bioturbated)	.50
Sandstone, fine-grained, massive; scattered molluscan fossils, locally bioturbated	2.90
Sandstone, fine-grained, laminated	.30
Sandstone, fine- to medium-grained, massive to trough cross-stratified, locally parallel-stratified and hummocky cross-stratified; scattered molluscan fossils; some pebbles at base; maximum clast size 2 cm	4.50
Conglomerate and conglomeratic sandstone; some lenses of sandstone, medium- to coarse-grained; maximum clast size 7 cm; abundant broken molluscan shells	1.05
Sandstone, fine-grained; wavy stratification	.25
Conglomerate; maximum clast size 2 cm; scattered molluscan fossils; thin lenses of sandstone	.60
Osburger Gulch Sandstone Member—*Continued*:	
Sandstone, fine-grained, silty; low-angle trough cross-strata and parallel stratification; some scattered lenses with molluscan fossils, bioturbated, concretionary	6.90
Sandstone, fine- to medium-grained, massive; scattered molluscan fossils, concretionary	.70
Sandstone, fine- to medium-grained; low-angle trough cross-strata	1.00
Sandstone, fine- to medium-grained; scattered molluscan fossils, concretionary	.25
Sandstone, fine- to medium-grained; trough cross-strata and crude parallel-strata, bioturbated	1.50
Sandstone, fine- to medium-grained; scattered molluscan fossils, concretionary	.22
Sandstone, fine- to medium-grained; trough cross-strata, bioturbated	2.60
Sandstone, fine-grained; trough cross-strata and parallel-strata; hummocky cross-strata at top	1.00
Sandstone, very fine grained to fine-grained, thoroughly bioturbated	.80
Sandstone, fine- to medium-grained, massive at base to parallel-stratified at top; erosive base	.60
Sandstone, fine-grained; hummocky cross-strata	.50
Conglomerate; maximum clast size 8 cm; scattered molluscan fossils	.10
Sandstone, fine-grained, bioturbated	.10
Sandstone, fine- to medium-grained; scattered pebbles; maximum clast size 3 cm; hummocky cross-strata	1.50
Sandstone, medium- to coarse-grained, conglomeratic; maximum clast size 3 cm; abundant molluscan fossils; erosive base	.60
Sandstone, fine-grained, thoroughly bioturbated	.10
Sandstone, fine- to medium-grained; hummocky cross-strata	.60
Sandstone, fine-grained, thoroughly bioturbated	.40
Sandstone, fine- to medium-grained; low-angle trough cross-strata at base and hummocky cross-strata at top	1.20
Sandstone, fine-grained, thoroughly bioturbated	1.30
Sandstone, fine- to medium-grained, parallel-stratified and hummocky cross-stratified	2.40
Sandstone, very fine grained, thoroughly bioturbated	1.00
Sandstone, fine- to medium-grained, conglomeratic; maximum clast size 6 cm; parallel-strata and hummocky cross-strata; scattered plant fossils	1.50
Conglomerate; maximum clast size 13 cm; lens-shaped	.30
Sandstone, very fine grained to fine-grained; trough cross-strata at base; parallel-strata and hummocky cross-strata at top, bioturbated	1.10
Conglomerate; maximum clast size 10 cm	.15

	Thickness (in meters)
Osburger Gulch Sandstone Member—*Continued*:	
Sandstone, fine-grained; trough cross-strata in lower part; parallel-strata and hummocky cross-strata in upper part	2.00
Conglomerate; maximum clast size 10 cm	.10
Sandstone, fine-grained; parallel-strata and hummocky cross-strata	.50
Conglomerate; maximum clast size 5 cm; scattered molluscan fossils	.07
Sandstone, fine-grained; parallel-strata and hummocky cross-strata	1.00
Conglomerate; maximum clast size 10 cm; erosive base	.23
Sandstone, very fine grained to fine-grained; parallel-strata and hummocky cross-strata	.40
Sandstone, fine- to medium-grained, massive	1.40
Conglomerate; maximum clast size 15 cm; channeled base	1.40
Sandstone, medium- to coarse-grained, lens-shaped	.10
Conglomerate; maximum clast size 32 cm; channeled base	.65
Sandstone, coarse- to very coarse grained; scattered pebbles; maximum clast size 5 cm; trough and tabular cross-strata; channeled base	2.40
Sandstone, fine-grained, thoroughly bioturbated	.50
Sandstone, fine-grained; scattered granules and pebbles; maximum clast size 0.5 cm; parallel strata and hummocky cross-strata	.80
Sandstone, fine-grained; scattered pebbles; maximum clast size 6 cm; massive to low-angle cross-strata, bioturbated	.50
Conglomerate; maximum clast size 6 cm	.20
Conglomeratic sandstone; maximum clast size 3 cm; trough cross-strata; erosive base	2.80
Sandstone, medium- to coarse-grained at base, fine-grained at top; scattered pebbles in lower part; maximum clast size 2 cm; massive at base to trough cross-stratified at top	.45
Conglomeratic sandstone; maximum clast size 10 cm; massive; molluscan fossil debris at base	.40
Sandstone, medium- to coarse-grained; scattered pebbles; maximum clast size 2 cm; massive to trough cross-stratified	1.20
Conglomerate; maximum clast size 4 cm	.03
Sandstone, fine-grained to very coarse grained; massive, bioturbated	.25
Conglomeratic sandstone; maximum clast size 7 cm; massive	.80
Conglomerate; maximum clast size 7 cm; massive	.30
Conglomerate; maximum clast size 1 cm; massive	.12
Sandstone, medium-grained, massive	.10
Conglomerate; maximum clast size 7 cm; massive	.65
Sandstone, fine-grained; scattered pebbles; maximum clast size 5 cm; parallel-strata and trough cross-strata, bioturbated	.90

	Thickness (in meters)
Osburger Gulch Sandstone Member—*Continued*:	
Conglomerate; maximum clast size 3 cm; massive; erosive base	.03
Sandstone, very coarse grained; low-angle trough cross-strata	.03
Conglomerate; maximum clast size 2 cm; reverse graded	.12
Sandstone, very fine grained to fine-grained, thoroughly bioturbated	.45
Conglomeratic sandstone; maximum clast size 3 cm; trough cross-strata	.60
Sandstone, fine- to medium-grained; scattered pebbles; maximum clast size 1 cm; massive at base; tabular cross-strata at top	1.55
Conglomeratic sandstone; maximum clast size 0.5 cm; massive, bioturbated	.95
Conglomerate; maximum clast size 3 cm; massive	.14
Sandstone, medium-grained, massive	.05
Conglomerate; maximum clast size 2 cm; massive	.20
Sandstone, medium-grained, massive	.05
Conglomerate; maximum clast size 6 cm; massive	.10
Sandstone, very coarse grained, massive	.12
Conglomerate; maximum clast size 9 cm; massive	.15
Sandstone, very coarse grained, low-angle cross-strata	.20
Conglomerate; maximum clast size 3 cm; massive	.03
Conglomeratic sandstone; maximum clast size 4 cm; massive	.40
Conglomeratic sandstone; maximum clast size 0.5 cm; trough cross-strata	.10
Conglomerate; maximum clast size 8 cm; massive	.50
Granule conglomerate; tabular cross-strata; lens-shaped	.08
Conglomerate; maximum clast size 7 cm; massive	.14
Granule conglomerate; tabular cross-strata; lens-shaped	.12
Conglomerate; maximum clast size 5 cm; massive	.05
Sandstone, medium- to coarse-grained; small-scale trough cross-strata	.55
Sandstone, fine-grained, massive, bioturbated	.05
Sandstone, medium-grained; lens of conglomerate near top with maximum clast size 2 cm; small-scale trough cross-strata	3.20
Sandstone, medium- to coarse-grained; small-scale trough cross-strata; mudstone rip-up clasts	2.55
Conglomerate; maximum clast size 7 cm; massive	.40
Sandstone, fine-grained, massive	.23
Covered interval (float of sandstone)	9.00
Sandstone, fine-grained, massive	.60
Sandstone, very fine grained to fine-grained, massive, bioturbated	.10
Sandstone, fine- to medium-grained, massive to parallel-stratified	.80

	Thickness (in meters)
Osburger Gulch Sandstone Member—*Continued*:	
Sandstone, very fine grained to fine-grained, massive, bioturbated	.70
Sandstone, fine- to medium-grained, massive to parallel-stratified; scattered fragments of plant fossils	.80
Sandstone, fine-grained, massive, bioturbated	.08
Sandstone, medium-grained, massive to parallel-stratified	.18
Sandstone, fine- to medium-grained, massive; molluscan fossils, bioturbated	.35
Sandstone, medium-grained, massive; scattered fragments of plant fossils	.18
Sandstone, very fine grained to fine-grained; abundant molluscan fossils in growth positions	3.00
Covered interval (float of sandstone)	1.20
Sandstone, medium- to coarse-grained; trough cross-stratified	1.00
Covered interval (float of sandstone)	1.00
Conglomeratic sandstone, coarse-grained; maximum clast size 3 cm; trough cross-stratified	2.00
Covered interval (float of siltstone of lower part of Osburger Gulch Sandstone Member)	15.50
Total thickness of the Osburger Gulch Sandstone Member	116.50
Conformable contact.	
Klamath River Conglomerate Member:	
Covered interval (float of conglomerate and pebbly mudstone)	8.00
Conglomerate; maximum clast size 6 cm; matrix supported; mudstone matrix; clasts subangular to subrounded; reddish weathering	4.50
Unconformable contact.	
Covered interval (float of basement complex)	11.00
Applegate Group (basement complex):	
Metasedimentary and metavolcanic rocks of Triassic age	

The color of sandstone from the Osburger Gulch Sandstone Member is generally medium gray (N5) on fresh, unweathered surfaces, and moderate yellowish brown (10YR 5/4) on weathered surfaces. The interbedded conglomerate may have a darker color because of its abundant dark clasts.

LITHOLOGY

The Osburger Gulch Sandstone Member consists mostly of sandstone, but it also includes some conglomerate, siltstone, and shale. In the type section, it consists almost wholly of sandstone, conglomeratic sandstone, and conglomerate, except for the poorly exposed basal siltstone unit that is about 15.5 m thick. Molluscan fossils are very common locally, both in growth position and as transported clasts. Plant fossil fragments are present locally on some bedding surfaces. Bioturbation is common and generally increases in abundance upward within the member; in the upper part of the member, beds of fine-grained sandstone are locally so thoroughly bioturbated that no remnants of any original stratification remain.

Conglomeratic clasts in the type section of the Osburger Gulch Sandstone Member consist principally of a mixture of metavolcanic and metasedimentary rocks derived from the underlying Applegate Group (56 percent), and quartzite and chert (41 percent). A small number of granitic or dioritic clasts is also present (table 2). Along the southbound lane of Interstate Highway 5, about 0.5 km west of the type section, conglomerate clasts in the Osburger Gulch Sandstone Member consist of metavolcanic and metasedimentary rocks from the underlying Applegate Group (63 percent), quartzite and chert (33 percent), and granitic or dioritic clasts (4 percent). Conglomerate clasts in the Osburger Gulch Sandstone Member to the north and south of the type area are more variable in composition but generally consist of metavolcanic or metasedimentary rocks, quartzite, chert, and granitic or dioritic clasts.

The basal part of the Osburger Gulch Sandstone Member in its type area consists of about 15.5 m of nonresistant siltstone that is best exposed along the northbound lane of Interstate Highway 5, about 0.5 km west of the type section. This siltstone contains scattered but locally abundant molluscan fossils and abundant plant fossil fragments. The siltstone is micaceous and carbonaceous, commonly with platy or scaly structure. The siltstone is generally thoroughly bioturbated, but locally it is laminated and ripple laminated. Very fine grained sandstone is present as both laminae and as grains scattered in the siltstone. This basal siltstone unit is present only in the type area and, in particular, in the type section; it is apparently a thin lens that pinches out within a few kilometers to the northwest and southeast.

Overlying the basal siltstone in the type area is a very resistant sandstone unit that forms rugged sandy bluffs. This sandstone unit is about 5 m thick in the type section, although much of it is covered there, and is as much as 50 m thick in other areas. This sandstone unit consists chiefly of thick beds of large-scale trough cross-stratified, conglomeratic, medium-grained to very coarse grained sandstone. Conglomerate is generally randomly distributed in the sandstone or is concentrated as thin lenses in the axes of trough cross-strata. This resistant sandstone unit was mapped separately by Nilsen and others (1983) as unit s (of Hornbrook Formation), which

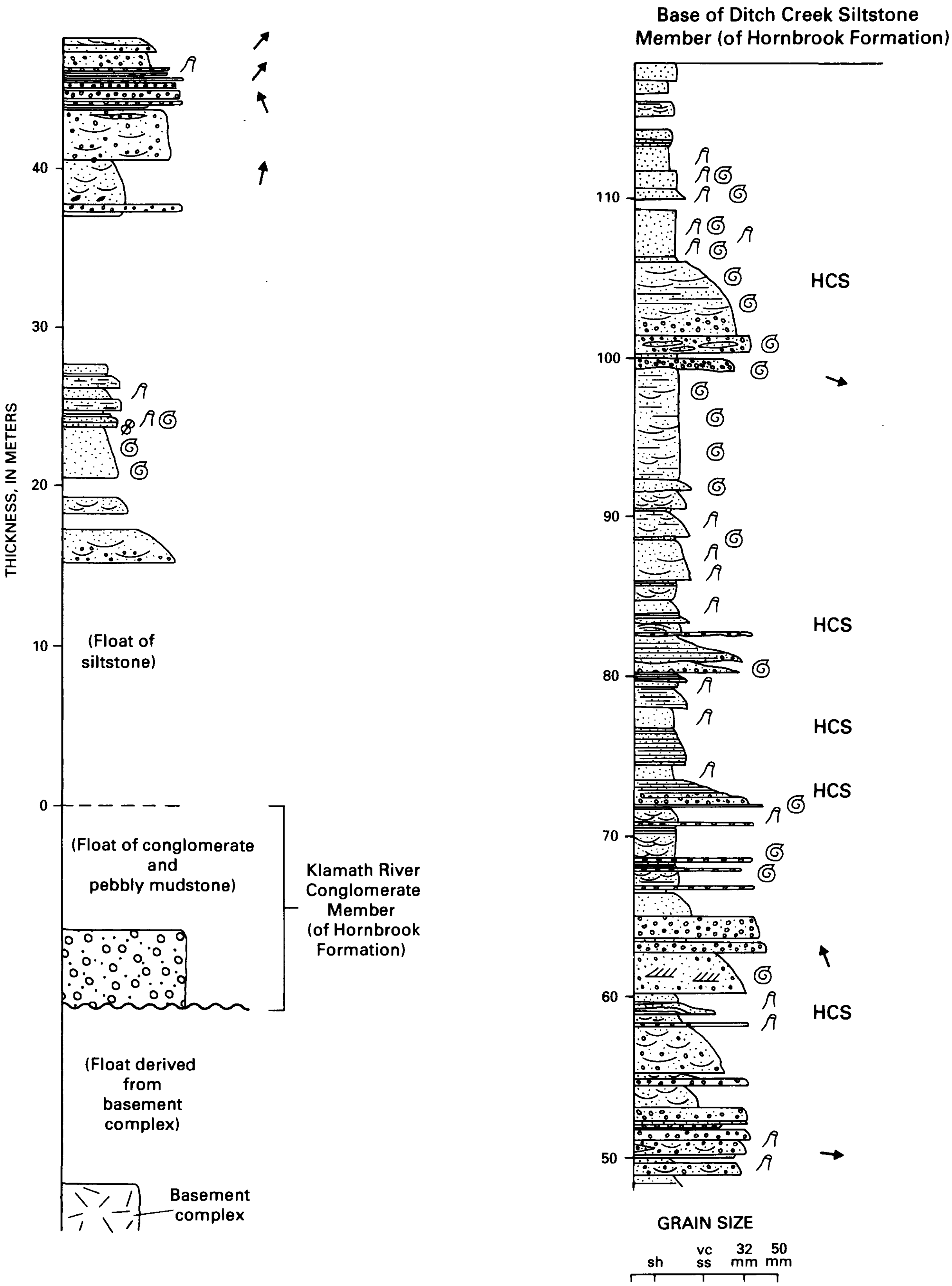


FIGURE 12.—Type section of the Osburger Gulch Sandstone Member of the Hornbrook Formation. See figure 10 for explanation of symbols. Abbreviations: sh, shale; vc, very coarse grained; ss, sandstone. Gaps in lithology represent covered intervals.

TABLE 2.—*Composition of conglomerate clasts in the type section of the Osburger Gulch Sandstone Member and along the southbound lane of Interstate Highway 5, 0.5 km west of the type section*

[Type section located in SE¼NE¼ sec. 32, T. 47 N., R. 6 W., Hornbrook 15-minute quadrangle. Data are from Barats and others (1984, table 1) and are based on two random samples of 100 clasts larger than 2 cm in longest dimension]

	Type section	Along Interstate 5
Metavolcanic rocks	55	52
Metasedimentary rocks	1	4
Metamorphic rocks (unspecified)	0	7
Quartzite	39	19
Chert (including jasper)	2	14
Granite-diorite	3	4
Total	100	100

forms a mappable unit in the southern part of the Cottonwood Creek valley area, in the Shasta Valley-Yreka area, and in the Soap Creek Ridge outlier west of Yreka. Most of the prominent bluffs east of Yreka consist of this unit. This sandstone is marine because it locally contains scattered molluscan fossils. In this report, unit s is incorporated within the lowermost part of the Osburger Gulch Sandstone Member. In the northwestern Cottonwood Creek valley area, the Bear Creek valley area, and the Jacksonville area, this basal unit could not be differentiated at the mapping scale of 1:62,500, but it is commonly present in these areas as a thin lithologic unit that is less resistant than it is in the southern Cottonwood Creek valley and adjacent areas.

The middle part of the Osburger Gulch Sandstone Member in the type section consists generally of sandstone that is finer grained than that in the lower part and that contains some thin beds of conglomerate. This middle part is about 45 m thick in the type section and is as much as 60 m thick in other areas. The sandstone is parallel-stratified, trough cross-stratified, or massive, and it is commonly bioturbated to some extent. The conglomeratic interbeds form layers that are more laterally continuous than in the lower part, commonly with erosive bases. Molluscan fossils are both scattered within the sandstone or concentrated as clasts within some of the conglomeratic beds.

The upper part of the Osburger Gulch Sandstone Member in the type section is generally finer grained than the lower and middle parts and is characterized by more abundant hummocky cross-strata and bioturbation. The upper part is about 51 m thick in the type section and is as much as 100 m thick in other areas. It contains some thick conglomerate interbeds and scattered molluscan fossils.

Over its entire outcrop region, the Osburger Gulch Sandstone Member varies considerably in lithology, although it is almost always predominantly composed of sandstone and contains at least some molluscan fossils. Locally, it is very conglomeratic and in some places displays at its base large rounded boulders of basement rocks in a matrix of sandstone containing molluscan fossils. Such marine boulder conglomerate is common at the base of the member in the Jacksonville area, for instance, where it has been mined for gold. At a mine about 5 km southwest of Jacksonville (NE corner of sec. 11, T. 38 S., R. 3 W., Gold Hill 15-minute quadrangle), boulders as long as 200 cm that are subrounded to well rounded rest directly on red, fine-grained paleosol formed on the underlying basement complex. Within the sandstone matrix of the marine boulder conglomerate are large gastropods and other molluscan fossils. More typical fine- to coarse-grained sandstone that is massive to parallel-stratified and bioturbated overlies the boulder conglomerate. In much of the Bear Creek valley area, the Osburger Gulch Sandstone Member is generally less than 50 m thick and forms a thin veneer of coarse sediment that lies directly on the basement complex because the Klamath River Conglomerate Member is absent. Near the town of Ashland (NW¼ sec. 5, T. 39 S., R. 1 E., Ashland 15-minute quadrangle), the basal part of the Osburger Gulch Sandstone Member consists of a well-sorted coquina of broken shell fragments, generally 0.5–1.0 cm long, mixed with terrigenous detritus. This coquina is several meters thick and is massive to crudely parallel-stratified.

Thus, it can be seen that the lithology of the basal part of the Osburger Gulch Sandstone Member is variable. It ranges from siltstone in the type area to boulder conglomerate, coquina, large-scale trough cross-stratified conglomeratic sandstone, and massive to parallel-stratified sandstone or conglomeratic sandstone in other areas. However, the major part of the member consists of medium- to thick-bedded marine sandstone, with subordinate amounts of conglomerate and siltstone.

STRATIGRAPHIC RELATIONS

Where the Klamath River Conglomerate Member is absent, the Osburger Gulch Sandstone Member rests either unconformably on the pre-Upper Cretaceous basement rocks or on a paleosol developed on those rocks; locally, it rests nonconformably on Jurassic plutonic rocks. Where the Klamath River Conglomerate Member is present, the Osburger Gulch Sandstone Member rests with apparent conformity on it. The contact between the Klamath River Conglomerate Member and the Osburger Gulch Sandstone Member in the type area is marked by the following upward changes: (1) Change from brown, red, and reddish-brown colors on weathered surfaces to a moderately yellowish-brown color; (2) change in conglomerate composition from clasts that are almost wholly derived from the underlying basement to a more polymict composition; (3) change in conglomerate clast texture from angular and subrounded to well rounded; (4) change in the conglomerate fabric from matrix-supported and poorly oriented clasts to clast-supported and well-oriented clasts; (5) change in fossil content from an absence of fossils or (locally) some broken plant fossils to molluscan fossils; (6) change in lithology from dominantly conglomerate to dominantly sandstone; (7) change in stratification from massive and very poorly stratified to well stratified, marked by cross-strata, parallel-strata, and hummocky strata; (8) change from no bioturbation to abundant bioturbated intervals; (9) change from poorly sorted sandstone to well-sorted sandstone; and (10) change from compositionally immature sedimentary rock to compositionally mature sedimentary rock. Most of these changes reflect the differences in depositional process and depositional environment between the two members.

In other areas, the contact between the Klamath River Conglomerate Member and the Osburger Gulch Sandstone Member may be more difficult to ascertain, particularly where the former is very thin. However, some of the criteria listed above are generally applicable in most areas, such as differences in color, dominant lithology, texture and composition, fossil content, and types of stratification. The nonmarine Klamath River Conglomerate Member is locally organized into fining-upward cycles of conglomerate, sandstone, and mudstone that reflect fluvial conditions of sedimentation; these cycles are not present in the Osburger Gulch Sandstone Member. Mudstone deposits in the Klamath River Conglomerate Member locally contain paleosols and root structures of plants in growth position, whereas no paleosols and only transported fossil plant fragments are found in the Osburger Gulch Sandstone Member.

The upper contact between the Osburger Gulch Sandstone Member and the Ditch Creek Siltstone Member in the type area is gradational and marked by the gradual upward change from well-stratified and well-sorted very fine grained to medium-grained sandstone with some conglomerate below to poorly stratified and poorly sorted siltstone and silty very fine grained sandstone above. The contact is generally placed at the lithologic change from predominantly sandstone to predominantly siltstone or silty very fine grained sandstone. The Ditch Creek Siltstone Member is generally much less resistant than the Osburger Gulch Sandstone Member, so the contact between them is commonly marked by a topographic bench or step and lack of good exposures above the bench. The Ditch Creek Siltstone Member is commonly darker on fresh and weathered surfaces than is the Osburger Gulch Sandstone Member, a difference that reflects its greater content of clay minerals and textural immaturity. The Ditch Creek Siltstone Member is also more thoroughly bioturbated and locally contains abundant calcareous concretions that may follow bedding surfaces or form subspherical bodies.

Locally, however, the contact between the Osburger Gulch Sandstone Member and the Ditch Creek Siltstone Member is so gradational that it is very difficult to determine in a measured section. In such areas, I place the boundary at the highest bed of fine-grained sandstone.

Lateral contacts and stratigraphic relations of the Osburger Gulch Sandstone Member cannot be observed in outcrop. It is present in all outcrop areas as a laterally continuous thin sheet of marine sandstone at or near the base of the Hornbrook Formation. Initially, it was probably deposited in all directions from the present outcrops and is undoubtedly present in the subsurface to the northeast.

THICKNESS

The Osburger Gulch Sandstone Member is generally 75–150 m thick but can be either thinner or thicker locally; in one area near Ashland, it appears to be completely missing. At its type section, south of Hornbrook, it is 116.5 m thick. The equivalent unit of Peck and others (1956), measured west of Hornbrook, which includes the upper part of their member I and the lower part of their member II (of Hornbrook Formation), is about 132 m thick (fig. 6). Jones (1959) measured a thickness of 213–243 m for his unit A (of Hornbrook Formation), which includes, however, the Klamath River Conglomerate Member, the Osburger Gulch Sandstone Member, and the Ditch Creek Siltstone Member. A thickness of 247 m, which includes the thickness of the underlying Klamath River Conglomerate Member, was determined for the lower arenaceous member of the Hornbrook Formation of

Elliott (1971) and for unit A (of Hornbrook Formation) of M.A. Elliott (unpub. data, 1980), both of which are partly equivalent to the Osburger Gulch Sandstone Member (fig. 6), at the north end of the Cottonwood Creek valley area. In the Bear Creek valley area, McKnight (1971) determined a thickness of 110 m for deposits equivalent to both the Osburger Gulch Sandstone Member and the underlying Klamath River Conglomerate Member. Bourgeois and Leithold (1983) and Bourgeois (1984) cited a measured thickness of 105–110 m for the equivalent of the Osburger Gulch Sandstone Member in roadcuts along the north- and southbound lanes of Interstate Highway 5 south of Hornbrook; this section, from which I have subtracted the thickness of the Klamath River Conglomerate Member shown on their figure 8, is located directly west of the type section. Bourgeois and Leithold (1983) and Bourgeois (1984) also measured a thickness of what appears to be about 95 m for the Osburger Gulch Sandstone Member near the Siskiyou Summit between Hilt and Ashland. I subsequently measured this section, exposed in roadcuts along the west side of the southbound lane of Interstate Highway 5 (NW¼ sec. 21, T. 40 S., R. 2 E., Ashland 15-minute quadrangle) and obtained a thickness of 127.5 m.

The Osburger Gulch Sandstone Member appears to be thinnest in parts of the Bear Creek valley area, particularly in the areas 0–5 km northwest of and 10–15 km southeast of downtown Ashland. In the area about 5 km northwest of Ashland (southeast corner sec. 31, T. 38 S., R. 1 E., Ashland 15-minute quadrangle), the Osburger Gulch Sandstone Member is locally missing, and siltstone of the Ditch Creek Siltstone Member rests directly on basement rocks. The Osburger Gulch Sandstone Member is also relatively thin along the southwest flank of Black Mountain, between the Cottonwood Creek valley area and the Shasta Valley area.

The Osburger Gulch Sandstone Member appears to be thickest at the northwest end of the Cottonwood Creek valley area. It is also relatively thick in the Shasta Valley area, where it forms a widespread cover.

In summary, the Osburger Gulch Sandstone Member alternately thickens and thins in a northwest-southeast direction, parallel to the outcrop belt. The member has an observed minimum thickness of 0 m and a maximum thickness of possibly 250 m; it probably averages about 100 m in thickness.

DEPOSITIONAL ENVIRONMENT

Sedimentary structures, textures, trace fossils, and molluscan fossils suggest that the Osburger Gulch Sandstone Member was deposited on a marine shelf. It overlies either basement rocks unconformably or nonmarine strata conformably and thus records transgression of the late Early(?) and early Late Cretaceous sea over the Klamath Mountains area. The conformably overlying Ditch Creek Siltstone Member appears to have been deposited generally in somewhat deeper, or at least lower energy, marine conditions, evidence supporting the idea that the Osburger Gulch Sandstone Member represents the basal deposits of a transgressive sea.

The general vertical trends in measured sections of the Osburger Gulch Sandstone Member suggest an upward change generally from very high energy, nearshore conditions to lower energy, offshore conditions. The lower part of the Osburger Gulch Sandstone Member characteristically consists of medium- to large-scale trough cross-stratified conglomeratic sandstone (unit s of Nilsen and others, 1983). This unit contains sparse trace fossils, scattered, highly abraded shell debris, and abundant conglomerate, and it consists of mostly medium-grained to very coarse grained sandstone. This lower part suggests deposition in high-energy nearshore conditions. The local presence of coquinoid conglomerate, planar stratification with heavy mineral concentrations, and marine boulder conglomerate supports this suggestion.

In its type area, the fossiliferous siltstone unit at the base of the Osburger Gulch Sandstone Member represents a different depositional environment. The siltstone contains molluscan megafossils in growth position, abundant plant debris locally concentrated into coaly laminae, abundant and variable bioturbation, and abundant ripple cross-lamination and disrupted planar laminae. These deposits probably accumulated in lagoonal conditions along a part of the transgressive Cretaceous shoreline that had a more complex pattern.

The middle and upper parts of the Osburger Gulch Sandstone Member are characterized generally by sandstone that is finer grained than that of the lower part, hummocky cross-stratification, planar stratification, erosion surfaces, amalgamation of sandstone beds, abundant bioturbation, molluscan fossils in growth position, sheets of pebble to cobble conglomerate locally containing abundant molluscan shell fragments, and (toward the top of the member) some interbeds of siltstone. Trough cross-strata are locally present in the middle and upper parts of the member, but they are generally of much smaller amplitude, are developed in finer grained sandstone, and are less abundant than in the lower part of the member.

The middle and upper parts of the Osburger Gulch Sandstone Member appear to have most of the characteristics of deposits on wave-dominated shelves. The abundant hummocky cross-stratified units probably reflect wave reworking of the bottom, with bioturbated very fine grained to fine-grained sandstone and siltstone deposited during periods of low wave activity. Conglomeratic sheets, both those containing lithic pebbles and those containing shell debris, were probably transported offshore by storm-generated currents.

The molluscan fauna of the Hornbrook Formation is also generally indicative of high-energy shallow-marine conditions. Oysters, Turritellas, and other gastropods and pelecypods generally prefer well-agitated, sandy, or pebbly substrates. Trace fossils include *Ophiomorpha* and other deposit-feeding forms suggestive generally of shallow-marine conditions.

Bourgeois and Leithold (1983) and Bourgeois (1984) concluded that the two sections of the Osburger Gulch Sandstone Member that they measured were typical of storm- and wave-dominated shelf sedimentation. Gaona (1984) inferred deposition in lagoonal, nearshore, and offshore environments. Elliott (1971) suggested shallow-marine to nearshore deposition for all of the Hornbrook Formation, including the strata herein assigned to the Osburger Gulch Sandstone Member. McKnight (1971) concluded that his unit Khs_1 in the Bear Creek valley area, which is equivalent, in part, to the Osburger Gulch Sandstone Member, was deposited in a neritic environment characterized by low- to high-energy conditions.

AGE AND CORRELATION

The age of the Osburger Gulch Sandstone Member has been determined in most areas from megafossil collections. Megafossils reported herein from at or near its base at three localities in the Hornbrook and Yreka areas (app. I) are indicative of middle Turonian age.

Peck and others (1956) summarized age data for the lower part of the Hornbrook Formation from megafossil collections by previous workers. They concluded that except for one well-preserved ammonite and one fragment of an ammonite from the Jacksonville area, all previously reported megafossils from the basal part of the Hornbrook Formation are suggestive of Turonian age. A well-preserved specimen of the ammonite *Mantelliceras*, obtained from a quarry about 1.5 km northwest of Jacksonville (SW¼ sec. 29, T. 37 S., R. 2 W., Medford 15-minute quadrangle) indicated to Peck and others (1956) a Cenomanian age for the lower part of the Osburger Gulch Sandstone Member in this area. An ammonite fragment from the Dark Hollow area (sec. 13, T. 38 S., R. 2 W., Medford 15-minute quadrangle) southeast of Jacksonville, identified by Peck and others (1956) as *Anagaudryceras sacya* (Forbes), generally ranges in age from Albian to Cenomanian. Peck and others (1956) inferred the age of strata equivalent to the uppermost part of the Osburger Gulch Sandstone Member in the southern Cottonwood Creek valley area to be late Turonian.

Jones (1959) indicated a late Turonian and early Coniacian age for strata equivalent to the Osburger Gulch Sandstone Member based on ammonite collections from the unit in the Hornbrook-Yreka area. D.L. Jones (in Popenoe and others, 1960) concluded that no early or middle Turonian megafossils are present in the Yreka-Hornbrook area and that the lower part of the Hornbrook Formation is of late Turonian and early Coniacian age in that area.

For the northern part of the outcrop area of the Hornbrook Formation, D.L. Jones (in Popenoe and others, 1960) concluded that there are no megafossils in the lower part of the Hornbrook Formation south of the Dark Hollow area that were older than Turonian. McKnight (1971, p. 11) reported several fossil localities from the lower part of the Hornbrook Formation in the Ashland area; identifications by D.L. Jones indicated Turonian or late Turonian ages from ammonites and molluscan fossils in these collections.

Jones (1960b) found the basal marine Cretaceous strata of the Grave Creek area to be of Albian age. Sliter and others (1984, fig. 2), on the basis of all previous megafossil age determinations, concluded that the age of the Osburger Gulch Sandstone Member and strata correlative with it ranges (from northwest to southeast) from middle Albian in the Grave Creek area to late Albian(?) to middle Cenomanian in the Dark Hollow area, early to middle Turonian in the Ashland area, middle Turonian to early Coniacian in the Hornbrook area, to early Coniacian in the Black Mountain area. Thus, the age of the Osburger Gulch Sandstone Member within the main outcrop area of the Hornbrook Formation, excluding the Grave Creek area, is here considered to be late Albian(?) to early Coniacian.

