Graywacke of Buchia Ridge and Correlative Lower Cretaceous Rocks in the Goodnews Bay and Bethel Quadrangles, Southwestern Alaska

CONTRIBUTIONS TO STRATIGRAPHY

GEOLOGICAL SURVEY BULLETIN 1529-C

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By J. M. HOARE *and* W. L. COONRAD

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GRAYWACKE OF BUCHIA RIDGE AND CORRELATIVE LOWER CRETACEOUS ROCKS IN THE GOODNEWS AND BETHEL QUADRANGLES, SOUTHWESTERN ALASKA

By J. M. HOARE and W. L. COONRAD

ABSTRACT

Lithologically distinct coeval strata of Lower Cretaceous age occur in four northeast-trending belts in the Goodnews Bay and Bethel quadrangles, southwestern Alaska. The belts are, from southeast to northwest, the Buchia Ridge belt, Ungalikthluk belt, Mount Oratia belt, and Eek Mountains belt. The belts are largely bounded by thrust faults. Rocks in the Mount Oratia and Eek Mountains belts are stongly deformed and infolded with older rocks, whereas the Ungalikthluk and Buchia Ridge belts are mildly deformed and (except for intrusive rocks of Tertiary age) include only rocks of Early Cretaceous age.

The Buchia Ridge belt is composed mainly of graywacke and related rocks defined as the graywacke of Buchia Ridge. This formation is exposed in a wedge-shaped area of about 350 km^2 in the Goodnews Bay A–2, A–3, B–2, and B–3 quadrangles. The beds of this unit are deformed into a southeast-dipping homocline in a thrust sheet that is underlain and overlain by highly deformed older volcanic and sedimentary strata of Jurassic and Early Cretaceous(?) age. The graywacke of Buchia Ridge is estimated to be about 5,000 m thick. The lower part of the formation is thick-bedded graywacke, siltstone, and conglomerate; the upper part shale, shaly siltstone, and thin-bedded graywacke and calcarenite. The lower part contains abundant *Buchia* of Valanginian age; the upper part sparse *Inoceramus* and *Belemnites*of Hauterivian age. If the section is not repeated by faults or folds, it is the thickest, least deformed section of Lower Cretaceous sedimentary rocks known in southwestern Alaska.

The Ungalikthluk belt consists of isolated synclinal outcrop areas of limestone, greenish limy grit, and conglomerate overlain by noncalcareous graywacke and grit. Although the total outcrop area is no more that 4 km^2, these erosional remnants form a distinct belt northwest of the Buchia Ridge belt.

Locally, *Buchia crassicolis* is found in the limestone, indicating that the Ungalikthluk sequence is coeval with the graywacke of Buchia Ridge.

The Mount Oratia belt, up to 25 km wide and extending more than 120 km northeast from the central part of the Goodnews Bay B–5 quadrangle, is bounded on the southeast and northwest sides by southeast-dipping reverse faults. Rocks within the belt are strongly folded and cut by many faults.

Stratigraphy in the Mount Oratia belt is not definitely known because of structural complexity, but in general consists of an upper section of thickbedded graywacke, shale, and other sedimentary rocks and a lower section of multicolored tuff and other volcanic rocks. Locally, there are small areas of Permian and Triassic rocks that are probably faulted in. The occurrence of *Buchia crassicolis* and radiolarians identified as forms of Early Cretaceous (Valanginian) age within the Mount Oratia belt again indicates contemporaneity with rocks in the other belts.

The Eek Mountains belt, 2–25 km in width, extends northeastward about 75 km from the Goodnews Bay C–6 quadrangle. The belt encompasses a large anticline consisting of older rocks flanked by Cretaceous rocks. The rocks in the belt are strongly folded and commonly overturned northwestward.

The Lower Cretaceous (Valanginian) section in the Eek Mountains belt consists of graywacke, shale, argillite, and conglomerate at least 1,000 m thick. The tuff and other volcanogenic rocks of the Mount Oratia belt have not been identified within the Eek Mountains sequence.

Buchia crassicolis has been found in thin calcareous beds and in pebbly sandstone at several places within the Eek Mountains belt, thus substantiating an age coeval with rocks in the other three belts.

INTRODUCTION

New fossil collections and a better understanding of the geology obtained during a recent investigation has increased our knowledge of the lithologic character and distribution of Lower Cretaceous strata in the Goodnews Bay and Bethel quadrangles, Alaska (fig. 1). We now know that Lower Cretaceous strata include a thick section of fine- to coarse-grained clastic rocks, a thick section of tuff, tuffaceous sedimentary rocks, volcanic breccia, and other volcanic rocks, and a thin section of limy grit and limestone. Many of these rocks resemble older Paleozoic and Mesozoic rocks and were previously mapped in the Gemuk Group of Carboniferous to Cretaceous age; others were mapped in the Kuskokwim Group of Early and Late Cretaceous age (Hoare and Coonrad, 1959, 1961). With the discovery of many new fossil localities, it is now possible to recognize four northeast- trending belts that contain lithologically distinct coeval strata of Early Cretaceous age. For descriptive purposes, these belts, from southeast to northwest, are called the Buchia Ridge, Ungalikthluk, Mount Oratia, and Eek Mountains belts (fig. 1).

The four belts are apparently in thrust plates separated by reverse faults, most of which dip southeastward. The distance between the belts has been foreshortened an unknown amount by northwest-directed folding and thrusting.

