UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

PRELIMINARY GEOLOGIC MAP OF THE GOODNEWS A-3 QUADRANGLE AND PARTS OF THE A-2 and B-2 QUADRANGLES, ALASKA

By

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EXPLANATORY NOTES

INTRODUCTION

The geologic map provides new data on the age and structure of rocks exposed north of Bristol Bay, southwest Alaska. This information will be useful in evaluating the petroleum potential of Bristol Bay. The map includes the Goodnews A-3 quadrangle and parts of the A-2 and B-2 quadrangles. In the A-3 quadrangle the geology is plotted on a modern topographic base. But there are no modern maps of the A-2 and B-2 quadrangles and the geology is plotted on a drainage base taken from the 1953 Alaska Reconnaissance (1:250,000) Topographic Series. The geologic map is based upon field work done by helicopter in 1974 and upon a boat traverse down the Kulukak River by W. L. Coonrad and M. E. Kauffman in 1953. Most of the earlier field work was done in the B-2 and A-2 quadrangles; whereas the 1974 field work was mostly in the A-3 quadrangle.

Megafossil collections were identified and interpreted by David L. Jones of the U.S. Geological Survey. Robert Tschudy of the U.S. Geological Survey studied the pollen collection.

Volcanic rocks (Jv) The oldest rocks in the map area consist of a thick and highly varied sequence of tuffs, breccias, and flows. No fossils have been found in these rocks in the map area, but they are assigned an Early Jurassic age because: (1) they underlie marine sedimentary rocks of Middle Jurassic age and (2) they strike toward Hagemeister Island about 75 km to the southwest where Early Jurassic fossils occur in a sequence of similar interbedded flows and volcanogenic sediments.

The composition of the volcanic rocks ranges from quartz-rich "cherty" tuffs to mafic lava flows. Most of the tuffs and flows are andesitic and trachytic in composition. At two places mafic flows exhibit possible pillow structures. If they are pillow structures, they, like the marine fossils on Hagemeister Island, indicate a marine origin for at least some of the volcanic rocks.

Schist and phyllite (Js) The Jurassic volcanic rocks are locally recrystallized to fine-grained schist and phyllite. The metamorphic areas are adjacent to large faults and are apparently due to dynamic metamorphism under high pressure. The degree of metamorphism dies out away from the faults and also parallel to the faults. Three such areas of metamorphic rocks were recognized in the mapped area and there probably are others. In the Bethel quadrangle, 140 km to the north, tuffs and mafic flows of Permian age are metamorphosed in a similar manner adjacent to the Togiak fault (Hoare and Coonrad, 1959, and unpublished notes).

Weary graywacke (Jwg) The Weary graywacke is informally named for its exposures on the Weary River. The Weary River is a sluggish tributary of the Snake River which enters Bristol Bay east of the map area. The formation is a thick marine sequence of interbedded graywacke, argillite and conglomerate. The rocks are characteristically strongly indurated, thick-bedded or massive and highly fractured. It is commonly difficult to recognize bedding on the ridges. But large water-polished exposures in the sea cliffs south of the mapped area reveal that the rocks are highly deformed. Structural complexity precludes an accurate thickness estimate, but the unit is probably on the order of 2,000 to 5,000 m thick. Earlier reconnaissance mapping (Mertie, 1938; Hoare and Coonrad, 1961) suggests that the Weary graywacke is widely exposed in the mountains north of Bristol Bay and probably constitutes most of the rocks exposed in the vicinity of the Wood River lakes as far north as Lake Nerka. It is also widely exposed west and northwest of the mapped area in the mountains drained by the upper parts of the Goodnews and Kanektok rivers.

The Middle Jurassic age assignment is based upon fossil belemnites (Cylindroteuthis) found in the sea cliffs, northwest side of Kulukak Bay, a few kilometers south of the mapped area. The fossils were identified by D. L. Jones of the U.S. Geological Survey.

Buchia Ridge graywacke (Kbg) The Buchia Ridge graywacke is informally named for Buchia Ridge, a prominent topographic feature about 25 km long which trends northeast between the Kulukak and upper Ungalikthluk rivers. The formation consists of at least 1,600 m of marine sedimentary rocks. These rocks were previously mapped (Hoare and Coonrad, 1961) as Kuskokwim Group. But during the recent investigation abundant fossil pelecypods were found (see Table 1) which were assigned, by D. L. Jones, an Early Cretaceous (Valanginian) age. The formation is truncated obliquely by the Kulukak fault on the east side of the Kulukak Valley. Close to the Kulukak fault the rocks are sheared and contorted, but elsewhere they dip consistently southeast and are only moderately deformed. Indeed, the Buchia Ridge graywacke formation is less deformed than any comparable thickness of Early Cretaceous rocks known in southwest Alaska.