The Osburger Gulch Sandstone Member is thus for the most part correlative with strata of Albian to Coniacian age in surrounding areas. The upper parts of Albian and possibly Cenomanian marine sedimentary strata of the Hudspeth and Gable Creek Formations that crop out near Mitchell, Oregon (Wilkinson and Oles, 1968; Kleinhans and others, 1984), the Bernard Formation in the Suplee area, and subsurface marine strata in the adjacent Ochoco basin (Thompson and others, 1984) probably correlate with the

Osburger Gulch Sandstone Member. Cretaceous strata of the Days Creek Formation at Days Creek and Cretaceous strata at O'Brien, Oregon, are probably mostly older than the Osburger Gulch Sandstone Member. Cretaceous strata along the southwestern coast of Oregon also appear to be either older or younger than the Osburger Gulch Sandstone Member (Dott, 1971).

To the south, in the northern Sacramento Valley area, the Osburger Gulch Sandstone Member is probably correlative with the lower part of Turonian to Senonian strata of the Great Valley sequence that crop out near Redding, California (Popenoe, 1943; Matsumoto, 1960). It is also partly correlative with the upper members (the Bald Hills Member and Gas Point Member) of the Budden Canyon Formation of Murphy and others (1969), which crop out about 30 km southwest of Redding. The Bald Hills Member consists chiefly of beds and lenses of sandstone, conglomerate, and pebbly mudstone in mudstone and siltstone; it is about 570 m thick and is late Albian through Cenomanian and possibly early Turonian in age (Murphy and Rodda, 1960). The Gas Point Member consists chiefly of siltstone and mudstone with some interbeds of sandstone; it is about 1,150 m thick and ranges from Cenomanian to late Turonian or possibly early Coniacian in age (Murphy and others, 1969, p. 23).

The Osburger Gulch Sandstone Member appears to be older than most of the Chico Formation to the south in the Chico area of the Sacramento Valley (Haggart and Ward, 1984). It does correlate, however, with much of the middle part of the Great Valley sequence on the west side of the Sacramento Valley. It correlates with strata assigned to the Boxer and Cortina Formations of Dickinson and Rich (1972), which include the previously defined Venado and Yolo Formations of Bowen (1962) of the subsurface part of the Sacramento Valley. The Osburger Gulch Sandstone Member is also correlative with parts of the Franciscan assemblage, chiefly the Coastal belt terrane, which includes strata of Late Cretaceous and early Tertiary age.

DITCH CREEK SILTSTONE MEMBER

DEFINITION

The name "Ditch Creek Siltstone Member" was applied by Nilsen (1984a) to almost continuous outcrops of dominantly marine strata in the lower part of the Hornbrook Formation that are predominantly composed of siltstone. The member was named for exposures adjacent to Ditch Creek, about 3.2 km west of Hornbrook, Calif. The type section, however, was measured in roadcuts along the northbound lane of Interstate Highway 5 adjacent to and west of the Klamath River, about 3 km south of the town of Hornbrook (figs. 8, 13).

The Ditch Creek Siltstone Member is, in ascending stratigraphic order, the third (or middle) member of the Hornbrook Formation. It is equivalent to the upper part of member II (units 8 and 9) (of Hornbrook Formation) as mapped by Peck and others (1956) (fig. 6). The Ditch Creek Siltstone Member is also equivalent to the finer grained upper part of unit A (of Hornbrook Formation) of Jones (1959), unit Khs_2 (of Hornbrook Formation) of McKnight (1971), unit B (of Hornbrook Formation) of M.A. Elliott (unpub. data, 1980), and unit b (of Hornbrook Formation) as mapped by Nilsen and others (1983).

The Ditch Creek Siltstone Member rests conformably on the Osburger Gulch Sandstone Member. I believe that it is generally overlain conformably, although locally possibly unconformably, by the Rocky Gulch Sandstone Member of the Hornbrook Formation. Other workers, however, believe that the upper contact is unconformable in the Hornbrook and Black Mountain areas (fig. 6; Sliter and others, 1984). Locally, in the Ashland area, the Ditch Creek Siltstone Member is overlain unconformably by Tertiary nonmarine sedimentary rocks.

The lower boundary of the Ditch Creek Siltstone Member is marked by the abrupt to gradational upward change from dominantly resistant, cross-stratified to hummocky cross-stratified, fine-grained sandstone of the upper part of the Osburger Gulch Sandstone Member to less resistant, massive and highly bioturbated, poorly sorted, very fine grained silty sandstone and siltstone of the Ditch Creek Siltstone Member. The lower boundary is arbitrarily placed at the top of the highest bed of well-sorted, fine-grained sandstone. The boundary in most outcrops is typically marked by a pronounced topographic bench that separates the less resistant Ditch Creek Siltstone Member, which commonly underlies low-lying valleys and ravines, from the ridge crests and higher topography underlain by the more resistant Osburger Gulch Sandstone Member.

The upper boundary of the Ditch Creek Siltstone Member is marked by the gradational to abrupt upward change from massive, concretionary siltstone of the Ditch Creek Siltstone Member to massive, very thick bedded sandstone of the Rocky Gulch Sandstone Member. The contact is arbitrarily placed at the base of the first bed of sandstone that is more than 1 m thick. This contact is erosional in the

Hornbrook area, as can easily be seen from the roadcuts that expose the contact along Interstate Highway 5 at the type section of the Ditch Creek Siltstone Member (Nilsen and others, 1984, stop 4).

Based on the erosional nature of the contact in this area and the apparent lack of fossils representing some stages of the Late Cretaceous, Peck and others (1956), Jones (1959), Peterson (1967), Elliott (1971; unpub. data, 1980), and Sliter and others (1984) inferred the presence of a major intraformational unconformity between the Ditch Creek Siltstone Member and the overlying Rocky Gulch Sandstone Member. The hiatus represented by the proposed unconformity was thought to include late Coniacian, Santonian, and early Campanian time. However, at many other localities the same contact is very gradational and nonerosional. For example, McKnight (1971) did not recognize an unconformity in exposures of the Hornbrook Formation in the Bear Creek valley area. In mapping the Hornbrook Formation between Jacksonville to the north and Yreka to the south, Nilsen and others (1983) recognized no physical evidence for a major unconformity at the top of the Ditch Creek Siltstone Member. The erosional surface appears to be areally restricted to the Hornbrook area.

AREAL EXTENT

The Ditch Creek Siltstone Member extends almost continuously along the entire outcrop extent of the Hornbrook Formation as a poorly exposed unit that underlies a series of narrow, discontinuous valleys. It appears to be present everywhere, albeit locally very thin, as a fine-grained member between coarser and more resistant strata of the underlying Osburger Gulch Sandstone Member and of the overlying Rocky Gulch Sandstone Member.

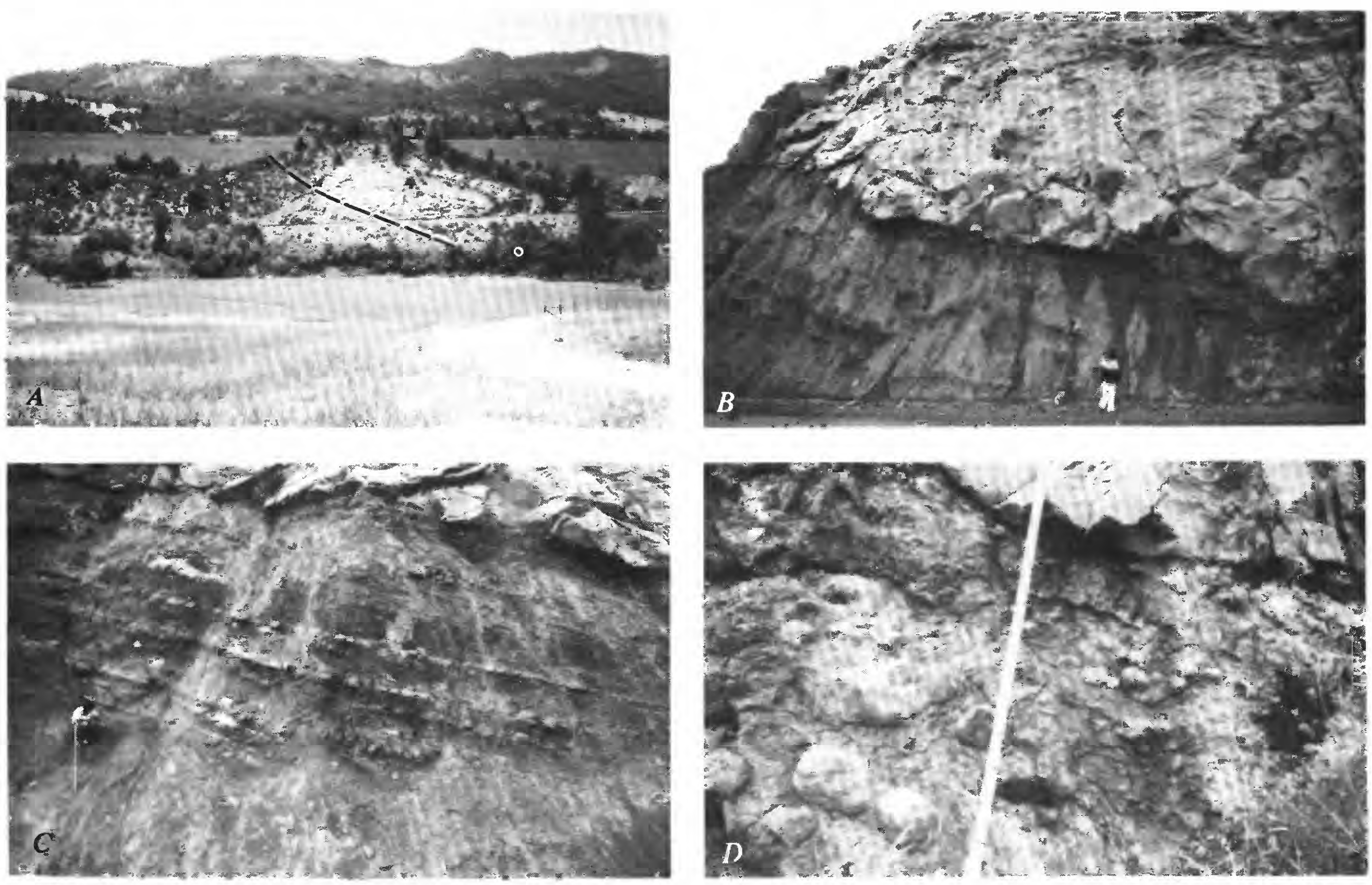


FIGURE 13.—Upper part of type section of the Ditch Creek Siltstone Member of the Hornbrook Formation. *A*, View westward across Klamath River showing contact, marked by dashed line, between the Ditch Creek Siltstone Member to left and the Rocky Gulch Sandstone Member of the Hornbrook Formation to right. *B* and *C*, Contact between two members, showing irregularity and erosive character, concretionary nature of the Ditch Creek Siltstone Member, and massive character of the Rocky Gulch Sandstone Member. *D*, Abundant concretions in uppermost part of the Ditch Creek Siltstone Member; staff is 1.5 m long and is divided into 10-cm intervals.

The northernmost outcrops of the Ditch Creek Siltstone Member are located in the western part of the Dark Hollow area, about 6 km southeast of Jacksonville and 6 km south-southwest of Medford (S½ sec. 11, T. 38 S., R. 2 W., Medford 15-minute quadrangle). In this area, the Ditch Creek Siltstone Member underlies a number of interconnected narrow valleys and is generally poorly exposed except at a few roadcuts.

The Ditch Creek Siltstone Member is covered by Quaternary alluvial fans marginal to Bear Creek valley between the eastern edge of the Dark Hollow area southwest of Phoenix, Oregon (NW¼NW¼ sec. 2, T. 38 S., R. 1 W., Medford 15-minute quadrangle), and the Bear Creek valley area about 2 km southeast of Talent, Oregon (S⅛ sec. 70 and W½ sec. 72, T. 38 S., R. 1 W., Talent 15-minute quadrangle). It crops out discontinuously through the rest of the Bear Creek valley to the Siskiyou Summit fault, except for the region between downtown Ashland and Clayton Creek, where it is covered by Quaternary alluvial fans derived from the Klamath Mountains to the southeast.

In the Cottonwood Creek valley area, the Ditch Creek Siltstone Member crops out discontinuously from the Siskiyou Summit fault to the southwest flank of Black Mountain. It is locally covered in the central part of the Cottonwood Creek valley area by Klamath-derived Quaternary alluvial fans, Quaternary alluvial terrace deposits, and Quaternary alluvium (pl. 1). Some of the best exposures of the member are in the mountainous areas west and south of Hilt, California, at the north end of the Cottonwood Creek valley and along roadcuts of Interstate Highway 5 adjacent to and west of the Klamath River at the south end of the Cottonwood Creek valley area.

In the northern Shasta Valley area, the Ditch Creek Siltstone Member crops out south of Black Mountain and along the southeast flank of Paradise Craggy, east of the Ager fault. The southernmost exposures of the member are located in roadcuts through a small hill where Tertiary igneous rocks have intruded along the contact between the Ditch Creek Siltstone Member and the Rocky Gulch Sandstone Member (NW corner of sec. 25, T. 46 N., R. 6 W., Copco 15-minute quadrangle). Farther south in the Shasta Valley and in the Yreka area, the Ditch Creek Siltstone Member does not crop out; here it appears to be covered by Quaternary alluvium, alluvial-fan deposits, and debris-avalanche deposits. The member does not crop out in the outlier along Soap Creek Ridge west of Yreka; here, as in other outliers west of Jacksonville, Oregon, it has been removed by erosion, and only a thin sedimentary veneer consisting of the Klamath River Conglomerate Member and Osburger Gulch Sandstone Member remains.

TYPE SECTION

The type section of the Ditch Creek Siltstone Member was measured in roadcuts on the west side of the northbound lane of Interstate Highway 5 in the NE¼NE¼ sec. 32, T. 47 N., R. 6 W., Hornbrook 15-minute quadrangle (fig. 14). The member is almost completely exposed along the roadcuts, with few covered intervals.

	Thickness (in meters)
Hornbrook Formation:	
Rocky Gulch Sandstone Member (lower part):	
Conglomeratic medium-grained sandstone, massive; maximum clast size 2 cm; abundant rip-up clasts of mudstone	0.70
Unconformable(?) contact.	
Ditch Creek Siltstone Member:	
Siltstone and silty very fine grained sandstone, massive, thoroughly bioturbated; very abundant spherical carbonate concretions of 10-20 cm diameter; abundant molluscan fossils; tubular fossil-like calcareous burrows	2.20
Siltstone and very fine grained sandstone, massive, thoroughly bioturbated; abundant spherical carbonate concretions of 3–5 cm diameter; fossil plant fragments	3.90
Sandstone, very fine grained, massive	.20
Siltstone and very fine grained sandstone massive, thoroughly bioturbated, concretionary	.60
Sandstone, very fine grained, massive	.22
Siltstone and very fine grained sandstone, massive, thoroughly bioturbated	.75
Sandstone, very fine grained, massive	.22
Siltstone and very fine grained sandstone, massive, thoroughly bioturbated	.20
Sandstone, very fine grained, massive, concretionary	.06
Siltstone and very fine grained sandstone, massive, thoroughly bioturbated	.30
Sandstone, very fine grained, massive, concretionary	.07
Sandstone, very fine grained, silty, concretionary, thoroughly bioturbated	3.90
Sandstone, very fine grained, massive, concretionary, bioturbated	.10
Siltstone and very fine grained sandstone, massive, concretionary, thoroughly bioturbated	2.05
Sandstone, very fine grained, massive, bioturbated	.20
Siltstone and very fine grained sandstone, massive; fossil plant fragments, thoroughly bioturbated	.24
Sandstone, very fine grained, massive, concretionary, bioturbated	.28

	Thickness (in meters)
Ditch Creek Siltstone Member—*Continued*:	
Siltstone and very fine grained sandstone, massive, thoroughly bioturbated	.06
Sandstone, very fine grained, massive, concretionary	.11
Siltstone and very fine grained sandstone, massive, thoroughly bioturbated	.55
Sandstone, very fine grained, silty, massive, concretionary	.10
Siltstone and very fine grained sandstone, massive; scattered molluscan fragments, concretionary, thoroughly bioturbated	1.60
Sandstone, very fine grained, massive, bioturbated	.11
Siltstone and very fine grained sandstone, massive; fossil plant fragments, thoroughly bioturbated	.16
Sandstone, very fine grained, massive, bioturbated	.12
Siltstone and very fine grained sandstone, massive; fossil plant fragments, thoroughly bioturbated	.11
Sandstone, very fine grained, massive, concretionary, bioturbated	.08
Siltstone and very fine grained sandstone, massive, thoroughly bioturbated	.18
Sandstone, very fine grained, laminated	.12
Siltstone and very fine grained sandstone, massive; fossil plant fragments, bioturbated	.10
Sandstone, very fine grained, massive, concretionary, bioturbated	.10
Siltstone and very fine grained sandstone, massive; fossil plant fragments, thoroughly bioturbated	.92
Sandstone, very fine grained, laminated	.10
Sandstone, very fine grained, and siltstone; laminated fossil plant fragments, bioturbated	.32
Sandstone, very fine grained, massive, concretionary, bioturbated	.17
Sandstone, very fine grained, silty; molluscan fossils; fossil plant fragments, bioturbated	.70
Sandstone, very fine grained, laminated, concretionary	.10
Siltstone and very fine grained sandstone, laminated; fossil plant fragments	.22
Sandstone, very fine grained, massive, bioturbated at top	.20
Sandstone, very fine grained, silty, massive, bioturbated	.87
Sandstone, very fine grained, massive	.22
Sandstone, very fine grained, silty, massive; fossil plant fragments	.52
Sandstone, very fine grained to fine-grained, massive, concretionary	.15
Siltstone and sandstone, very fine grained; fossil plant fragments, bioturbated	2.75
Sandstone, very fine grained, laminated	.22
Siltstone and very fine grained sandstone, massive, thoroughly bioturbated	.20
Sandstone, very fine grained, laminated	.15
Siltstone and very fine grained sandstone, massive, thoroughly bioturbated	.60

	Thickness (in meters)
Ditch Creek Siltstone Member—*Continued*:	
Sandstone, very fine grained, massive to laminated	.15
Siltstone and very fine grained sandstone, massive, bioturbated, mostly covered	2.25
Siltstone and very fine grained sandstone, massive, thoroughly bioturbated	.50
Sandstone, very fine grained, massive, bioturbated	.30
Covered interval (float of siltstone and very fine-grained sandstone)	3.60
Sandstone, very fine grained to fine-grained, massive, concretionary	.45
Sandstone, very fine grained to fine-grained, massive, concretionary, bioturbated	.50
Siltstone and very fine grained sandstone, partly laminated; fossil plant fragments	1.00
Sandstone, very fine grained, massive, bioturbated	.40
Siltstone and very fine grained sandstone, massive; fossil plant fragments, thoroughly bioturbated	.45
Sandstone, fine-grained, massive; fossil plant fragments, bioturbate	.50
Siltstone and very fine grained sandstone, massive; fossil plant fragments, thoroughly bioturbated	.55
Sandstone, very fine grained to fine-grained, massive, bioturbated	.23
Siltstone and very fine grained sandstone, massive, thoroughly bioturbated	1.32
Sandstone, very fine grained to fine-grained, massive to partly laminated	1.05
Siltstone and very fine grained sandstone, massive, thoroughly bioturbated	1.25
Sandstone, fine-grained, silty, massive, thoroughly bioturbate	.70
Siltstone and very fine grained sandstone, massive, thoroughly bioturbate	1.12
Sandstone, very fine grained, massive to partly laminate	.33
Sandstone, very fine grained, massive, thoroughly bioturbated	.18
Sandstone, very fine grained, laminated in lower part, bioturbated in upper part	.08
Siltstone and very fine grained sandstone, massive, bioturbated	.07
Sandstone, very fine grained, massive in lower part, laminated at top	.40
Siltstone and very fine grained sandstone, massive; fossil plant fragments, thoroughly bioturbated	1.32
Sandstone, very fine grained to fine-grained; fossil plant fragments; laminated in lower part, bioturbated in upper part	.30
Siltstone and very fine grained sandstone, massive; fossil plant fragments, thoroughly bioturbated	1.95
Sandstone, very fine grained, massive; fossil plant fragments, thoroughly bioturbated	.40
Siltstone and very fine grained sandstone, laminated; fossil plant fragments, bioturbated	1.70

	Thickness (in meters)
Ditch Creek Siltstone Member—*Continued*:	
Sandstone, very fine grained, massive; fossil plant fragments, thoroughly bioturbated	.90
Siltstone and very fine grained sandstone, partly laminated; fossil plant fragments, bioturbated	5.70
Sandstone, very fine grained, massive to laminated; fossil plant fragments	.06
Siltstone and very fine grained sandstone, massive; fossil plant fragments, thoroughly bioturbated	1.40
Sandstone, very fine grained, laminated; fossil plant fragments, bioturbated	.08
Siltstone, sandy, massive to laminated; fossil plant fragments; ammonite fossils, bioturbated	2.30
Covered interval (float mostly of very fine grained sandstone, silty, laminated)	.75
Total thickness of the Ditch Creek Siltstone Member	61.64
Conformable contact.	
Osburger Gulch Sandstone Member:	
Covered interval (float mostly of very fine grained, massive sandstone)	.75
Sandstone, very fine grained, massive; molluscan fossils, bioturbated	1.40

The colors of the Ditch Creek Siltstone Member are, for siltstone, medium dark gray (N4) on fresh surfaces and moderate yellowish brown (10YR 5/4) on weathered surfaces; for sandstone, medium gray (N5) on fresh surfaces and moderately yellowish brown (10YR 5/4) on weathered surfaces; and for the abundant concretions, medium dark gray (N4) on fresh surfaces and dark yellowish brown (10YR 6/6) and light brown (5YR 5/6) on weathered surfaces.

LITHOLOGY

The Ditch Creek Siltstone Member consists mostly of siltstone and silty very fine grained sandstone. In some areas it contains fine-grained sandstone and mudstone in its lower part, where it grades upward from the Osburger Gulch Sandstone Member. Where it is gradational upward into the overlying Rocky Gulch Sandstone Member in many exposures outside of the Hornbrook area, it locally contains some interbedded sandstone and mudstone in its upper part. Conglomerate is absent from the Ditch Creek Siltstone Member, in contrast to its common presence in the overlying and underlying sandstone members.

Molluscan fossils are locally abundant both in growth position and as transported fragments. Bioturbation is extremely abundant and dense; it has destroyed most of the original stratification and sedi-

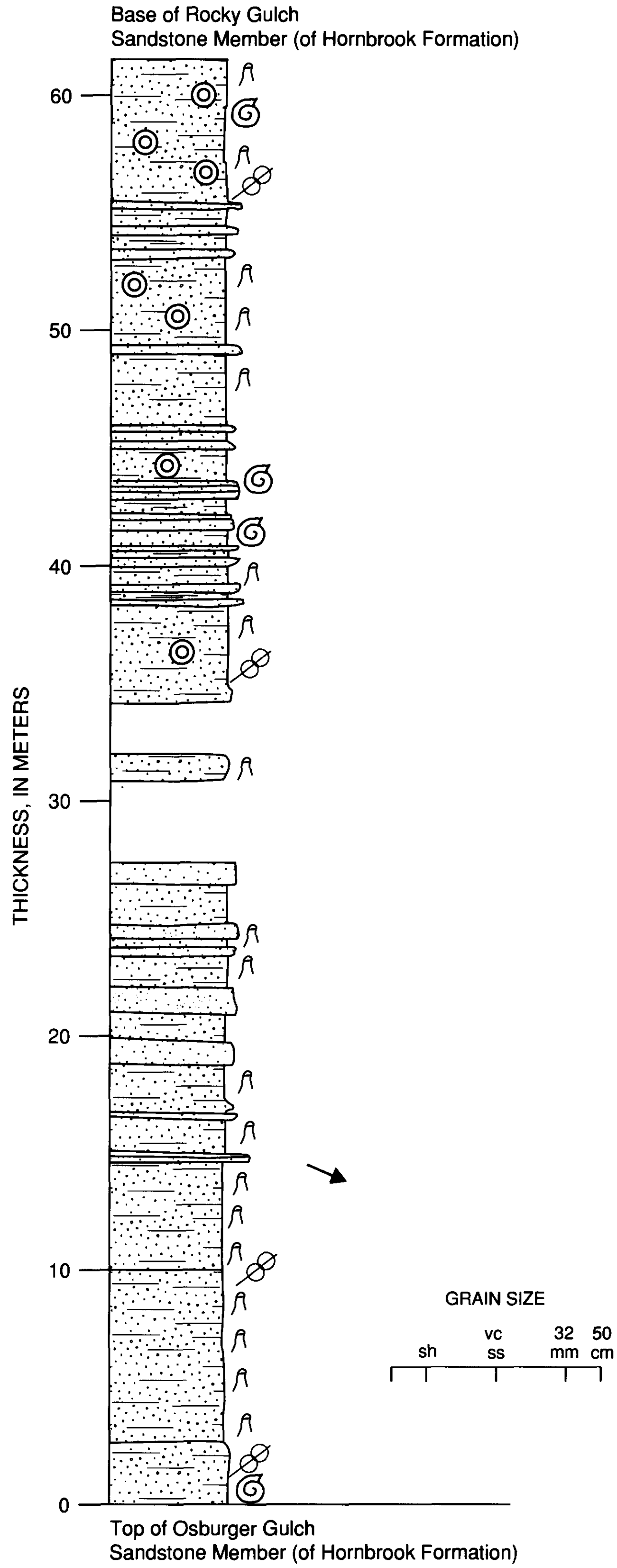


FIGURE 14.—Type section of the Ditch Creek Siltstone Member of the Hornbrook Formation. See figure 10 for explanation of symbols and caption of figure 12 for explanation of abbreviations. Gaps in lithology represent covered intervals.

mentary structures in the siltstone and sandstone. The intense bioturbation has resulted in the member commonly having a monotonous and homogeneous character, with a minimal amount of bedding or layering. Plant debris is also very abundant and present in almost every sample; it is typically finely comminuted and thus has not been helpful for dating the member.

In the Shasta Valley area, a coal bed is present in what has been mapped (Nilsen and others, 1983) as the Ditch Creek Siltstone Member near the Hagedorn Ranch adjacent to the Yreka-Ager Road, about 4.5 km southwest of Willow Creek School (SW¼ SW¼ sec. 24, T. 46 N., R. 6 W., Copco 15-minute quadrangle). This coal was previously thought to be of Tertiary age (Averill, 1935). The coal bed was mined in the past, as indicated by two dump piles of mine tailings; O'Brien (1947) reported some production figures for the coal mine in the early 1900's. Averill (1935) concluded that the coal bed was an average of 0.6 m thick and was very irregular in thickness. The apparent lateral discontinuity of the coal bed could result from minor fault offsets.

The coal is a high-volatile B bituminous coal whose geochemistry has been summarized by Zigler and Nilsen (1984). Many of the geochemical characteristics of the coal are summarized in tables 3 and 4. The coal has a dry-base density of 1.40 gm/cm^3, an ash content of 28.2 percent, and a vitrinite reflectance value (based on 100 measurements) of 0.63, which is characteristic of high-volatile B bituminous coal. The maceral content, based on 1,000 analyses, was 87 percent vitrinite (cell wall and material in solution), 1 percent sporinite (plant spores), 3 percent cutinite (plant leaf material), 2 percent resinite (plant resins), 5 percent semifusinite and 1 percent fusinite (carbonized plant remains), 1 percent macrinite and inertodetrinite (other carbonized materials), and 1 percent detrinite. The coal is clearly derived from terrestrial plants, based on the amounts of sulfur ash and volatile matter; a nonmarine origin is probable (R. Stanton, oral commun., November 1983), although deposition could have been close to a marine shoreline.

In its type section, the Ditch Creek Siltstone Member consists almost entirely of massive, bioturbated siltstone and silty to very fine grained sandstone with scattered marine megafossils and abundant fossil plant debris. The unit is thin bedded to very thickly bedded, with beds ranging from 6 cm to 5.70 m in thickness. The member is relatively uniform lithologically from base to top in its type section, except for an increasing number of calcareous concretions upward and a great abundance of concretions at the very top of the section. Some beds of sandstone are laminated or partly laminated; this lamination may originally have been characteristic of the sediment at the time of deposition in the vicinity of the type section, before postdepositional burrowing destroyed most of the primary sedimentary structures. In one bed of laminated, very fine grained to fine-grained sandstone in the lower part of the section, about 15 m above the base, primary current lineation with an east-southeast or west-northwest trend was observed. The beds of silty sandstone are of four types: (1) massive throughout, with some distinct burrows present; (2) massive at the base grading upward into laminated sandstone, with the entire bed containing some distinct burrows; (3) massive or laminated at the base and thoroughly bioturbated, with no distinct burrows, at the top; and (4) thoroughly bioturbated throughout, with no laminations and few distinct burrows. No cycles are apparent in the type section, although the alternation of finer and coarser grained beds is characteristic of the member.

The Ditch Creek Siltstone Member southeast of its type section near Hornbrook is poorly and incompletely exposed. It is chiefly covered along the southern and western flanks of Black Mountain by landslides, although two prominent outcrops on the south flank of the mountain (NW¼ sec. 14, T. 46 N., R. 6 W., Hornbrook 15-minute quadrangle) appear beneath the landslide cover (pl. 1). Here the Ditch Creek Siltstone Member consists, at least in part, of massive, thoroughly bioturbated, silty fine-grained sandstone. This sandstone rests directly on more resistant pebbly sandstone of the Osburger Gulch Sandstone Member that is trough cross-stratified and contains some marine molluscan fossils. The bioturbated sandstone is overlain directly by mudstone and thinly interbedded sandstone of the Blue Gulch Mudstone Member, with the Rocky Gulch Sandstone Member missing.

In the Shasta Valley area, at the south end of its outcrop belt, the Ditch Creek Siltstone Member crops out in some hilly areas and in several roadcuts along the Yreka-Ager Road. In addition to the coal that forms part of it, the member here appears to consist mostly of siltstone and very fine grained sandstone that contains marine molluscan fossils and is commonly bioturbated. The molluscan fossils, which include pelecypods and oysters, are present both in growth position and as transported fragments.

North of its type section, in the Cottonwood Creek valley area, the Ditch Creek Siltstone Member is generally poorly exposed and appears to consist mostly of concretionary siltstone and silty very fine grained sandstone. Scattered small exposures of the member along the bottom of Cottonwood Creek between Hilt and Hornbrook (sec. 1, T. 47 N., R. 7 W.,

TABLE 3.—*Geochemistry of coal sample collected from the Ditch Creek Siltstone Member near the Hagedorn Ranch in the Shasta Valley area*

[Data from Zigler and Nilsen (1984, table 1); SW¼SW¼ sec. 24, T. 46 N., R. 6 W., Copco 15-minute quadrangle. Analysis by U.S. Geological Survey Analytical Laboratory in Lakewood, Colorado]

Major elements

Element	Percent	Parts per million
Ca	0.84/0.86	—
Mg	.67/.66	—
Na	.16/<.03	—
K	1.39/<.30	—
P	.24	2270
P_2O_5	.15	—
Mn	—	155
Fe	2.70	25,000
Cl	<.02	—
Si	—	267,000
Al	15.80/16.00	—
Ti	.55/.52	—

Rare earth elements

Element	Percent	Parts per million
Ce	—	130
Pr	—	<50
Nd	—	20
Sm	—	<50
Eu	—	<10
Gd	—	<50
Tb	—	<50
Dy	—	<20
Ho	—	<20
Er	—	<20
Tm	—	—
Yb	—	<5
Lu	—	—

Minor elements

Element	Percent	Parts per million
Ag	—	<10
As	—	<50
Au	—	<40
B	—	—
Ba	—	1,100
Be	—	<5
Bi	—	<50
Cd	—	<10/.20
Co	—	31
Cr	—	120
Cu	—	200
F	.018	—
Ga	—	30
Ge	—	<50
Hg	—	.12
La	—	60
Li	—	120
Mn	—	70
Mo	—	<10
Nb	—	<20
Ni	—	110
Pb	—	30/30
Sc	—	50
Sn	—	—
Sr	—	1,100
Ta	INAA(23/1)	<200
Th	INAA(4.50/4.25)	<20
U	—	<500
V	—	360
W	—	—
Y	—	60
Zn	—	200
Zr	—	—

Hornbrook 15-minute quadrangle; not shown on pl. 1) consist of siltstone and mudstone that contain abundant interbeds of graded fine-grained sandstone. The beds of graded sandstone, which appear to be most abundant in the lower part of the member, have prominent sole marks (chiefly large flute casts) and are organized into Bouma sequences. The member is here cut by numerous subvertical cross-faults that trend northerly, northeasterly, and easterly. Some of these faults are filled with sandstone dikes that are offset by successive periods of faulting.