The boundaries of the belts are drawn to enclose known Lower Cretaceous fossil localities, shown on the geologic map of the Goodnews and Hagemeister Island quadrangles region (Hoare and Coonrad, 1978, sheet 1) and rocks that resemble those in which the fossils occur. Most boundaries are approximate but are locally sharply de-

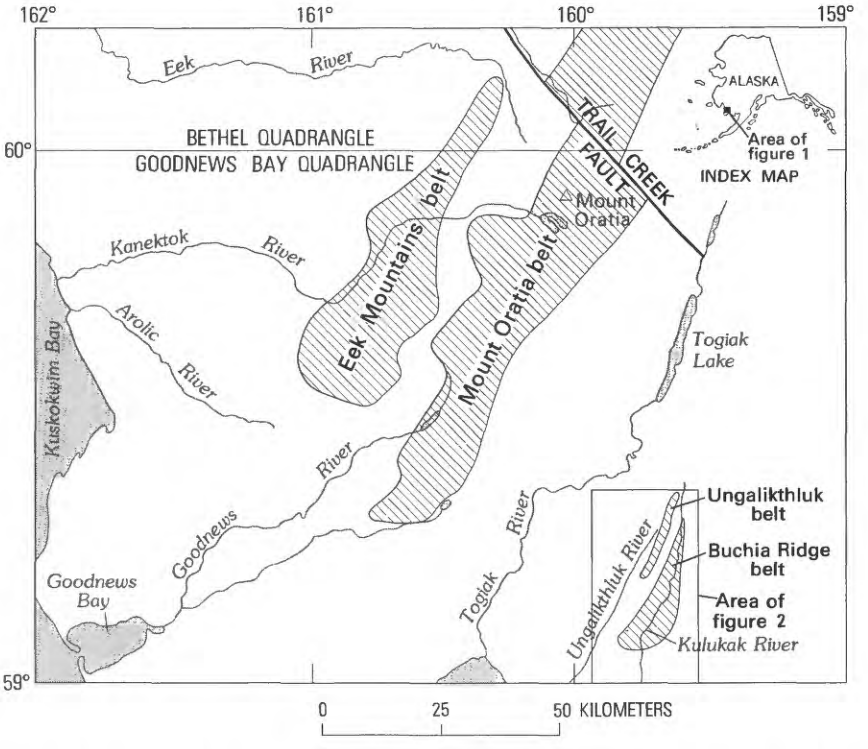


FIGURE 1.—Location of four belts (lined areas) of correlative Lower Cretaceous rocks in the Goodnews Bay and Bethel quadrangles, Alaska.

fined by faults. In the Eek Mountains and Mount Oratia belts, the rocks are strongly deformed, and the Lower Cretaceous rocks are locally faulted and folded in with older Paleozoic and Mesozoic rocks. In the Ungalikthluk and Buchia Ridge belts, the rocks are only mildly deformed and, except for a few Tertiary intrusive rocks, all of them are Early Cretaceous age. Other rocks of possible Early Cretaceous age lie east and west of the upper Togiak River in the northeast corner of the Goodnews Bay quadrangle.

BUCHIA RIDGE BELT

The Buchia Ridge belt consists of a thick section of fine-, medium-, and coarse-grained marine clastic sedimentary rocks. These rocks form Buchia Ridge, a prominent isolated ridge between the valleys of the Ungalikthluk and Kulukak Rivers in the Goodnews Bay A–2 and A–3 quadrangles and underlie the Kulukak River valley north and east

of the Buchia Ridge (fig. 2). The rocks are deformed into a southeast-dipping homocline, and, if not repeated by concealed faults, they con-