Many beds in the Buchia Ridge graywacke are brown-weathering and are calcareous, whereas no distinctly calcareous beds were found in the Weary graywacke. Most of the lithit clasts in the Buchia Ridge graywacke are rounded fragments of argillite and graywacke derived from the Weary graywacke formation. Volcanic clasts are also present but are apparently much less abundant.

Calcareous grit and limestone (Kcg) The thickness of the calcareous grit and limestone unit was measured near the north edge of the mapped area and found to be 175 meters. These highly calcareous rocks contain Buchia cf. B. pacifica of Valanginian age and are approximately coeval with the Buchia Ridge graywacke which also contains Valanginian fossils. The two coeval facies are lithologically quite unlike in their content of calcium carbonate and also in their content of lithic clasts. As previously pointed out, the Buchia Ridge graywacke contains abundant clasts of sedimentary rock derived from the Weary graywacke and relatively few volcanic clasts. But in the calcareous grit and limestone facies, the clasts are mostly fragments of volcanic rocks and fine-grained quartz-chlorite schist and phyllite. These clasts came from the Jurassic volcanic rocks (Jv) and the areas of metamorphic rocks (Js) which occur along the faults. The contrast between the two facies suggests that they were probably deposited some distance apart, although they are now only 2 to 5 kilometers apart. The two facies define two juxtaposed belts on either side of the Buchia Ridge fault. They probably are telescoped by northwest transport.

The presence of schist clasts in these rocks of Early Cretaceous age and the lack of sedimentary rocks of Late Jurassic age suggest that the area was emergent and tectonically active in Late Jurassic time.

Sedimentary rocks (Ks) Most of the strata in this unit were previously thought to be of Late Cretaceous age and were assigned to the Kuskokwim Group (Hoare and Coonrad, 1961). However, a new age assignment for the fossils in the unit and new stratigraphic evidence indicates that they are Early Cretaceous (Hauterivian) age. The strata that make up this map unit consist of (a) a relatively thick sequence of dominantly fine-grained calcareous rocks which dips consistently eastward and apparently overlies the Buchia Ridge graywacke (Kbg), and (b) a thin section of non-calcareous graywackes which overlies the calcareous grits (Kcg).

The calcareous sequence (a) contains some pebble conglomerate and graywacke but is chiefly calcareous shaly siltstones with some fine-grained calcarenites. These rocks crop out at intervals along the Kulukak River and apparently underlie the Kulukak Valley east of Buchia Ridge. To the east and south they are structurally overlain by volcanic rocks (Jv) along the Kulukak and East Kulukak thrust faults. These rocks have yielded two small fossil collections (Loc. 2, 3) which consist of *Inoceramus* prisms, large fragmentary *Inoceramus*, and thick-bodied belemnites. D. L. Jones has assigned an Early Cretaceous (Hauterivian) age to the fossils.

West of Buchia Ridge the rocks mapped in this unit are chiefly shales and shaly siltstones with some graywacke. Some of these rocks are calcareous, others are not. No fossils have been found in these rocks and their age and stratigraphic position is unclear. They are interpreted as being correlative with the sparsely fossiliferous rocks in the Kulukak Valley and separated from the Buchia Ridge graywacke by a reverse fault.

The non-calcareous graywackes (b) that overlie the Buchia-bearing calcareous grits of Valanginian age are exposed in two areas, a short distance east of the upper Ungalikthluk River and on the west side of the Kulukak Valley near the north edge of the mapped area. In both areas the rocks occur in shallow, south-plunging synclines and it seems likely that they are the remnants of a much thicker section of rocks. The rocks are well-exposed in the northern area and have a thickness of 140 meters. They consist of fine- to medium-grained graywackes and several thick grit beds. In general, the bedding becomes thicker downward and the lower 25 meters is massive. The rocks are mostly dark gray but some beds are reddish due to their content of maroon argillite clasts. The grit layers contain abundant white quartz, argillite, and schist clasts which are identical to those found in the underlying calcareous grits.

The graywackes are structurally conformable with the underlying calcareous grits (Kcg) but the abrupt lithologic change indicates that the two formations were separated by an erosion interval. Also, in the southern area the graywackes overlie calcareous grits (Kcg) at the north end of the area and schistose volcanic rocks (Js) farther south where the calcareous grits were presumably eroded away before the graywackes were deposited.