Farther north in the Cottonwood Creek valley area, the Ditch Creek Siltstone Member is generally coarser grained than it is at the type section. In a second measured section at the north end of the Cottonwood Creek valley west of Hilt (NE¼ sec. 26, T. 48 N., R. 7 W., Hornbrook 15-minute quadrangle), the lower and middle parts of the member contain abundant beds of fine-, medium-, and coarse-grained sandstone as thick as 2.5 m. These beds are distinctly graded and locally contain both granule-size detritus in their basal parts and large rip-up clasts of shale and fine-grained sandstone suspended in the sandstone. These graded beds of sandstone are interbedded with shale, silty shale, and siltstone, and they generally have erosive contacts with the shale. Flute casts, groove casts, and flame structures are present on the soles of the sandstone beds; dish structure, pillar structure, parallel stratification, convolute lamination, current ripple markings, and fossil plant fragments are present within the sandstone beds.

The upper part of the second section consists of massive, concretionary, thoroughly bioturbated shale with very thin interbeds of massive to laminated,

TABLE 4.—*Maceral analysis of coal sample collected from the Ditch Creek Siltstone Member near the Hagedorn Ranch in the Shasta Valley area*

[Data from Zigler and Nilsen (1984, table 2). Analysis by U.S. Geological Survey Analytical Laboratory in Lakewood, Colorado, on dry mineral-free basis from 1,000 point counts, using technique described by Crelling (1980, p. 25)]

Maceral group	Maceral	Description	Volume percent
Vitrinite	—	Plant cell wall material.	87
Exinite-liptinite		Waxy and resinous parts of plants:	
	sporinite	plant spores	1
	cutinite	plant leaf material	3
	resinite	plant resins	2
Inertinite		Plant material strongly altered during coalification:	
	semifusinite	carbonized plant remains	5
	fusinite	other carbonized material	1
	macrinite	do.	<1
	inertodetrinite	do.	<1
	detrinite	do.	1

locally current ripple-marked, concretionary siltstone. Plant fragments are very abundant in this part of the section. The section is abruptly overlain by very thick beds of conglomeratic sandstone of the Rocky Gulch Sandstone Member. Thus, the Ditch Creek Siltstone Member near Hilt, California, forms a very distinct fining-upward unit, changing from sandstone at its base to shale at its top.

In the Bear Creek valley area, the Ditch Creek Siltstone Member is not well exposed. McKnight (1971) described it as mudstone, shale, siltstone, and sandstone, with concretions locally abundant at its top. The base of the Ditch Creek Siltstone Member is exposed at the top of a measured section of the Osburger Gulch Sandstone Member along the southbound lane of Interstate Highway 5 near the Siskiyou Summit (NW¼ sec. 21, T. 40 S., R. 2 E., Ashland 15-minute quadrangle). The lowest 5 m consist chiefly of siltstone with some interbeds of silty very fine grained sandstone. The siltstone is generally very concretionary and bioturbated, and it contains megafossils consisting of ammonites and locally abundant pelecypods and gastropods in growth position. The interbedded sandstone is massive to laminated and locally graded.

Between Ashland and the Siskiyou Summit fault, there are few outcrops of the Ditch Creek Siltstone Member. Massive siltstone and very fine grained sandstone containing abundant molluscan and ammonite fossils crop out along the bed of the Southern Pacific Railroad about 12 km southeast of Ashland (NW¼SW¼ sec. 5, T. 40 S., R. 2 E., Ashland 15-minute quadrangle). An outcrop of the Ditch Creek Siltstone Member adjacent to Interstate Highway 5 about 9 km southeast of Ashland (SW corner of sec. 30, T. 39 S., R. 2 E., Ashland 15-minute quadrangle) consists mostly of mudstone with thin interbeds of bioturbated silty very fine grained sandstone. Along State Highway 99 northeast of its crossing with the Southern Pacific Railroad, about 2 km northwest of downtown Ashland (NE¼NW¼ sec. 5, T. 39 S., R. 1 E., Ashland 15-minute quadrangle), the Ditch Creek Siltstone Member consists almost wholly of silty mudstone with a few thin interbeds of concretionary siltstone.

The northwesternmost exposures of the Ditch Creek Siltstone Member are in several good roadcuts in the Dark Hollow area between Talent and Jacksonville along Dark Hollow Road. The chief lithologies include siltstone, silty mudstone, and silty very fine grained sandstone. The siltstone and silty mudstone typically are massive, highly bioturbated, and locally fossiliferous (mollusks and ammonites). The interbeds of silty very fine grained sandstone typically are laterally discontinuous, concretionary, partly bioturbated, and massive. However, the sandstone interbeds are locally laminated, current ripple-marked, and graded; they locally also have sharp, partly erosional contacts with the underlying siltstone or silty mudstone.

In summary, the lithology of the Ditch Creek Siltstone Member consists mostly of siltstone, silty mudstone, and silty very fine grained sandstone, partly to wholly bioturbated. It locally contains massive to laminated and ripple-marked beds of sandstone, particularly near its basal contact with the Osburger Gulch Sandstone Member. It forms a generally thin and nonresistant unit that in many areas is extensively covered by Quaternary deposits.

STRATIGRAPHIC RELATIONS

The Ditch Creek Siltstone Member everywhere rests gradationally and conformably on the Osburger Gulch Sandstone Member. The contact is mapped where the predominant lithology changes from sandstone to siltstone, silty very fine grained sandstone, interbedded sandstone, and siltstone. It can be placed in measured sections at the top of the highest bed of fine-grained sandstone.

The Ditch Creek Siltstone Member is overlain almost everywhere by the Rocky Gulch Sandstone Member. In the Hornbrook area, this upper contact has previously been interpreted as a regional unconformity because it is clearly erosional. However, north and south of the Hornbrook area, the contact is generally gradational, although it may locally be marked by a minor erosional surface. In the Dark Hollow area along Dark Hollow Road (SW¼ sec. 18, T. 38 S., R. 2 W., Medford 15-minute quadrangle), continuous roadcuts across the contact clearly show the gradational nature of the contact, with increasing amounts of sandstone present upward in the Ditch Creek Siltstone Member. In this report, the upper contact is considered generally conformable, although locally, as in the Hornbrook area, it is possibly unconformable. However, additional age data from the Ditch Creek Siltstone Member and the Rocky Gulch Sandstone Member throughout the region would clearly be helpful in better defining the possible presence of a hiatus.

The upper contact of the Ditch Creek Siltstone Member with the Rocky Gulch Sandstone Member is generally placed at the upward lithologic change from siltstone or silty mudstone to sandstone. The contact in the Hornbrook area and in other parts of the Cottonwood Creek valley area is typically very sharp and easily determined. To the north, particularly in the Dark Hollow area, where the contact is gradational, I place the contact at the base of the first bed of fine-to-medium- or medium-grained sandstone.

On the south flank of Black Mountain, directly north of the Shasta Valley, I interpret field relations to indicate that the overlying Rocky Gulch Sandstone Member is missing, which leaves mudstone of the Blue Gulch Mudstone Member resting directly on the Ditch Creek Siltstone Member (Nilsen and others, 1983; pl. 1). The contact here appears to be conformable, although it is possible that there is a significant hiatus present; this area of generally poor outcrops has been interpreted differently by Sliter and others (1984). The contact is easily determined here, however, because the unit mapped as the Ditch Creek Siltstone Member consists almost wholly of massive, bioturbated, fine-grained sandstone and is more resistant than the overlying mudstone.

Lateral contacts and gradations of the Ditch Creek Siltstone Member cannot be observed in outcrop. The member is present in all outcrop areas as a laterally continuous thin sheet of siltstone and silty fine-grained sandstone above the equally continuous Osburger Gulch Sandstone Member. The Ditch Creek Siltstone Member probably initially persisted in all directions from the present outcrop belt and is undoubtedly present in the subsurface to the northeast.

THICKNESS

The Ditch Creek Siltstone Member is generally 20–80 m thick, although its thickness has not been determined in very many areas because of the lack of completely exposed sections. At its type section, south of Hornbrook, it is 61.64 m thick. The equivalent unit of Peck and others (1956), measured west of Hornbrook, which includes the upper part of their member II (fig. 6), is about 80.5 m thick. Jones (1959) measured a thickness of 213–243 m for his unit A, which includes of the Klamath River Conglomerate Member, the Osburger Gulch Sandstone Member, and the Ditch Creek Siltstone Member.

Elliott (1971) determined a thickness of 58.2 m for his Henley mudstone unit of the Hornbrook Formation and a similar thickness for his unit B of the Hornbrook Formation (M.A. Elliott, unpub. data, 1980) at the north end of the Cottonwood Creek valley, both of which are equivalent to the Ditch Creek Siltstone Member. In the Bear Creek valley area, McKnight (1971) obtained a thickness of 23 m for his unit Khs_2, which is equivalent to the Ditch Creek Siltstone Member.

I measured another section of the Ditch Creek Siltstone Member along Cottonwood Creek at the north end of the Cottonwood Creek valley, about 2 km south of Hilt (NE¼SW¼ sec. 26, T. 48 N., R. 7 W., Hornbrook 15-minute quadrangle). At this locality, the Ditch Creek Siltstone Member is 77.41 m thick.

No sections of the Ditch Creek Siltstone Member have been measured in the Dark Hollow area or in the Shasta Valley area, and thus its thicknesses near the northwestern and southeastern limits of its outcrop area are not known. It appears in general to be as much as 4 or 5 times thicker in the Cottonwood Creek valley area than in the Bear Creek valley area. However, it is also possible that it irregularly thickens and thins in different areas.

DEPOSITIONAL ENVIRONMENT

The Ditch Creek Siltstone Member appears to have been deposited chiefly in a low-energy outer-shelf environment. It consists mostly of bioturbated siltstone and silty very fine grained sandstone; the lack of preservation of planar stratification, trough cross-stratification, or hummocky cross-stratification indicates that sedimentation rates were generally slow, which allowed ample time for thorough bioturbation and mixing of sediments. Sandstone interbeds may have been deposited by storm-generated rip currents or turbidity currents; however, these beds are generally so thoroughly bioturbated that the lack of original bed boundaries and internal structures prevents a clear interpretation of their process of deposition.

Lateral changes in facies within the Ditch Creek Siltstone Member suggest that it may have been deposited in deeper marine conditions to the north and in shallow-marine to locally nonmarine conditions to the south. Deposits to the north between the Hilt and Dark Hollow areas form at least locally well-bedded sequences, with graded beds of sandstone interbedded with massive siltstone. Many of the sandstone beds are well graded and have elements of the Bouma sequence; sole markings are locally preserved at the bases of these beds, and bioturbation is less abundant. The coarsest grained beds, some containing abundant granule-size detritus near their bases, are present in the lower part of the member near Cottonwood Creek, west and southwest of Hilt. Dish structures, beds of massive sandstone, and sandstone dikes are present locally in the member in this area.

In the type section south of Hornbrook and in the southern Cottonwood Creek valley area in general, the Ditch Creek Siltstone Member consists of thoroughly bioturbated massive siltstone and silty very fine grained and fine-grained sandstone. This unit was probably deposited in more shallow-marine conditions, as is indicated by more abundant molluscan fossils.

Farther south, along the south flank of Black Mountain, the Ditch Creek Siltstone Member crops out in isolated patches as a bioturbated, cross-stratified fine-grained sandstone. Here it appears to be a nearshore or possibly lagoonal deposit.

In the southernmost outcrops of the Ditch Creek Siltstone Member located in the northern Shasta Valley area, coal of probable nonmarine origin is interbedded with fossiliferous marine siltstone. The coal suggests at least local subaerial exposure and accumulation of organic matter in a probable freshwater swamp. Exposures of the Ditch Creek Siltstone Member in the northern Shasta Valley area are generally poor, but marine megafossils suggest a shallow-marine, locally lagoonal depositional environment.

AGE AND CORRELATION

The Ditch Creek Siltstone Member contains abundant megafossils (chiefly pelecypods, gastropods, and ammonites) that provide age control. I have also collected foraminiferal samples that provide some additional ages. The largest collection of megafossils that I obtained from the Ditch Creek Siltstone Member, from the Dark Hollow area (USGS Mesozoic locality M7686), indicates a Turonian age for its upper part (app. I). The foraminiferal collections (app. II) are indicative of a middle Turonian age in the Ashland area (USGS Mesozoic localities Mf6590 and Mf6591), a middle Turonian age in the Dark Hollow area (USGS Mesozoic locality Mf6592), a late Turonian to Coniacian age for a sample taken in the northern Cottonwood Creek valley area near Bailey Hill from about 2 m below the contact with the Rocky Gulch Sandstone Member (USGS Mesozoic locality Mf6581), and a late Turonian to Coniacian age for a sample taken about halfway between Hilt and Hornbrook from the middle part of the Ditch Creek Siltstone Member (USGS Mesozoic locality Mf6580). Based on these foraminiferal and megafossil ages, the Ditch Creek Siltstone Member appears to be younger to the south, from middle Turonian in the Dark Hollow and Bear Creek valley areas to late Turonian to Coniacian in the Cottonwood Creek valley area. No Santonian ages have been obtained to date from either megafossils or foraminifers.

Peck and others (1956) concluded, on the basis of molluscan and ammonite collections, that the upper part of their member II, equivalent to the Ditch Creek Siltstone Member, was of Turonian age. On the basis of ammonite and other molluscan faunas, Jones (1959) considered his unit A, which includes the Klamath River Conglomerate Member and the

Osburger Gulch Sandstone Member, as well as the Ditch Creek Siltstone Member, to be of Turonian and early Coniacian age. Sliter and others (1984) suggested ages of early Turonian in the Dark Hollow area, middle Turonian in the Ashland area, and early Coniacian in the Hornbrook area for strata mapped herein as the Ditch Creek Siltstone Member. Partly correlative strata in the Grave Creek and Black Mountain areas may be of Cenomanian and early Coniacian ages, respectively (Sliter and others, 1984).

Thus, the Ditch Creek Siltstone Member in its main outcrop area ranges in age from early Turonian to early Coniacian and is correlative with strata of Turonian to Coniacian age in surrounding areas. Part of the sequence to the north in the subsurface Ochoco basin near Mitchell, Oregon, probably correlates with the Ditch Creek Siltstone Member (Thompson and others, 1984). To the south, the Ditch Creek Siltstone Member is probably correlative with parts of the Great Valley sequence near Redding (Popenoe, 1943; Matsumoto, 1960), the Gas Point Member of the Budden Canyon Formation of Murphy and others (1969) southwest of Redding, the Great Valley sequence along the west side of the Sacramento Valley (Ingersoll, 1979), and the Coastal belt terrane of the Franciscan assemblage. It appears to be mostly older than the Coniacian to Campanian Great Valley sequence in the Chico area on the east side of the Sacramento Valley (Haggart and Ward, 1984).

ROCKY GULCH SANDSTONE MEMBER

DEFINITION

The name "Rocky Gulch Sandstone Member" was applied by Nilsen (1984a) to almost continuous outcrops of marine sandstone strata in the lower part of the Hornbrook Formation. The member was named for exposures in Rocky Gulch, located about 2 km southwest of Hornbrook, Calif. The type section, however, was measured in roadcuts along the northbound lane of Interstate Highway 5 adjacent to and west of the Klamath River, about 3 km south of the town of Hornbrook (figs. 8, 15).

The Rocky Gulch Sandstone Member is the fourth member, in ascending stratigraphic order, of the Hornbrook Formation (fig. 6). It is equivalent to member III and the lower part of member IV (units 10 and 11) (of Hornbrook Formation) as mapped by Peck and others (1956), unit B (of Hornbrook Formation) of Jones (1959), unit Khs_3 (of Hornbrook Formation) of McKnight (1971), unit C (of Hornbrook Formation) of M.A. Elliott (unpub. data, 1980), and unit c (of Hornbrook Formation) as mapped by Nilsen and others (1983).

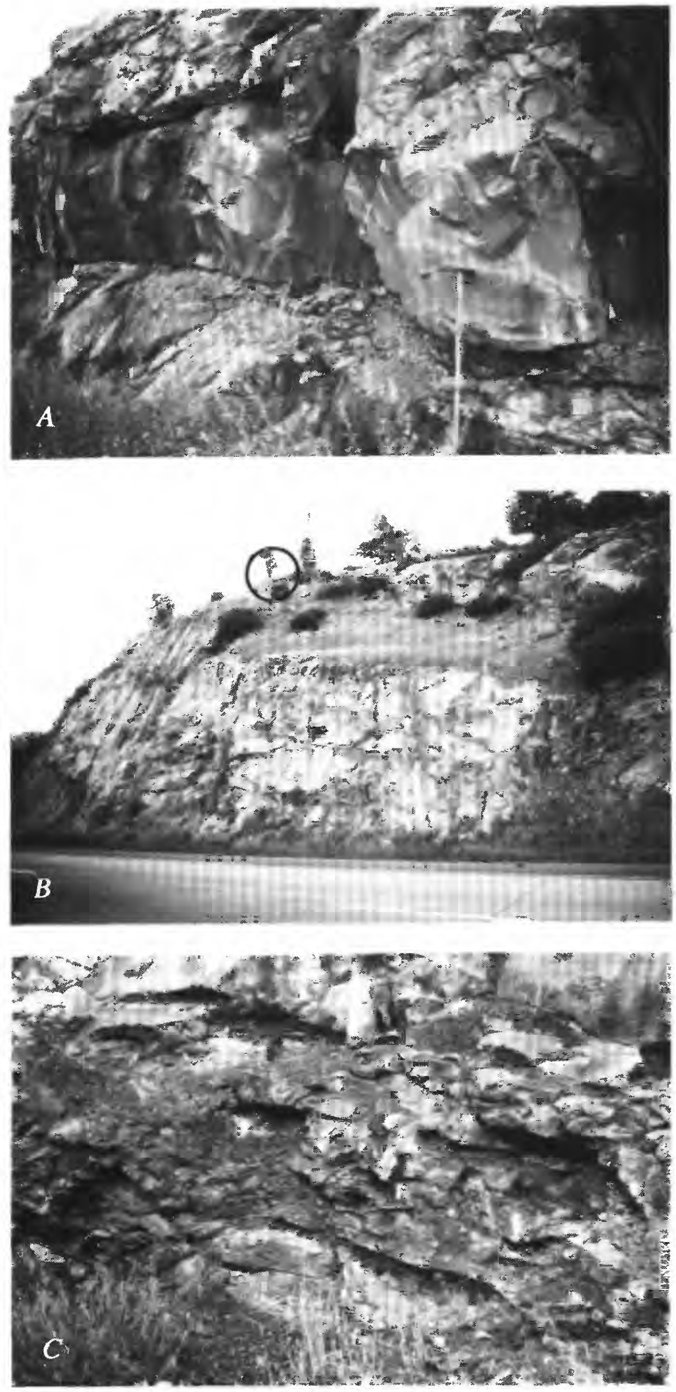


FIGURE 15.—Type section of the Rocky Gulch Sandstone Member of the Hornbrook Formation. *A*, Massive beds of sandstone in lower part of the Rocky Gulch Sandstone Member containing prominent shale interval. Staff is 1.5 m long. *B*, Massive sandstone cut by vertical fault; person circled for scale. *C*, Conglomerate composed of shale rip-up clasts. Rock hammer is 35 cm long.

The Rocky Gulch Sandstone Member was thought by most previous workers, despite the lack of fossil collections from it, to rest unconformably on underlying strata equivalent to the Ditch Creek Siltstone Member of the Hornbrook Formation. Although this contact is erosional in some exposures in the type area of the Hornbrook Formation, it appears to be gradational in most other areas to the northwest and southeast. As a result, I provisionally herein consider the contact to be generally conformable, pending accumulation of additional fossil age data, although it is locally erosive and may possibly be unconformable in the type area. The Rocky Gulch Sandstone Member is overlain conformably by the Blue Gulch Mudstone Member of the Hornbrook Formation and is typically a resistant unit that underlies a single ridge crest; in most areas, this ridge crest is flanked by a narrow valley to the southwest underlain by the less resistant underlying Ditch Creek Siltstone Member and a broad valley to the northeast underlain by the less resistant overlying Blue Gulch Mudstone Member (fig. 3).

The lower boundary of the Rocky Gulch Sandstone Member is defined by the abrupt to gradational and locally erosional upward change from predominantly massive bioturbated siltstone of the Ditch Creek Siltstone Member to thick beds of massive to graded sandstone that is locally conglomeratic. The lower contact, in sections that are gradational, is arbitrarily placed at the base of the first bed of sandstone that is more than 1 m thick.

The upper boundary of the Rocky Gulch Sandstone Member is typically gradational and marked by the gradual upward decrease in thickness and coarseness of sandstone beds and the increasing thickness of siltstone and mudstone. Because the Rocky Gulch Sandstone Member is typically organized into fining-upward and thinning-upward cycles, the boundary can generally be placed at the top of the highest cycle. In detailed measured sections, the top of the uppermost bed of fine- or medium-grained sandstone that is thicker than 30 cm was used to define the top of the Rocky Gulch Sandstone Member.

AREAL EXTENT

The Rocky Gulch Sandstone Member extends almost continuously in a northwest-southeast direction for nearly the entire outcrop extent of the Hornbrook Formation (pl. 1). It is generally well exposed, forming a low, generally narrow ridge between the higher elevations of the Klamath Mountains and the Cascade Range. It appears to be missing only locally, along the southern flank of Black Mountain, in parts of secs. 10, 11, 14, and 15, T. 46 N., R. 6 W., Hornbrook 15-minute quadrangle, where it appears that the Blue Gulch Mudstone Member rests directly on the Ditch Creek Siltstone Member (pl. 1).

The northernmost outcrops of the Rocky Gulch Sandstone Member are located about 3 km southeast of Medford, in roadcuts adjacent to Interstate Highway 5 (N½ sec. 51, SE corner of sec. 41, and NE corner of sec. 32, T. 37 S., R. 1 W., Medford 15-minute quadrangle). The best exposures in this northern area, however, are in roadcuts along the northeast side of Interstate Highway 5 (S½ sec. 51, E½ sec. 48, and NE corner of sec. 38, T. 37 S., R. 1 W., Medford 15-minute quadrangle) about 1 km to the southeast of the northernmost outcrops (Nilsen and others, 1984, stop 10). The freeway roadcuts expose a thickness of about 70 m of the Rocky Gulch Sandstone Member; at the southeastern end of the roadcut, the Rocky Gulch is juxtaposed by faulting with Tertiary nonmarine conglomerate of the Payne Cliffs Formation of McKnight (1971, 1984). These strata of the Rocky Gulch Sandstone Member were mapped by Wells (1956) as the Eocene Umpqua Formation, by McKnight (1971) as the Payne Cliffs Formation, and by Smith and others (1982) as Tertiary nonmarine strata. However, there is little doubt, on the basis of foraminiferal faunas, petrography, and character of the sedimentary sequences, that these rocks are properly assigned to the Rocky Gulch Sandstone Member of the Hornbrook Formation.

The Rocky Gulch Sandstone Member also crops out extensively in the Dark Hollow area, where it underlies a prominent northwest-trending ridge. The member does not crop out farther west or north in the Jacksonville or Medford Valley areas, however.

The southernmost outcrops of the Rocky Gulch Sandstone Member are in some low ridges along the northern margin of the Shasta Valley. The southernmost outcrops form an outlier along a low ridge about 2 km southwest of Mary's Peak (central part of sec. 25, T. 46 N., R. 6 W., Copco 15-minute quadrangle). Other good exposures are present a few kilometers to the northwest (W½ sec. 24, E½ sec. 23, T. 46 N., R. 6 W., Hornbrook and Copco 15-minute quadrangles). The Rocky Gulch Sandstone Member is not exposed in the Yreka or Soap Creek Ridge areas.

TYPE SECTION

The type section of the Rocky Gulch Sandstone Member of the Hornbrook Formation was measured from roadcuts along the northbound lane of Interstate Highway 5 in the NE¼NE¼ sec. 32, T. 47 N., R. 6 W., Hornbrook 15-minute quadrangle (fig. 16). The member is almost completely exposed along the highway and begins directly above the top of the type section of the Ditch Creek Siltstone Member (Nilsen and others, 1984, stop 4).

	Thickness (in meters)
Hornbrook Formation:	
Blue Gulch Mudstone Member (lower part):	
Mudstone, massive	
Conformable contact.	
Rocky Gulch Sandstone Member:	
Sandstone, fine- to medium-grained, massive	0.70
Shale, silty, massive	.55
Sandstone, fine- to medium-grained, massive	.40
Siltstone, massive	.15
Sandstone, very fine grained; hummocky cross-laminae	.20
Sandstone, graded, fine- to medium-grained, massive; scattered mudstone rip-up clasts	1.40
Sandstone, graded, fine- to medium-grained, massive; scattered mudstone rip-up clasts	1.50
Sandstone, graded, fine- to medium-grained and massive in lower part, very fine grained and laminated in upper 5 cm	1.50
Sandstone, graded, fine- to medium-grained and massive in lower part, very fine grained and laminated in upper 5 cm	1.90
Siltstone, massive	.10
Sandstone, slightly graded, fine- to medium-grained, massive; scattered mudstone rip-up clasts; erosive base	.85
Shale, massive	.10
Sandstone, very fine grained; hummocky cross-laminae, bioturbated	.10
Sandstone, fine- to medium-grained, massive	.07
Shale, massive	.30
Sandstone, very fine grained; hummocky cross-laminae	.30
Sandstone, graded, fine-grained, massive; erosive base	4.50
Sandstone, graded, fine- to medium-grained, massive	4.50
Shale, silty, massive	4.00
Covered interval	2.00
Sandstone, graded, fine-grained, partly covered, mostly massive but partly parallel-stratified, bioturbated	2.80
Covered interval (float mostly of shale)	7.20
Shale, silty, massive, bioturbated	1.25
Sandstone, very fine grained; hummocky cross-laminae	.25
Sandstone, graded, fine-grained, massive	.52
Siltstone and shale, laminated	.15
Sandstone, graded, fine-grained, massive	.75
Sandstone, very fine grained, laminated	.40
Sandstone, graded, fine- to medium-grained, massive; erosive base	3.00
Sandstone, very fine grained to fine-grained, laminated	.40

	Thickness (in meters)
Rocky Gulch Sandstone Member—*Continued*:	
Sandstone, graded, fine- to medium-grained, massive; erosive base	1.60
Shale, massive	.30
Sandstone, graded, fine- to medium-grained, massive	.20
Covered interval (float of shale)	.30
Sandstone, graded, fine- to medium-grained, massive	.25
Covered interval (float of shale)	.70
Sandstone, graded, fine- to medium-grained, massive	3.00
Covered interval (float of shale)	2.50
Sandstone, graded, medium-grained at base and fine-grained at top, massive; erosive base	5.70
Sandstone, graded, fine-grained, massive in lower part, laminated at top	.25
Covered interval (float of sandstone)	5.60
Sandstone, graded, fine- to medium-grained, massive; erosive base	5.00
Covered interval (float mostly of shale)	2.70
Shale, silty, massive	.70
Sandstone, very fine grained; hummocky cross-laminae	.10
Siltstone, massive to laminated, bioturbated	1.10
Sandstone, graded, fine- to medium-grained, massive	5.70
Sandstone, coarse-grained, conglomeratic, graded, massive; maximum clast size 1 cm	.50
Sandstone, graded, medium-grained	2.60
Sandstone, coarse-grained, conglomeratic, graded, massive; maximum clast size 0.5 cm; mudstone rip-up clasts; erosive base	.50
Sandstone, fine- to medium-grained, massive	5.20
Covered interval (float of sandstone)	.20
Sandstone, graded, medium-grained, massive	1.10
Sandstone, coarse-grained, conglomeratic, graded, massive; maximum clast size 0.5 cm; mudstone rip-up clasts; erosive base	.40
Sandstone, graded, fine- to medium-grained, massive	3.10
Covered interval	4.90
Sandstone, coarse-grained, conglomeratic, graded, massive; maximum clast size 0.5 cm; mudstone rip-up clasts; erosive base	1.00
Sandstone, graded, medium-grained, massive	4.30
Sandstone, coarse-grained, conglomeratic, graded, massive; maximum clast size 1 cm; mudstone rip-up clasts; erosive base	2.00
Shale, silty, massive	.05
Sandstone, fine- to medium-grained, massive, lenticular	.05
Shale, silty, massive	.10
Sandstone, graded, fine-grained, laminated	.30
Sandstone, graded, medium-grained, massive	2.50
Sandstone, medium- to coarse-grained, conglomeratic, graded, massive; maximum clast size 1 cm; erosive base	2.50
Shale, silty, massive	.15
Sandstone, very fine grained to fine-grained; current ripple markings	.15
Sandstone, graded, fine- to medium-grained, parallel-stratified	.20

	Thickness (in meters)
Rocky Gulch Sandstone Member—*Continued*:	
Sandstone, graded, medium-grained, massive	10.50
Sandstone, coarse-grained, conglomeratic, graded, massive; maximum clast size 2 cm; erosive base	2.85
Covered interval (float of very fine grained sandstone)	.80
Sandstone, graded, medium-grained, massive, concretionary	10.50
Sandstone, medium-grained, conglomeratic, graded, massive; maximum clast size 1 cm; mudstone rip-up clasts; erosive base	7.60
Shale, massive	.20
Sandstone, medium- to coarse-grained, conglomeratic, graded, massive; maximum clast size 2 cm; scattered mudstone rip-up clasts	4.65
Conglomerate, consisting of more than 80 percent mudstone rip-up clasts as large as 100 cm, less than 20 percent lithic pebbles as large as 8 cm, and some clasts of carbonate concretions; matrix of medium- to coarse-grained sandstone; erosive base	4.20
Sandstone, medium- to coarse-grained, graded, massive, conglomeratic in lower 100 cm; maximum clast size 2 cm	7.50
Conglomerate, matrix-supported; dominantly lithic clasts in lower part, maximum clast size 15 cm; dominantly mudstone rip-up clasts in upper part, maximum clast size 40 cm; massive; rare molluscan fossil fragments; erosive base	1.00
Sandstone, graded, medium- to coarse-grained, conglomeratic; scattered lithic pebbles less than 1 cm and mudstone rip-up clasts less than 50 cm in length; some swirly stratification and subparallel stratification	9.50
Conglomerate, massive; maximum clast size 2 cm; lens-shaped; erosive base	1.05
Sandstone, graded, medium-grained, massive, conglomeratic in lower 70 cm; lithic pebbles less than 2 cm in length; abundant mudstone rip-up clasts and clasts of carbonate concretions; erosive base	1.50
Total thickness of the Rocky Gulch Sandstone Member	171.19

Erosive contact, possibly unconformable.
Ditch Creek Siltstone Member:
Siltstone and silty very fine grained sandstone, massive, thoroughly bioturbated; abundant spherical carbonate concretions

The colors of the Rocky Gulch Sandstone Member are light brownish gray (5YR 6/1) for fresh sandstone and light brown (5YR 6/4), pale yellow brown (10YR 6/2), and moderate yellow brown (10YR 5/4) for weathered sandstone. The interbedded shale is medium dark gray (N4) or medium gray (N5) on fresh surfaces and moderate yellowish brown (10YR 5/4) on weathered surfaces. The mudstone rip-up clasts, abundant at the base of the member, are medium dark gray (N4) on fresh surfaces and pale yellowish brown (10YR 6/2) on weathered surfaces.

LITHOLOGY

The Rocky Gulch Sandstone Member consists predominantly of fine- to medium-grained sandstone. It is generally well bedded and evenly bedded. The sandstone beds, particularly the thinner beds in the upper part of the member, are generally separated by thin shale intervals; however, in the lower part of the member, and in the lower parts of thinning- and fining-upward cycles, the sandstone beds are commonly amalgamated. Conglomerate and siltstone are generally present in most sections. Conglomerate forms the dominant lithology in the Ditch Creek area, about 5 km northwest of the type section. Siltstone is present in the upper part of many sections as a current ripple-marked interval that rests on sandstone beds. However, sandstone probably forms 80–90 percent of the thickness of most sections.

The sandstone beds are generally of two types: (1) very thick to massive, internally structureless beds, and (2) thin to medium beds that are organized into Bouma sequences. The beds are typically organized into cycles of 5–10 beds that have a thinning- and fining-upward character. The lower parts of the cycles consist of very thick to massive beds that are generally amalgamated, as thick as 10 m or so, and are coarse-tail graded (that is, pebbles and granules are concentrated near the bases of the beds even though most of the sandstone does not appear to be graded). The basal surfaces of these beds are clearly erosive into underlying beds of shale or sandstone, but they do not form channels at outcrop scale. Flute casts, groove casts, and load casts are common sole markings on these basal surfaces. Rip-up clasts of shale and flaps of shale from the underlying bed that are partly torn up and embedded in the overlying bed of sandstone are locally common (Boggs and Swanson, 1970). Some beds contain a thick lower interval of rip-up-clast conglomerate where the contact with the underlying shale is conspicuously erosive. Dish structure and irregular, swirly lamination have been noted at several localities. The thicker beds are characteristically composed of medium-grained to very coarse grained sandstone. The tops of the beds, which are typically sharp and planar, are overlain abruptly by shale, except where amalgamation of sandstone beds is present These sandstone beds resemble turbidite facies B of Mutti and Ricci Lucchi (1972) except that they are laterally persistent and not clearly channelized.