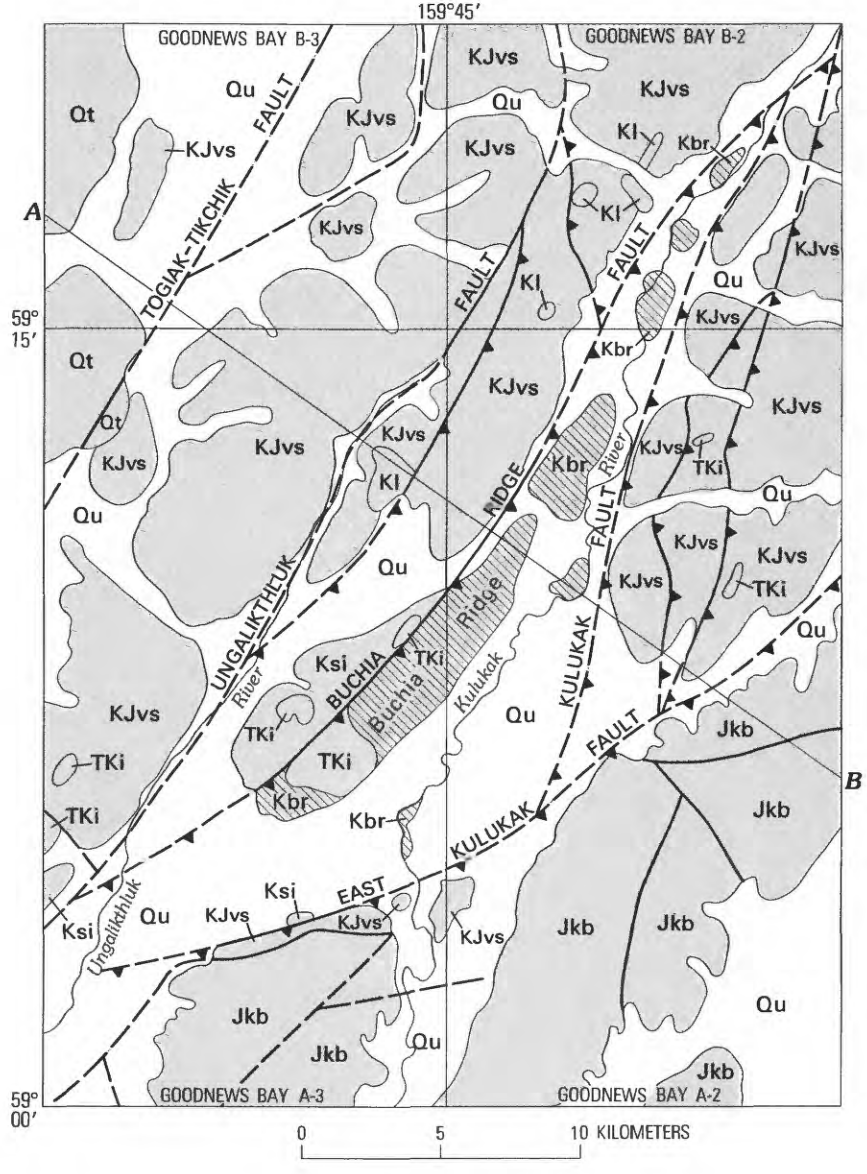
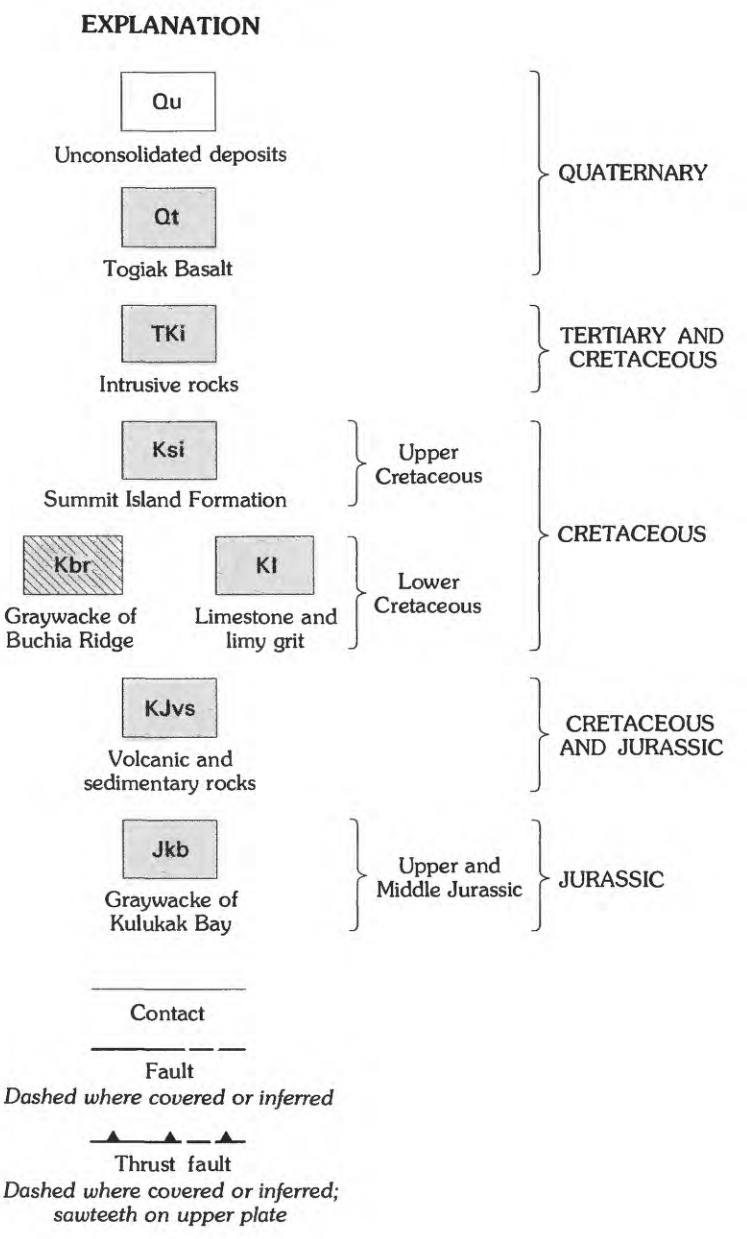


FIGURE 2.—Geologic map of parts of Goodnews Bay A–2, A–3, B–2, and B–3 quadrangles showing location of cross section *A–B* (see fig. 4).

stitute the thickest section of Lower Cretaceous sedimentary rocks known in southwestern Alaska. These rocks are here called the graywacke of Buchia Ridge.



GRAYWACKE OF BUCHIA RIDGE

The lower part of the graywacke of Buchia Ridge, at least 2,400 m thick, is mostly thick-bedded sandstone, siltstone, and conglomerate. These relatively resistant rocks form Buchia Ridge and small rocky hills in the upper valley of the Kulukak River. A composite section for the lower part of the formation was measured on Buchia Ridge and in the hills north of the ridge. The lower part of the section was measured in a steep gully on the northwest side of Buchia Ridge in sec. 4, T. 12 S., R. 62 W., Goodnews Bay A–2 quadrangle. The upper part of the section, which is offset approximately along strike about 5 km to the northeast, is in the small rocky hills at the northeast end of Buchia Ridge near the east side of the Kulukak River valley (secs. 34, 27, and 26, T. 11 S., R. 62 W., Goodnews Bay A–2 quadrangle) (fig. 3).

The upper part of the formation, about 2,500 m thick, is mostly shale and thin-bedded sandstone. These relatively nonresistant rocks underlie the Kulukak River valley east of Buchia Ridge and are very poorly exposed. Representative outcrops occur in cutbanks along the Kulukak River (secs. 29, 31, and 32, T.12 S., R. 62 W., Goodnews A–2 and A–3 quadrangles), and in low hills near the river (sec. 2, T. 12 S., R. 62 W., Goodnews Bay A–2 quadrangle) (fig. 3). Probably no more than a total of 300–400 m of strata is exposed in these two areas, and no section has been measured in the upper part of the formation.

The graywacke of Buchia Ridge is apparently restricted to a wedge-shaped area of about 350 km^2 truncated on the northwest by the Buchia Ridge fault, on the east by the Kulukak fault, and to the south by the East Kulukak fault (fig. 2). The faults dip southeastward and are probably thrust faults (fig. 4). In most areas, these faults juxtapose the graywacke of Buchia Ridge with older volcanic and fine-grained volcanogenic sedimentary rocks of Jurassic and probable Early Cretaceous age, but on the west side of Buchia Ridge toward its southern end, the Buchia Ridge fault juxtaposes the formation with a younger section of soft black shale that is probably in the Summit Island Formation of Late Cretaceous age.