Carbonaceous mudstone (Ksm) Several meters of soft, weakly consolidated mudstones crop out on the Ungalikthluk River near the south edge of the mapped area. The rocks are gray with a few thin black seams of carbonaceous material. They yielded a rich pollen assemblage which was studied by R. H. Tschudy of the U.S. Geological Survey. Mr. Tschudy reports as follows:

> "This assemblage is unlike any Cretaceous assemblage from United States or southern Canada. Several of the taxa have been reported previously from Arctic Canada----and the western Siberian lowlands. The assemblage does not correlate exactly with plant microfossil assemblages from either region, but no other reference material from Arctic Canada or Alaska yielding assemblages even remotely resembling this assemblage is available.
>
> The presence of specimens of EXPRESSIPOLLIS ACCURATUS, AQUILAPOLLENITES, aff. LILIACIDITES COMPLEXUS, and AZONIA PULCHELLA almost certainly indicates a Late Cretaceous age. I strongly suspect that this sample represents the Maestrichtian, but in the absence of adequate well-dated reference material, I am reluctant to assign this sample to a definite Late Cretaceous stage."

A much thicker section of mudstones and interbedded conglomerates crop out in the seacliffs at Nanavarchak Bay about 15 kilometers south of the mapped area. These rocks were previously thought to be of probable early Tertiary age (Hoare and Coonrad, 1961), but it now seems likely that they are Late Cretaceous. They contain thin carbonaceous shale and coal layers as well as fossil plants and are apparently non-marine.

The rocks are broken by faults and mildly folded and, at Nanavarchak Bay, they lie on strongly deformed graywacke and argillite of Middle Jurassic age (Jwg). They were apparently deposited after erosion had removed a thick section of Early Cretaceous strata in early Late Cretaceous time.

Olivine basalt (Qb) Olivine basalt flows in the northwestern part of the mapped area are part of an extensive lava field which extends south to the sea coast and west almost to the Togiak River. Most, or all, of the flows in the mapped area probably came from two eruptive centers which developed along the Togiak-Tikchik fault. The vent areas have been overridden and severely modified by glacial ice and it is necessary to interpret their location from the localized occurrence of oxidized pyroclastic and scoriaceous basalts. One such vent area is on top of an isolated, flat-topped mountain at the west edge of the mapped area. The mountain rises about 300 meters above the valley floor and apparently consists of near-horizontal basalt flows. It probably is the remnant of a volcano which was truncated by glacial ice.

The magnetic orientation of the flows was determined at several places and found to be normal. It seems likely that the basalts erupted during the present (Brunhes) polarity epoch which began about 7×10^5 years B.P. (Cox and others, 1963). They are clearly older than the last major ice advance and are Pleistocene in age.

Intrusive rocks (Tki, Tkd) Dikes, sills, and intrusive bodies of irregular or unknown shape cut the sedimentary and volcanic rocks at several places. The dikes and sills are mostly less than 10 meters thick and consist of quartz porphyry, diabase, or rocks of intermediate composition. Medium-grained biotite diorite forms a relatively large intrusive body on the south end of Buchia Ridge. The rock is poorly exposed but diorite probably underlies an area of at least 12 square kilometers. Intrusive bodies of this size are generally surrounded by a metamorphic aureole of baked and recrystallized rocks. But in this instance little or no metamorphism was noted near the diorite. Along its northern edge, the diorite body appears to overlie the sedimentary rocks of Buchia Ridge and it probably dips gently southward. It is interpreted to be a thick lens or tabular-shaped body of rock which has been exhumed by erosion. This interpretation is supported by observations made at Nanavarchak Bay, 27 kilometers to the south. Interbedded conglomerate and mudstone in the cliffs on the north side of the bay are capped by a flat-bottomed body of igneous rocks at least 35 meters thick that underlies an area of at least 10 square kilometers north of the bay. The source of the igneous body is apparently a 5- to 6-meter feeder dike which is exposed in the sea cliffs.

The absolute age of the intrusive rocks is not known but they are clearly younger than the rocks they intrude. They are similar to, and probably the same age as, the intrusive rocks at Nanavarchak Bay. At Nanavarchak Bay about 15 kilometers south of the mapped area numerous mafic and siliceous dikes and sills intrude the carbonaceous mudstones and conglomerates of Late Cretaceous (Maestrichtian?) age. It seems likely that the intrusive rocks are of Tertiary or Late Cretaceous age.