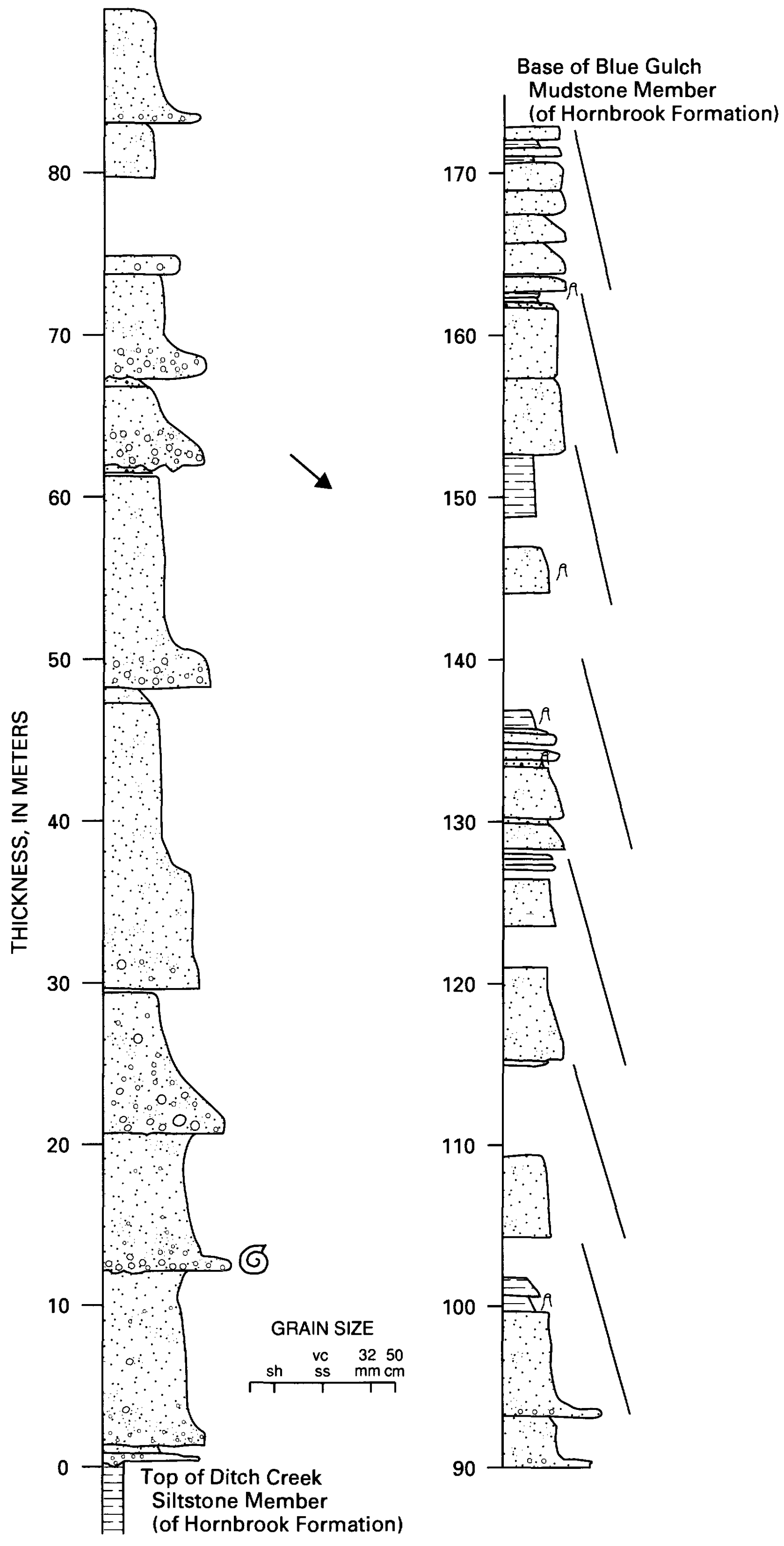


FIGURE 16.—Type section of the Rocky Gulch Sandstone Member of the Hornbrook Formation. See figure 10 for explanation of symbols and caption of figure 12 for explanation of abbreviations. Gaps in lithology represent covered intervals.

The upper parts of the fining- and thinning-upward cycles, as well as most of the upper part of the Rocky Gulch Sandstone Member, consist of beds of very fine grained to medium-grained sandstone. These beds typically range from 10 cm to 5 m in thickness and are laterally continuous. They are graded and separated by shale beds; amalgamation is uncommon. The basal surfaces are planar but erosive into the underlying shale beds. Flute casts, groove casts, prod marks and other tool marks, and minor load casts are present as sole markings. The upper surfaces are also planar but are gradational into overlying shale except where intervening siltstone deposits are present. These beds are massive or, more commonly, organized into Bouma sequences of the T_{a-e} or T_{b-e} type. They resemble turbidite facies C and D of Mutti and Ricci Lucchi (1972).

Beds of conglomerate that appear to be laterally continuous are present in many sections of the Rocky Gulch Sandstone Member. They appear to be most common in the lower part of the member, but conglomerate beds are also present in the upper part of the member, especially in the Bear Creek valley area. These conglomerate beds are generally graded with erosive basal surfaces and are composed of a variety of clasts. The beds generally range from 15 cm to 10 m in thickness. However, very coarse conglomerate units at least as thick as 60 m and possibly as thick as 95 m are present in the upper part of the Rocky Gulch Sandstone Member in the Ditch Creek area. The conglomerate beds generally consist of well-rounded clasts of pebble size, but in the Ditch Creek area, boulders as long as 32 cm are present. The conglomerate is typically well bedded, imbricated, and clast supported; it has a matrix of smaller clasts and sandstone and contains in a few places medium- to large-scale tabular cross-strata. Although no pebble counts were made in the type section of the Rocky Gulch Sandstone Member, a pebble count from the Ditch Creek area yielded an average composition of 53 percent quartzite, 23 percent metavolcanic rocks, 13 percent chert, 7 percent granitic rocks, and 4 percent metasedimentary rocks. The conglomerate beds appear to be similar to the facies A turbidites of Mutti and Ricci Lucchi (1972).

Siltstone beds locally overlie the graded beds of fine- to medium-grained sandstone in the Bear Creek valley and Cottonwood Creek valley areas (Nilsen and others, 1984, p. 24–25, 33–36; Nilsen, 1984d). These siltstone beds commonly truncate the upper parts of Bouma sequences in the sandstone beds and are overlain abruptly to gradationally by shale. The siltstone is typically wavy bedded or parallel laminated and locally contains current ripple markings and convolute laminations. These beds appear to be contourite deposits (Bouma and Hollister, 1973).

Interbedded shale is generally less than 1 m thick and is commonly covered by colluvium. In the lower parts of the Rocky Gulch Sandstone Member, the shale is commonly massive and contains evenly distributed silt grains, whereas in the upper parts, the shale locally contains thin beds or laminae of siltstone that have sharp, erosive bases and are graded. Bioturbation is not abundant, but *Nereites*-facies grazing burrows have been observed on a few bedding surfaces.

STRATIGRAPHIC RELATIONS

The Rocky Gulch Sandstone Member rests locally with erosional contact but generally conformably on the Ditch Creek Siltstone Member and is conformably overlain by the Blue Gulch Mudstone Member. The lower contact is placed where the predominant lithology changes upward from siltstone to sandstone, and the upper contact is set at the upward change from sandstone to mudstone.

The lower contact is clearly erosional in the Hornbrook area and has previously been interpreted as an unconformity. However, to the northwest and southeast of the type area, the contact appears to be gradational, and it is considered herein to be generally conformable. Better age control would be helpful in completely defining the contact. I place the contact at the base of the first bed of fine- to medium-grained or medium-grained sandstone that is more than 1 m thick.

The upper contact is clearly gradational, although locally abrupt, and is placed at the top of the highest fining- and thinning-upward cycle of sandstone beds in the Rocky Gulch Sandstone Member. The boundary is placed at the top of the highest bed of fine-grained or medium-grained sandstone that is thicker than 30 cm.

Lateral stratigraphic relations of the Rocky Gulch Sandstone Member are poorly defined. The member undoubtedly extends northeastward beneath the Cascade Range, but the distance is not known because the subsurface structure is poorly known. To the southeast and northwest, it is covered and overlapped by Tertiary volcanic rocks and Quaternary alluvium in the Medford Valley and Shasta Valley areas. Stratigraphic equivalents of the Rocky Gulch Sandstone Member do not appear to be present in the Grave Creek area, so the member probably pinches out between the Dark Hollow area and the Grave Creek area. The Rocky Gulch Sandstone Member probably also originally extended southwestward over part of the Klamath Mountains, but the distance is impossible to determine.

THICKNESS

The Rocky Gulch Sandstone Member is relatively constant in thickness over its outcrop area, generally ranging from 115 to 225 m. Peck and others (1956) determined a thickness of 62.8 m and Jones (1959) a thickness of 40 m for strata equivalent to the Rocky Gulch Sandstone Member in the type area of the Hornbrook Formation. Elliott (1971) determined a thickness of 137 m in the northern Cottonwood Creek valley area and McKnight (1971) a thickness of 220 m in the Bear Creek valley for strata equivalent to the Rocky Gulch Sandstone Member.

I have measured a number of additional sections of the Rocky Gulch Sandstone Member north of the type section described herein, which is 171.2 m thick. A section adjacent to Ditch Creek (W½ sec. 18, T. 47 N., R. 6 W., Hornbrook 15-minute quadrangle), about 5 km northwest of the type section, yielded a thickness of 221.4 m. Two additional sections were measured south of Hilt in the northern Cottonwood Creek valley. The first, northeast of Cottonwood Creek (NW¼NE¼ sec. 1, T. 47 N., R. 7 W., Hornbrook 15-minute quadrangle), is 115 m thick and the second, along the west fork of Cottonwood Creek (NE¼SW¼ sec. 26, T. 48 N., R. 7 W., Hornbrook 15-minute quadrangle), is 126.4 m thick. Three partial sections of the Rocky Gulch Sandstone Member were also measured: (1) a thickness of 46 m for a section about 1 km northwest of the type section, along some roadcuts southwest of Interstate Highway 5 (center, sec. 29, T. 47 N., R. 6 W., Hornbrook 15-minute quadrangle); (2) a thickness of about 74 m for a section about 1 km northeast of downtown Ashland in roadcuts along Eagle Mill Road, adjacent to its intersection with Oak Street (SW¼ sec. 3, T. 38 S., R. 1 E., Ashland 15-minute quadrangle); and (3) a thickness of 75 m for a section 4 km southeast of Medford (SW¼ sec. 32, T. 37 S., R. 1 W., Medford 15-minute quadrangle).

The reasons for the low thicknesses obtained for the Rocky Gulch Sandstone Member by Peck and others (1956) and Jones (1959) in the type area are not certain, but they probably reflect differences in placement of the upper boundary of the member. To the southeast, the Rocky Gulch Sandstone Member appears to thin, and it is absent on the south flank of Black Mountain. To the northwest, the Rocky Gulch Sandstone Member appears to extend continuously to the Dark Hollow area with minor fluctuations in thickness.

DEPOSITIONAL ENVIRONMENT

The depositional environment of the Rocky Gulch Sandstone Member has been the subject of varied speculation by previous workers. Although they found no fossils in strata equivalent to the Rocky Gulch Sandstone Member, Peck and others (1956) apparently felt that the strata nevertheless were marine. Jones (1959), possibly influenced by his interpretation of an unconformity at the base of strata equivalent to the Rocky Gulch Sandstone Member, concluded that the strata were partly nonmarine in origin. Elliott (1971) inferred a moderate- to high-energy shallow-marine depositional environment for strata equivalent to the Rocky Gulch Sandstone Member chiefly on the basis of what he considered to be the dominant cross-bedded character of the unit; however, he considered at least one outcrop, about 2.5 km south of Hilt, to be of fluvial origin (Elliott, 1971, p. 37). McKnight (1971) concluded on the basis of sedimentary features that strata equivalent to the Rocky Gulch Sandstone Member in the Bear Creek valley area were deposited in marine, marginal marine, and nonmarine depositional environments.

On the basis of my detailed work on the Rocky Gulch Sandstone Member, which includes measurement of four complete and three partly complete sections and abundant sampling of shale interbeds for microfossils, I infer that the member is chiefly of deep-marine origin. There is no evidence for subaerial deposition by rivers or for high-energy or low-energy marine shelf sedimentation, as suggested by others. Medium- and large-scale cross-bedding is very rare in the Rocky Gulch Sandstone Member; complex patterns of jointing and curviplanar near-surface fracturing have been misinterpreted by previous workers to be cross-bedding. When examined in detail, these fractures were observed to cut across stratification.

Most beds of sandstone are normally graded, are separated by thin shale intervals or are amalgamated, and have sole markings at their base. Only fragments of molluscan shells have been observed, and these have been broken and abraded, clearly carried by currents that transported sand and gravel. Megafossils (including pelecypods and ammonites) reported by McKnight (1971) from sandstone in the lower part of his subunit Khs_{3a} suggest that this subunit may actually lie within the upper part of the Ditch Creek Siltstone Member.

The thick-bedded to massive sandstone beds that lack any internal stratification and dominate the lower part of the Rocky Gulch Sandstone Member were probably deposited by sediment gravity flows, most likely high-concentration turbidity currents, sandy debris flows, grain flows, or fluidized sediment flows. These beds, some as thick as 10 m, lack the internal sedimentary structures such as cross-stratification or thorough bioturbation that typify shallow-marine or fluvial sandstones. Their erosive bases, grading, and amalgamation suggest deposition by repeated sediment gravity flows of very sand-rich suspensions.

The thinner beds of sandstone that are graded and organized into T_{a-e} and T_{b-e} Bouma sequences were probably deposited by low-concentration turbidity currents. These beds are laterally continuous and most abundant in the upper part of the Rocky Gulch Sandstone Member. Reworking of the tops of many of these beds suggests the presence of contour currents.

The stratigraphic position of the Rocky Gulch Sandstone Member between outer-shelf deposits of the underlying Ditch Creek Siltstone Member and basin-plain deposits of the overlying Blue Gulch Mudstone Member, the organization of the Rocky Gulch Sandstone Member into laterally continuous fining- and thinning-upward cycles, the preponderance of sediment gravity-flow deposits, the lateral continuity of the member over a northwest-southeast distance of about 80 km despite a thickness of only 115–225 m, and the presence of reworked tops of some turbidite sandstones all suggest that the Rocky Gulch Sandstone Member was deposited as a turbidite apron mantling a regional submarine slope of the ancestral Klamath Mountains (Nilsen, 1984b). There is no evidence in the sedimentary record of the Hornbrook Formation for major deep-sea fan sedimentation.

AGE AND CORRELATION

No fossil ages had been previously determined from strata equivalent to the Rocky Gulch Sandstone Member. The unconformity postulated at the base of the Rocky Gulch Sandstone Member was thought by Peck and others (1956) and most subsequent workers to range from late Coniacian to early Campanian in age. The missing Santonian Stage is generally thought to be about 3 m.y. in length (Palmer, 1983; pl. 1).

Although I collected many samples of shale from the Rocky Gulch Sandstone Member for foraminiferal analysis, only one sample, from exposures along Interstate Highway 5 east of Medford (USGS Mesozoic locality Mf6587), yielded foraminifers (Nilsen and others, 1984, stop 10). These foraminifers are indicative of a middle Turonian age. Unfortunately, the sample is from a measured section in which the base is covered and the top is faulted, so it is not certain from which part of the Rocky Gulch Sandstone Member the sample was taken. However, the unit is virtually identical to other outcrops of the Rocky Gulch Sandstone Member and has confidently been mapped as such (Nilsen and others, 1983, pl. 1).

Samples from the type section of the Rocky Gulch Sandstone Member were barren of microfossils. A sample from the uppermost part of the underlying Ditch Creek Siltstone Member, taken from a section measured near Bailey Hill in the northern Cottonwood Creek valley (USGS Mesozoic locality Mf6581), is considered to be late Turonian to Coniacian in age based on benthic foraminifers; at this locality, the contact between the Ditch Creek Siltstone Member and the Rocky Gulch Sandstone Member appears to be gradational and conformable.

Thus the age of the Rocky Gulch Sandstone Member appears to be middle Turonian to Campanian(?). However, the age data are very sparse, and more fossiliferous samples from the member are needed to better define its age.

The Rocky Gulch Sandstone Member is, at least partly, correlative with a number of other geologic units in Oregon and northern California. It may correlate with part of the Cretaceous section at Grave Creek. It appears to be younger than exposed Cretaceous strata to the north in the Days Creek, Riddle, and Mitchell areas and to the west in the O'Brien area. It may correlate, however, with part of the subsurface sequence of the Ochoco basin (Thompson and others, 1984). It probably correlates in part with strata along the southwestern coast of Oregon that are at least partly of Campanian age [the Cape Sebastian Sandstone and Hunters Cove Formation of Dott (1971)].

To the south, the Rocky Gulch Sandstone Member may possibly be correlative with the uppermost part of the Budden Canyon Formation of Murphy and others (1969) southwest of Redding and with the Great Valley sequence near Redding (Popenoe, 1943; Matsumoto, 1960); however, these units are more probably at least partly older than the Rocky Gulch Sandstone Member. Farther south, the Rocky Gulch Sandstone Member is probably at least partly correlative with the Great Valley sequence on both the east and west flanks of the Sacramento Valley (Ingersoll, 1979; Haggart and Ward, 1984), and with parts of the Coastal belt terrane of the Franciscan assemblage.

BLUE GULCH MUDSTONE MEMBER

DEFINITION

The name "Blue Gulch Mudstone Member" was applied by Nilsen (1984a) to continuous outcrops of marine strata that are predominantly composed of mudstone; these strata form the uppermost member of the Hornbrook Formation. The member was named for exposures adjacent to Blue Gulch about 4 km south of Hornbrook, California (fig. 17). However, because the mudstone does not generally crop out very well, the type section is a composite one that was measured in four different places south and west of Hornbrook (fig. 8). The main part of the section, however, was measured across Blue Gulch.

The Blue Gulch Mudstone Member contains within it two prominent mappable lithologic units. The first is a sandstone lens that crops out only in the Hornbrook area; it is named the Rancheria Gulch Sandstone Beds (Nilsen, 1984a, b, c, d) for outcrops adjacent to Rancheria Gulch northwest of Hornbrook (figs. 6, 7). The lens is present in the lower part of the Blue Gulch Mudstone Member; it is underlain by about 80 m of strata that consist predominantly of mudstone and is overlain by about 690 m of strata that also consist predominantly of mudstone. The lens extends laterally for about 8 km before pinching out into mudstone to the northwest and southeast.

Stratigraphically higher within the Blue Gulch Mudstone Member is the Hilt Bed (Nilsen, 1984a, b, c, d) (figs. 6, 7), a thick single bed of sandstone that has been mapped almost continuously from the northern Shasta Valley to the Ashland area, a distance of about 45 km (pl. 1; Nilsen, 1983). The Hilt Bed forms a mappable bed overlain and underlain by thick sequences of strata that consist predominantly of mudstone. The lateral extent and persistence of the Hilt Bed along the outcrop belt of the Hornbrook Formation have facilitated mapping of the northeast-trending cross-faults that separate the outcrop belt into numerous separate fault-bounded blocks (pl. 1).

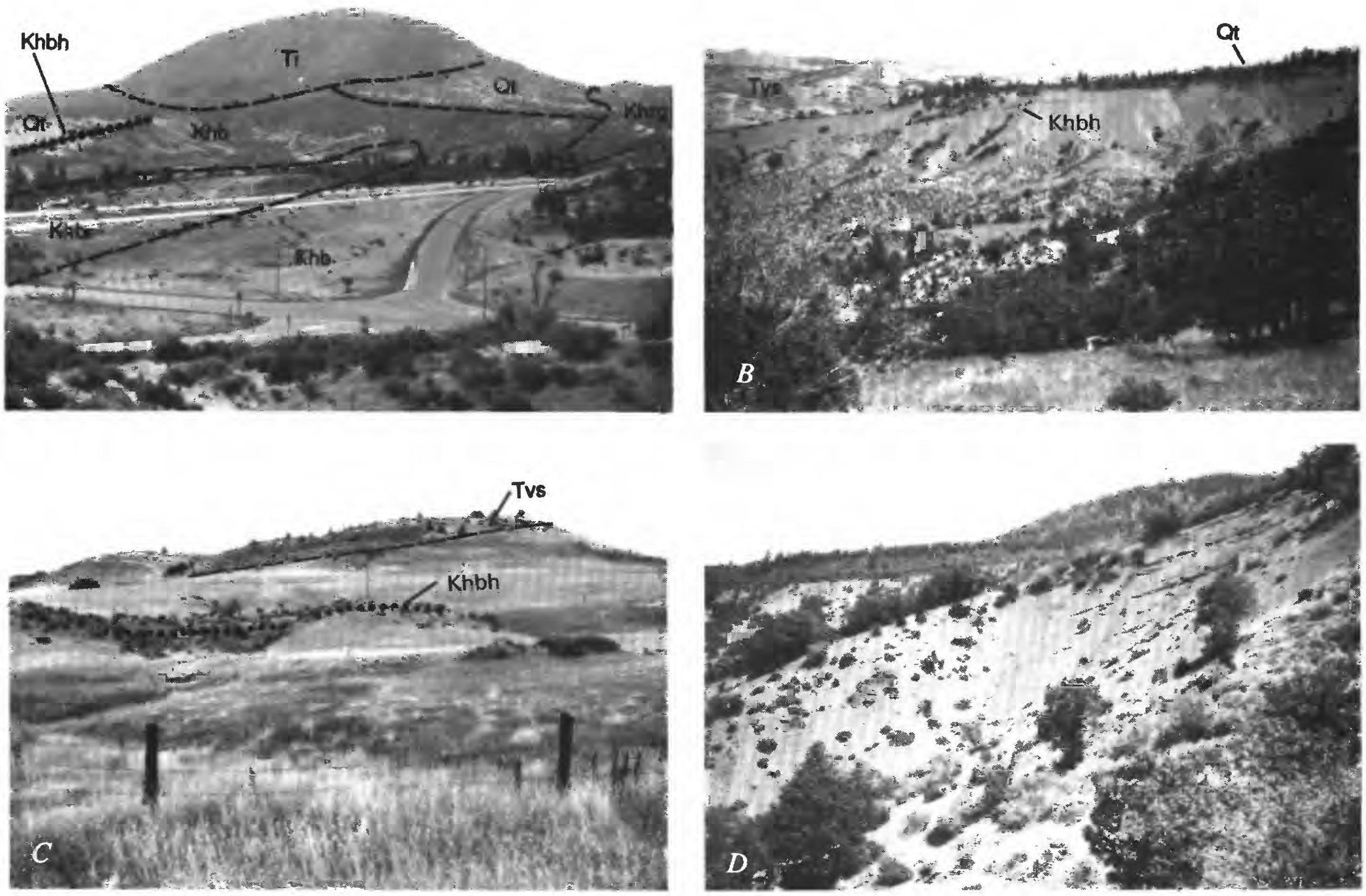
The Blue Gulch Mudstone Member is the fifth or uppermost member of the Hornbrook Formation. It is equivalent to the upper part of member IV and members V and VI (of Hornbrook Formation) as mapped by Peck and others (1956) (fig. 6). Their member V is equivalent to the Rancheria Gulch Sandstone Beds. The Blue Gulch Mudstone Member is also equivalent to unit C (of Hornbrook Formation) of Jones (1959), who correctly mapped a sandstone lens in the lower part of the unit in the Hornbrook area that is equivalent to the Rancheria Gulch Sandstone Beds. The Blue Gulch Mudstone Member is also equivalent to (1) McKnight's (1971) unit Khm in the Bear Creek valley area, which he considered to be the uppermost unit of his Hornbrook Formation; and (2) M.A. Elliott's (unpub. data, 1980) unit D, which he considered to be the uppermost unit of his Hornbrook Formation in the northern Cottonwood Creek valley area. Nilsen and others (1983) mapped the Blue Gulch Mudstone Member as their unit d of the Hornbrook Formation; they mapped the Rancheria Gulch Sandstone Beds as separate subunits l_1 and l_2 and the Hilt Bed as subunit m within unit d (fig. 6).

The Blue Gulch Mudstone Member rests conformably on the Rocky Gulch Sandstone Member throughout the outcrop area of the Hornbrook Formation except along the south flank of Black Mountain (parts of secs. 10, 11, 14, and 15, T. 46 N., R. 6 W., Hornbrook 15-minute quadrangle), where the Rocky Gulch Sandstone Member appears to be missing. In this area, the lithologies of patchy outcrops beneath large landslides derived from the intrusive rocks of Black Mountain suggest that the Blue Gulch Mudstone Member rests directly on massive, thoroughly bioturbated, silty fine-grained sandstone thought to be the Ditch Creek Siltstone Member. However, this contact was not directly observed in the field.

The Blue Gulch Mudstone Member is overlain unconformably by either conglomeratic Tertiary nonmarine strata or by Tertiary volcanic rocks. The Tertiary sedimentary rocks, thought to be Eocene in age, were mapped by Wells (1939, 1956) as the Eocene Umpqua Formation, by McKnight (1971, 1984) as the Payne Cliffs Formation, and by Beaulieu and Hughes (1977) as unnamed Eocene sedimentary rocks; these strata overlie the Blue Gulch Mudstone Member in most of the Bear Creek valley area but appear to be missing in the Cottonwood Creek valley area. Similar but much thinner conglomeratic nonmarine strata rest unconformably on the Blue Gulch Mudstone Member in the northeastern Shasta Valley; these unnamed Tertiary sedimentary rocks were mapped by Nilsen and others (1983) in this area and are shown on plate 1.

Tertiary volcanic rocks of the western Cascade Range unconformably overlie the Blue Gulch Mudstone Member in the Cottonwood Creek valley area, between the Siskiyou Summit fault and the northern margin of the Shasta Valley. These volcanic rocks were mapped by Wells (1956), in ascending order, as the Eocene Colestin Formation and the Oligocene Roxy Formation. In northern California, the volcanic rocks form part of the Western Cascade Series of Williams (1949) and have been subdivided by Hammond (1983) and discussed by Vance (1984).

The lower boundary of the Blue Gulch Mudstone Member is marked by the abrupt to gradual upward change from graded beds of fine- to medium-grained sandstone with some thin interbeds of mudstone that characterize the upper part of the Rocky Gulch Sandstone Member to bioturbated mudstone with a few thin interbeds of siltstone and very fine grained sandstone that characterizes the lower part of the Blue Gulch Mudstone Member. The Rocky Gulch Sandstone Member consists chiefly of sandstone and contains beds as thick as several meters; mudstone or shale is typically subordinate and forms thin but laterally continuous interbeds. The Rocky Gulch Sandstone Member is typically organized into fining-upward cycles, and the top of the uppermost cycle marks the stratigraphic boundary between the members. Because the Rocky Gulch Sandstone Member is a resistant unit that underlies a series of ridges and the Blue Gulch Mudstone Member is a much less resistant unit that underlies the main parts of the Bear Creek, Cottonwood Creek, and Shasta valleys, the



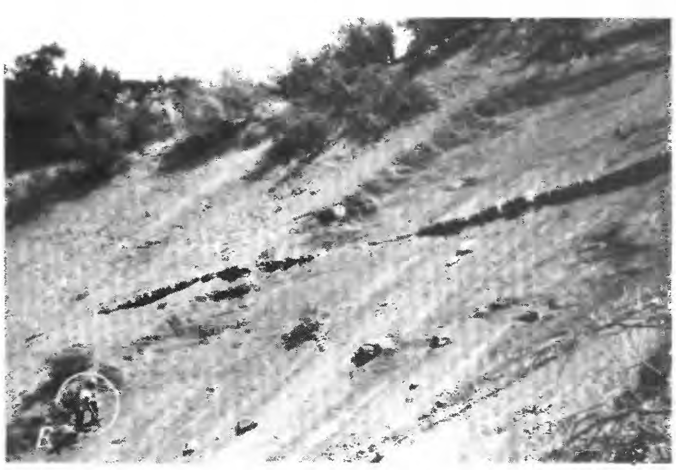


FIGURE 17.—Blue Gulch Mudstone Member of the Hornbrook Formation. Khbh, Cretaceous Hilt Bed (of Blue Gulch Mudstone Member); Khb, Cretaceous Blue Gulch Mudstone Member; Khbr, Cretaceous Rancheria Gulch Sandstone Beds (of Blue Gulch Mudstone Member); Khrg, Cretaceous Rocky Gulch Sandstone Member (of Hornbrook Formation); Qt, Quaternary terrace deposits; Ti, Tertiary intrusive rocks; Tvs, Tertiary volcanic and sedimentary rocks. Contact, dashed line, approximately located. *A*, View southeast of type section on north flank of Black Mountain. *B*, View east of type section across Blue Gulch from ridge crest underlain by Rocky Gulch Sandstone Member located in W½ sec. 33, T. 47 N., R. 6 W., Hornbrook 15-minute quadrangle. *C*, View northeast of upper part of type section of the Blue Gulch Mudstone Member, east of Hornbrook, California, in sec. 21, T. 47 N., R. 6 W., Hornbrook 15-minute quadrangle. *D* and *E*, Outcrops of siltstone and interbedded mudstone in type section east of Blue Gulch. Resistant bed is approximately 40 cm thick.

boundary is also generally marked by a pronounced topographic change. I suggest that the base of the Blue Gulch Mudstone Member in detailed measured sections be placed at the top of the uppermost bed of fine- or medium-grained sandstone that is thicker than 30 cm.

The upper boundary of the Blue Gulch Mudstone Member is typically well marked by the unconformity at the base of the overlying Tertiary sequence and by an abrupt change in lithology from bioturbated marine mudstone that is locally fairly resistant as a result of baking by overlying or locally intrusive volcanic rocks to more poorly lithified, unbioturbated, nonmarine conglomerate and sandstone or volcanic rocks. I have not observed a paleosol at the top of the member at any locality. The Tertiary sedimentary rocks consist of polymict, imbricated conglomerate interbedded with medium-grained to granular arkosic sandstone; these sedimentary rocks were probably deposited by braided streams. Bedded mudstone or shale is generally missing from the lower part of the Tertiary section, which is dominated by conglomerate and sandstone. Directly above the unconformity, however, angular to poorly rounded blocks of the Blue Gulch Mudstone Member are incorporated in the lower part of the Tertiary section. These blocks have clearly been eroded from the underlying mudstone.

The surface of the unconformity locally has been eroded deeply into the Blue Gulch Mudstone Member. In the Ashland area, the Blue Gulch Mudstone Member has been completely removed in some locations by erosion, so that the Tertiary nonmarine rocks rest directly on the Ditch Creek Siltstone Member and Rocky Gulch Sandstone Member. In this area, the contact between the Hornbrook Formation and the younger rocks is clearly an angular unconformity, whereas in most other parts of the outcrop area, the contact is essentially disconformable. The downcutting has probably caused the erosion of the Hilt Bed in much of the Bear Creek valley area north of Ashland.

Where the upper contact of the Blue Gulch Mudstone Member is marked by volcanic rocks resting on marine mudstone, there is commonly abundant deformation in the upper part of the underlying mudstone. Slump folding, faulting, shearing, veining, and extensional fracturing affect the mudstone just below the unconformable contact with the volcanic rocks. These features probably reflect surface processes (chiefly subaerial landsliding) caused by the outpouring of thick flows of lava on relatively unstable slopes underlain by the mudstone.

AREAL EXTENT

The Blue Gulch Mudstone Member extends essentially continuously for about 73 km, almost the entire outcrop extent of the Hornbrook Formation. However, it is generally poorly exposed and underlies grassy slopes and valleys. Along the northeastern margins of the Bear Creek and Cottonwood Creek valleys, it underlies moderate to steep slopes held up by resistant Tertiary volcanic rocks. The best exposures of the Blue Gulch Mudstone Member are along the northwest side of Black Mountain in the Blue Gulch area, where major downcutting has exposed the mudstone in the floor of Blue Gulch and its tributary drainage network. Other good exposures are generally more areally restricted; they include outcrops on the floors of Bear Creek and Cottonwood Creek and some of their tributaries, outcrops adjacent to resistant Tertiary intrusive rocks, and exposures made by roadcuts, especially large freeway cuts, along Interstate Highway 5 and by railroad cuts in both the Bear Creek and Cottonwood Creek valley areas. However, very large areas that are probably underlain at depth by the Blue Gulch Mudstone Member in the Medford and Shasta Valleys are covered by Quaternary alluvium.

Because the Blue Gulch Mudstone Member is the thickest member of the Hornbrook Formation, it generally has the widest outcrop width. However, in part of the Bear Creek valley between Ashland and Talent, it is very thin because of major erosion at the base of the Tertiary sedimentary rocks.

The northernmost outcrops of the Blue Gulch Mudstone Member are located at Hanley Hill in the Medford Valley, about 4.5 km northeast of Jacksonville and 5 km west-northwest of Medford (sec. 22, SE part of sec. 68, and NW corner of sec. 70, T. 37 S., R. 2 W., Medford 15-minute quadrangle). This hill is underlain by resistant Tertiary intrusive rocks and by strata of the Blue Gulch Mudstone Member that are also resistant because they were baked and contact metamorphosed by the heat of the intrusive rocks. The presence of the Blue Gulch Mudstone Member at Hanley Hill, in the northeastern parts of the Dark Hollow area, and in a broad low hill about 3 km south-southeast of Medford (parts of secs. 31, 37, 43, 45, 46, 47, and 54, T. 37 S. and T. 38 S., R. 1 W., Medford 15-minute quadrangle) suggests that it underlies much of the Medford Valley but is buried beneath thick Quaternary alluvial and alluvial-fan deposits.

