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# OPHIOLITIC TERRANE BORDERING THE YUKON-KOYUKUK BASIN, ALASKA

by

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## INTRODUCTION

This is one of a series of open-file reports that present the results of a comprehensive study of the ophiolitic terranes of Alaska and contiguous parts of northeast Russia. The study was carried out by the U.S. Geological Survey, the Alaska Division of Geological and Geophysical Surveys, and the Far East Branch of the Academy of Sciences of the USSR between 1989 and 1991. Other reports in this series will include a geologic map, a metallogenic map, and reports summarizing the lithology, thickness, age, geochemistry, and geologic setting of each of the major ophiolitic terranes in Alaska and northeast Russia. This report focuses on the ophiolitic terrane bordering the Yukon-Koyukuk basin of northern and western Alaska. For location of specific geographic and geologic features mentioned in this report and for information on the regional geologic setting of this and the other ophiolitic terranes of Alaska, the reader should consult Open-File Report 92-20A in this series by Patton and others (1992).

### Definition of terms

The term *ophiolite*, as used in this report, follows the definitions of Steinmann (1927) and the Geological Society of America Penrose Conference on ophiolites (Penrose Field Conference, 1972). It refers to an association of mafic and ultramafic rocks that, in a complete sequence, is characterized from bottom to top by tectonized ultramafic rock, a transitional zone of interlayered ultramafic and mafic cumulates, layered gabbro, massive gabbro, a mafic sheeted dike complex, and pillow basalt. Most workers now regard ophiolite assemblages as allochthonous fragments of oceanic crust and upper mantle that formed along mid-ocean ridges, in small marginal basins, or as basement to island arcs. The ophiolitic terrane bordering the Yukon-Koyukuk basin clearly has been emplaced or "obducted" onto older continental crust and is characteristic of the "Tethyan-type" of ophiolite as defined by Moores (1982) and Coleman (1984). The geologic setting of this ophiolite terrane contrasts with the the "Cordilleran-type" ophiolitic terranes in southern Alaska, which characteristically have been underthrust by younger accretionary flysch deposits.

*Ophiolitic terranes* are defined in this series of reports as fault-bounded belts of oceanic rocks that contain ophiolite complexes. The ophiolitic terrane bordering the Yukon-Koyukuk basin has been assigned to the Angayucham, Tozitna, and Innoko lithotectonic terranes by Jones and others (1987).

# OPHIOLITIC TERRANE

The ophiolitic terrane bordering the Yukon-Koyukuk basin consists of an imbricate assemblage of oceanic rocks that occur as: 1) narrow basinward-dipping, slab-like bodies rimming the northern and southeastern margins of the Yukon-Koyukuk basin, and as 2) allochthonous synformal remnants distributed along the Ruby geanticline on the southeastern flank of the basin (Plate 1, col. F) (Patton and others, 1992). The slab-like bodies that rim the basin form a narrow nearly continuous belt for 500 km along the south edge of the Brooks Range from the lower Kobuk River to the northeast apex of the Yukon-Koyukuk basin, and for 400 km along the northwest boundary of the Ruby geanticline from the northeast apex of the basin to the Kaltag fault. The synformal bodies on the Ruby geanticline consist of six large allochthonous masses and numerous small klippe distributed over a distance of more than 1100 km from the eastern Brooks Range to the lower Yukon River. In addition to these two major belts, small bodies of probably correlative oceanic rocks are present in two other localities: 1) on upfaulted blocks within the Yukon-Koyukuk basin south of the Kaltag fault (Patton, 1991; Patton and Moll, 1985), and 2) on the Seward Peninsula near and along the western margin of the Yukon-Koyukuk basin (Till and others, 1986; Patton and others, unpublished map, 1992).

The ophiolitic terrane bordering the Yukon-Koyukuk basin is made up of three broad thrust panels, which comprise a reversely stacked sequence that progresses from cumulus and mantle peridotites in the highest panel to continental slope deposits in the lowest. The thrust panels have been informally named from top to bottom: Kanuti, Narvak, and Slate Creek (Patton and Box, 1989).

