STATE OF ALASKA

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DIVISION OF MINES AND GEOLOGY

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GEOLOGIC REPORT NO. 37

Geology and Geochemistry in the Southeastern Part of the Cosmos Hills, Shungnak D-2 Quadrangle, Alaska

By

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June 1969

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GEOLOGY AND GEOCHEMISTRY IN THE SOUTHEASTERN PART OF THE COSMOS HILLS, SHUNGNAK D-2 QUADRANGLE, ALASKA

By

Crawford E. Fritts

ABSTRACT

Recent detailed geologic mapping and geochemical sampling in the Cosmos Hills revealed new information about stratigraphy, structure, metamorphism, and mineralization. The area studied is five miles south of Bornite, Alaska. Four main stratigraphic formations ranging in age from Early Paleozoic to Cretaceous are recognized. The most important geologic structure is a window 20 miles long and five to eight miles wide bounded by two major low-angle overthrust faults. Lower and upper plates of allochthonous rocks of Early Paleozoic and Cretaceous ages, respectively, have been thrust over autochthonous dolomitic limestone of Middle Devonian age. The limestone contains chalcopyrite, bornite, and chalcocite of economic interest at Bornite. Overthrust faulting was preceded by emplacement of granite, doming, progressive regional metamorphism, and block faulting in Cretaceous time. The overthrust faulting was accompanied by dynamic metamorphism and followed by high-angle faulting in post-Cretaceous time. No evidence was found to show that copper mineralization accompanied emplacement of the granite. Placer gold deposits of Pleistocene age have been most productive on streams characterized by gradients of 150 to 200 feet per mile in areas underlain mainly by phyllite cut by quartz veins. Jade (nephrite) derived from small bodies of highly sheared serpentinite is recovered from old placer tailings. The serpentinite also contains noncommercial quantities of magnetite, chromite, and asbestos, as well as traces of cobalt and nickel.

INTRODUCTION

The Alaska Division of Mines and Geology continually collects and evaluates geological and geochemical data in parts of the State known or thought to offer the greatest potential for development of mineral resources. The Cosmos Hills in western Arctic Alaska contain the largest known undeveloped copper deposit in the State. This report describes geological mapping and geochemical sampling done in the Cosmos Hills in 1968.

LOCATION AND ACCESS

The Cosmos Hills form an isolated highland 10 x 27 miles near the southern flank of the Brooks Range about 300 miles northwest of Fairbanks. These hills rise from 400 to as much as 3440 feet above sea level. They extend east southeast across the boundary between the Ambler River and Shungnak quadrangles. This report concerns mainly the northern third of the Shungnak D-2 quadrangle, which contains approximately 1/3 of the Cosmos Hills (fig 1).