The graywacke of Buchia Ridge strikes N. 45 E. and dips 20–80 SE. The trend of the Buchia Ridge fault parallels the trend of the formation, but the Kulukak fault trends N. 10–15 E., cutting obliquely across the unit. The two faults converge northward, apparently joining the head of the Kulukak River valley (fig. 2). Near the Kulukak fault, some of the fine-grained rocks in the graywacke of Buchia Ridge are highly contorted and sheared, but elsewhere the structure of the formation is homoclinal. If the formation is not repeated by concealed faults or folds, it is about 5,000 m thick. This is the thickest, least de-

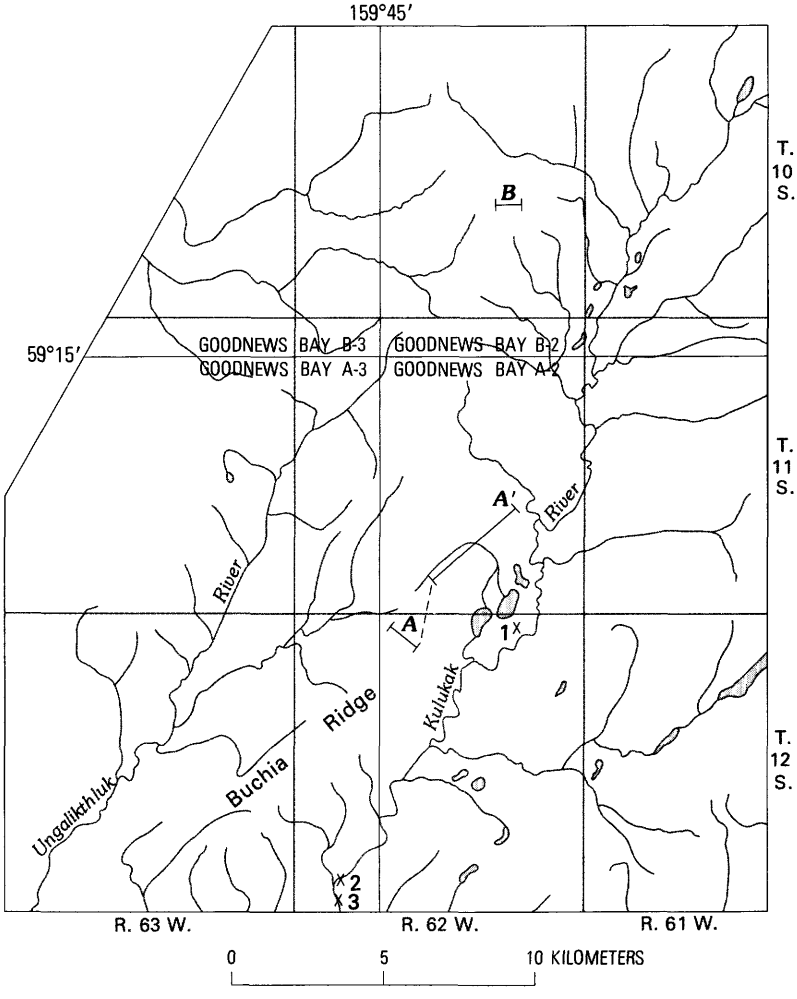


FIGURE 3.—Parts of Goodnews Bay A–2, A–3, B–2, and B–3 quadrangles showing location of composite measured section of lower part of graywacke of Buchia Ridge (*A*, *A'*), representative outcrops of upper part of graywacke of Buchia Ridge (1, 2, 3), and measured section of Ungalikthluk belt of correlative rocks (*B*). See figure 5 for measured sections.

formed section of Lower Cretaceous sedimentary rocks known in southwestern Alaska.

At the measured section on the northwest side of Buchia Ridge (fig. 3), the base and probably 100–200 m of the lowest beds of the formation are covered, but at least 1,000 m of the overlying section is continuously exposed in a steep gully (fig. 5). The section becomes

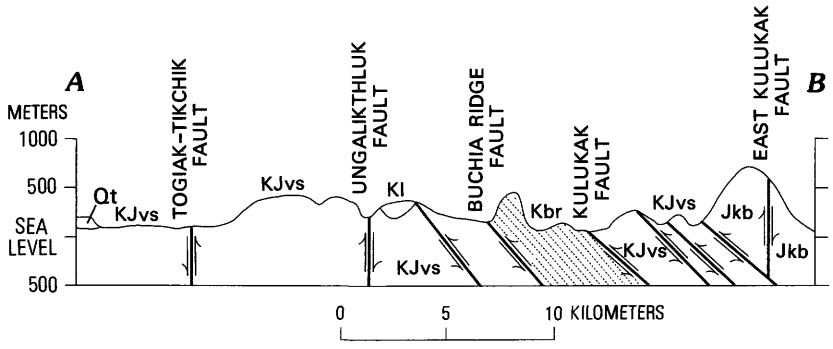


FIGURE 4.—Cross section showing structural relations of graywacke of Buchia Ridge and correlative rocks in Ungalikthluk belt. See figure 2 for location of section and explanation of units. Arrows on faults indicate direction of relative movement. Vertical exaggeration x5.

coarser grained and more conglomeratic upward. The lower part of the section consists of well-bedded fine- and medium-grained sandstone with siltstone interbeds and a few thin layers of pebble conglomerate and pebbly sandstone. Beds range in thickness from 0.1 m to 3–4 m. Siltstone beds are generally massive, characterized by hackly fracture, and weather spheroidally. Conglomerate beds become thicker and more numerous upward and contain large clasts. Several coquinas of *Buchia crassicolis* shells as thick as 1.5 m are interbedded with conglomerate and conglomeratic sandstone 100–200 m below the crest of Buchia Ridge. The upper part of the composite section (fig. 5) consists of about 1,400 m of mostly pebble-cobble conglomerate, and pebbly sandstone. These rocks form many small rocky hills extending northeast from the northeast end of Buchia Ridge. As the hills are near the Kulukak fault (figs. 2,4), beds in this part of the section may be repeated by faulting.