Beaulieu and Hughes (1977), in their map of central Jackson County, Oregon, showed additional and more widespread outcrop areas of mid-Cretaceous and Upper Cretaceous strata in the Medford Valley area, including outcrops as far north as the area northwest of Central Point (secs. 4, 46, 47, 61, 62, and 63, T. 36 S., R. 2 W., Medford 15-minute quadrangle). However, they did not indicate the rock types present in these areas and appear to have included some lower Tertiary strata within their mapped Cretaceous unit, which makes it impossible to determine if any of these areas are underlain by the Blue Gulch Mudstone Member. In addition, the lack of measured strikes and dips in these areas makes stratigraphic assignment difficult. My own mapping in these areas (pl. 1) failed to reveal any outcrops of the Blue Gulch Mudstone Member north of Hanley Hill, nor did I find any field indications that other members of the Hornbrook Formation crop out in the areas mapped by Beaulieu and Hughes (1977) in the northern part of the Medford 15-minute quadrangle.

Smith and others (1982) also show large areas of outcrop of Cretaceous sedimentary strata in the Medford Valley, particularly north of the Jacksonville and Dark Hollow areas. Some of these outcrop areas appear to be north of the Hanley Hill area. However, they did not divide the Cretaceous strata into subunits. My own mapping in the Medford Valley has failed to reveal any outcrops of the Blue Gulch Mudstone Member in the areas shown by Smith and others (1982), other than those mapped outcrops shown in plate 1 of this report.

Farther southeastward, the Blue Gulch Mudstone Member does not crop out between the Dark Hollow area and Talent. In this area, it was apparently overlain unconformably, covered by Quaternary alluvial and alluvial-fan deposits, and partly eroded prior to deposition of the Tertiary nonmarine strata. Southeastward from Talent, however, it crops out more continuously to the northern Shasta Valley.

Between Talent and Ashland in the northern Bear Creek valley, the outcrop width of the Blue Gulch Mudstone Member is narrow and the member is poorly exposed. Between Ashland and the Siskiyou Summit fault in the Bear Creek valley, its outcrop width is wider and it is better exposed because it has been uplifted adjacent to numerous resistant Tertiary intrusive rocks.

In the Cottonwood Creek valley area, the Blue Gulch Mudstone Member crops out extensively, with the best exposures of its lower part located south of the Klamath River near Blue Gulch, and the best exposures of its upper part located on the hillsides east of Hornbrook and in the Bailey Hill area southeast of Hilt.

In the northern Shasta Valley area, the outcrop width of the Blue Gulch Mudstone Member reaches its maximum of more than 5 km. The southernmost exposures of the Blue Gulch Mudstone Member are on two low ridges about 1.5 km south of Marys Peak (NE¼ sec. 25, T. 46 N., R. 6 W., and NW¼ sec. 30, T. 46 N., R. 5 W., Copco 15-minute quadrangle) and on a flat plateau about 2.5 km to the east (NE¼ sec. 29, T. 46 N., R. 5 W., Copco 15-minute quadrangle). The Blue Gulch Mudstone Member crops out extensively in the northern Shasta Valley, where it is upheld by numerous Tertiary intrusive rocks, but it is entirely missing from the central and southern parts of the Shasta Valley. In these areas, it appears to be concealed beneath unconformably overlying Quaternary alluvial deposits, alluvial-fan deposits, and volcanogenic debris-avalanche deposits. It probably extends for some distance in the subsurface southeast of the Shasta Valley but is completely concealed in that direction by Tertiary volcanic rocks.

TYPE SECTION

The type section of the Blue Gulch Mudstone Member (fig. 18) was measured in four areas (fig. 8): (1) the lower part, 164.42 m thick, from the top of the underlying Rocky Gulch Sandstone Member to the top of the Rancheria Gulch Sandstone Beds, was measured near Rancheria Gulch in the SW¼ sec. 20, T. 47 N., R. 6 W., Hornbrook 15-minute quadrangle, directly west of the Henley exit on Interstate Highway 5; (2) the interval from the top of the Rancheria Gulch Sandstone Beds to the top of the Hilt Bed (297.2 m thick) was measured across Blue Gulch, southeast of the Klamath River, in the NE¼ sec. 33 and NW¼ sec. 34, T. 47 N., R. 6 W., Hornbrook 15-minute quadrangle; (3) an interval of mudstone and thin-bedded turbidites above the Hilt Bed (a total of 133.27 m) was measured in the SW¼SE¼ sec. 21, T. 47 N., R. 6 W., Hornbrook 15-minute quadrangle, on the hillside about 1 km southeast of the town of Hornbrook, north of the Klamath River; and (4) the upper 255.00 m was measured in the hills northeast of Blue Gulch in the NE¼ sec. 34 and the SE¼ sec. 27, T. 47 N., R. 6 W., Hornbrook 15-minute quadrangle, south of the Klamath River. This last interval includes a covered interval of 186.27 m across a prominent Quaternary alluvial terrace north of Klamathon Spring (fig. 8). Thus, the total thickness of the Blue Gulch Mudstone Member in its composite type section is 849.87 m (fig. 18); this total does not include the thickness of two Tertiary intrusions in the upper part of the member, but it does include the thickness of the Rancheria Gulch Sandstone Beds in its type section and the thickness of the Hilt Bed in this section rather than in its type section.

	Thickness (in meters)
Volcanic rocks and volcaniclastic sedimentary rocks of Tertiary age (lower part).	
Unconformable contact.	
Hornbrook Formation:	
Blue Gulch Mudstone Member:	
Siltstone and sandstone, very fine grained, interbedded, bioturbated; scattered plant fossils	4.25
Sandstone, very fine grained to fine-grained, graded, bioturbated; T_{abcde} Bouma sequence	.40
Siltstone, massive; plant fossil fragments	.05
Sandstone, very fine grained to fine-grained, graded, bioturbated; T_{ae} Bouma sequence	.38
Mudstone and siltstone, thoroughly bioturbated; scattered plant fossils	3.30
Basalt, Tertiary, intrusive	(2.25)
Sandstone, very fine grained to fine-grained; tightly folded tectonically adjacent to overlying intrusive rock	.67
Siltstone and mudstone, thoroughly bioturbated; scattered plant fossils	1.50
Sandstone, very fine grained, graded, bioturbated; T_{abcde} Bouma sequence	.14
Mudstone with thinly interbedded siltstone turbidites, bioturbated	.75
Sandstone, very fine grained, graded, bioturbated, concretionary	.10
Mudstone with thinly interbedded siltstone turbidites, bioturbated	4.30
Sandstone, very fine grained to fine-grained, graded, bioturbated; T_{abce} Bouma sequence	.16
Mudstone with thinly interbedded siltstone turbidites, bioturbated	7.50
Sandstone, very fine grained, bioturbated	.05
Mudstone with thinly interbedded siltstone turbidites, bioturbated	10.50
Sandstone, very fine grained to fine-grained; T_{ace} Bouma sequence	.12
Mudstone with thinly interbedded siltstone turbidites, bioturbated	8.85
Basalt, Tertiary, intrusive	(1.10)
Sandstone, very fine grained; T_{abcde} Bouma sequence	.15
Mudstone with thinly interbedded siltstone turbidites	.60
Sandstone, very fine grained; T_{abcde} Bouma sequence	.90
Mudstone with thinly interbedded siltstone turbidites	9.00
Covered interval (float of mudstone)	7.50
Mudstone with thinly interbedded siltstone turbidites	7.50
Covered interval (float of mudstone)	186.27
Mudstone, massive	16.50
Sandstone, very fine grained; T_{bcde} Bouma sequence	.05
Mudstone, massive	9.00
Sandstone, very fine grained; T_{bcde} Bouma sequence	.05
Mudstone, massive	6.30
Sandstone, very fine grained; T_{bcde} Bouma sequence	.08
Mudstone, massive	4.40
Sandstone, very fine grained; T_{bcde} Bouma sequence	.15
Blue Gulch Mudstone Member—*Continued*:	
Mudstone, massive	2.50
Sandstone, very fine grained to fine-grained; T_{bcde} Bouma sequence	.12
Mudstone, massive	2.35
Sandstone, very fine grained; T_{bcde} Bouma sequence	.18
Mudstone, massive	8.95
Sandstone, very fine grained; T_{bcde} Bouma sequence	.05
Mudstone, massive	8.40
Sandstone, very fine grained; T_{cde} Bouma sequence	.05
Mudstone, massive	5.85
Sandstone, very fine grained; T_{cde} Bouma sequence	.08
Mudstone, massive	4.50
Sandstone, very fine grained to fine-grained; T_{bcde} Bouma sequence with convolute lamination	.45
Mudstone, massive	3.15
Sandstone, very fine grained to fine-grained; T_{bcde} Bouma sequence	.55
Mudstone, massive	3.20
Sandstone, very fine grained; T_{bcde} Bouma sequence	.10
Mudstone, massive	1.73
Sandstone, fine-grained; T_{abcde} Bouma sequence	.40
Mudstone, massive	4.25
Sandstone, fine-grained; T_{abcde} Bouma sequence	.43
Mudstone, massive	1.52
Sandstone, fine-grained; T_{bcde} Bouma sequence	.15
Mudstone, massive	.22
Sandstone, very fine grained; T_{ce} Bouma sequence	.05
Mudstone, massive	.55
Sandstone, very fine grained; T_{ce} Bouma sequence	.05
Mudstone, massive	1.12
Sandstone, very fine grained; T_{ce} Bouma sequence	.05
Mudstone, massive	1.15
Sandstone, fine-grained; T_{abcde} Bouma sequence	.22
Mudstone, massive	1.10
Sandstone, very fine grained to fine-grained; T_{abcde} Bouma sequence	.20
Mudstone, massive	.55
Sandstone, very fine grained; T_{bcde} Bouma sequence	.15
Mudstone, massive	1.35
Sandstone, very fine grained; T_{bcde} Bouma sequence	.10
Mudstone, massive	2.40
Sandstone, very fine grained; T_{bcde} Bouma sequence	.18
Mudstone, massive	9.05
Sandstone, very fine grained; T_{bcde} Bouma sequence	.10
Mudstone, massive	2.25
Sandstone, very fine grained; T_{bcde} Bouma sequence	.15

	Thickness (in meters)
Blue Gulch Mudstone Member—*Continued*:	
Mudstone with a few thinly interbedded siltstone turbidites	4.35
Sandstone, very fine grained; T_{bcde} Bouma sequence	.20
Mudstone, massive, mostly covered	22.30
Hilt Bed; chiefly sandstone, fine- to very fine grained, graded; $T_{abababcde}$ Bouma sequence	3.31
Mudstone, massive, partly covered	28.50
Sandstone, very fine grained; T_{cde} Bouma sequence	.06
Mudstone, massive	1.80
Sandstone, very fine grained to fine-grained; T_{bcde} Bouma sequence	.18
Mudstone, massive	4.95
Sandstone, very fine grained to fine-grained; T_{bcde} Bouma sequence	.10
Mudstone, massive	1.90
Sandstone, fine-grained; T_{abcde} Bouma sequence	.33
Mudstone, massive	49.50
Siltstone; T_{de} Bouma sequence, concretionary	.15
Mudstone, massive	13.50
Sandstone, fine-grained; T_{bcde} Bouma sequence	.40
Mudstone, massive	12.00
Sandstone, very fine grained; T_{bcde} Bouma sequence	.30
Mudstone, massive	18.00
Sandstone, very fine grained; T_{bcde} Bouma sequence	.25
Mudstone with some thinly interbedded siltstone turbidites	14.50
Sandstone, fine-grained; T_{bcde} Bouma sequence	.23
Mudstone, silty, massive	22.00
Sandstone, very fine grained; T_{cde} Bouma sequence	.20
Mudstone, silty, massive	1.20
Sandstone, very fine grained; T_{cde} Bouma sequence	.12
Mudstone, silty, carbonaceous, concretionary, massive	56.80
Covered interval (float of mudstone)	1.40
Siltstone, partly laminated	3.00
Covered interval (float of siltstone)	9.00
Siltstone, massive; fossil plant fragments, concretionary	4.90
Covered interval (float of siltstone)	10.77
Siltstone, massive, carbonaceous; fossil plant fragments, bioturbated	3.80
Siltstone and very fine grained sandstone, massive, concretionary, thoroughly bioturbated	.30
Siltstone, massive; fossil plant fragments, thoroughly bioturbated	.80
Sandstone, very fine grained; T_{cde} Bouma sequence, bioturbated at top	.03
Siltstone; massive fossil plant fragments, thoroughly bioturbated	.35
Sandstone, very fine grained, massive; fossil plant fragments, thoroughly bioturbated, concretionary	.75
Siltstone and very fine grained sandstone; massive fossil plant fragments, thoroughly bioturbated	4.15

	Thickness (in meters)
Blue Gulch Mudstone Member—*Continued*:	
Sandstone, fine- to medium-grained; T_{abcde} Bouma sequence, bioturbated, concretionary	.20
Siltstone and very fine grained sandstone, massive; fossil plant fragments, thoroughly bioturbated	1.80
Siltstone and very fine grained sandstone, massive, thoroughly bioturbated, concretionary	.25
Siltstone and very fine grained sandstone, massive, carbonaceous, bioturbated	1.55
Siltstone and very fine grained sandstone, massive to laminated; fossil plant fragments, bioturbated, concretionary	.65
Siltstone and very fine grained sandstone, massive; fossil plant fragments, thoroughly bioturbated	9.05
Covered interval (float of siltstone and very fine grained sandstone)	4.20
Siltstone and very fine grained sandstone, massive, thoroughly bioturbated	3.40
Siltstone and very fine grained sandstone, massive to laminated, bioturbated	.20
Siltstone and very fine grained sandstone, massive, thoroughly bioturbated	1.10
Siltstone and very fine grained sandstone, massive to laminated, bioturbated	.45
Sandstone, very fine grained, and siltstone, massive, thoroughly bioturbated	1.20
Sandstone, very fine grained, and siltstone, laminated	.30
Sandstone, very fine grained, and siltstone, massive, thoroughly bioturbated	3.30
Rancheria Gulch Sandstone Beds; chiefly sandstone, fine-grained, massive and hummocky cross-stratified; molluscan fossils, partly bioturbated	85.77
Mudstone, massive, bioturbated (partly covered)	8.00
Sandstone, very fine grained; hummocky cross-laminae and convolute laminations	.10
Siltstone, massive, bioturbated	.80
Sandstone, very fine grained; hummocky cross-laminae; convolute laminations; current ripple markings	.10
Siltstone, massive, bioturbated	.20
Sandstone, very fine grained; silty; hummocky cross-laminae	.05
Siltstone, massive, bioturbated	.10
Sandstone, very fine grained; hummocky cross-laminae	.05
Siltstone, massive, bioturbated	.20
Sandstone, very fine grained; hummocky cross-laminae, bioturbated	.15
Siltstone, massive, bioturbated	.15
Sandstone, very fine grained; hummocky cross-laminae, bioturbated	.03
Siltstone, massive, bioturbated	.10
Sandstone, very fine grained; hummocky cross-laminae	.10
Siltstone, massive	.02
Siltstone, very fine grained; convolute laminae and hummocky cross-laminae	.06
Siltstone, massive	.30
Sandstone, very fine grained; hummocky cross-laminae	.04

	Thickness (in meters)
Blue Gulch Mudstone Member—*Continued*:	
Siltstone, massive	.50
Sandstone, very fine grained; hummocky cross-laminae	.05
Siltstone, massive	.50
Sandstone, very fine grained; hummocky cross-laminae	.05
Siltstone, massive	.30
Sandstone, very fine grained; hummocky cross-laminae	.05
Siltstone, massive, bioturbated	.50
Sandstone, very fine grained; hummocky cross-laminae, bioturbated	.05
Siltstone, massive, bioturbated	.30
Sandstone, very fine grained; hummocky cross-laminae, bioturbated	.05
Siltstone, massive, bioturbated	.30
Sandstone, very fine grained; hummocky cross-laminae, bioturbated	.05
Siltstone, massive, bioturbated	.30
Sandstone, very fine grained; hummocky cross-laminae and convolute laminae, bioturbated	.05
Siltstone, massive	.20
Sandstone, very fine grained; hummocky cross-laminae, bioturbated	.20
Siltstone, massive, bioturbated	.20
Sandstone, very fine grained; hummocky cross-laminae	.05
Siltstone, massive, bioturbated	.05
Sandstone, very fine grained; hummocky cross-laminae	.05
Siltstone, massive to partly laminated, bioturbated	1.30
Sandstone, very fine grained; laminated	.20
Siltstone, massive, bioturbated	.05
Sandstone, very fine grained; hummocky cross-laminae	.05
Siltstone, very fine grained; hummocky cross-laminae	.02
Sandstone, very fine grained; hummocky cross-laminae	.05
Siltstone, massive	.02
Sandstone, very fine grained; hummocky cross-laminae, bioturbated	.05
Siltstone, massive, bioturbated	.03
Sandstone, very fine grained; hummocky cross-laminae	.02
Siltstone, massive	.05
Sandstone, very fine grained; hummocky cross-laminae	.03
Siltstone, massive, bioturbated	.15
Sandstone, very fine grained, laminated	.05
Siltstone, massive	.70
Sandstone, very fine grained, laminated	.05
Siltstone, massive, bioturbated	.10
Sandstone, very fine grained, laminated	.05
Siltstone, massive	.20
Sandstone, very fine grained, laminated	.06
Siltstone, massive, bioturbated	.02
Sandstone, very fine grained, laminated	.03
Siltstone, massive	.15
Sandstone, very fine grained; hummocky cross-laminae	.02

	Thickness (in meters)
Blue Gulch Mudstone Member—*Continued*:	
Siltstone, massive, bioturbated	.02
Sandstone, very fine grained; hummocky cross-laminae	.04
Siltstone, massive	.05
Sandstone, very fine grained; hummocky cross-laminae	.03
Siltstone, massive, bioturbated	.30
Siltstone and very fine grained sandstone; hummocky cross-laminae	.40
Siltstone, massive, bioturbated	.20
Sandstone, very fine grained, laminated	.05
Siltstone, massive	.20
Sandstone, very fine grained, laminated	.10
Siltstone and very fine grained sandstone, laminated	.20
Sandstone, very fine grained; hummocky cross-laminae	.05
Siltstone, massive	.15
Sandstone, very fine grained; hummocky cross-laminae	.05
Siltstone, massive	1.30
Sandstone, fine-grained, ungraded, parallel-laminated at base, convolute-laminated in middle, and ripple-marked at top	.10
Siltstone, massive, bioturbated	3.60
Sandstone, fine-grained, laminated	.05
Siltstone, massive, bioturbated	1.60
Sandstone, very fine grained; hummocky cross-laminae	.10
Siltstone, massive, bioturbated	.05
Sandstone, very fine grained; hummocky cross-laminae	.10
Siltstone, massive, bioturbated, partly covered	4.60
Sandstone, fine-grained; hummocky cross-laminae	.08
Siltstone, massive	.20
Sandstone, very fine grained; hummocky cross-laminae	.03
Siltstone, massive, bioturbated	.50
Sandstone, very fine grained; hummocky cross-laminae	.02
Siltstone, massive, bioturbated	.60
Sandstone, very fine grained; hummocky cross-laminae, bioturbated	.05
Siltstone, massive, bioturbated	.50
Sandstone, very fine grained; hummocky cross-laminae, bioturbated	.05
Siltstone, massive, bioturbated	3.40
Sandstone, very fine grained; hummocky cross-laminae, bioturbated	.05
Siltstone, massive, bioturbated	.30
Sandstone, very fine grained; hummocky cross-laminae, bioturbated	.15
Siltstone, massive	.40
Sandstone, very fine grained; hummocky cross-laminae	.05
Siltstone, massive	.40
Sandstone, very fine grained; hummocky cross-laminae	.03
Siltstone, massive	.20
Sandstone, very fine grained; hummocky cross-laminae	.02

	Thickness (in meters)
Blue Gulch Mudstone Member—*Continued*:	
Siltstone, massive	.30
Sandstone, very fine grained; hummocky cross-laminae	.03
Siltstone, massive	.15
Sandstone, very fine grained; hummocky cross-laminae	.10
Siltstone, massive; fossil plant fragments, thoroughly bioturbated, concretionary	14.50
Sandstone, very fine grained, laminated, bioturbated	.05
Siltstone, massive, bioturbated	1.80
Sandstone, very fine grained; hummocky cross-laminae, bioturbated	.05
Siltstone, massive, bioturbated	.15
Sandstone, very fine grained; hummocky cross-laminae, bioturbated	.10
Siltstone, massive, bioturbated	.70
Sandstone, very fine grained; hummocky cross-laminae, bioturbated	.03
Siltstone, massive, bioturbated	.40
Sandstone, very fine grained; hummocky cross-laminae, bioturbated	.05
Siltstone, massive, bioturbated	.50
Sandstone, very fine grained; hummocky cross-laminae, bioturbated	.01
Siltstone, massive, bioturbated	.10
Sandstone, very fine grained; hummocky cross-laminae, bioturbated	.04
Siltstone, massive, bioturbated	.20
Sandstone, very fine grained; hummocky cross-laminae, bioturbated	.15
Siltstone, massive, bioturbated	.50
Sandstone, very fine grained; hummocky cross-laminae, bioturbated	.10
Siltstone, massive, bioturbated	.40
Sandstone, very fine grained; hummocky cross-laminae, bioturbated	.03
Siltstone, massive, bioturbated	.50
Sandstone, very fine grained; hummocky cross-laminae, bioturbated	.04
Siltstone, massive, bioturbated	.70
Sandstone, very fine grained; hummocky cross-laminae, bioturbated	.05
Siltstone, massive, bioturbated	.45
Sandstone, very fine grained; hummocky cross-laminae, bioturbated	.06
Siltstone, massive, bioturbated	.50
Sandstone, very fine grained; hummocky cross-laminae, bioturbated	.07
Siltstone, massive, bioturbated	.90
Sandstone, very fine grained; hummocky cross-laminae, bioturbated	.04
Siltstone, massive, thoroughly bioturbated	2.30
Mudstone, massive, partly bioturbated	2.10
Sandstone, very fine grained; hummocky cross-laminae	.02
Mudstone, massive	.15
Sandstone, very fine grained; hummocky cross-laminae, bioturbated	.02
Mudstone, massive	.20
Sandstone, very fine grained; hummocky cross-laminae	.02

	Thickness (in meters)
Blue Gulch Mudstone Member—*Continued*:	
Mudstone, massive, bioturbated	1.70
Sandstone, very fine grained; hummocky cross-laminae, bioturbated	.04
Mudstone, massive, bioturbated	.20
Sandstone, very fine grained; T_{ce} Bouma sequence	.02
Mudstone, silty, massive	.50
Covered interval (float of mudstone)	1.50
Sandstone, very fine grained; T_{ce} Bouma sequence	.03
Mudstone, silty, massive	.20
Sandstone, very fine grained; T_{ce} Bouma sequence	.03
Covered interval (float of mudstone)	1.20
Sandstone, very fine grained, and siltstone; T_{ce} Bouma sequence	.02
Covered interval (float of mudstone)	1.90
Sandstone, very fine grained, ripple-marked	.01
Mudstone, massive	.20
Sandstone, very fine grained; T_{ce} Bouma sequence	.01
Mudstone, silty, massive	.10
Sandstone, very fine grained; T_{ce} Bouma sequence	.02
Mudstone, silty, massive	.15
Sandstone, very fine grained; T_{ce} Bouma sequence	.03
Mudstone, massive	.20
Sandstone, very fine grained; T_{ce} Bouma sequence	.03
Mudstone, silty, massive	.35
Sandstone, very fine grained, laminated	.02
Mudstone, silty, massive	.20
Sandstone, very fine grained, ripple-marked	.04
Mudstone, massive	.45
Sandstone, very fine grained; T_{cde} Bouma sequence	.20
Mudstone, silty, massive	.10
Sandstone, fine-grained; T_{cde} Bouma sequence	.12
Mudstone, silty, massive	.25
Sandstone, very fine grained; T_{cde} Bouma sequence	.02
Mudstone, silty, massive	.55
Sandstone, medium-grained, laminated, concretionary	.16
Mudstone, silty, massive	.60
Sandstone, very fine grained; T_{cde} Bouma sequence	.04
Mudstone, silty, massive	.30
Sandstone, very fine grained, micaceous; T_{ce} Bouma sequence	.03
Shale, silty, massive, micaceous	.40
Total thickness of the Blue Gulch Mudstone Member (including the Rancheria Gulch Sandstone Beds and Hilt Bed)	849.87

Conformable contact.

	Thickness (in meters)
Rocky Gulch Sandstone Member (upper part):	
Sandstone, medium- to coarse-grained, graded, massive; rip-up clasts	1.0

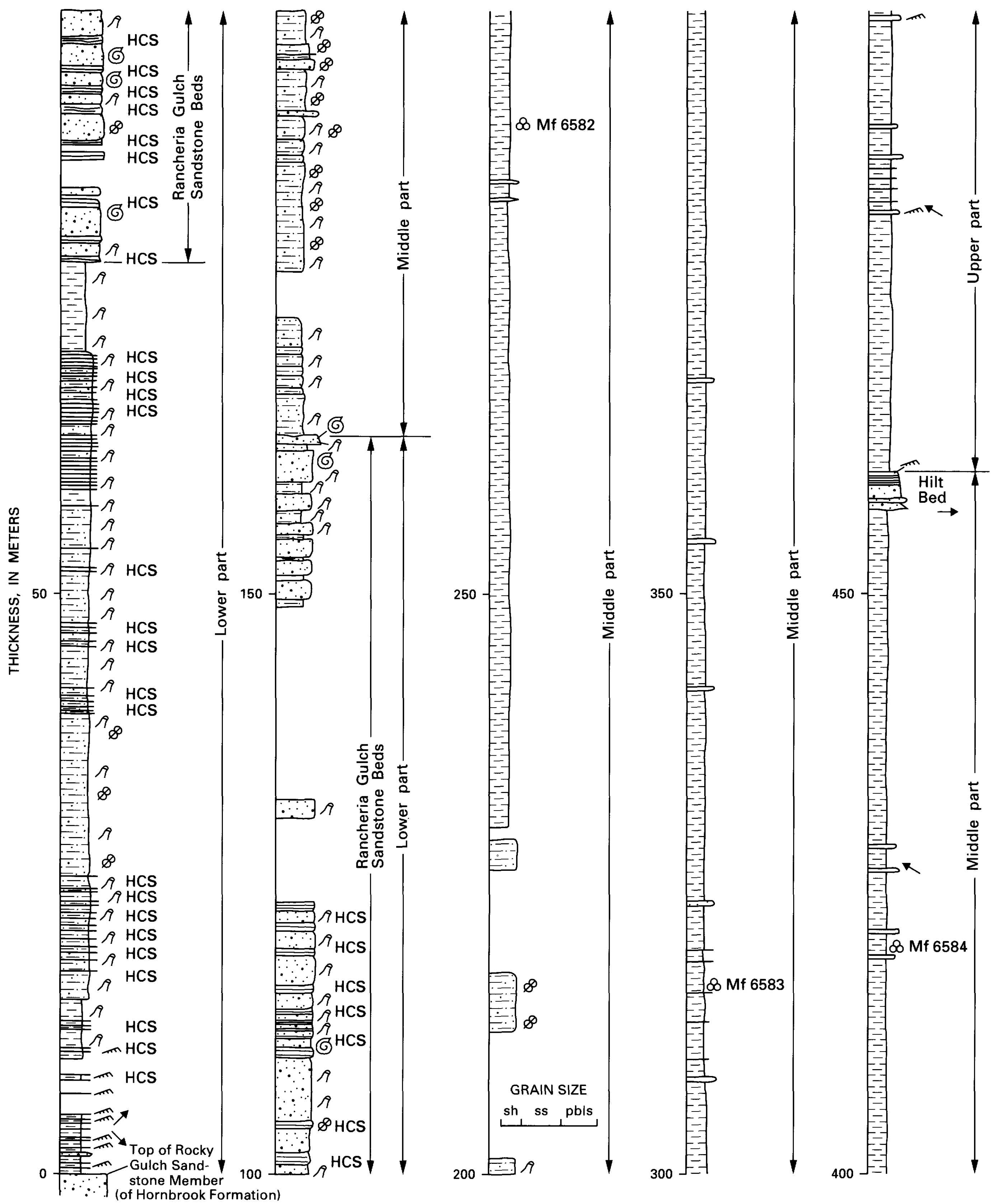
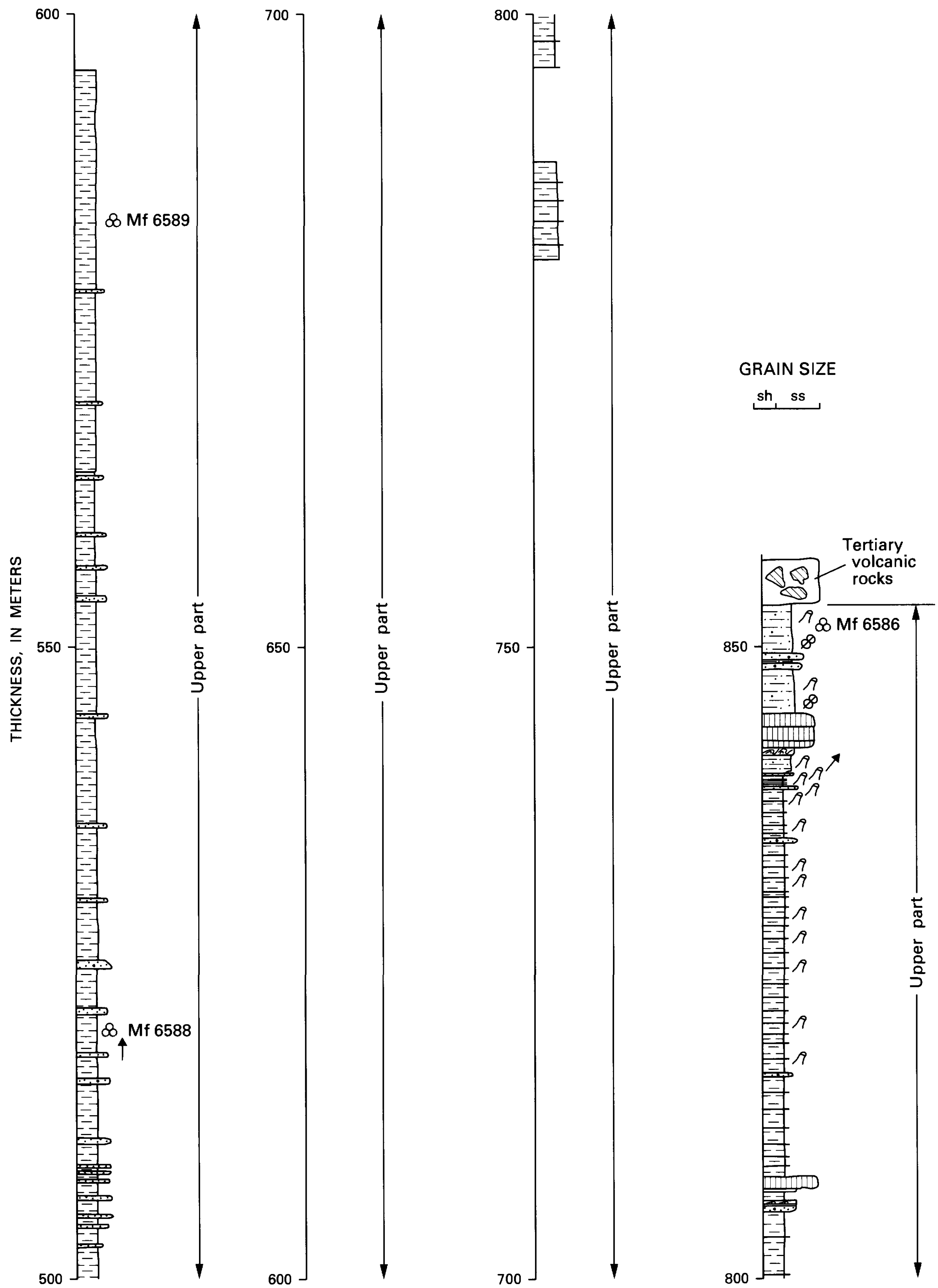


FIGURE 18.—Type section of the Blue Gulch Mudstone Member (including its Rancheria Gulch Sandstone Beds and Hilt Bed) of the Hornbrook Formation. See figure 10 for explanation of symbols and caption of figure 12 for explanation of abbreviations (pbls,



pebbles). Numbers designated with Mf indicate USGS Mesozoic microfossil localities that have yielded foraminifers. Gaps in lithology represent covered intervals.

The colors of the Blue Gulch Mudstone Member vary slightly. In its lower part, below the Rancheria Gulch Sandstone Beds, mudstone and siltstone are medium dark gray (N4) or medium gray (N5) on fresh surfaces and moderate yellowish brown (10YR 5/4) on weathered surfaces, whereas sandstone is medium gray (N5) on fresh surfaces and pale yellowish brown (10YR 6/2) on weathered surfaces. In its middle and upper parts, above the Rancheria Gulch Sandstone Beds, mudstone is medium gray (N5), medium dark gray (N4), olive gray (5Y 4/1), and brownish gray (5YR 4/1) on fresh surfaces and pale yellowish brown (10YR 6/2) or grayish green (10GY 5/2) on weathered surfaces. The sandstone interbeds are medium gray (N5), light olive gray (5Y 5/2), or yellowish gray (5Y 7/2) on fresh surfaces and moderate yellowish brown (10YR 5/4) on weathered surfaces.