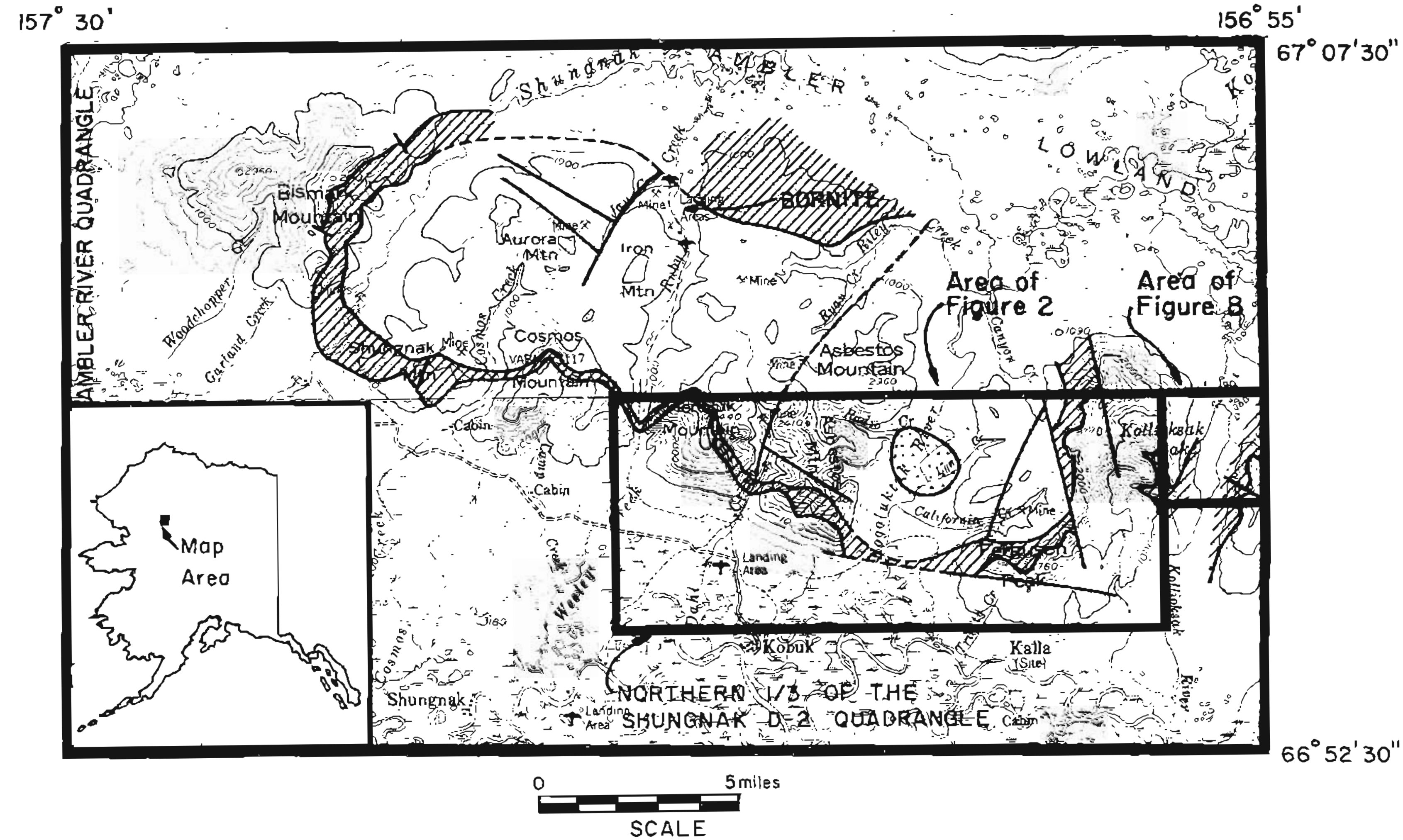

Figure 1

Generalized geologic map of the Cosmos Hills, Alaska, showing the locations of Bornite, Kobuk, Shungnak, and the areas mapped in 1968 (Figures 2 and 8). Diagonal pattern indicates strata of probable early Paleozoic age bounded by two major overthrust faults, which form the frame of a window discussed in the text. These rocks surround strata of known Paleozic age, and are bounded on the west, south and east by strata of Cretaceous age. Dots indicate intrusive granite of early Cretaceous age. Geologic data in the northern and western parts of the Cosmos Hills are modified from Patton, Miller and Tailleur (1968).

Access to the mapped area is mainly by air, but partly by road and water. A large gravel landing strip was maintained by Wien Consolidated Airlines at Dahl Creek during June and July 1968. Similar strips are maintained at the village of Kobuk and at Bornite, the exploration camp of Bear Creek Mining Company and Kennecott Copper Corporation. These communities are immediately south and five miles north of the mapped area, respectively (fig 1). A good gravel road extends from Bornite to Dahl Creek and to the mining companies' Kobuk River landing (fig 2, in pocket). A poorer road extends from Dahl Creek to Kobuk, which is the easternmost point reached by tugboats and barges on the Kobuk River. Cat trails lead to old placer workings on Dahl and California Creeks, but only the Dahl Creek trail is in reasonably good condition. The central and eastern parts of the area, respectively, can be reached from Kobuk by canoe via the Kogoluktuk River and by float plane via Kollioksak Lake (fig 1).

PURPOSE AND FIELD WORK

Review of geological literature concerning the Cosmos Hills and consultation with geologists familiar with the area revealed a definite need for detailed investigation of local bedrock. Bear Creek and Kennecott personnel had been engaged in intensive study of the copper deposit at Bornite since 1957, but only reconnaissance mapping of the Cosmos Hills by the mining companies and by the U. S. Geological Survey had been done prior to 1968. While much already was known about the area, at least two major problems involving the copper-bearing strata were controversial and deserved further attention. (1) The copper deposit at Bornite was known to be stratigraphically controlled, and was thought to be of low-temperature hydrothermal origin. The source of the copper, however, was unknown. Mafic igneous or meta-igneous rocks were considered one possible source. However, recognition of intrusive granite by the U. S. Geological Survey provided another possible source for mineralizing solutions, thereby indicating a need for further mapping and geochemical sampling near the granite. (2) The copper-bearing strata were known to thin westward and to terminate abruptly eastward near Dahl and Riley Creeks. The thinning and distribution of these strata could be explained either by erosion before deposition of overlying formations or by faulting. The possibility of overthrust faulting seemed especially important to the present writer. Erosion presumably could have removed copper-bearing strata, whereas faulting could have merely offset them or covered them with other rocks. Detailed mapping of the Cosmos Hills, therefore, seemed essential.