Conglomerate clasts are well-rounded pebbles and cobbles as large as 10 cm of hard graywacke and siltstone, cherty tuff, and less abundant porphyritic volcanic rocks. The sedimentary clasts resemble, and apparently derive from, the graywacke of Kulukak Bay of Jurassic age, widely exposed to the south and southeast. The tuff and fine-grained volcanic clasts probably derive from Jurassic and probable Lower Cretaceous strata that constitute most of the mountains to the east, west, and north. Sandstone in the graywacke of Buchia Ridge is hard, gray and brown weathering—a typical graywacke. It is a poorly sorted mixture of angular to well-rounded grains, chiefly lithic fragments, with lesser amounts of quartz and feldspar. The cementing material is "argillite "and calcite. Reaction between the cement and the mineral and lithic grains has blurred the outline of many of the grains.

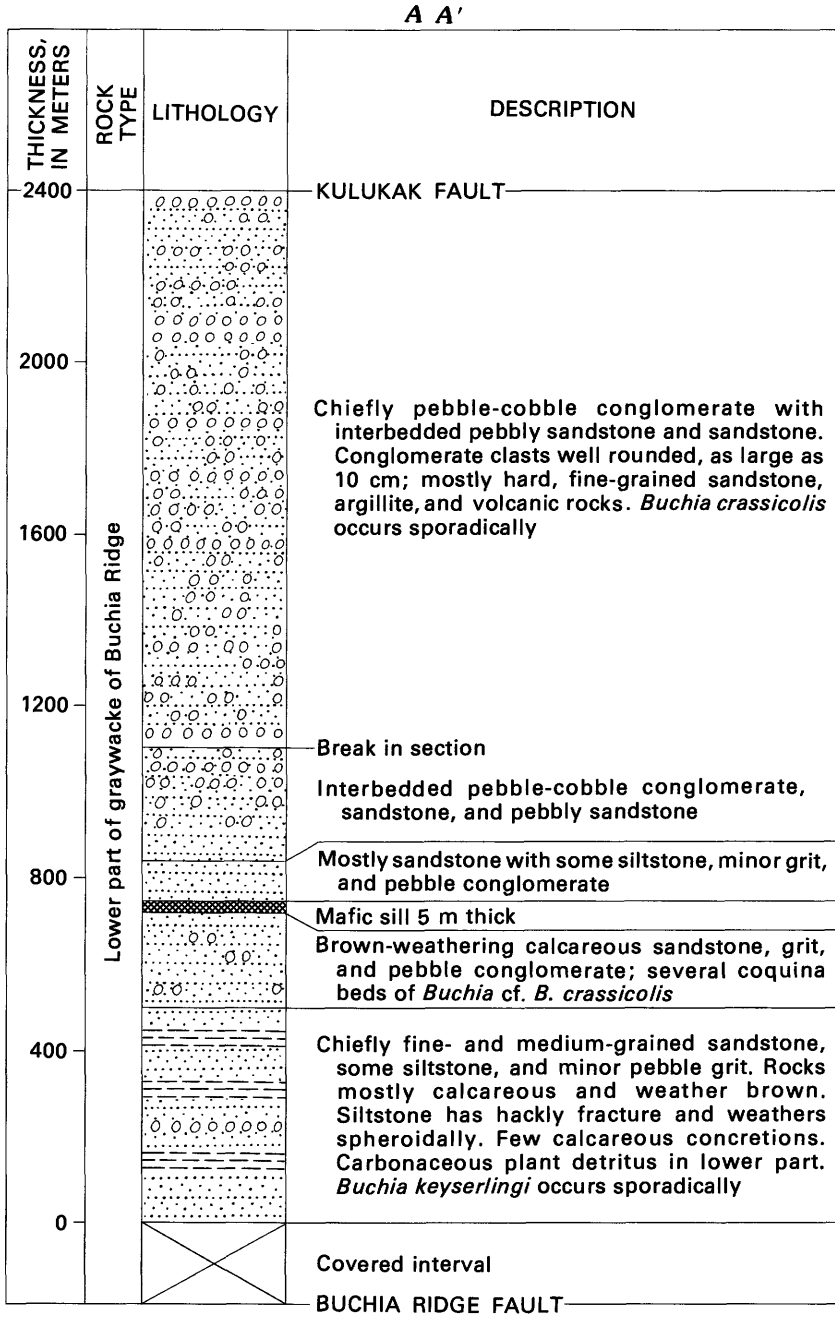
The upper, dominantly fine-grained part of the graywacke of Buchia Ridge consists of calcareous black shale, thin-bedded calcareous siltstone, sandstone, calcarenite, and minor gritstone. These rocks crop out in a few low cutbanks along the Kulukak River and in low hills in the Kulukak River valley east of Buchia Ridge (figs. 2, 3). The valley in this area is much wider than elsewhere, presumably because it is underlain by the less resistant thin-bedded and shaly rocks that constitute the upper part of the formation. The rocks dip 40–70 SE. wherever exposed. This dip and the width of the valley suggest a minimum thickness of 2,500 m. The east side of the valley is defined by a southeast-dipping fault (figs. 2, 4), however, and it would not be surprising to find that the shaly rocks are repeated by faulting.

AGE

The graywcke of Buchia Ridge is of Early Cretaceous age. The lower coarser-grained strata underlying Buchia Ridge contain abundant *Buchia* of Valanginian age; the upper fine-grained part has yielded sparse *Inoceramus*, thick-bodied *Belemnites*, and one ammonite of Hauterivian age (D. L. Jones, written commun., 1975, and table 1). These are the only strata of Hauterivian age yet recognized in this part of southwestern Alaska, but strata of Valanginian age, as indicated by the occurrence of *Buchis crassicolis*, are fairly widespread in the country northwest and north of Buchia Ridge. Most of these correlative rocks occur in three northeast-trending belts that are described below.