LITHOLOGY

The Blue Gulch Mudstone Member consists chiefly of mudstone, which is commonly silty and dominantly nonfissile. Areally it can be divided into two distinct lithologic assemblages. In the type area, adjacent to the town of Hornbrook, where the Rancheria Gulch Sandstone Beds form part of the Blue Gulch Mudstone Member, it contains more interbeds and irregularly distributed bioturbated siltstone and very fine grained sandstone, especially in its lower part, directly above and below the Rancheria Gulch Sandstone Beds. In other areas to the northwest and southeast of the Hornbrook area, where the Rancheria Gulch Sandstone Beds are absent, the Blue Gulch Mudstone Member consists more uniformly of mudstone with thin interbeds of very fine grained sandstone.

In the type area, I informally divide the Blue Gulch Mudstone Member into lower, middle, and upper parts (fig. 18). The lower part of the Blue Gulch Mudstone Member (from the top of the Rocky Gulch Sandstone Member to the top of the Rancheria Gulch Sandstone Beds), 164.42 m thick, consists chiefly of massive, bioturbated siltstone with abundant but thin interbeds of very fine grained sandstone and the overlying Rancheria Gulch Sandstone Beds. However, the lowermost 10 m, directly above the Rocky Gulch Sandstone Member, consist of nonbioturbated mudstone with thin interbeds of graded, very fine grained sandstone. The sandstone interbeds are as thick as 20 cm and are similar lithologically to some of the coarser and thicker beds of sandstone in the upper part of the underlying Rocky Gulch Sandstone Member. The beds are graded, nonbioturbated, and laterally continuous; in addition, they have erosive bases, generally become thinner upward within the 10-m interval, and are organized into Bouma (1962) sequences of the T_{ce} type. This lowest interval clearly reflects the upward continuation of depositional environments similar to those that characterized the Rocky Gulch Sandstone Member. The lithology of the Rancheria Gulch Sandstone Beds is discussed in a later section.

The middle part of the Blue Gulch Mudstone Member (from the top of the Rancheria Gulch Sandstone Beds to the top of the Hilt Bed), 297.18 m thick, consists of several different lithologies. The lowermost 70 m consist chiefly of massive bioturbated siltstone with thin interbeds of massive to laminated very fine grained sandstone. This part of the Blue Gulch Mudstone Member is lithologically similar to the section below the Rancheria Gulch Sandstone Beds and is generally coarser than the main part of the member. This sequence changes gradually upward in the following ways: (1) the massive siltstone changes to silty mudstone and finally to mudstone; (2) the interbeds of sandstone become more distinct, well-bedded, and graded, and toward the top of the 70-m-thick interval, they are internally organized into Bouma sequences; (3) the amount of bioturbation in both the siltstone to mudstone and the sandstone interbeds decreases progressively; and (4) the abundance of plant fragments and carbonate concretions also decreases.

The uppermost 227 m of the middle part of the Blue Gulch Mudstone Member in the Hornbrook area consist of massive mudstone with thin to medium, graded interbeds of laterally continuous siltstone and very fine grained sandstone. This is the most common lithology in the Blue Gulch Mudstone Member, and it is observed from 270 m below the top of the Hilt Bed within the middle part to about 345 m above the top of the Hilt Bed within the upper part of the member. Thus, a thickness of about 572 m of the Blue Gulch Mudstone Member contains the dominant mudstone lithology. The mudstone forms massive intervals as thick as 50 m that do not contain interbeds of sandstone or siltstone that are as thick as 5 cm. The mudstone can locally be divided into two types: medium-gray (N5) to medium-dark-gray (N4) mudstone that characteristically forms thick layers between the sandstone interbeds; and olive-gray (5Y 4/1) to brownish-gray (5YR 4/1) mudstone that characteristically forms thinner layers that rest directly on the top of the graded interbeds of sandstone. The mudstone locally contains tests of large foraminifers that can be seen with the naked eye or with a hand lens. Bioturbation is locally present in this mudstone interval of the member, but it is not as common as it is in underlying and overlying intervals and generally is present as solitary burrows rather than as massively bioturbated beds.

The abundant sandstone and siltstone interbeds within this mudstone interval are graded, have sharp erosive bases, and are organized into Bouma sequences (generally T_{bcde}, T_{cde}, and T_{de}). These beds are typically laterally continuous at outcrop scale and rarely exhibit any prominent lateral changes in thickness, grain size, or Bouma sequence. The beds of sandstone generally range in thickness from less than 1 cm to 55 cm, although one 90-cm-thick bed was observed in the type section near the top of this 572-m-thick interval. In the type section, only interbeds of sandstone or siltstone that are thicker than 5 cm were measured and are plotted on the section (fig. 18).

The upper part of the Blue Gulch Mudstone Member, 388.47 m thick, can be subdivided into two subunits: a lower subunit of about 345 m of mudstone with graded interbeds of siltstone and very fine grained sandstone, and an upper subunit of about 43 m of bioturbated siltstone with abundant interbeds of sandstone (fig. 18). The latter subunit in the Hornbrook area and in the type section resembles the 70-m-thick interval above the Rancheria Gulch Sandstone Beds within the middle part of the member. It consists dominantly of massive bioturbated siltstone with abundant interbeds of very fine grained to fine-grained sandstone. Plant fossils are present in the upper part of this subunit, and bioturbation has locally completely destroyed the bedding. Basalt intrusions have caused local deformation of the interbedded sandstone and siltstone—small folds, faults, and other structural disturbances can be attributed to forceful intrusion of the basalt. In outcrops without intrusive rocks but with deformation, the deformation locally resembles synsedimentary slumping rather than deformation related to intrusion of the basalt. This sandstone-rich uppermost interval of the Hornbrook Formation in its type area is commonly missing in other areas because of erosive downcutting of the surface of unconformity at the top of the Hornbrook Formation.

In outcrops to the northwest and southeast of the type area of the Hornbrook Formation, the Blue Gulch Mudstone Member is lithologically more uniform. It generally consists of mudstone with interbeds of very fine grained sandstone and is similar to the 572-m-thick interval of mudstone and interbedded sandstone within the middle part of the type section. The mudstone is typically non-bioturbated or poorly bioturbated, containing only solitary burrows. The sandstone interbeds are more abundant near the base of the member, where they resemble the sandstone beds of the upper part of the Rocky Gulch Sandstone Member. The sandstone beds are always characterized by normal grading, erosive bases, lateral continuity, few lateral changes in either thickness or grain size, and Bouma T_{b-e} to T_{c-e} sequences. Abundant sole markings, including flute casts, groove casts, and prod casts, permit the determination of paleocurrent directions. The Hilt Bed is present everywhere between Ashland and the northern Shasta Valley except where it has been eroded off along the pre-Tertiary unconformity. Thus, the Blue Gulch Mudstone Member is lithologically relatively uniform over most of its outcrop area and is easily mapped on the basis of its dominant lithology.

The only other lithologies of local significance in the Blue Gulch Mudstone Member are coarse-grained sandstone and conglomerate that form graded beds and that contain large fossil fragments. In the Cottonwood Creek valley area (SW¼SE¼ sec. 7, T. 47 N., R. 6 W., Hornbrook 15-minute quadrangle), for example, a thick bed of poorly graded granular sandstone crops out in one location. The bed contains abundant broken molluscan shell debris throughout and rip-up clasts of shale within its lower part, and it has flute casts on its basal surface. The bed is 4.2 m thick and is intercalated within typical mudstone of the Blue Gulch Mudstone Member. The contact with overlying mudstone is abrupt rather than gradational. The bed is massive and contains no sedimentary structures or divisions of the Bouma sequence. The bed appears to be laterally discontinuous, for it has not been found in any other places. This bed is clearly distinct from the Hilt Bed, which crops out nearby at a lower stratigraphic position within the Blue Gulch Mudstone Member.

In the Dark Hollow area, conglomeratic beds with abundant broken megafossil debris are locally abundant within the upper part of the Blue Gulch Mudstone Member above the Hilt Bed. Conglomeratic beds have been observed in roadcuts on the west side of Dark Hollow Road (NW¼NW¼ sec. 12, T. 38 S., R. 2 W., Medford 15-minute quadrangle), on the east side of Dark Hollow Road (SE¼ sec. 50, T. 38 S., R. 2 W., Medford 15-minute quadrangle), and on the north side of Pioneer Road (SW¼NE¼ sec. 51, T. 38 S., R. 1 W., Medford 15-minute quadrangle). These beds of conglomerate are interbedded with typical mudstone of the Blue Gulch Mudstone Member that contains abundant thin interbeds of normally graded siltstone and very fine grained sandstone that are organized into T_{c-e} Bouma sequences. The conglomeratic beds are as thick as 0.5 m and contain clasts of subangular to angular chert and quartzite as large as 3 cm. These beds also contain angular, broken molluscan shell debris. Some of the conglomerate beds are reverse graded, in contrast to the interbeds of sandstone and siltstone. The conglomerate beds are also massive and contain no internal sedimentary structures or divisions of the Bouma sequence. The tops of the beds have a sharp, rather than gradational, contact with the overlying mudstone. The thickness of some of the beds changes laterally, and marked lateral changes in grain size take place over distances of a few meters. Synsedimentary folding is associated with some of the conglomerate beds.

Outcrops of boulder and cobble conglomerate in the Dark Hollow area contain both rounded and angular clasts of carbonate concretions and fewer clasts of shale, quartzite, fossiliferous sandstone, siltstone, and granitic and metamorphic rocks. The clasts are poorly sorted to locally well sorted, are as large as 2 m, and are supported by a mudstone matrix. The conglomerate crops out as small patches in roadcuts along Pioneer Road (near the NE corner of sec. 13, T. 38 S., R. 2 W., and NE¼ sec. 49, T. 38 S., R. 2 W., Medford 15-minute quadrangle). Although these patches of conglomerate initially appear to form interbeds within the Blue Gulch Mudstone Member, careful mapping has shown them to be irregular secondary subhorizontal lenses that rest unconformably on dipping mudstone of the Blue Gulch Mudstone Member. The patches form a linear trend that strikes about 120° and that appears to represent weathered blocks that have been cemented along a fault; travertinelike carbonate materials in the matrix and around some clasts suggest that heated waters from mineral springs may have contributed to the cementation of the blocks.

STRATIGRAPHIC RELATIONS

The Blue Gulch Mudstone Member rests conformably on the Rocky Gulch Sandstone Member in all areas except on the south flank of Black Mountain, where, in my opinion, it rests directly and possibly unconformably on the Ditch Creek Siltstone Member in areas where the Rocky Gulch Sandstone Member is locally absent (Nilsen and others, 1983; pl. 1). The lower contact is gradational to abrupt but typically well marked in the field.

The upper contact of the Blue Gulch Mudstone Member is generally a well-marked unconformity between the fine-grained Cretaceous marine rocks and the Tertiary nonmarine conglomeratic or volcanic rocks. In the Medford Valley, Bear Creek valley, and part of the Shasta Valley areas, the Blue Gulch Mudstone Member is overlain by conglomerate, whereas in the Cottonwood Creek valley, Black Mountain, and most of the Shasta Valley areas, it is overlain by volcanic rocks. In the Bear Creek valley area northwest of Ashland, the erosional unconformity cuts deeply into the Hornbrook Formation, through the Hilt Bed and most of the Blue Gulch Mudstone Member; the Tertiary conglomerate in this area locally rests on the Ditch Creek Siltstone Member or Rocky Gulch Sandstone Member.

Lateral stratigraphic relations of the Blue Gulch Mudstone Member are poorly defined. The member undoubtedly extends northeastward beneath the Cascade Range but for a distance that is not known because the subsurface structure is poorly known. To the southeast, the Blue Gulch Mudstone Member is covered by Tertiary volcanic rocks in most of the Shasta Valley area. The Blue Gulch Mudstone Member does not appear to change lithologically in its southeasternmost outcrops, and thus it originally must have extended farther to the southeast as essentially the same lithologic unit.

To the northwest, the Blue Gulch Mudstone Member is covered by Quaternary alluvial fill in the Medford Valley. Farther north, the Tertiary volcanic rocks rest directly on basement rocks of the Klamath Mountains, covering the Hornbrook Formation if it does extend northward in the subsurface. However, Cretaceous strata are exposed farther to the northwest as a downfaulted block in the Grave Creek area of the northern Klamath Mountains. The Blue Gulch Mudstone Member may have originally extended at least as far north as the Grave Creek area, which is located 50 km north of the outcrops of the Hilt Bed in the Dark Hollow area.

THICKNESS

The thickness of the Blue Gulch Mudstone Member varies greatly over the outcrop area of the Hornbrook Formation, chiefly because of erosion of its top beneath the pre-Tertiary unconformity. At its type section, it is 849.87 m thick, including the Rancheria Gulch Sandstone Beds and the Hilt Bed. In the area west of Hornbrook, Peck and others (1956) in their type section measured an incomplete thickness of 552 m in strata that are equivalent to the Blue Gulch Mudstone Member; although this thickness includes the Rancheria Gulch Sandstone Beds, it does not include the upper part of the Blue Gulch Mudstone Member. Jones (1959) determined a thickness of about 1200 m for strata equivalent to the Blue Gulch Mudstone Member in the type area near Hornbrook.

Farther north, Elliott (1971) measured a thickness of 796 m of strata equivalent to the Blue Gulch Mudstone Member in the Bailey Hill area, near Hilt, California. Peck and others (1956) estimated a thickness of about 180 m for strata equivalent to the Blue Gulch Mudstone Member near Ashland. In the Bear Creek valley area, McKnight (1971) obtained a thickness of about 585 m for strata equivalent to the Blue Gulch Mudstone Member. I have measured a partial section of about 75 m of the Blue Gulch Mudstone Member about 5 km east of Ashland. No sections of the Blue Gulch Mudstone Member have been measured in the Dark Hollow area.

In summary, the Blue Gulch Mudstone Member appears to be about 800–900 m thick in the Cottonwood Creek valley area, where its type area is located. To the north and south its thickness has not been reliably measured, but it probably varies widely as a result of major amounts of erosion along the pre-Tertiary unconformity. There is no evidence of major preerosion thinning or thickening of the member.

DEPOSITIONAL ENVIRONMENT

The Blue Gulch Mudstone Member, particularly its thick upper middle and lower upper parts, appears to have been deposited mostly in deep-marine environments. The extensive mudstone that forms the chief lithology contains abundant benthic foraminifers that suggest at least bathyal depths. Numerous ammonites and planktonic foraminifers, as well as a lack of massive amounts of bioturbation, support a low-energy deep-marine setting. The sandstone interbeds are turbidites, and their lateral continuity, organization into Bouma sequences, and lack of thinning-upward or thickening-upward cycles suggest that they are basin-plain turbidites. The remarkable lateral continuity of the Hilt Bed also supports the concept of deposition in a deep-marine basin-plain setting. The scattered conglomeratic beds that contain broken fossils were probably deposited by debris flows that moved downslope and spread out along the floor of the basin plain as laterally discontinuous, massive, locally reverse-graded beds; these beds also locally disrupted or deformed underlying layers of mudstone and interbedded turbidite sandstone.

The lower part, lower middle part, and uppermost part of the Blue Gulch Mudstone Member in its type area, however, represent deposition in shallow-marine environments. The Rancheria Gulch Sandstone Beds in the type area are thought to have been deposited in an outer-shelf environment subject to storm-wave activity. The Blue Gulch Mudstone Member directly above and below the Rancheria Gulch Sandstone Beds is siltier and more bioturbated, contains fewer turbidite interbeds, and was probably deposited in outer-shelf to slope environments. The interval above the Rancheria Gulch Sandstone Beds grades upward into the true basin-plain deposits of the middle part of the Blue Gulch Mudstone Member in its type area. The uppermost part of the Blue Gulch Mudstone Member in its type section is again siltier, more massive, and more bioturbated, marking probably an upward change to shallower marine environments.

AGE AND CORRELATION

The age of the Blue Gulch Mudstone Member has been determined chiefly from shallow-marine mollusks found in the Rancheria Gulch Sandstone Beds and from ammonites and benthic and planktonic foraminifers found within the middle and upper parts of the member. Age determinations, however, are not always compatible, and the lower age limit of the Blue Gulch Mudstone Member remains somewhat problematical. No fossils have been recovered from the lower part of the Blue Gulch Mudstone Member below the Rancheria Gulch Sandstone Beds in the type area.

Peck and others (1956) obtained no fossil evidence in the type area from strata of the lower part of the Blue Gulch Mudstone Member that are equivalent to the Rancheria Gulch Sandstone Beds, nor from the underlying interval of siltstone and mudstone between the Rancheria Gulch Sandstone Beds and the top of the Rocky Gulch Sandstone Member. However, they did obtain abundant ammonite fossils and *Inoceramus* from the upper part of the Blue Gulch Mudstone Member. They concluded that this part of the member was middle to late Campanian in age. However, it must be remembered that they did not sample the uppermost 250 m of the Blue Gulch Mudstone Member.

Jones (1959) concluded that strata equivalent to the Blue Gulch Mudstone Member were of middle Campanian to Maestrichtian(?) age on the basis of ammonites and *Inoceramus*. Elliott (1971) also inferred a middle Campanian to Maestrichtian(?) age for strata equivalent to the Blue Gulch Mudstone Member. McKnight (1971), on the basis of fossil identifications by D.L. Jones of his collections from the Bear Creek valley area, inferred a Campanian or early Maestrichtian age for strata equivalent to the Blue Gulch Mudstone Member.

Foraminiferal collections from the lower middle part of the Blue Gulch Mudstone Member above the Rancheria Gulch Sandstone Beds in the type area near Blue Gulch (USGS Mesozoic localities Mf6399 and Mf6583) are indicative of a middle Campanian to early Maestrichtian age (app. II; fig. 18). Other collections from the lower part of the Blue Gulch Mudstone Member north of the type area and north of the outcrop limit of the Rancheria Gulch Sandstone Beds at the north end of the Cottonwood Creek valley area (USGS Mesozoic locality Mf6411) and the south end of the Bear Creek valley (USGS Mesozoic localities Mf6401 and Mf6402) are indicative of late Turonian to early Coniacian and of Campanian to early Maestrichtian ages (app. II).

Foraminiferal collections from the upper middle and lower upper parts of the Blue Gulch Mudstone Member from the type section at Blue Gulch and southeast of Hornbrook (USGS Mesozoic localities Mf6584, Mf6588, and Mf6589) are indicative of (in ascending stratigraphic order) late Santonian to late Campanian, Campanian, and Campanian to early Maestrichtian ages (app. II; fig. 18). Foraminiferal collections from the middle part of the Blue Gulch Mudstone Member north of the type area are indicative of Campanian to early Maestrichtian age at the north end of the Cottonwood Creek valley (USGS Mesozoic locality Mf6403), and Coniacian to Maestrichtian age near Ashland in the Bear Creek valley area (USGS Mesozoic localities Mf6410 and Mf6579).

A foraminiferal collection from near the top of the Blue Gulch Mudstone Member in the type section (USGS Mesozoic locality Mf6586) is indicative of a Santonian to Maestrichtian age.

Samples collected from evenly spaced intervals by M.A. Elliott in 1971 from his measured section of strata equivalent to the Blue Gulch Mudstone Member near Bailey Hill in the northern part of the Cottonwood Creek valley area were processed in 1982 by the U.S. Geological Survey for foraminiferal assemblages. These samples, in ascending stratigraphic order (USGS Mesozoic localities Mf6335 to Mf6352), are indicative of Campanian to early Maestrichtian ages (app. II). However, the uppermost two samples from this section were barren of microfossils.

The available fossil age data from the Blue Gulch Mudstone Member provide ambiguous results. No fossils, either microfossils or megafossils, have been collected from the lower part of the Blue Gulch Mudstone Member in the type area, the siltstone-dominated interval between the top of the Rocky Gulch Sandstone Member and the basal part of the Rancheria Gulch Sandstone Beds. Microfossils and previous collections of ammonites generally have indicated Campanian to early Maestrichtian ages; however, samples from the Dark Hollow area are indicative of ages that could be as old as late Turonian (localities FL 8 and FL 117 in figure 2 of Sliter and others, 1984), a sample from the Ashland area is indicative of an age that could be as old as Coniacian (USGS Mesozoic locality Mf6410), and a sample from the type area is indicative of an age that could be as old as Santonian (USGS Mesozoic locality Mf6586). In summary, the age of the Blue Gulch Mudstone Member appears to range from late Turonian to early Maestrichtian, a span of about 18 m.y. It appears to be oldest in the Dark Hollow area (late Turonian) and youngest in the Cottonwood Creek valley area (chiefly Campanian and early Maestrichtian), a trend consistent with the overall pattern of the Hornbrook Formation of younger ages from northwest to southeast. Because no ages have been obtained from the lowest part of the member below the Rancheria Gulch Sandstone Beds in the type area, it could possibly range downward in age in that area into the middle or late Coniacian.

The proposed late Turonian to early Maestrichtian age of the Blue Gulch Mudstone Member suggests that it is, at least, partly correlative with Cretaceous strata exposed along the southwest coast of Oregon—the Cape Sebastian Sandstone and Hunters Cove Formation of Dott (1971)—but younger than other Cretaceous strata exposed farther north in the Days Creek, Riddle, and Mitchell areas. It is, at least, partly correlative with subsurface deposits of the Ochoco basin (Thompson and others, 1984) adjacent to Mitchell but younger than the Cretaceous strata to the west at O'Brien.

To the south, the lower part of the Blue Gulch Mudstone Member is probably partly correlative with the upper part of the Great Valley sequence near Redding, which is as young as Santonian(?) (Popenoe, 1943; Matsumoto, 1960). It should also be, at least, partly correlative with the upper part of the Gas Point Member of the Budden Canyon Formation of Murphy and others (1969), which crops out about 30 km southwest of Redding and may be as young as early Coniacian (Murphy and others, 1969).

Farther south, the Blue Gulch Mudstone Member at least partly correlates with the Great Valley sequence on both the east side of the Sacramento Valley near Chico (Haggart and Ward, 1984) and on the west side of the Sacramento Valley (Ingersoll, 1979), where it is very thick. The Blue Gulch Mudstone Member is also correlative with parts of the Coastal belt terrane of the Franciscan assemblage (Evitt and Pierce, 1975).

RANCHERIA GULCH SANDSTONE BEDS

DEFINITION

The name "Rancheria Gulch Sandstone Beds" was applied by Nilsen (1984a) to outcrops of marine sandstone strata within the lower part of the Blue Gulch Mudstone Member of the Hornbrook Formation. The unit was named for exposures adjacent to Rancheria Gulch, located about 1.5 km southwest of Hornbrook, Calif. The type section was measured across a pair of low ridges located to the west and north of the U.S. Forest Service Forestry Camp, which is located west of Interstate Highway 5, adjacent to the Henley-Hornbrook exit (figs. 8, 19; Nilsen and others, 1984, stop 5).

The Rancheria Gulch Sandstone Beds are restricted areally to a northwest-trending belt that is located about 1 km to the southwest of Hornbrook, between Ditch Creek on the northwest and Osburger Gulch on the southeast. The unit forms a lens of sandstone within the lower part of the Blue Gulch Mudstone Member. The unit is both underlain and overlain by mudstone of the Blue Gulch Mudstone Member and pinches out laterally to the northwest and southeast into mudstone.

The Rancheria Gulch Sandstone Beds were designated as member V of the Hornbrook Formation by Peck and others (1956), who did not describe the unit's lens-shaped geometry. D.L. Jones (unpub. mapping) mapped most of the extent of the Rancheria Gulch Sandstone Beds in the Hornbrook area and included them within the lower part of his unit C (of Hornbrook Formation) (Jones, 1959). McKnight (1971) did not recognize the Rancheria Gulch Sandstone Beds in the Bear Creek valley area. Elliott (1971; unpub. data, 1980) did not map the Rancheria Gulch Sandstone Beds or differentiate them within his Bailey Hill mudstone unit of his Hilt unit or his unit D of the Hornbrook Formation (fig. 6A). Nilsen and others (1983) mapped the Rancheria Gulch Sandstone Beds as l_1 and l_2, two sandstone lenses within the lower part of their unit d of the Hornbrook Formation.

The Rancheria Gulch Sandstone Beds rest conformably on the lower part of the Blue Gulch Mudstone Member. The lower boundary is marked by the abrupt upward lithologic change from mudstone, siltstone, and some thin beds of very fine grained sandstone of the upper part of the lower Blue Gulch Mud-

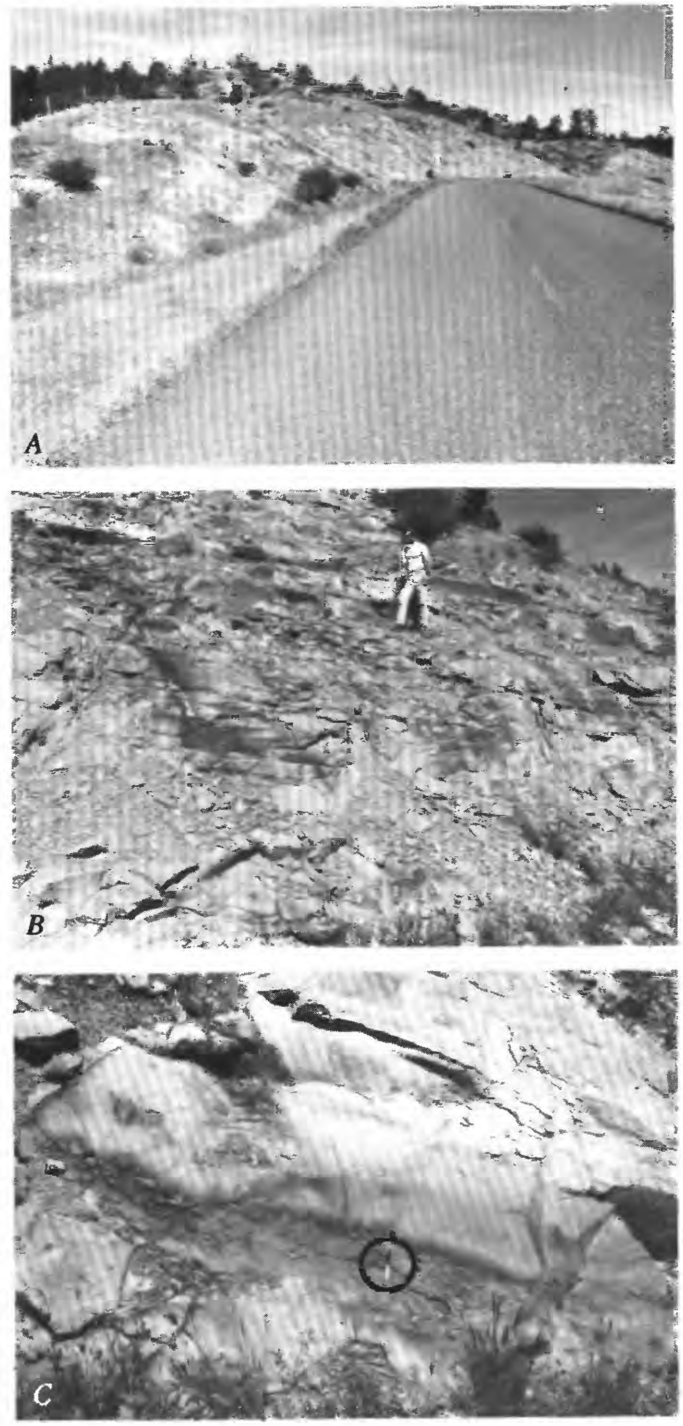


FIGURE 19.—Type section of the Rancheria Gulch Sandstone Beds of the Blue Gulch Mudstone Member of the Hornbrook Formation. *A*, View northwest, showing ridge underlain by the Rancheria Gulch Sandstone Beds (of the Blue Gulch Mudstone Member) and massive quarry exposures (roadcut is about 10 m high at bend in road). *B*, Hummocky cross-stratified and parallel-stratified fine-grained sandstone exposed in quarry; beds dip toward the viewer. *C*, Alternating beds of light-colored hummocky cross-stratified sandstone and less resistant dark-colored bioturbated sandstone; pen in bioturbated interval circled for scale.

stone Member to repetitive and amalgamated beds of massive or hummocky cross-stratified fine-grained sandstone. This contact is generally clear, and there is little evidence of interfingering along it. The underlying mudstone and siltstone is generally massive and bioturbated, and it contains a few scattered beds of very fine grained sandstone that are generally less than 15 cm thick, ripple-marked, and hummocky cross-stratified. The overlying sandstone contains beds of fine-grained sandstone as thick as 4 m and few, if any, siltstone or mudstone interbeds in its lower part.

The upper contact of the Rancheria Gulch Sandstone Beds with the middle part of the Blue Gulch Mudstone Member is conformable and more gradational than the lower contact. It is marked by an upward change in predominant lithology from very fine grained to fine-grained sandstone with some interbedded mudstone and siltstone to massive siltstone with some thin interbeds of very fine grained sandstone. The contact is arbitrarily placed at the top of the highest bed of fine-grained sandstone thicker than 30 cm.

The Rancheria Gulch Sandstone Beds typically form two subparallel ridges held up by the resistant sandstone. Nilsen and others (1983) recognized and mapped two subunits of the Rancheria Gulch Sandstone Beds based on this outcrop pattern. However, measured sections have failed to reveal a major shale or siltstone interval between the sandstone ridges, and in this report, subunits l_1 and l_2 of Nilsen and others (1983) are grouped together as one map unit (pl. 1).

AREAL EXTENT

The Rancheria Gulch Sandstone Beds are areally restricted to the southern Cottonwood Creek valley-northern Black Mountain area, southwest of Hornbrook, California. The unit crops out between Ditch Creek and Osburger Gulch over a northwest-southeast distance of about 8 km. I have not recognized at the same stratigraphic level any detached or separated bodies of sandstone to the northwest or southeast of the main lens, so that it appears to pinch out laterally in a well-defined manner within mudstone of the Blue Gulch Mudstone Member.

The northwestern limit of outcrops of the Rancheria Gulch Sandstone Beds is on the narrow southern end of the divide between Cottonwood Creek and Hutton Creek (SW¼SE¼ sec. 7, T. 47 N., R. 6 W., Hornbrook 15-minute quadrangle). The unit is very thin in this area and is truncated by a minor northeast-trending fault that cuts through the northwest corner of sec. 18, T. 47 N., R. 6 W., Hornbrook 15-minute quadrangle; the lens does not continue northwest of this fault.

The southeastern limit of outcrops of the Rancheria Gulch is on the northwest flank of Black Mountain, between Osburger Gulch and Blue Gulch. The last mapped patch of the unit is in the NW¼NW¼ sec. 3, T. 46 N., R. 6 W., Hornbrook 15-minute quadrangle. Because of the large area covered by landslides along the flanks of Black Mountain, it is possible that the unit may extend farther south along the western and southwestern flanks of Black Mountain. However, the Rancheria Gulch Sandstone Beds do not crop out along the northeastern edge of the Shasta Valley, where the Blue Gulch Mudstone Member crops out extensively.

TYPE SECTION

The type section of the Rancheria Gulch Sandstone Beds of the Blue Gulch Mudstone Member of the Hornbrook Formation was measured southeast of Rancheria Gulch in the center of the S½SW¼ sec. 20, T. 47 N., R. 6 W., Hornbrook 15-minute quadrangle (fig. 8). This section begins in some roadcuts along an access roadway to a house, extends northeastward into and across a large quarry west of the U.S. Forest Service Forestry Camp, and continues northward along another road that borders the quarry. The section is about 86 m thick and is almost completely exposed (fig. 20). It consists almost wholly of very fine grained and fine-grained sandstone. The basal and upper contacts with the Blue Gulch Mudstone Member are well exposed.