Structure The rocks in and near the map area record a lengthy history of compressional deformation in Mesozoic time and a shorter period of extensional deformation in Cenozoic time. The rocks of Jurassic and Cretaceous ages are folded to varying degrees and broken by six large faults. Four of the faults--the Buchia Ridge, Kulukak, East Kulukak, and an unnamed fault near the east edge of the map area--are interpreted as thrust faults. They dip southeastward, probably at a low angle, and show northwest transport. The Ungalikthluk fault is enigmatic. However, it probably also dips southeast at a somewhat steeper angle. The Togiak-Tikchik fault apparently dips steeply northwestward. It is interpreted as an extensional feature, characterized by dip-slip and probable strike-slip movements.

In the northern part of the map area the rocks generally strike between N.N.E. and N.E. But farther south and continuing to the coast, the prevailing structural trend is more to the east and southeast. The significance of the change in trend is not yet known, but it apparently occurs at the East Kulukak fault. This suggests that the East Kulukak fault is an important tectonic feature. It may define the edge of a large thrust plate.

The Early Cretaceous rocks provide evidence for two deformational events. They contain schist and phyllite clasts which are particularly abundant adjacent to the Ungalikthluk fault. The clasts are identical to fine-grained volcanic rocks which were dynamically metamorphosed near the Ungalikthluk fault. Their occurrence in Early Cretaceous strata and the apparent lack of Late Jurassic deposits indicate that the area was tectonically active and emergent in Late Jurassic time.

The Early Cretaceous rocks include two unlike lithologic facies. The western highly calcareous facies is in depositional contact with Early Jurassic volcanic rocks. But the eastern conglomeratic facies, the Buchia Ridge graywacke, is allocthonous. It is in fault contact with the underlying volcanic rocks. The two unlike facies were presumably deposited some distance apart. However, they now crop out in two belts on either side of the Buchia Ridge fault which are only 2 km to 5 km apart. It seems likely that the Early Cretaceous rocks were telescoped by several kilometers of northwest transport on the Buchia Ridge fault after they were deposited. Additional evidence for post-Early Cretaceous fault activity is provided by the Kulukak fault where Jurassic volcanic rocks have been thrust on top of the Early Cretaceous strata.

The Early Cretaceous rocks are at least 2,500 m thick and may have a thickness of 3,500 m. At the time they were deposited they must have been widely distributed in and near the map area. However, no rocks of Early Cretaceous age were found in a wide reconnaissance around the map area. They are apparently restricted to an area of about 350 km^2 between the Kulukak and Ungalikthluk faults. They are surrounded by older, more massive rocks which are less susceptible to erosion. These observations all suggest that the Early Cretaceous rocks must have been preserved from erosion. It seems likely that they were preserved beneath a thrust sheet which moved northwestward on the Kulukak fault. This would require a minimum of about 10 km tectonic transport.

At Nanavarchak Bay 15 km south of the map area non-marine deposits of Late Cretaceous (Maestrichtian?) age overlie strongly folded sedimentary rocks of mid-Jurassic age. The lack of Early Cretaceous rocks suggests that the area was emergent and tectonically active in pre-Late Cretaceous time. However, the Late Cretaceous rocks are also deformed. They occur in a syncline which trends east or southeast. On the east side of Nanavarchak Bay the south limb of the syncline is apparently faulted off by one or two reverse faults which trend ENE and dip south. Northwest transport on these faults suggests that the rocks were deformed by southeast compression in post-Late Cretaceous time. The Cretaceous and Jurassic rocks at Nanavarchak Bay are also displaced by northwest-trending normal faults. These faults dip steeply northeast or southwest and show a few meters or several meters vertical displacement.

The Togiak-Tikchik fault is part of the Denali fault system which extends across Alaska and is considered to be a major crustal fracture.

In general, the Denali fault system is characterized by large right-lateral strike-slip offset but it also shows dip-slip and reverse movements. In the map area the Togiak-Tikchik fault is concealed by unconsolidated deposits and there is no direct evidence of the nature of fault activity. However, the straight east wall of Togiak Valley and the volcanic rocks which erupted in Togiak Valley in Late Cenozoic time suggest a possible structural interpretation. The volcanic rocks are alkali-olivine basalts which are generally considered to originate in the mantle. They characteristically erupt in the vicinity of large tensional crustal fractures. In other words, it seems likely that the Togiak Valley is a tensional feature; it probably is a graben or rift valley. If this interpretation is valid, the straight east wall of Togiak Valley is probably the scarp of a west-dipping normal fault.