UNGALIKTHLUK BELT

The Ungalikthluk belt (fig. 1) consists of limestone, greenish limy grit, and conglomerate overlain by noncalcareous graywacke and grit that crop out at several isolated places on the ridge 3–5 km northwest of Buchia Ridge and the upper valley of the Kulukak River (figs. 1, 2). The total area underlain by these rocks is no more than 2–4 km^2. The structure of the rocks is synclinal. The isolated outcrops are apparently erosional remnants of a northeast-trending belt of rocks. At two localities (sec. 19, R. 62 W., T. 11 S., Goodnews Bay A–3 quadrangle; sec. 2, R. 62 W., T. 11 S., Goodnews Bay B–2 quadrangle), the limy grit appears to be in depositional contact with highly deformed tuff and volcanogenic sedimentary rocks of Jurassic and probable Early Cretaceous age. At a third locality (sec. 23, R. 62 W., T. 10 S., Goodnews Bay B–2 quadrangle), the contact is a steep southeast-dipping reverse fault.


A A'
THICKNESS, IN METERS
ROCK TYPE
LITHOLOGY
DESCRIPTION
2400
2000
1600
1200
800
400
0
Lower part of graywacke of Buchia Ridge
KULUKAK FAULT
Chiefly pebble-cobble conglomerate with interbedded pebbly sandstone and sandstone. Conglomerate clasts well rounded, as large as 10 cm; mostly hard, fine-grained sandstone, argillite, and volcanic rocks. Buchia crassicolis occurs sporadically
Break in section
Interbedded pebble-cobble conglomerate, sandstone, and pebbly sandstone
Mostly sandstone with some siltstone, minor grit, and pebble conglomerate
Mafic sill 5 m thick
Brown-weathering calcareous sandstone, grit, and pebble conglomerate; several coquina beds of Buchia cf. B. crassicolis
Chiefly fine- and medium-grained sandstone, some siltstone, and minor pebble grit. Rocks mostly calcareous and weather brown. Siltstone has hackly fracture and weathers spheroidally. Few calcareous concretions. Carbonaceous plant detritus in lower part. Buchia keyserlingi occurs sporadically
Covered interval
BUCHIA RIDGE FAULT

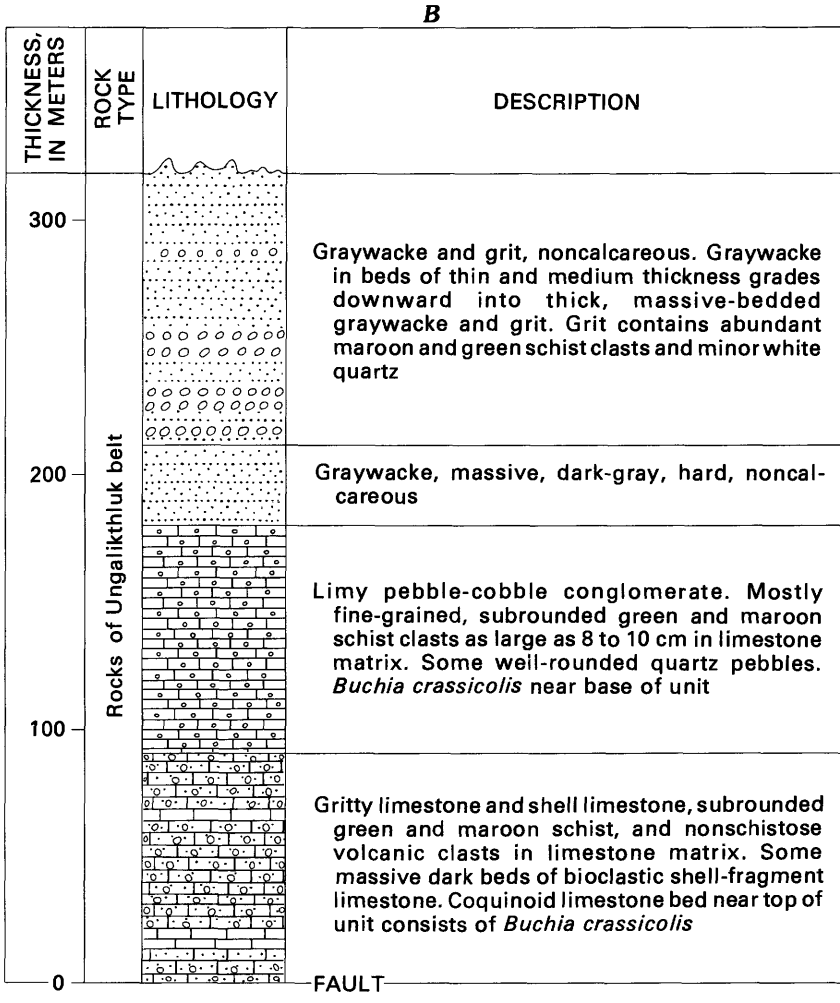


FIGURE 5.—Composite measured section of lower part of graywacke of Buchia Ridge (*A*, *A'*) and representative section of correlative rocks of Ungalikthluk belt (*B*). Locations of sections in figure 3.

The bioclastic limestone is mostly microscopic shell fragments. *Buchia crassicolis* occurs in some limestone beds, and it seems likely that the bioclastic limestone is made up largely of *Buchia* shell fragments. The limy grit consists of subrounded green and maroon lithic fragments and a few well- rounded white quartz pebbles. The lithic

TABLE 1.—*Fossils from the graywacke of Buchia Ridge and correlative rocks in the Goodnews Bay and Bethel quadrangles, Alaska*

[Radiolaria identified by E. A. Pessagno, Jr.; other fossils identified by D. L. Jones and R. W. Imlay]