	Thickness (in meters)
Hornbrook Formation (upper part):	
Blue Gulch Mudstone Member (middle part):	
Siltstone, massive, bioturbated	2.00
Conformable contact.	
Rancheria Gulch Sandstone Beds:	
Sandstone, medium-grained, massive; abundant molluscan fossil debris, bioturbated	.45
Sandstone, very fine grained, and siltstone, massive, bioturbated	.85
Sandstone, fine-grained, massive; scattered molluscan fossils, bioturbated	2.60
Siltstone, massive, bioturbated	1.10
Sandstone, very fine grained, silty, massive, bioturbated	1.40
Mudstone, silty, bioturbated	.70
Sandstone, very fine grained, massive, bioturbated	1.20

	Thickness (in meters)
Rancheria Gulch Sandstone Beds—*Continued*:	
Mudstone, silty, massive	.10
Sandstone, very fine grained, massive, bioturbated	.20
Sandstone, very fine grained, with thin interbeds of siltstone and mudstone	5.50
Covered interval (float of siltstone and shale)	17.00
Sandstone, fine-grained, massive, bioturbated	1.50
Covered interval	7.50
Sandstone, fine-grained; hummocky cross-strata	.30
Sandstone, fine-grained, massive, bioturbated	1.45
Sandstone, fine-grained; hummocky cross-strata	.20
Sandstone, fine-grained, massive, bioturbated	2.00
Sandstone, fine-grained; hummocky cross-strata	.20
Sandstone, fine-grained, massive, bioturbated	2.40
Sandstone, fine-grained; hummocky cross-strata	.15
Sandstone, fine-grained, massive, bioturbated	1.80
Sandstone, fine-grained; hummocky cross-strata	.25
Sandstone, fine-grained, massive, bioturbated; scattered molluscan fossils	.40
Sandstone, fine-grained; hummocky cross-strata	.25
Sandstone, fine-grained, massive, bioturbated	.65
Sandstone, fine-grained; hummocky cross-strata	.10
Sandstone, fine-grained, massive, bioturbated; scattered molluscan fossils	.35
Sandstone, fine-grained; hummocky cross-strata, bioturbated	.15
Sandstone, fine-grained, massive, bioturbated	.65
Sandstone, fine-grained; hummocky cross strata, bioturbated	.70
Sandstone, fine-grained, massive, bioturbated; scattered fossil plant fragments	6.00
Sandstone, fine-grained; hummocky cross-strata, bioturbated	.30
Sandstone, fine-grained, massive, bioturbated	2.20
Sandstone, fine-grained; hummocky cross-strata	.70
Sandstone, fine-grained, massive, bioturbated	3.90
Sandstone, fine-grained; hummocky cross-strata	.25
Sandstone, fine-grained, massive; molluscan fossils	2.90
Sandstone, fine-grained; hummocky cross-strata	.12
Sandstone, fine-grained, massive; molluscan fossils	1.40
Sandstone, fine-grained; hummocky cross-strata	.20
Sandstone, fine-grained, massive, bioturbated	.20
Sandstone, fine-grained; hummocky cross-strata	.70
Sandstone, fine-grained, massive, bioturbated	.75
Sandstone, fine-grained; hummocky cross-strata	1.10
Sandstone, fine-grained, massive; scattered plant fossils	2.20

	Thickness (in meters)
Rancheria Gulch Sandstone Beds—*Continued*:	
Sandstone, fine-grained; hummocky cross-strata	.50
Sandstone, fine-grained, massive, bioturbated, mostly covered	1.00
Sandstone, fine-grained; hummocky cross-strata	.40
Covered interval (float of sandstone)	3.00
Sandstone, fine-grained, massive	.65
Covered interval	.45
Sandstone, fine-grained, massive	.25
Sandstone, fine-grained; hummocky cross-strata	.10
Sandstone, fine-grained, massive, bioturbated; scattered molluscan fossils	.10
Sandstone, fine-grained; hummocky cross-strata	.12
Sandstone, fine-grained, massive; scattered molluscan fossils	.40
Sandstone, fine-grained; hummocky cross-strata	.60
Sandstone, fine-grained, massive	.10
Sandstone, fine-grained; hummocky cross-strata	.48
Sandstone, fine-grained, massive; scattered molluscan fossils	.70
Sandstone, fine-grained; hummocky cross-strata	.20
Sandstone, fine-grained, massive, bioturbated	1.35
Sandstone, very fine grained to fine-grained; hummocky cross-strata	.20
Sandstone, fine-grained, massive	.15
Total thickness of the Rancheria Gulch Sandstone Beds	85.77
Conformable contact.	
Blue Gulch Mudstone Member (lower part):	
Siltstone and mudstone, interbedded, laminated and ripple-marked, bioturbated; plant fossil fragments	10.00

The colors of the Rancheria Gulch Sandstone Beds are generally uniform. The sandstone is very light gray (N7) on fresh surfaces and light brown (5YR 5/6) or moderate yellowish brown (10YR 5/4) on weathered surfaces. The calcareous concretions are typically moderate brown (5YR 3/4) on weathered surfaces.

LITHOLOGY

The Rancheria Gulch Sandstone Beds consist chiefly of fine-grained sandstone. In the type section, strata consist predominantly of alternating beds of massive sandstone and hummocky cross-stratified sandstone, both of which commonly are bioturbated. The hummocky cross-stratified beds decrease in abundance upward; they are not present in the uppermost 15 m and may be absent from the uppermost

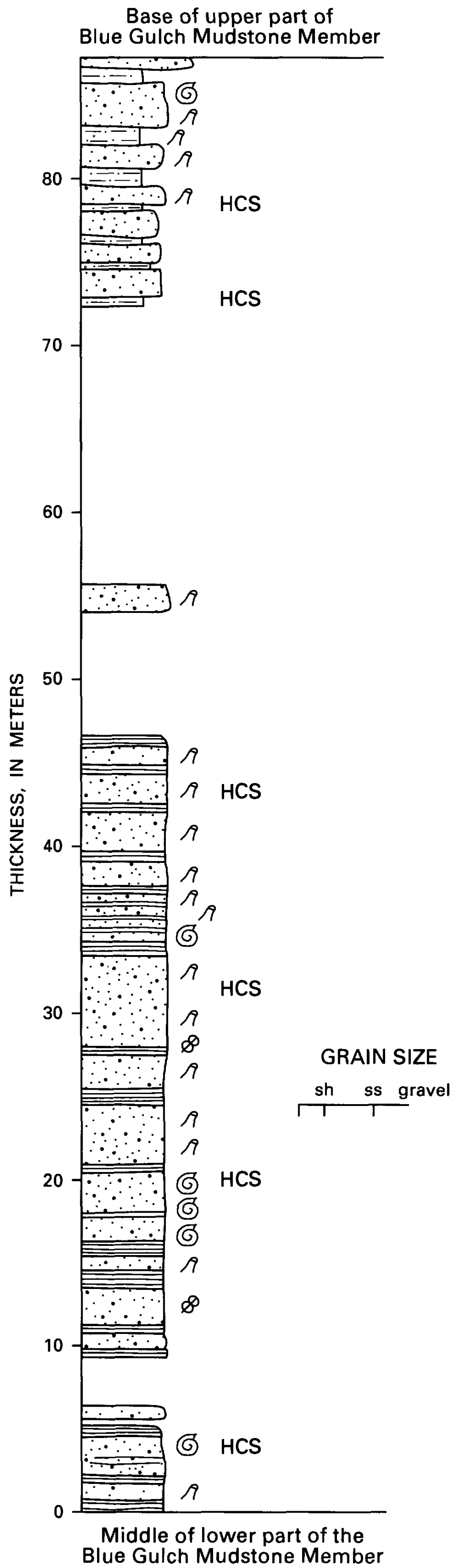


FIGURE 20.—Type section of the Rancheria Gulch Sandstone Beds of the Blue Gulch Mudstone Member of the Hornbrook Formation. See figure 10 for explanation of symbols. Gaps in lithology represent covered intervals.

30 m. The beds of massive sandstone range from about 10 cm to 6 m in thickness, and the beds of hummocky cross-stratified sandstone range from about 10 cm to 1.10 m in thickness. The thickest beds of sandstone are generally present in the middle part of the type section, with thinner beds near the base and at the top.

The upper part of the type section contains interbeds of bioturbated siltstone and silty mudstone as thick as 1.1 m; these interbeds mark the gradational upper contact with the overlying mudstone of the middle part of the Blue Gulch Mudstone Member. In other sections, there are minor interbeds of siltstone in the lower part of the unit. Sandstone of the upper part of the type section is generally finer grained, being typically very fine grained sandstone rather than fine-grained sandstone. However, the uppermost bed in the type section consists of massive medium-grained sandstone that contains the coarsest grain sizes observed in the entire section. No conglomerate has been observed within the Rancheria Gulch Sandstone Beds.

Burrowing is common in the sandstone as well as in the siltstone and silty mudstone of the Rancheria Gulch Sandstone Beds. The burrows are typically solitary, but some beds (especially beds of mudstone and siltstone) are so thoroughly bioturbated that stratification is totally destroyed and individual trace fossils cannot be identified. The burrows are typically feeding burrows that penetrate subvertically into the beds, but some grazing traces on bedding surfaces are also present.

Megafossils, including pelecypods and gastropods, are found at several levels within the Rancheria Gulch Sandstone Beds. They are present both in growth position within the massive fine-grained sandstone and as transported and reworked fossil debris, commonly near the base of the hummocky cross-stratified beds. The megafossils are generally more abundant in the lower parts of the unit, although the uppermost bed of medium-grained sandstone in the type section contains abundant transported megafossil debris. Scattered plant fossils are present within massive beds of sandstone as well as on bedding surfaces of hummocky cross-stratified sandstone.

STRATIGRAPHIC RELATIONS

The Rancheria Gulch Sandstone Beds form a mappable unit within the lower part of the Blue Gulch Mudstone Member of the Hornbrook Formation in the Hornbrook area. The unit conformably overlies, underlies, and pinches out laterally to the northwest and southeast into mudstone of the Blue Gulch Mudstone Member. No other lenses of sandstone or groups of sandstone beds have been observed in other outcrop areas of the lower part of the Blue Gulch Mudstone Member that can be correlated with the Rancheria Gulch Sandstone Beds. The lens probably also pinches out in the subsurface to the northeast, but there are no available drill-hole data to confirm this.

THICKNESS

The Rancheria Gulch Sandstone Beds range in thickness from 0 to at least 85.77 m, its measured thickness at the type section. Peck and others (1956) measured a section of their member V, which is equivalent to the Rancheria Gulch Sandstone Beds, on the ridge south of Rancheria Gulch in the same area as the type section of the Rancheria Gulch Sandstone Beds and obtained a thickness of 94.8 m. Just west of Blue Gulch, in the main part of the type section of the Blue Gulch Mudstone Member (center of sec. 33, T. 47 N., R. 6 W., Hornbrook 15-minute quadrangle), I measured an additional section of the Rancheria Gulch Sandstone Beds that is 62.55 m thick.

The Rancheria Gulch Sandstone Beds appear to be thickest in the Rancheria Gulch area. The unit thins rapidly northwestward, pinching out over a distance of about 3.5 km. It thins more gradually to the southeast, pinching out beneath landslides on the flanks of Black Mountain 4.5 to 10 km southeast of Rancheria Gulch. The unit thus appear to be asymmetrical in northwest-southeast cross section, with its thicker part situated toward the northwest.

DEPOSITIONAL ENVIRONMENT

The molluscan megafossils, abundant bioturbation, hummocky cross-stratification, and narrow range of clast sizes within the Rancheria Gulch Sandstone Beds suggest its deposition in a wave-dominated, high-energy, middle- to outer-shelf environment. Megafossils reported from the Rancheria Gulch Sandstone Beds such as the bivalve genus *Meekia* (Saul and Popenoe, 1962) were shallow-marine, infaunal suspension feeders that preferred a sandy substratum and a well-agitated open coastline (Sundberg, 1980, 1982). The bivalve genus *Cucullaea* was an infaunal deposit feeder that preferred silty and sandy substrates (Rhoads and others, 1972). The bivalve genus *Glycimeris* was an infaunal suspension feeder indicative of paralic, high-energy environments (Stanley, 1970) that probably lived at water depths of 5–100 m (Sundberg, 1982). Trace fossils include *Ophiomorpha*, *Thalassinoides*, and other deposit feeding burrows that are generally indicative of shallow-marine, high-energy environments (Frey and others, 1978).

The abundant hummocky cross-stratification, which is commonly amalgamated in the Rancheria Gulch Sandstone Beds, is characteristic of storm- and wave-dominated sedimentation on a high-energy marine shelf (Dott and Bourgeois, 1982). The amalgamation results from frequent storm-induced currents below the effective wave base that scour away evidence of fair-weather deposition. Storm reworking of shelf sediments is also indicated by beds of hummocky cross-stratified sandstone with highly bioturbated siltstone and silty mudstone in their upper parts and, locally, in their lower parts; this lithologic association suggests that there was episodic scour and deposition by storm surges to yield the hummocky cross-stratified sandstone, followed by fair-weather deposition of mud and silt and the return of burrowing organisms. The lack of conglomerate and of coarser grades of sand suggests that deposition took place on the middle to outer parts of the shelf, where rip currents or surf-zone processes that might transport coarse material were not active.

AGE AND CORRELATION

The age of the Rancheria Gulch Sandstone Beds is constrained by megafossil collections from within the unit and by foraminiferal collections from the overlying mudstone of the Blue Gulch Mudstone Member. No foraminiferal collections have been obtained from within the lens itself.

Peck and others (1956) reported the presence of numerous ammonites from the upper part of the unit, apparently from the mudstone and siltstone beds that are abundant near the gradational upper contact with the overlying middle part of the Blue Gulch Mudstone Member. They collected specimens of *Metaplacenticeras pacificum* (Smith), *M. californicum* (Anderson), *Desmophyllites* sp. juv., *Gaudryceras* cf. *G. denmanense* (Whiteaves), *Pachydiscus* sp., *Eupachydiscus* cf. *E. perplicatus* (Whiteaves), and *E.* cf. *E. haradai* (Jimbo) from the uppermost part of the beds on the south side of the Klamath River, west of Blue Gulch (SW¼NE¼ sec. 33, T. 47 N., R. 6 W., Hornbrook 15-minute quadrangle). They also collected specimens of *Inoceramus* cf. *I. pertenuis* Meek and Hayden as well as several other pelecypods and gastropods. Anderson (1902, p. 78, 80, 90, 98) had previously collected some similar ammonites from the upper part of the Rancheria Gulch Sandstone Beds, or possibly from the overlying mudstone of the Blue Gulch Mudstone Member, near Henley. These ammonites and the accompanying *Inoceramus* are strongly suggestive of a late Campanian age for the uppermost part of the Rancheria Gulch Sandstone Beds (Peck and others, 1956, p. 1981). Sliter and others (1984, fig. 2) reported the presence of late Campanian megafossils from the lower, middle, and upper parts of the Rancheria Gulch Sandstone Beds (USGS Mesozoic localities M382, M385, and M387).

Thus, the age of the Rancheria Gulch Sandstone Beds appears to be late Campanian, about 75 to 79 Ma. The beds are at least partly correlative in Oregon with Cretaceous strata along the southwest coast—the Cape Sebastian Sandstone and Hunters Cove Formation of Dott (1971)—and with subsurface Cretaceous strata of the Ochoco basin near Mitchell (Thompson and others, 1984). In northern California, the beds are, at least, partly correlative with the Great Valley sequence near Chico (Haggart and Ward, 1984) and along the west side of the Sacramento Valley (Ingersoll, 1979), as well as with parts of the Coastal belt terrane of the Franciscan assemblage (Evitt and Pierce, 1975).

HILT BED

DEFINITION

The Hilt Bed is a prominent 2- to 5-m-thick marker bed of sandstone that forms the boundary between the middle and upper parts of the Blue Gulch Mudstone Member of the Hornbrook Formation in its type section (figs. 7, 18). In the type section of the Blue Gulch Mudstone Member, the Hilt Bed is situated about 458 m above the base of the Blue Gulch Mudstone Member, 294 m above the top of the Rancheria Gulch Sandstone Beds, and 388.5 m below the unconformable upper contact of the Blue Gulch Mudstone Member with the overlying Tertiary volcanic rocks (fig. 18).

Most of the Blue Gulch Mudstone Member, except for the Rancheria Gulch Sandstone Beds, consists of mudstone with thin to very thin interbeds of siltstone and sandstone. The Hilt Bed, in contrast, is a very thick bed of sandstone, locally almost 5 m thick (fig. 21). It is the only very thick bed of sandstone that I have observed within the Blue Gulch Mudstone Member except for the beds of sandstone within the Rancheria Gulch Sandstone Beds and a single unique outcrop of a very thick individual bed of massive sandstone (SW¼SE¼ sec. 7, T. 47 N., R 6W., Hornbrook 15-minute quadrangle). This latter bed, 4.20 m thick, consists of massive, graded, granule conglomerate to medium-grained sandstone that contains abundant molluscan fossil debris and rip-up clasts of shale. The bed is wholly different in internal organization and composition from the Hilt Bed, is disrupted by cross-faults, and is not laterally persistent. Although this bed crops out in close proximity to the Hilt Bed, its distinct lithology suggests that it is a different areally restricted thick bed.

Because the Hilt Bed is the only very thick, laterally persistent bed of sandstone within the Blue Gulch Mudstone Member and is more resistant than the predominant mudstone lithology, it forms a prominent topographic bench on slopes underlain by the member. However, because it is offset by numerous northeast-trending faults, the Hilt Bed is rarely present at similar elevations on slopes for more than a few kilometers. The basal part of the Hilt Bed is abruptly scoured into underlying mudstone, whereas its uppermost part is gradational into overlying mudstone.

AREAL EXTENT

The Hilt Bed forms a prominent marker bed within the Blue Gulch Mudstone Member of the Hornbrook Formation from the area of Willow School at the north end of the Shasta Valley to the Lithia Spring area east of Ashland in the northern Bear Creek valley area (pl. 1). The Hilt Bed may also extend farther to the northwest in the northern Bear Creek valley area, but the Blue Gulch Mudstone Member there is mostly covered by Quaternary alluvium and, farther north, by Tertiary volcanic rocks. In addition, the Hilt Bed may extend farther south into the Shasta Valley area, but the lower part of the Blue Gulch Mudstone Member in that area is covered by Quaternary alluvium.

The distribution of the Hilt Bed within the main outcrop area of the Hornbrook Formation in the Bear Creek valley and Cottonwood Creek valley areas is shown by Nilsen and others (1983), who mapped the Hilt Bed as their subunit m within the lower part of their unit d of the Hornbrook Formation. In every area between the northern Shasta Valley and Ashland where the lower part of the Blue Gulch Mudstone Member is sufficiently well exposed, the Hilt Bed forms a mappable marker bed.

TYPE SECTION

The type section of the Hilt Bed of the Blue Gulch Mudstone Member of the Hornbrook Formation was measured in a roadcut along an access road east of Interstate Highway 5 in the NW¼SW¼ sec. 24, T. 48 N., R. 7 W., Hornbrook 15-minute quadrangle (fig. 22; pl. 1). The roadcut is on the opposite side of Interstate Highway 5 from the store at Hilt, adjacent to the Hilt exit (Nilsen and others, 1984, stop 7).

	Thickness (in meters)
Hornbrook Formation:	
Blue Gulch Mudstone Member (upper part):	
Mudstone, massive	
Conformable contact.	
Hilt Bed:	
Sandstone, very fine grained, and siltstone, ripple-marked and laminated	0.10
Sandstone, very fine grained, parallel-stratified	.12
Sandstone, fine-grained, massive	.10
Sandstone, very fine grained, parallel-stratified	.35
Sandstone, fine-grained, massive	.08
Sandstone, fine-grained, parallel-stratified	.48
Sandstone, fine- to medium-grained, massive; mudstone rip-up clasts; flute casts at base	2.85
Total thickness of the Hilt Bed	4.08
Conformable but erosive contact.	
Blue Gulch Mudstone Member (middle part):	
Mudstone, massive	

The Hilt Bed is yellowish gray (5Y 7/2) on fresh surfaces and moderate yellowish brown (10YR 5/4) on weathered surfaces. These colors vary little over its entire outcrop extent.

LITHOLOGY

The Hilt Bed everywhere consists of sandstone. It can generally be divided into nine lithic divisions, all of which are present in almost every outcrop. These divisions correspond to the divisions that Bouma (1962) determined for graded turbidite beds, but they are vertically organized in a rather unorthodox fashion. The organization of the Hilt Bed is a compound $T_{abababcde}$ sequence, in which the basal *a* division is typically the thickest, and overlying divisions are of variable thickness but are generally thinner.

The lowermost *a* division typically consists of a fine- to medium-grained sandstone, commonly with

FIGURE 21.—Hilt Bed of the Blue Gulch Mudstone Member of the Hornbrook Formation in its type section and adjacent areas. *A* and *B*, Type section of the Hilt Bed (of Blue Gulch Mudstone Member) east of Hilt overpass on Interstate Highway 5 and east of store at Hilt; note thin-bedded basin-plain turbidites stratigraphically above and below the Hilt Bed. Roadcut is approximately 10 m in height. *C* and *D*, Reference section of the Hilt Bed (of Blue Gulch Mudstone Member), west of store at Hilt. Note slump block of Hilt Bed (B) in right side of outcrop and fault (F) truncating right, or east, end of outcrop.

coarse-grained sandstone at its base and with rip-up clasts of mudstone scattered throughout. This division is typically massive and graded, with the grading most typically expressed as coarse-tail grading. Flute casts and groove casts are commonly present along the basal surface of the bed, where it clearly rests with erosional contact on underlying mudstone.

The overlying *b* division is typically fine-grained sandstone that is parallel stratified. It grades upward from the *a* division and commonly contains abundant mica and plant fragments.

The second *a* division consists of massive fine-grained sandstone that is generally slightly coarser than the underlying *b* division. This *a* division generally rests with slight erosional contact on the underlying *b* division. Overlying this second *a* division is the second *b* division, which consists of parallel-stratified very fine grained to fine-grained sandstone.

The upper part of the Hilt Bed consists of a complete T_{abcde} Bouma sequence. The *a* division consists of massive fine-grained sandstone, the *b* division of parallel-stratified very fine grained sandstone, the *c* division of ripple-marked very fine grained sandstone, the *d* division of laminated siltstone and very fine grained sandstone, with abundant mica flakes

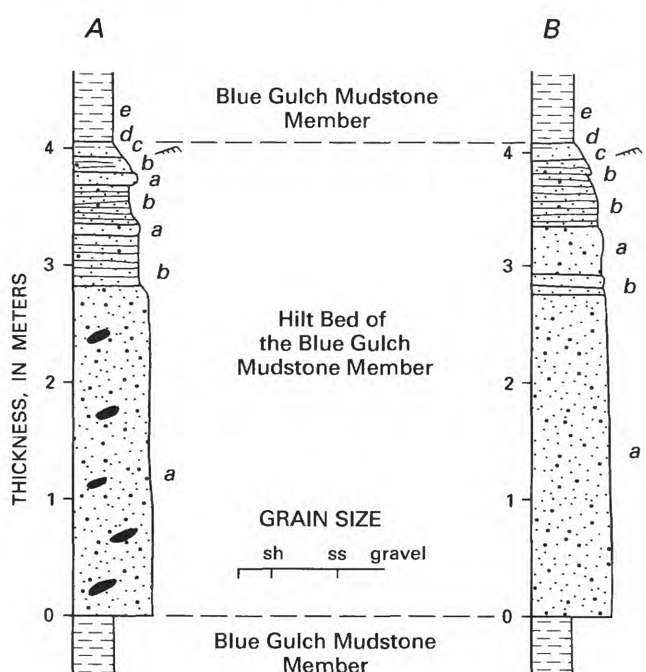


FIGURE 22.—Type section and reference section of the Hilt Bed of the Blue Gulch Mudstone Member of the Hornbrook Formation. *A*, Type section, east of store at Hilt. *B*, Reference section, west of store at Hilt. Lowercase letters *a–e* correspond to divisions that Bouma (1962) defined for graded turbidite beds. See figure 10 for explanations of symbols.

and finely comminuted plant debris, and the *e* division of mudstone that grades up into the overlying upper part of the Blue Gulch Mudstone Member. In most sections and in the type section shown in figure 22, the mudstone of the *e* division of the Hilt Bed cannot be distinguished from mudstone of the overlying Blue Gulch Mudstone Member; as a result, it is not included within the thicknesses measured for the Hilt Bed.

The lowermost *a* division is typically the thickest division and forms a steep clifflike exposure. The uppermost divisions are generally thinner, are less resistant, and in some areas are partly to wholly covered by soil and colluvium derived from the overlying mudstone. In a few localities, however, the lowermost *a* division is missing.

STRATIGRAPHIC RELATIONS

The Hilt Bed appears to be a laterally continuous marker bed of gradually changing thickness that is conformable within the Blue Gulch Mudstone Member. It is everywhere both underlain and overlain by mudstone and thin-bedded sandstone of the Blue Gulch Mudstone Member. It probably pinches out laterally in most directions into the mudstone deposits, but this characteristic is not observed in outcrop.

THICKNESS

The Hilt Bed is thickest near Bailey Hill in the Cottonwood Creek valley area, where it is 4.71 m thick (SW¼NE¼ sec. 25, T. 48 N., R. 7 W., Hornbrook 15-minute quadrangle). It generally thins progressively northwestward, and the following thicknesses for it have been successively measured north of the Bailey Hill area: (1) 4.08 m at the type section (NW¼SW¼ sec. 24, T. 48 N., R. 7 W., Hornbrook 15-minute quadrangle); (2) 4.06 m at its reference section (SW¼NW¼ sec. 24, T. 48 N., R. 7 W., Hornbrook 15-minute quadrangle); (3) 3.77 m southeast of the town of Cole (NW¼NW¼ sec. 23, T. 48 N., R. 7 W., Hornbrook 15-minute quadrangle); (4) 3.55 m northwest of Cole (NW¼NW¼ sec. 13, T. 41 S., R. 1 E., Ashland 15-minute quadrangle); (5) 1.46 m north of Cole, where the basal T_a division is missing (NW¼SE¼ sec. 12, T. 41 S., R. 1 E., Ashland 15-minute quadrangle; (6) 2.10 m near Steinman at the southeast end of the Bear Creek valley area (SW¼NE¼ sec. 16, T. 40 S., R. 2 E., Ashland 15-minute quadrangle); (7) 2.84 m near Lithia Spring east of Ashland (SW¼SW¼ sec. 51, T. 39 S., R. 1 E., Ashland 15-minute quadrangle); and (8) 2.69 m near the Ashland airport, east of Ashland (NW¼NW¼ sec. 20, T. 39 S., R. 1 E., Ashland 15-minute quadrangle). Thus, with the exception of sections 5 and 6, the Hilt Bed gradually decreases in thickness (from 4.71 to 2.69 m) northwest of the Bailey Hill area, a distance of about 29.5 km.

South of its thickest section near Bailey Hill, the Hilt Bed also progressively thins. The following thicknesses for it have been successively measured from north to south: (1) 4.05 m about 3 km south of Bailey Hill near bench mark 2749 in the Cottonwood Creek valley area (SW¼ sec. 31, T. 48 N., R. 6 W., Hornbrook 15-minute quadrangle); (2) 3.45 m near Hutton Creek (NW¼SE¼ sec. 6, T. 47 N., R. 6 W., Hornbrook 15-minute quadrangle; (3) 3.55 m near Hutton Creek (SW¼SE¼ sec. 7, T. 47 N., R. 6 W., Hornbrook 15-minute quadrangle); (4) 2.95 m about 1 km northwest of Hornbrook (SE¼SW¼ sec. 17, T. 47 N., R. 6 W., Hornbrook 15-minute quadrangle); (5) 2.99 m about 1 km southeast of Hornbrook (NE¼SW¼ sec. 21, T. 47 N., R. 6 W., Hornbrook 15-minute quadrangle); (6) 3.00 m about 1.5 km southeast of Hornbrook (SW¼SE¼ sec. 21, T. 47 N., R. 6 W., Hornbrook 15-minute quadrangle); (7) 3.60 m about 2 km southeast of Hornbrook adjacent to bench mark 2110 (SW¼NE¼ sec. 28, T. 47 N., R. 6 W., Hornbrook 15-minute quadrangle); (8) 3.31 m in the type section of the Blue Gulch Mudstone Member (NW¼NW¼ sec. 34, T. 47 N., R. 6 W., Hornbrook 15-minute quadrangle); and (9) 1.61 m near Willow Creek School at the north end of the Shasta Valley (NE¼SW¼ sec. 7, T. 46 N., R. 5 W., Copco 15-minute quadrangle). Thus, the Hilt Bed decreases irregularly southeastward from a maximum thickness near Bailey Hill of 4.71 m to a minimum thickness near Willow Creek School of 1.61 m, a distance of about 18.5 km.

DEPOSITIONAL ENVIRONMENT

The Hilt Bed represents a multiple or compound turbidite deposit in a deep-marine setting. The presence of the Bouma sequence within the bed, of grading within the bed, of the erosional basal contact with mudstone, and of sole markings at the base of the bed all suggest deposition by a turbidity current below wave base. The multiple or compound nature of the turbidite, in which three separate Bouma sequences constitute the Hilt Bed, suggests that three separate turbidity currents were generated (possibly by the same triggering event) to produce the bed. The absence of interbedded shale, the lateral continuity and extent of the three turbidites, and the incompleteness of the two lower Bouma sequences suggest that the three turbidity currents flowed to the basin floor at almost the same time to produce the Hilt Bed.

AGE AND CORRELATION

The Hilt Bed, based on ages of benthic and planktonic foraminifers included within mudstone underlying and overlying it, is apparently of late Campanian age. At its type section, foraminifers from 35 m beneath the Hilt Bed are indicative of a late Santonian to late Campanian age (USGS Mesozoic locality Mf6584). Because of its deposition by turbidity currents, the Hilt Bed is probably not time transgressive or regressive; rather, it was probably deposited within a few hours to a few days, thus forming a very useful marker bed.

The Hilt Bed is, at least, partly correlative with Campanian rocks in southwestern Oregon [the Cape Sebastian Sandstone and the Hunters Cove Formation of Dott (1971)] and in northern California (the Great Valley sequence and the Coastal belt terrane of the Franciscan assemblage).

SUMMARY AND CONCLUSIONS

This paper summarizes the lithostratigraphic and biostratigraphic aspects of the Cretaceous Hornbrook Formation of southwestern Oregon and north-central California. The formation, originally named by Peck and others (1956) for exposures near Hornbrook, California, was divided into five members by Nilsen (1984a).

The basal member, the Klamath River Conglomerate Member, consists of discontinuous nonmarine deposits, 36.5 m thick in its type section, that rest on basement rocks of the Klamath Mountains. These strata were deposited as alluvial fans and braided streams. They commonly include a basal weathered breccia or conglomeratic grus. The deposits have been derived from the locally subjacent and nearby basement rocks. The member is most likely of Albian, Cenomanian, and Turonian age, although no age-diagnostic fossils have been obtained from it.

Shallow-marine strata of the conformably overlying Osburger Gulch Sandstone Member, 116.5 m thick in its type section, were deposited in shoreline to middle-shelf environments. Trough cross-stratified, medium-grained to very coarse grained, conglomeratic sandstone characterizes its lower nearshore deposits and hummocky cross-stratified, very fine grained to fine-grained sandstone characterizes its upper storm-dominated middle-shelf deposits. An abundant molluscan fauna is indicative of a late

Albian(?) to early Coniacian age for the unit, which generally is younger toward the southeast.

The conformably overlying Ditch Creek Siltstone Member, 61.6 m thick in its type section, was deposited in outer-shelf to upper-slope environments. It consists of thoroughly bioturbated, massive siltstone and silty very fine grained sandstone that in some places contains graded storm deposits of sandstone and thin turbidites. In the northern Shasta Valley, a bituminous coal bed is intercalated with mollusk-bearing siltstones, which implies at least local subaerial exposure. Megafossils and foraminifers from the member generally are indicative of an early Turonian to early Coniacian age, which generally is younger toward the southeast.

The Rocky Gulch Sandstone Member, 171.2 m thick in its type section, consists predominantly of turbidite sandstone organized into repetitive fining- and thinning-upward cycles. Although various depositional environments have been proposed by others in the past, the Rocky Gulch Sandstone Member appears to have been deposited as an apron on a submarine slope. The upper part of the member locally contains interbedded siltstone that appears to be of contourite origin. A single collection of foraminifers from this member is indicative of a middle Turonian age, but the member apparently ranges in age from middle Turonian to Campanian(?).

The conformably overlying Blue Gulch Mudstone Member, about 849.9 m thick in its type section, consists in most areas of hemipelagic mudstone with thin-bedded basin-plain turbidites. In the type area of the Hornbrook Formation, however, it contains a prominent lens of shallow-marine, hummocky cross-stratified, megafossiliferous sandstone within its lower part. This lens, the Rancheria Gulch Sandstone Beds, is 0–86 m thick, with a thickness of 85.8 m in its type section. The Rancheria Gulch Sandstone Beds are underlain and overlain by shallow-marine, bioturbated siltstone, mudstone, and very fine grained sandstone. Molluscan fossils from the sandstone beds are indicative of a late Campanian age. Most of the middle and upper parts of the Blue Gulch Mudstone Member in the type area consist of basin-plain turbidites and hemipelagic mudstone. The lower, lower middle, and uppermost parts of the member in its type section, however, appear to represent deposition in shallower depths. A thick compound turbidite bed, the Hilt Bed, is present between the middle and upper parts of the Blue Gulch Mudstone Member and can be mapped for a lateral distance of about 48 km within the Hornbrook Formation. This bed is as thick as 4.71 m near Hilt and thins from there to the northwest and southeast. Foraminiferal fossils from the Blue Gulch Mudstone Member are indicative of ages ranging from late Turonian to early Maestrichtian; in the type area, it appears to be Santonian to early Maestrichtian in age.

A major unconformity had been previously postulated within the type area of the Hornbrook Formation between strata equivalent to the Ditch Creek Siltstone Member and the Rocky Gulch Sandstone Member. The unconformity was thought to span the late Coniacian to early Campanian interval. However, the contact appears to be gradational in most areas and locally erosive in the type area. The varying ages reported herein from new collections of foraminifers and megafossils suggest that the unconformity, if present, is of local significance only.

The Hornbrook Formation records sedimentation within a basin located along the northeastern margin of the Klamath Mountains during the late Early and Late Cretaceous time. The basin may have originally extended farther to the northeast, connecting with the subsurface Ochoco basin and the Mitchell, Suplee, and Prairie Creek areas, as well as farther to the south, connecting with the Redding area and the Great Valley forearc basin. The petrography of framework grains of sandstone (Golia and Nilsen, 1984) and conglomerate clasts (Barats and others, 1984), as well as paleocurrents and facies associations (Nilsen, 1984d), strongly suggest that the basement rocks of the Klamath Mountains to the southwest were the chief source terrain for the Hornbrook Formation.