### *Kanuti thrust panel*

The upper or Kanuti thrust panel consists of an ophiolite complex characterized by a tectonite mantle suite in the lower part and a cumulus magmatic suite in the upper part (Plate 1, col. A) (Loney and Himmelberg, 1989). The mantle suite typically is composed of variably serpentinized harzburgite and dunite and the magmatic suite of layered gabbro, clinopyroxenite, and wehrlite. Massive gabbro generally forms the erosional top of the thrust panel. No rocks characteristic of higher levels of an ophiolite succession, such as sheeted dikes and pillow basalt, have been found. The upper contact of the Kanuti thrust panel is covered by overlapping Cretaceous sedimentary rocks around the margins of the basin, but regional structural relationships strongly suggest that in the subsurface the mafic-ultramafic assemblage is overlain by arc volcanic rocks of the Early Cretaceous to Middle Jurassic Koyukuk terrane. Evidence that the ophiolite complex may have formed the foundation upon which the Koyukuk arc was built was discovered recently south of the Kaltag fault on an upfaulted block within the basin (Patton, 1991). Here the Koyukuk arc volcanic rocks are underlain by an assemblage of trondhjemitic, tonalitic, gabbroic, and ultramafic rocks that yield Middle and Late Jurassic K-Ar ages. This mafic-ultramafic assemblage cannot be traced directly into the Kanuti thrust panel at the margins of the basin, but the similarity in K-Ar isotopic ages strongly suggest that it is part of the same ophiolite complex.

*Geochemistry* The suggestion that the Kanuti ophiolite complex formed in a volcanic arc rather that a mid ocean ridge environment is also supported by the geochemistry of the mantle and cumulus peridotite and gabbro (Loney and Himmelberg, 1989). Olivine and plagioclase compositions for cumulus gabbro lie in the volcanic arc field rather than in the MORB (mid ocean ridge basalt) field in Beard's (1986) discriminant diagram (Plate 1, col. E). Likewise the Cr#(100Cr/Cr+Al) and Mg#(100Mg/Mg+$Fe^{2+}$) for chromian spinels from mantle and cumulus peridotite and dunite, when plotted on the discriminant diagram of Dick and Bullen (1984), are not restricted to the field of abyssal peridotites, but show a wide range of values that are more typical of ophiolites generated in an arc setting.

*Age* Six K-Ar ages from hornblende ranging from 138 to 185 Ma with an average age of 159 Ma have been obtained from the magmatic suite of the Kanuti thrust panel at widely scattered localities around the perimeter of the Yukon-Koyukuk basin (Plate 1, col. C). Four of the analyzed samples are from hornblende pegmatite and hornblendite dikes and two are from hornblende gabbro. Two $^{40}Ar$-$^{39}Ar$ analyses of hornblende from hornblendite and hornblende pegmatite dikes yielded an age of 162 Ma.

*Metamorphic sole*

The base of the Kanuti thrust panel is commonly marked by a thin (<25m thick) fault slice of garnet amphibolite and pyroxene granulite with a strong tectonite fabric. These high grade metamorphic rocks together with blocks of sheared and mylonitized serpentinite characterize the the thrust fault zone that separates the Kanuti panel from the underlying Narvak panel. In the Kanuti River area the basal thrust and the thin band of high grade metamorphic rocks cuts across the folded contact between mantle suite and the magmatic suite so that in places the mantle suite is missing and the magmatic suite rests directly on the metamorphic rocks (Loney and Himmelberg, 1989).

*Age* Four K-Ar ages ranging from 155 to 172 Ma and one $^{40}Ar$-$^{39}Ar$ incremental release spectra plateau age of 161 Ma were obtained for metamorphic hornblende from the amphibolite at widely scattered localities (Plate 1, col. C). The incremental heating data show no evidence of later argon loss and thus appear to date thrusting of the Kanuti panel onto the Narvak panel. As is the case for the Misheguk allochthon in the western Brooks Range (Patton, 1992), isotopic ages from the magmatic suite agree closely with the ages from the metamorphic sole, suggesting that the magmatic suite must have passed through the hornblende argon blocking temperature close to the time of thrusting.

### *Narvak thrust panel*

The middle, or Narvak, thrust panel, the most widely exposed of the three panels, consists of multiple thrust sheets of pillow basalt, chert, gabbro, and diabase with minor amounts of basaltic tuffs and breccias and carbonate rocks. All of the rocks in the Narvak thrust panel are weakly metamorphosed to prehnite-pumpellyite facies with an overall increase in metamorphic grade structurally downward. Greenschist facies metamorphism and high-pressure blueschist metamorphism, as indicated by the presence of glaucophane, occur locally near the base of the thrust panel on the Ruby geanticline.