	Collection number and location																																						
	Graywacke of Buchia Ridge										Ungalikthluk belt			Mount Oratia belt																				Eek Mountains belt					
	M2690	M6290	M6294	M6298	M6301	M6302	M6296	M6299	M6300	M6303	M6295	74ACd29	74AHr41	21473	21474	21475	BA3–1716	BA3–1721	BA3–2446	GD3–2433	50AHr542	GC4–1325	GC4–1121	GC4–2086	M6639	M6643	M6641	M6642	M6647	M6640	M6646	M6645	M6634	M6648	M6649	M6650	M6644	53ACd1049	50AHr708
Buchia crassicolis								X	X	X				X			X											X		X				X			X	X	X
Buchia cf. *B. crassicolis*				X							X				X	X		X	X	X	X										X	X				X			
Buchia crassicolis solida				X		X																													X				
Buchia cf. *B. pacifica*												X	X																										
Buchia keyserlingi							X																								X								
Buchia sublaevis					X	X																						X		X							X		
Buchia fragments																													X										
Inoceramus sp.	X	X	X																																				
Simhirskites sp.	X																																						
Belemnites sp.		X	X																																				
Pseudoencurtis n. sp.																						X	X	X															
Parvicingula n. sp. aff. *P. rothwelli*																						X	X	X															
Pseudodictromitria carpatica																							X	X															
Worm tubes																													X										
Bivalves indet.																									X	X	X					X							

fragments are fine- grained tuff and volcanogenic sedimentary rocks metamorphosed to phyllite and low-grade quartz-chlorite-sericite schist. The metamorphic clasts, which tend to be tabular in shape, are as large as 10 cm accross, but most are much smaller. They apparently derive from nearby strata that were tectonically metamorphosed by movement on the Ungalikthluk fault 1–3 km to the northwest. Because the limestone matrix does not have a metamorphic fabric, the clasts came from rock that was metamorphosed in pre-Early Cretaceous (Late Jurassic?) time.

The measured section in sec. 23, R. 62 W., T. 10 S., Goodnews Bay B–2 quadrangle (*B* in figs. 3, 5) gave a thickness of about 175 m for the limestone and grit sequence. Both here and at a second locality southwest of it (sec. 19, R. 62 W., T. 11 S., Goodnews Bay A–3 quadrangle), about 140 m of thin-bedded to massive noncalcareous graywacke and pebble conglomerate overlies the calcareous sequence. Clasts in the conglomerate include abundant green and maroon metamorphic rocks identical to those in the underlying calcareous grit and some white quartz pebbles. The graywacke and conglomerate sequence appears to be structurally conformable with the underlying calcareous sequence, but the abrupt change in lithologic character indicates that the two sequences are stratigraphically separated by an erosion interval. And in the southern locality, the graywacke not only overlies the calcareous grit but also rests directly upon schistose volcanogenic rocks that underlie the calcareous grit.

The occurrence of *Buchis crassicolis* in the limestone indicates that the limestone and limy grit sequence is coeval with the coarse conglomeratic section of the graywacke of Buchia Ridge. The present proximity of these dissimilar rocks suggests that the distance between them has been foreshortened by several kilometers of northwest transport on the Buchia Ridge fault (fig. 2).

MOUNT ORATIA BELT

The third belt (fig. 1), named for Mount Oratia, one of the highest peaks in this part of Alaska (1,420 m.), is 15–25 km wide and more than 120 km long. It extends from the headwaters of the Goodnews River, near the middle of the Goodnews Bay B–5 quadrangle, northeastward across the southern part of the Bethel A–3 quadrangle and probably into the adjoining Sleetmute quadrangle, where Cady (1955) originally defined the Gemuk Group. The description here of the rocks in the Mount Oratia belt applies only to rocks in the Goodnews Bay and Bethel quadrangles.

Rocks of the Mount Oratia belt are strongly folded, cut by many

faults, and commonly overturned northwestward. Within the belt are at least two small areas of Permian and Triassic rocks, probably faulted in. The northwest and southeast sides of the belt are defined by southeast-dipping low- and high-angle reverse faults. The northern part of the belt is thrust northwestward on younger rocks of Cretaceous (Albian?) age. To the southwest, the belt is juxtaposed with older rocks of Permian and Triassic ages. The northwest side of the belt is offset in three or four places by left-lateral displacement on northwest-trending faults. The southeast side is flanked by volcanic and sedimentary rocks, mostly Jurassic in age.

The rocks in the belt are a colorful assemblage of various kinds of tuffs, volcanogenic sedimentary rocks, massive graywacke, conglomerate, argillite, a few flows, and a few impure limestone beds. Structural complexity precludes certain knowledge of the stratigraphy, but in synclinal structures, the upper part of the section is generally thick-bedded graywacke and shale, the lower part tuff and other volcanic rocks. The Lower Cretaceous section probably grades downward into lithologically similar rocks of Jurassic age. No megafossils of Jurassic age have been found, but some cherty rocks contain Late Jurassic radiolarians (E. A. Pessagno, Jr., written commun., 1977).

The tuffaceous rocks are mostly green and gray; some are red, yellow, brown, or black. They range from thin-bedded cherty rocks to massive coarse-grained crystal-lithic tuff. The most distinctive rock in the belt is the massive andesitic crystal- lithic tuff (at least 1,000 m thick) that forms many high peaks and jagged ridge crests. This tuff consists of green, rarely red or black, cherty tuff fragments, plagioclase (oligoclase- andesine), and minor amounts of fine-grained porphyritic volcanic rock fragments. Quartz is rare or absent. The angular to subrounded lithic clasts range in size from microscopic to 20 cm but are mostly less than 1 cm. Plagioclase grains are mostly broken twinned laths less than 1 mm in size. Massive beds several meters thick are common, but most of the tuff shows light-gray and dark-green bedding bands 1 mm to several centimeters thick. The light bands are plagioclase-rich; the green bands are mostly lithic clasts. Lithic clasts in plagioclase-rich beds commonly grade from coarse to fine upward. Layers of fine-grained gray and green cherty tuff are interbedded with the massive crystal-lithic tuff. These cherty layers resemble the clasts in the crystal-lithic tuff. Much of the fine-grained tuff, including that interbedded with the crystal-lithic tuff, is laumontitized and has developed a chalky mottled appearance; the clasts and plagioclase in the massive crystal-lithic tuff are not laumontitized. In the Bethel A–3 quadrangle, some of the graywacke is tuffaceous and is laumontitized with a mottled appearance; massive black

"argillite" beds are crisscrossed with tiny laumontite veinlets on irregular fracture surfaces.