About 150 km north of the map area in the Bethel quadrangle (Hoare and Coonrad, 1959) the Togiak-Tikchik fault clearly dips steeply westward but the sense of movement is reversed; the west side is up.

REFERENCES

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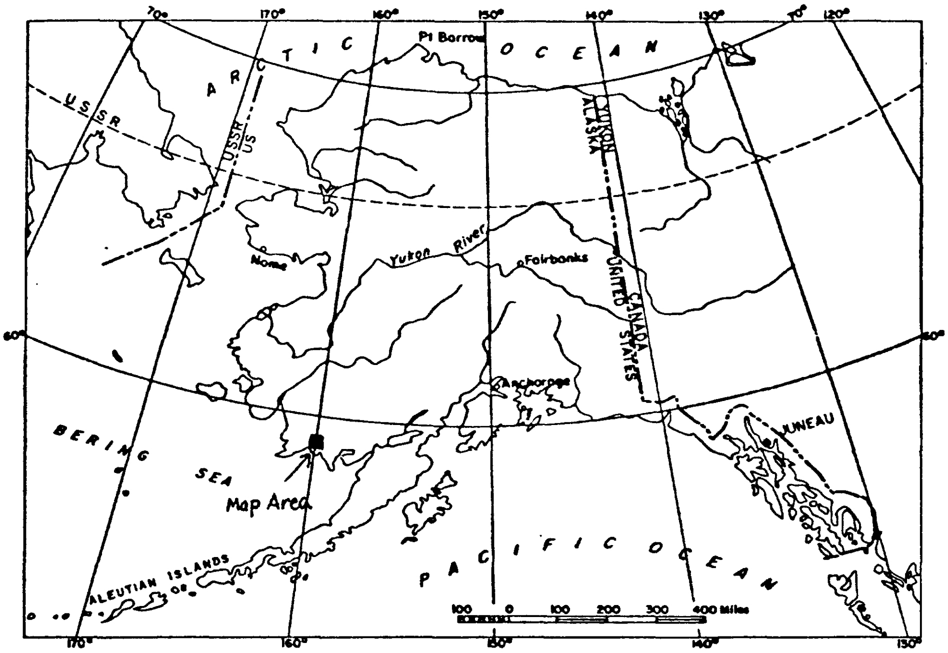
______1961, Geologic map of the Goodnews quadrangle, Alaska: U.S. Geol. Survey Misc. Geol. Inv. Map I-339, scale 1:250,000.

Mertie, J. B., Jr., 1938, The Nushagak district, Alaska: U.S. Geol. Survey Bull. 903, 96 p.

FOSSIL COLLECTIONS

Map No.	USGS No.	Identification*	Age
1	D4733	pollen	Late Cretaceous (Maestrichtian)
2	M6290	*Inoceramus* sp. *Belemnites*	Early Cretaceous (Hauterivian)
3	M6294	*Inoceramus* sp. *Belemnites*	Early Cretaceous (Hauterivian)
4	M6298	*Buchia crassicolis* *Buchia crassicolis solida*	Early Cretaceous (Valanginian)
5	M6301	*Buchia sublaevis*	Early Cretaceous (Valanginian)
6	M6302	*Buchia sublaevis* *Buchia crassicolis solida*	Early Cretaceous (Valanginian)
7	M6296	*Buchia keyserlingi*	Early Cretaceous (Valanginian)
8	M6299	*Buchia* cf *B. crassicolis*	Early Cretaceous (Valanginian)
9	M6300	*Buchia crassicolis*	Early Cretaceous (Valanginian)
10	M6303	*Buchia crassicolis*	Early Cretaceous (Valanginian)
11.	M6295	*Buchia* cf *B. pacifica*	Early Cretaceous (Valanginian)
12.	---	*Buchia* cf *B. pacifica*	Early Cretaceous (Valanginian)

*Palynology collection identified by Robert H. Tschudy; other collections identified by D. L. Jones


ARCTIC OCEAN
Pt Barrow
USSR
USSR
US
YUKON
ALASKA
Nome
Yukon River
Fairbanks
CANADA
UNITED STATES
Anchorage
JUNEAU
BERING SEA
Map Area
PACIFIC OCEAN
ALEUTIAN ISLANDS
100 0 100 200 300 400 Miles
170°
160°
150°
140°
130°
120°
60°

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