The Narvak thrust panel is interpreted to represent an assemblage of oceanic crustal rocks obducted onto the continental margin during arc collision in Late Jurassic to Early Cretaceous time. The lower (Devonian to Permian) part of the Narvak panel locally contains carbonate turbidites(?) with mixed conodont faunas that appear to have been reworked from a shallow water carbonate platform sequence, suggesting that this part of the Narvak panel formed near the continental margin. The upper (Triassic to Lower Jurassic) part of the panel lacks continentally-derived sediments and is believed to have formed some distance from the continental margin. The REE (rare-earth element) and trace element abundances of the basalts relative to chondrite are shown on Plate 1, col. E. Their pattern in these diagrams and their distribution in various trace element discriminant plots published previously by Barker and others (1988) and by Pallister and others (1989) suggest that the basalts formed in an ocean island or seamount environment.

*Age* Systematic sampling for radiolaria from cherts in well-exposed sections along the southern edge of the Arctic Alaska terrane indicates that the thrust panel ranges in age from Devonian to Early Jurassic (Plate 1, col. C). Carbonate rocks, which are confined to the lower part of the thrust panel, yield mixed conodont faunas ranging in age from Ordovician to Late Mississippian (A. G. Harris, written communication, 1985), and sparse megafossils of Devonian, Mississippian(?), and Permian age. Some of the conodont faunas clearly have been reworked from shallow water sources.

It has been suggested that the Narvak panel together with the lower crustal and mantle rocks of the Kanuti panel may represent a nearly complete dismembered ophiolites sequence (Patton and others, 1977; Roeder and Mull, 1978). However, the recently acquired fossil data show that the rocks of the Narvak panel span a wide age range from Devonian to Jurassic and probably pre-date the magmatic suite in the Kanuti panel. Thus it appears unlikely that the two panels represent a single vertical succession of oceanic crustal and upper mantle rocks.

### *Slate Creek thrust panel*

The lowest or Slate Creek thrust panel is composed chiefly of phyllite and metagraywacke with minor amounts of carbonate rock, basalt flows, and basalt breccia. The phyllite and metagraywacke are overprinted by an incipient penetrative metamorphic fabric, but turbidite features such as graded bedding, sole marks, etc., are locally discernible. The thrust panel is locally missing along the southeast margin of the basin and on the Ruby geanticline, south of the Kaltag fault. The phyllite and metagraywacke are provisionally assigned a Devonian protolith age based on sparse palynoflora collections (Plate 1, col. C).

The Slate Creek panel is interpreted to consist of continental slope and rise deposits that accumulated along a middle Paleozoic continental margin. The bulk of the panel is composed of fine-grained siliciclastic turbidites, but the presence of coarse volcanic-rich breccias and of exotic blocks of shallow water carbonate rocks, locally enveloped in basalt flows, suggests that deposition may have been accompanied by rifting along the continental margin.

## UNDERLYING CONTINENTAL ROCKS OF THE BORDERLANDS OF THE YUKON-KOYUKUK BASIN

The borderlands of the Yukon-Koyukuk basin on which the ophiolitic terrane has been emplaced are composed of metamorphosed Proterozoic and lower Paleozoic continental margin assemblages, which have been designated the Arctic Alaska, Ruby, and the Seward terranes by Jones and others, (1987). Recent detailed mapping and isotopic studies indicate that protolith ages of these parautochthonous metamorphic assemblages range from Late Proterozoic to Devonian (Plate 1, col. C). Both the Ruby and eastern part of the Seward terranes are widely intruded by granitic plutons of mid-Cretaceous age. All three of the terranes are characterized by grossly similar assemblages of pelitic schist, quartzite, and carbonate rocks with lesser amounts of metabasite and orthogneiss. Regional greenschist facies metamorphism predominates, but local areas of amphibolite facies and of high-pressure blueschist facies metamorphism have been recognized in all three terranes (Patton and others, 1992). The regional blueschist-greenschist metamorphism of the continental borderlands is thought to be related to arc collision and partial subduction of these continental terranes beneath the ophiolitic terranes in Late Jurassic and Early Cretaceous. Isotopic determinations on blueschist-greenschist facies metamorphic mineral assemblages from the southern Brooks Range and Ruby geanticline provide a large number of K-Ar cooling ages ranging from 85 to 136 Ma and $^{40}Ar$-$^{39}Ar$ ages ranging from 120-130 Ma (Plate 1, col. C).

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