The Early Cretaceous age of this belt of rocks is based on the occurrence of *Buchia crassicolis* and radiolarians (table 1). Radiolarians found in cherty tuff at three localities in the Goodnews Bay C–4 quadrangle near the southwest end of the belt were identified and assigned an Early Cretaceous (Valanginian) age by E. A. Pessagno, Jr. (written commun., 1977). Near the northeast end of the belt in the Goodnews Bay D–3 and Bethel A–3 quadrangles, *Buchia crassicolis* occurs in calcareous graywacke and conglomerate and in impure limestone. These megafossils were identified by D. L. Jones (written commun., 1977) and R. W. Imlay (written commun., 1948, 1950).

EEK MOUNTAINS BELT

The fourth and northwesternmost belt (fig. 1), named for the Eek Mountains, extends northeastward about 75 km from the Goodnews Bay C–5 and C–6 quadrangles into the Bethel A–4 quadrangle. The overall structure of the belt is that of a large northeast-plunging anticline tapering in width northeastward from a maximum of about 25 km to 2 or 3 km in the Bethel A–4 quadrangle. The anticline is cored by older rocks of Paleozoic and Mesozoic age and flanked by Cretaceous rocks. The rocks in the belt are strongly folded and commonly overturned northwestward. They are cut by southeast-dipping reverse faults and locally offset to the northwest by northwest-trending tear faults.

The lower Cretaceous rocks in the Eek Mountains belt that are correlative with the graywacke of Buchia Ridge contain *Buchia crassicolis* of Valanginian age. No rocks of Hauterivian age, such as form the upper part of the graywacke of Buchia Ridge, have been recognized in or near the Eek Mountains belt, but they may be present, as the age of much of the thick Cretaceous section is only approximately known. For most of its length, the Eek Mountains belt is flanked on either side by the Kuskokwim Group (Cady and others, 1955; Hoare and Coonrad, 1959, 1961, 1978) which is of late Early Cretaceous (Albian) and Late Cretaceous (Cenomanian and Turonian) age. A regional unconformity separates the Kuskokwim Group from the Lower Cretaceous section. There is no obvious angular discordance between the two units but the Kuskokwim Group is generally not difficult to recognize.

The Kuskokwim Group consists of a thick basal conglomerate overlain by a thick section of black micaceous shaly rocks that grade upward into several thousand meters of interbedded graywacke and shale. The conglomerate is noncalcareous and no fossils have been

found in it. It is a poorly sorted mixture of well-rounded to subangular pebbles, cobbles, and boulders of gneiss, schist, white quartz, volcanic rocks, and rare sandstone derived from the underlying Lower Cretaceous section. The source of the quartz and metamorphic clasts in the conglomerate and the mica in the shaly rocks was a belt of Precambrian metamorphic rocks that is parallel to, and a short distance northwest of, the Eek Mountains belt. Apparently the Precambrian rocks were not exposed in Early Cretaceous time, because no metamorphic clasts of Precambrian rocks are known in the calcareous fossiliferous Lower Cretaceous conglomerate.

The Lower Cretaceous section consists of graywacke, shale, argillite, and conglomerate. No tuff, tuffaceous sedimentary rocks, or laumontitized rocks that constitute much of the Lower Cretaceous section in the Mount Oratia belt have been recognized in the Eek Mountains belt. The stratigraphic succession is not certainly known, but it seems likely that most of the massive finer grained rocks are in the lower part of the section; conglomerate and well-bedded sandstone and shale are probably in the upper part of the section. Locally the rocks are thin bedded, but in general they are thick bedded to massive with alternating sandstone and shale intervals 5–20 m thick. The sandstone is gray, brown-weathering, hard, and fine to medium grained. It has a blocky fracture and bedding is commonly difficult to recognize. Shaly rocks commonly show good fracture cleavage. Massive dark-colored beds of argillite are characterized by a fine hackly fracture. The sandstone is mostly somewhat calcareous, locally highly calcareous, and contains layers of calcareous pebble conglomerate. Most of the fossils occur in these highly calcareous beds. Calcareous pebble-cobble conglomerate with interbedded pebbly limestone containing *Buchis crassicolis* crops out at several places along the northwest side of the Eek Mountains belt. Near the southwest end of the belt, conglomerate containing fossiliferous pebbly limestone beds is at least 100 m thick; elsewhere it is much thinner. Clasts in the conglomerate are well rounded and chiefly, or entirely, fine-grained cherty tuff and porphyritic volcanic rock.

The base of the Lower Cretaceous section has not been recognized because the structure is complex and strata of Permian and Triassic age also include sedimentary rocks that are very similar to those of Early Cretaceous age. No Jurassic fossils have been found in the Eek Mountains belt, but since sparsely fossiliferous rocks of Jurassic age are widespread both to the northwest and southeast, it seems likely that they are present in the Eek Mountains belt.

The thickness of the Lower Cretaceous section is indeterminate because the rocks are highly deformed, the base of the section has not been recognized, and an unknown amount has been eroded off the top. It probably is at least 1,000 m thick and may be as thick as 3,000–4,000 m.

The age of the rocks is based on the occurrence of *Buchia crassicolis* (table 1) found at several localities on the northwest and southeast flanks of the Eek Mountains belt (fig. 1). These fossils occur in thin beds of impure limestone, highly calcareous pebble conglomerate, and pebbly sandstone. The thin fossil horizons generally occur in thick sections of nonfossiliferous rocks, but the location of the fossils in the section is generally not known.

OTHER CORRELATIVE(?) ROCKS

Other rocks of probable Early Cretaceous age lie north of Buchia Ridge on both sides of the upper Togiak River (fig. 1). No diagnostic fossils of Early Cretaceous age have been found in this large area, but many of the rocks, including a thick sequence of laumontitized tuffs and tuffaceous sedimentary rocks, resemble the Lower Cretaceous section in the Mount Oratia belt. Radiolarians found in cherty rocks a short distance east of the upper Togiak River include a species of *Parvicingula* that ranges in age from Late Jurassic (Kimmeridgian) into Early Cretaceous (Valanginian) (E. A. Pessagno, written commun., 1977). The stratigraphic position of the radiolarians is not certainly known, but their occurrence suggests the general age range of the rocks, some of which are probably correlative with the graywacke of Buchia Ridge.

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