The Hornbrook Formation is also an overlap assemblage that rests unconformably on various Paleozoic, Triassic, and Jurassic terranes that constitute the Klamath Mountains (Irwin, 1960, 1966, 1981, 1984, 1985, 1989; Harper and Wright, 1984; Wright and Fahan, 1988). These terranes form a broad west-facing arcuate structure and are separated from each other by major east-dipping thrust faults. Sedimentary, metamorphic, and igneous rocks of various ages and degrees of structural complexity make up these terranes, which appear to consist mostly of fragments of oceanic crust and island arcs. Irwin (1981) concluded that the Paleozoic rocks of the eastern Klamath Mountains formed a volcanic arc built on ultramafic rocks that was intermittently active from the early Paleozoic to the Jurassic. He suggested that accretion of the various tectonic slices that form the western Klamath Mountains to the Paleozoic nucleus occurred during the Jurassic and not during previous time intervals. The terranes were intruded by plutons of Jurassic and earliest Early Cretaceous age (Irwin, 1984; Mankinen and others, 1988), and uplift of these rocks took place in the Early Cretaceous to form the

Klamath source terrain for the Hornbrook Formation.

The Hornbrook Formation records a major transgression from the east or northeast onto the Klamath Mountains. The transgression is recorded by basal middle Albian marine strata in the Grave Creek area, upper Albian(?) to middle Cenomanian strata in the Dark Hollow area, Turonian strata in the Bear Creek valley and Cottonwood Creek valley areas, and lower(?) Coniacian strata in the Black Mountain area (Sliter and others, 1984). This transgression may have continued southward to the Redding area, where Santonian strata rest directly on the basement rocks of the Klamath Mountains (Haggart, 1986a, b). However, these transgressive deposits probably record northward and eastward transgression from the Great Valley forearc basin. It is more likely that the transgressive strata of the Hornbrook Formation and Grave Creek area originally were continuous with eastward- or northeastward-transgressing Albian, Cenomanian, and Turonian shallow-marine deposits of the Mitchell, Suplee, and Grand Prairie Creek areas of central Oregon (fig. 1). This interpretation, however, depends upon the unproven existence of Cretaceous strata in the subsurface beneath the southern Cascade Range and beneath parts of the volcanic plateau of central Oregon to the east. The presence of a thick sequence of Upper Cretaceous strata that are partially correlative with the Hornbrook Formation in the subsurface Ochoco basin, however, supports this tentative conclusion (Thompson and others, 1984). During Cenozoic time, significant rotation and possible translation of the Cascade Range and parts of the volcanic plateau, as well as minor rotation of the Blue Mountains, might have caused major disruption of the postulated subsurface Cretaceous sequence in central Oregon (Beck, 1986; Beck and others, 1986; Wells and Heller, 1988).

The basin within which the Hornbrook Formation was deposited may have originally extended northeastward across much of central Oregon as a single large basin; alternatively, two separate Early to Late Cretaceous basins may have existed, the second one in the Ochoco-Mitchell area (fig. 1). In either case, the basin(s) would have been bounded by uplifted areas in western Idaho, eastern Oregon, northwestern Nevada, the Sierra Nevada of northern California and its continuation beneath the Modoc Plateau, and the Klamath Mountains. These areas were underlain by Paleozoic, Triassic, and Jurassic metamorphic rocks and Mesozoic plutons.

Because the age of emplacement of granite plutons of the Idaho batholith is chiefly Late Cretaceous, about 95–65 Ma (Hyndman, 1983; Lund and Snee, 1988; Hyndman and Sears, 1988), the Hornbrook-Ochoco basin most likely represents a forearc basin that developed between an oceanic subduction complex to the west and the batholith to the east. The Hornbrook-Ochoco basin was a fairly complex forearc basin, however, because it was bounded on the southwest by the older accreted terranes of the Klamath Mountains basement complex and the Jurassic and older plutons that intruded these terranes.

The Hornbrook Formation is overlain with angular unconformity by lower Tertiary nonmarine sedimentary and volcanic rocks. The surface of this unconformity cuts down at least several hundred meters into the upper part of the Hornbrook Formation, so that Tertiary strata locally rest directly on the Ditch Creek Siltstone Member and the Rocky Gulch Sandstone Member in the Ashland area.

The Hornbrook Formation was tilted northeastward sometime between the end of its deposition and the initiation of deposition of the lower Tertiary deposits, probably during post-early Maestrichtian to pre-Eocene time. The lower Tertiary strata and the Hornbrook Formation were subsequently tilted northeastward an additional amount, probably in the middle or late Tertiary. The Hornbrook strata were offset firstly along northwest-trending, steeply northeast-dipping normal faults and secondly along northeast-trending cross-faults characterized by varying types of movement (pl. 1). These faults may be related to prominent northwest-southeast-directed extensional tectonism during the Oligocene and Miocene that has been reported by Schweickert and Irwin (1989) in several parts of the southern Klamath Mountains.

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APPENDIXES I AND II

APPENDIX I.—MEGAFOSSILS COLLECTED FROM THE HORNBROOK FORMATION

See plate 1 for locations of samples; all collections by T.H. Nilsen and identifications by J.W. Miller of the U.S. Geological Survey. Samples are grouped in numerical order by member.

Osburger Gulch Sandstone Member

USGS Mesozoic locality M7682.—Roadcut on west side of northbound lane of Interstate Highway 5, directly west of the type section of the Osburger Gulch Sandstone Member; collected from basal bed of lower siltstone unit of the Osburger Gulch Sandstone Member (SE¼ sec. 32, T. 47 N., R. 6 W., Hornbrook 15-minute quadrangle).
Gastropod: *Turritella hearni* Anderson
Age: Turonian

USGS Mesozoic locality M7683.—Outcrop of fine- to medium-grained sandstone on northeast-facing slope about 3 km southeast of Paradise Craggy. Collected from basal beds of the Osburger Gulch Sandstone Member where they rest on the top of the Klamath River Conglomerate Member (SE¼NW¼ sec. 26, T. 46 N., R. 6 W., Hornbrook 15-minute quadrangle).
Gastropods: *Calva regina* Popenoe
Glycimeris pacificus (Anderson)
Meekia takeona Saul and Popenoe
Pterotrigonia evansana (Meek)
Age: Turonian

USGS Mesozoic locality M7685.—Outcrop of conglomeratic sandstone along west flank of crest of Soap Creek Ridge in outliers of the Hornbrook Formation about 8.5 km southwest of Yreka. Collected from basal trough cross-stratified beds of the Osburger Gulch Sandstone Member (NE¼NE¼ sec. 2, T. 44 N., R. 8 W., Yreka 15-minute quadrangle).
Peleycpods: *Cucullaea* sp.
Ostrea sp.
Pachycardium remondianum (Gabb)
Gastropod: *Acteonella ovufirnus* Gabb
Age: Turonian

Ditch Creek Siltstone Member

USGS Mesozoic locality M7686.—Roadcut along the northeast side of Dark Hollow Road in upper part of the Ditch Creek Siltstone Member. Collected from silty very fine grained sandstone (SW¼ sec. 13, T. 38 S., R. 2 W., Medford 15-minute quadrangle).
Pelecypods: *Avicula roguensis* Anderson
Cucullaea sp.
Gastropods: *Atresus liratus* Gabb
Cerithium sp.
Volutoderma mitraeformis (Gabb)
Age: Turonian

APPENDIX II.—FORAMINIFERS COLLECTED FROM THE HORNBROOK FORMATION

See plate 1 for locations of samples; benthic foraminiferal identifications by Kristin McDougall and William V. Sliter, and planktonic foraminiferal identifications by William V. Sliter. Samples are grouped in numerical order by member.

Ditch Creek Siltstone Member

USGS Mesozoic locality Mf650.—Collected from mudstone exposed in floor of Cottonwood Creek (SW¼NE¼ sec. 1, T. 47 N., R. 7 W., Hornbrook 15-minute quadrangle), Siskiyou County, Calif. (lat 41°57' N., long 122°36' W.). Middle part of the Ditch Creek Siltstone Member.
Collector.—T.H. Nilsen, 1982.
Benthic foraminifers: *Astacolus jarvisi* (Cushman)
Bathysiphon vitta Nauss
Cribrostomoides cretaceus Cushman and Goudkoff
Dorothia oxycona (Reuss)
Gaudyrina tailleuri (Tappan)
Gavelinella plummerae (Tappan)
G. popenoi (Trujillo)
Gyroidinoides birdi (Trujillo)
Haplophragmoides excavatus Cushman and Waters
Saccammina complanata (Franke)
Saracenaria triangularis (d'Orbigny)
Stilostomella impensia (Cushman)
Inoceramus prisms
Echinoid spines
Age: Late Turonian to Coniacian

USGS Mesozoic locality Mf6581.—Collected from natural outcrop of mudstone on southwest side of ridge located about 0.5 km northeast of Cottonwood Creek (NW¼NE¼ sec. 1, T. 47 N., R. 7 W., Hornbrook 15-minute quadrangle), Siskiyou County, Calif. (lat 41°57' N., long 122°36' W.). Uppermost part of the Ditch Creek Siltstone Member, about 2 m below contact with the Rocky Gulch Sandstone Member.
Collector.—T.H. Nilsen, 1982.
Benthic foraminifers: *Ammodiscus cretaceus* (Reuss)
Astacolus jarvisi (Cushman)
Bathysiphon vitta Nauss
Cribrostomoides cretaceus Cushman and Goudkoff
Dorothia oxycona (Reuss)
Gaudyrina tailleuri (Tappan)
Gavelinella plummerae (Tappan)
Gyroidinoides bandyi (Trujillo)
Haplophragmoides excavatus Cushman and Waters
Fish debris
Inoceramus prisms
Radiolarians
Age: Late Turonian to Coniacian.

USGS Mesozoic locality Mf6590.—Collected from mudstone exposed in roadcuts along Siskiyou Boulevard in northwest part of Ashland, just north of the Southern Pacific railroad overpass (SW corner of sec. 38, T. 38 S., R. 1 E., Ashland 15-minute quadrangle), Jackson County, Ore. (lat 42°13' N., long 122°43' W.). Lower part of the Ditch Creek Siltstone Member.

Collector.—T.H. Nilsen, 1982.

Benthic foraminifers: *Conorboides stormi* Brotzen
- *Cribrostomoides trifolium* (Egger)
- *Dentalina gracilis* (d'Orbigny)
- *Dorothia oxycona* (Reuss)
- *Gaudryina tailleuri* (Tappan)
- *Hoeglundina supracretacea* (ten Dam)
- *Inoceramus* prisms
- Gastropod fragments
- Pelecypod molds

Planktonic foraminifers: *Dicarinella canaliculata* (Reuss)
- *D. imbricata* (Mornod)
- *Marginotruncana renzi* (Gandolfi)
- *Praeglobotruncana helvetica* (Bolli)
- *P. praehelvetica* (Trujillo)
- *Whiteinella baltica* Douglas and Rankin

Age: Middle Turonian

USGS Mesozoic locality Mf6591.—Collected from mudstone exposed in roadcuts along Siskiyou Boulevard in northwest part of Ashland, north of the Southern Pacific railroad overpass (SW corner of sec. 38, T. 38 S., R. 1 E., Ashland 15-minute quadrangle), Jackson County, Ore. (lat 42°13' N., long 122°43' W.). Middle part of the Ditch Creek Siltstone Member.

Collector.—T.H. Nilsen, 1982.

Benthic foraminifers: *Ammodiscus cretaceus* (Reuss)
- *Dorothia oxycona* (Reuss)
- *Gaudyrina tailleuri* (Tappan)
- *Gavelinella plummerae* (Tappan)
- *Hoeglundina supracretacea* (ten Dam)
- *Lenticulina modesta* (Bandy)
- *L. muensteri* (Roemer)
- Echinoid fragment
- Gastropod fragments
- Ostracode

Planktonic foraminifers: *Dicarinella canaliculata* (Reuss)
- *D. imbricata* (Mornod)
- *Marginotruncana renzi* (Gandolfi)
- *Praeglobotruncana helvetica* (Bolli)
- *P. praehelvetica* (Trujillo)

Age: Middle Turonian

USGS Mesozoic locality Mf6592.—Collected from mudstone in roadcut along the north side of Dark Hollow Road (SW corner of sec. 50, T. 38 S., R. 2 W., Medford 15-minute quadrangle), Jackson County, Ore. (lat 42°15' N., long 122°53' W.). Middle part of the Ditch Creek Siltstone Member.

Collector.—T.H. Nilsen, 1982.

Benthic foraminifers: *Astacolus jarvisi* (Cushman)
- *Cribrostomoides cretaceus* Cushman and Goudkoff
- *Dentalina gracilis* (d'Orbigny)
- *D. legumen* (Reuss)
- *Dorothia ellisorae* (Cushman)
- *Gavelinella plummerae* (Tappan)
- *G. popenoi* (Trujillo)
- *Globorotalites multiseptus* (Brotzen)
- *Haplophragmoides excavatus* Cushman and Waters
- *Hoeglundina supracretacea* (ten Dam)
- *Lenticulina californiensis* Trujillo
- *L. modesta* (Bandy)
- *L. pseudosecans* (Cushman)

Planktonic foraminifers: *Dicarinella imbricata* (Mornod)
- *Marginotruncana renzi* (Gandolfi)
- *Praeglobotruncana gibba* Klaus
- *P. helvetica* (Bolli)
- *P. praehelvetica* (Trujillo)

Age: Middle Turonian

Rocky Gulch Sandstone Member

USGS Mesozoic locality Mf6587.—Collected from shale interbedded with sandstone, exposed in roadcut along northeast side of Interstate Highway 5 (SW¼ sec. 32, T. 37 S., R. 1 W., Medford 15-minute quadrangle), Jackson County, Ore. (lat 42°18' N., long 122°50' W.). Middle part of the Rocky Gulch Sandstone Member.

Collector.—T.H. Nilsen, 1982.

Benthic foraminifers: *Astacolus jarvisi* (Cushman)
- *Bandyella greatvalleyensis* (Trujillo)
- *Cribrostomoides cretaceus* Cushman and Goudkoff
- *Dorothia ellisorae* (Cushman)
- *Gaudyrina tailleuri* (Tappan)
- *Haplophragmoides excavatus* Cushman and Waters
- *Lenticulina muensteri* (Roemer)
- *Lingulogavelinella globosa* (Brotzen)
- *Saccammina complanata* (Franke)
- Echinoid fragments

Planktonic foraminifers: *Dicarinella canaliculata* (Reuss)
- *D. imbricata* (Mornod)
- *Marginotruncana pseudolinneiana* Pessagno
- *Praeglobotruncana gibba* Klaus
- *P. helvetica* (Bolli)
- *Whiteinella baltica* Douglas and Rankin
- *W. brittonensis* (Loeblich and Tappan)

Age: Middle Turonian

Blue Gulch Mudstone Member

USGS Mesozoic localities Mf6335 to Mf6352.—Collected from mudstone of the Blue Gulch Mudstone Member where it crops out between Interstate Highway 5 and the top of Bailey Hill (NE¼ sec. 25, T. 48 N., R. 7 W., Hornbrook 15-minute quadrangle), Siskiyou County, Calif. (lat 41°59' N., long 122°37' W.). The samples were collected in stratigraphic order, with sample Mf6335 from near the base of the section and sample Mf6352 from the top of the section. Lower to upper parts of the Blue Gulch Mudstone Member.

Collector.—M.A. Elliott, 1971.

Mf6335

Benthic foraminifers: *Bathysiphon* spp.
Cribrostomoides cretaceus Cushman and Goudkoff
Haplophragmoides cf. *H. famosus* Takayanagi
Saracenaria triangularis (d'Orbigny)
Silicosigmoilina californica Cushman and Church
Age: Campanian to early Maestrichtian

Mf6336

Planktonic foraminifers: *Globotruncana arca* (Cushman)
G. bulloides Vogler
G. mariei Banner and Blow
G. ventricosa White
Heterohelix rumseyensis Douglas
Age: Middle Campanian to early Maestrichtian

Mf6337

Benthic foraminifers: *Ammobaculites* sp.
Bathysiphon spp.
Cribrostomoides cretaceus Cushman and Goudkoff
Dorothia oxycona (Reuss)
Gaudryina tailleuri (Tappan)
Silicosigmoilina californica Cushman and Church
Spiroplectammina chicoana Lalicker
Textularia sp.
Unidentified arenaceous species
Age: Campanian to early Maestrichtian

Mf6338

Benthic foraminifers: *Ammobaculites* sp.
Ammodiscus sp.
Bathysiphon spp.
Dorothia oxycona (Reuss)
Gaudryina tailleuri (Tappan)
Haplophragmoides cf. *H. famosus* Takayanagi
Silicosigmoilina californica Cushman and Church
Spiroplectammina chicoana Lalicker
Textularia sp.
Trochammina texana Cushman and W~ters
Unidentified arenaceous species
Age: Campanian to Maestrichtian

Mf6339

Barren of microfossils

Mf6340

Benthic foraminifers: *Bathysiphon vitta* Nauss
Cribrostomoides cretaceus Cushman and Goudkoff
??*Quinqueloculina* sp.
Silicosigmoilina californica Cushman and Church
Age: probably Campanian to early Maestrichtian

Mf6341

Benthic foraminifers: *Dorothia oxycona* (Reuss)
Globorotaloides michelinianus (d'Orbigny)
G. spineus (Cushman)
Gyroidinoides bandyi (Trujillo) G. nitidus (Reuss)
Nodosaria spp.
Osangularia cordieriana (d'Orbigny)
Pleurostomella subnodosa Reuss
Pyrulina apiculata (Marie)
Quadrimorphina allomorphinoides (Reuss)
Spiroplectammina chicoana Lalicker
Planktonic foraminifers: *Heterohelix glabrans* (Cushman)
Age: Campanian or early Maestrichtian, probably early Maestrichtian

Mf6342

Benthic foraminifers: *Bathysiphon* spp.
Cribrostomoides cretaceus Cushman and Goudkoff
C. spp
Dorothia bulletta (Carsey)
D. oxycona (Reuss)
Gavelinella sp.
Gaudryina tailleuri (Tappan)
Globorotaloides michelinianus (d'Orbigny)
G. spineus (Cushman)
Lenticulina sp.
Nodosaria sp.
Silicosigmoilina californica Cushman and Church
Spiroloculina cretacea Reuss
Unidentified arenaceous species
Age: Campanian to early Maestrichtian

Mf6343

Barren of microfossils

Mf6344

Benthic foraminifers: *Bathysiphon* spp.
Cribrostomoides cretaceus Cushman and Goudkoff
Silicosigmoilina californica Cushman and Church
Trochammina boehmi Franke
Unidentified arenaceous species
Age: Upper Cretaceous

Mf6345

Benthic foraminifers: *Bathysiphon vitta* Nauss
B. spp.
Cribrostomoides spp.
Dorothia oxycona (Reuss)
Silicosigmoilina californica Cushman and Church
Unidentified arenaceous species
Age: Upper Cretaceous

Mf6346

Planktonic foraminifers: *Globotruncana arca* (Cushman)
G. ventricosa White
Age: Middle Campanian to early Maestrichtian

Mf6347

Benthic foraminifers: *Cribrostomoides* spp.
Bathysiphon spp.
B. vitta Nauss
Dorothia oxycona (Reuss)
Gaudryina tailleuri (Tappan)
Reophax globosus Sliter
Silicosigmoilina californica Cushman and Church
Trochammina sp.
Unidentified arenaceous species
Age: Upper Cretaceous

Mf6348

Benthic foraminifers: *Ammodiscus cretaceus* (Reuss)
Bathysiphon spp.
Dorothia tailleuri (Tappan)
Silicosigmoilina californica Cushman and Church
Spiroplectammina sigmoidina Lalicker
Unidentified arenaceous species
Age: Campanian to early Maestrichtian

Mf6349

Benthic foraminifers: *Ammodiscus cretaceus* (Reuss)
Bathysiphon spp.
Cribrostomoides spp.
Gaudryina tailleuri (Tappan)
Reophax globosus Sliter
Silicosigmoilina californica Cushman and Church
Spiroloculina sp.
Trochammina sp.
T. texana Cushman and Waters
Unidentified arenaceous species
Age: Campanian to early Maestrichtian

Mf6350

No bulk material submitted

Mf6351

Barren of microfossils

Mf6352

Barren of microfossils

USGS Mesozoic locality Mf6399.—Collected from mudstone exposed along south bank of Blue Gulch, northwest side of Black Mountain (SE¼NE¼ sec. 33, T. 47 N., R. 6 W., Hornbrook 15-minute quadrangle), Siskiyou County, Calif. (lat 41°53' N., long 122°32' W.). Lower middle part of the Blue Gulch Mudstone Member, above the Rancheria Gulch Sandstone Beds.
Collector.—T.H. Nilsen, 1982.

Benthic foraminifers: *Astacolus jarvisi* (Cushman)
Bathysiphon vitta Nauss
Cribrostomoides cretaceus Cushman and Goudkoff
Dorothia bulletta (Carsey)
Gaudryina laevigata Franke
G. tailleuri (Tappan)
Gavelinella stephensoni (Cushman)
Hoeglundina supracretacea (ten Dam)
Lenticulina davisi (Bandy)
L. muensteri (Roemer)
L. spissocostata (Cushman)
Marginulina bullata Reuss
Pseudonodorsaria manifesta (Reuss)
Reophax globosus Sliter
Saracenaria navicula (d'Orbigny)
Silicosigmoilina californica Cushman and Church
Spiroplectammina chicoana Lalicker
Stilostomella impensia (Cushman)
Planktonic foraminifers: *Globotruncana arca* (Cushman)
G. bulloides Vogler
G. ventricosa White
Heterohelix rumseyensis Douglas
Age: Middle Campanian to early Maestrichtian

USGS Mesozoic locality Mf6401.—Collected from mudstone exposed along railroad cut west of Carter Creek (SW¼SE¼ sec. 16, T. 40 S., R. 2 E., Ashland 15-minute quadrangle), Jackson County, Ore. (lat 42°05' N., long 122°35' W.). Lower part of the Blue Gulch Mudstone Member.
Collector.—T.H. Nilsen, 1981.

Benthic foraminifers: *Astacolus* cf. *A. umbonatus* Loetterle
A. cf. *A. planiusculus* (Reuss)
Cribrostomoides cretaceus Cushman and Goudkoff
Dorothia ellisorae (Cushman)
D. oxycona (Reuss)
Gavelinella popenoi (Trujillo)
Globorotalites subconica (Morrow)
Gyroidinoides bandyi (Trujillo)
Trochammina texana Cushman and Waters
T. trifolia Egger
Planktonic foraminifers: *Archaeoglobigerina cretacea* (d'Orbigny)
Dicarinella cachensis (Douglas)
D. cf. *D. imbricata* (Mornod)
Marginotruncana marginata (Reuss)
M. pseudolinneiana Pessagno
Whiteinella archaeocretacea Pessagno
W. brittonensis (Loeblich and Tappan)
Age: Late Turonian to early Coniacian

USGS Mesozoic locality Mf6402.—Collected from mudstone exposed along railroad cut and road junction west of Carter Creek (SW¼NE¼ sec. 16, T. 40 S., R. 2 E., Ashland 15-minute quadrangle), Jackson County, Ore. (lat 42°06' N., long 122°35' W.). Lower part of the Blue Gulch Mudstone Member.
Collector.—T.H. Nilsen, 1981.

Benthic foraminifers: *Ammobaculites alexanderi* Cushman
Bathysiphon vitta Nauss
B. spp.
Cribrostomoides sp.

Dorothia oxycona (Reuss)
Gaudryina tailleuri (Tappan)
Globorotalites michelinianus (d'Orbigny)
Gyroidinoides bandyi Trujillo
G. goudkoffi (Trujillo)
Lenticulina sp.
Silicosigmoilina californica Cushman and Church
Trochammina boehmi Franke
Unidentified arenaceous species
Age: Campanian to early Maestrichtian, probably Campanian

USGS Mesozoic locality Mf6403.—Collected from mudstone exposed along railroad cut along east fork of Cottonwood Creek (SE¼NE¼ sec. 12, T. 41 S., R. 1 E., Ashland 15-minute quadrangle), Jackson County, Ore. (lat 42°01' N., long 122°39' W.). Lower part of the Blue Gulch Mudstone Member.
Collector.—T.H. Nilsen, 1981.
Benthic foraminifers: *Ammobaculites* sp.
Ammodiscus cretaceus (Reuss)
Bathysiphon vitta Nauss
B. spp.
Cyclammina sp.
Gaudryina laevigata Franke
G. tailleuri (Tappan)
Reophax globosus Sliter
Silicosigmoilina californica Cushman and Church
Spiroplectammina chicoana Lalicker
Trochammina boehmi Franke
Age: Campanian to early Maestrichtian

USGS Mesozoic locality Mf6410.—Collected from mudstone exposed along Dead Indian Road east of Ashland, Ore. (sec. 12, T. 39 S., R. 1 E., Ashland 15-minute quadrangle), Jackson County, Ore. (lat 42°11' N., long 122°39' W.). Middle part of the Blue Gulch Mudstone Member.
Collector.—T.H. Nilsen, 1981.
Benthic foraminifers: *Bathysiphon vitta* Nauss
Cribrostomoides spp.
Cyclammina sp.
Dorothia bulletta (Carsey)
D. oxycona (Reuss)
Gaudryina laevigata (Frank)
G. tailleuri (Tappan)
Globorotalites spineus (Cushman)
Gyroidinoides bandyi (Trujillo)
Nonionella spp.
Lenticulina ovalis (Reuss)
Reophax globosus Sliter
Silicosigmoilina californica Cushman and Church
Spiroplectammina chicoana Lalicker
Trochammina boehmi Franke
Age: Campanian to early Maestrichtian

USGS Mesozoic locality Mf6411.—Collected from mudstone exposed along Cottonwood Creek, 0.8 km north of Soda Springs, Calif. (SE¼NW¼ sec. 26, T. 48 N., R. 7 W., Hornbrook 15-minute quadrangle), Siskiyou County, Calif. (lat 41°59' N., long 122°38' W.). Lower part of the Blue Gulch Mudstone Member.
Collector.—T.H. Nilsen, 1981.
Benthic foraminifers: *Ammodiscus cretaceus* (Reuss)
Bathysiphon vitta Nauss
B. spp.
Dorothia oxycona (Reuss)
Gaudryina tailleuri (Tappan)
Silicosigmoilina californica Cushman and Church
Trochammina texana Cushman and Waters
Age: Campanian to early Maestrichtian

USGS Mesozoic locality Mf6579.—Collected from mudstone exposed in roadcut along southeast side of Dead Indian Road, about 5 km east of downtown Ashland (SW corner of sec. 12, T. 39 S., R. 1 E., Ashland 15-minute quadrangle), Jackson County, Ore. (lat 42°11' N., long 122°39' W.). Middle part of the Blue Gulch Mudstone Member.
Collector.—T.H. Nilsen, 1982.
Benthic foraminifers: *Bathysiphon vitta* Nauss
Cribrostomoides cretaceus Cushman and Goudkoff
Haplophragmoides excavatus Cushman and Waters
Reophax globosus Sliter
Age: Coniacian to Maestrichtian

USGS Mesozoic locality Mf6582.—Collected from mudstone exposed on lower part of ridge northeast of Blue Gulch (SW¼NW¼ sec. 34, T. 47 N., R. 6 W., Hornbrook 15-minute quadrangle), Siskiyou County, Calif. (lat 41°52' N., long 122°32' W.). Middle part of the Blue Gulch Mudstone Member, about 166 m stratigraphically below the base of the Hilt Bed.
Collector.—T.H. Nilsen, 1982.
Benthic foraminifers: *Saracenaria* cf. *S. navicula* (d'Orbigny)
Unidentified arenaceous species
Inoceramus prisms
Age: Late Cretaceous

USGS Mesozoic locality Mf6583.—Collected from mudstone exposed on middle part of ridge northeast of Blue Gulch (SW¼NW¼ sec. 34, T. 47 N., R. 6 W., Hornbrook 15-minute quadrangle), Siskiyou County, Calif. (lat 41°53' N., long 122°32' W.). Middle part of the Blue Gulch Mudstone Member, about 142 m stratigraphically below the base of the Hilt Bed.
Collector.—T.H. Nilsen, 1982.
Benthic foraminifers: *Ammodiscus cretaceus* (Reuss)
Bathysiphon vitta Nauss
Cribrostomoides cretaceus Cushman and Goudkoff
Dorothia bulletta (Carsey)
D. pupa (Reuss)
Gaudryina tailleuri (Tappan)
Gyroidinoides goudkoffi (Trujillo)
Rzehakina epigona (Rzehak)
Silicosigmoilina californica Cushman and Church
Radiolarians
Age: Campanian

USGS Mesozoic locality Mf6584.—Collected from mudstone exposed on upper part of ridge northeast of Blue Gulch (SW¼NW¼ sec. 34, T. 47 N., R. 6 W., Hornbrook 15-minute quadrangle), Siskiyou County, Calif. (lat 41°53' N., long 122°32' W.). Middle part of the Blue Gulch Mudstone Member, about 38 m stratigraphically below the base of the Hilt Bed.
Collector.—T.H. Nilsen, 1982.
Benthic foraminifers: *Ammodiscus cretaceus* (Reuss)
Bathysiphon vitta Nauss
Cribrostomoides cretaceus Cushman and Goudkoff
Gaudryina bentonensis (Carman)
G. laevigata Franke
G. tailleuri (Tappan)
Gyroidinoides trujillo Sliter
Haplophragmoides excavatus Cushman and Waters
H. famosus Takayanagi
Hyperammina erugata Sliter
Lenticulina ovalis (Reuss)
Saccammina complanata (Franke)
Saracenaria triangularis (d'Orbigny)
Silicosigmoilina californica Cushman and Church
Stilostomella impensia (Cushman)
Trochammina texana Cushman and Waters
Planktonic foraminifer: *Heterohelix rumseyensis* Douglas
Inoceramus prisms
Age: Late Santonian to late Campanian

USGS Mesozoic locality Mf6585.—Collected from mudstone exposed on top of ridge crest northeast of Blue Gulch (NW¼NE¼ sec. 34, T. 47 N., R. 6 W., Hornbrook 15-minute quadrangle), Siskiyou County, Calif. (lat 41°54' N., long 122°31' W.). Upper part of the Blue Gulch Mudstone Member, about 340 m stratigraphically above the base of the Hilt Bed.
Collector.—T.H. Nilsen, 1982.
Benthic foraminifers: *Bathysiphon vitta* Nauss
Cribrostomoides cretaceus Cushman and Goudkoff
Haplophragmoides famosus Takayanagi
Silicosigmoilina californica Cushman and Church
Age: Campanian to early Maestrichtian

USGS Mesozoic locality Mf6586.—Collected from mudstone exposed in east side of roadcut near reservoir located about 1.5 km southwest of abandoned site of Klamathon (NW¼SE¼ sec. 27, T. 47 N., R. 6 W., Hornbrook 15-minute quadrangle), Siskiyou County, Calif. (lat 41°53' N., long 122°31' W.). Uppermost part of the Blue Gulch Mudstone Member, about 2 m stratigraphically below upper contact with Tertiary volcanic rocks.
Collector.—T.H. Nilsen, 1982.
Benthic foraminifers: *Bathysiphon vitta* Nauss
Cribrostomoides cretaceus Cushman and Goudkoff
Dorothia bulletta (Carsey)
Haplophragmoides excavatus Cushman and Waters
H. famosus Takayanagi
Silicosigmoilina californica Cushman and Church
Age: Santonian to Maestrichtian

USGS Mesozoic locality Mf6588.—Collected from mudstone exposed in lower part of ridge east of Hornbrook (SW¼SE¼ sec. 21, T. 47 N., R. 6 W., Hornbrook 15-minute quadrangle), Siskiyou County, Calif. (lat 41°54' N., long 122°32' W.). Middle part of the Blue Gulch Mudstone Member, about 60 m stratigraphically above the base of the Hilt Bed.
Collector.—T.H. Nilsen, 1982.
Benthic foraminifers: *Bathysiphon varans* Sliter
B. vitta Nauss
Cribrostomoides cretaceus Cushman and Goudkoff
Dorothia pupa (Reuss)
Gaudryina tailleuri (Tappan)
Haplophragmoides excavatus Cushman and Waters
H. famosus Takayanagi
Silicosigmoilina californica Cushman and Church
Trochammina texana Cushman and Waters
Age: Campanian

USGS Mesozoic locality Mf6589.—Collected from mudstone exposed in middle part of ridge east of Hornbrook (SW¼SE¼ sec. 21, T. 47 N., R. 6 W., Hornbrook 15-minute quadrangle), Siskiyou County, Calif. (lat 41°54' N., long 122°32' W.). Middle part of the Blue Gulch Mudstone Member, about 126 m stratigraphically above the Hilt Bed.
Collector.—T.H. Nilsen, 1982.
Benthic foraminifers: *Bathysiphon varans* Sliter
B. vitta Nauss
Cribrostomoides cretaceus Cushman and Goudkoff
Dorothia bulletta (Carsey)
Gaudryina bentonensis (Carman)
G. laevigata Franke
Haplophragmoides excavatus Cushman and Waters
H. famosus Takayanagi
Saccammina complanata (Franke)
Silicosigmoilina californica Cushman and Church
Trochammina texana Cushman and Waters
Radiolarians
Age: Campanian to early Maestrichtian

USGS Mesozoic locality Mf6593.—Collected from shale in roadcut on east side of Dark Hollow Road, about 0.5 km south of South Stage Road (SE corner of sec. 50, T. 38 S., R. 2 W., Medford 15-minute quadrangle), Jackson County, Ore. (lat 42°17' N., long 122°53' W.). Upper part of the Blue Gulch Mudstone Member, above the Hilt Bed.
Collector.—T.H. Nilsen, 1982.
Benthic foraminifers: *Cribrostomoides cretaceus* Cushman and Goudkoff
Age: Indeterminate