Detailed geologic mapping and geochemical sampling by the Division of Mines and Geology were undertaken as part of a two or three year study of the entire Cosmos Hills highland. Mapping was begun in the Shungnak D-2 quadrangle, because this area offered (1) the best topographic base map, (2) the widest variety of lithologies, (3) the most complex geologic structure, and (4) the best opportunity to study the relationship between the emplacement of granite and the deformation, metamorphism, and possible mineralization of adjacent strata.

Field work was done on foot during June, July, and August 1968. Most traverses were made from camps near Dahl Creek and the Kogoluktuk River. Brief reconnaissance at the eastern edge of the area was accomplished from Kollioksak Lake. All mapping was done at scale 1:63,360 (1 inch = 1 mile), but data were compiled for publication at scale 1:48,000 (1 inch = 4,000 feet).

This report was prepared primarily to summarize the geology of the Cosmos Hills as known at the end of the 1968 field season on the basis of detailed mapping in and near the Shungnak D-2 quadrangle. Important new data concerning regional stratigraphy, structure, and geologic history are emphasized because of their significance in exploration in and near the western part of the Brooks Range. Economic geology and geochemistry in this quadrangle also are discussed. Previous literature concerning copper mineralization at Bornite is reviewed briefly because it constitutes background material related to the long-term study of the Cosmos Hills. Mineralization at Bornite, however, was not studied by the writer in the field in 1968.

ACKNOWLEDGEMENTS

Numerous people facilitated the recent work. Christopher P. Cameron took complete charge of geochemical sampling, thereby enabling the writer to devote full time to geologic mapping. We are especially grateful to C. G. Bigelow, A. A. Dundas, Paul Mogensen and others of Bornite and to Mr. and Mrs. James Edsall of Dahl Creek for numerous courtesies during the summer. We also express our appreciation to Michael Tickett, Mr. and Mrs. Guy Moyer, and Mr. and Mrs. Anthony Bernhardt of Kobuk for courtesies and assistance in reaching the Kogoluktuk River and Kollioksak Lake. C. E. Stout and William Munz of Dahl Creek discussed gold and jade recovery, respectively. Bigelow and Mogensen engaged in stimulating geological discussions with the writer during the summer. Similar discussions in the fall with I. L. Tailleur and W. P. Brosge of the U. S. Geological Survey also were very helpful and much appreciated. Tailleur was especially cooperative by making available to the writer preliminary maps and other data accumulated during geological reconnaissance in and near the Cosmos Hills. J. T. Dutro, Jr., of the U. S. Geological Survey studied crinoid-bearing limestone collected by the writer at Ferguson Peak. Geochemical samples were analyzed by members of the U. S. Geological Survey in Anchorage, Alaska. Analysts are acknowledged on Table 1 (in pocket). Hand samples were photographed by Gilbert R. Eakins of the Division of Mines and Geology.

PREVIOUS LITERATURE

Prospecting, mining, and geological reconnaissance in the Cosmos Hills have been described or mentioned in more than 60 reports since the gold rush of 1898. However, many references are brief, and at least 15 are unpublished. The available literature has been summarized by the writer in annotated bibliographies concerning (1) copper, (2) gold, and (3) serpentinite, asbestos, and jade. They are filed at the office of the Division of Mines and Geology at College. Only the more important references to bedrock geology, mineralization, and mining are mentioned here.

Smith and Eakin (1911) discussed early geological reconnaissance in the Cosmos Hills. They described copper mineralization in limestone near Ruby Creek and Aurora Mountain in the Ambler River quadrangle (fig 1). The authors pointed out that similar southeast-trending limestone in the Shungnak D-2 quadrangle ends abruptly at the west bank of Dahl Creek (fig 2). They noted that gold nuggets found at Dahl Creek exhibited much attached quartz, and that specks of free gold were visible in float quartz on hills nearby. They concluded that the placer gold was derived from auriferous quartz veins similar to those which cut carbonaceous phyllitic schist in and near the bed of Dahl Creek. The authors mentioned the abundance of magnetite and the presence of chromite and native silver in the placer concentrates of Dahl Creek, and emphasized the almost complete absence of garnet. They also mentioned the presence of conglomerate, greenstone, asbestos, and jade in and near the Cosmos Hills.

Smith and Mertie (1930) reviewed the little-known geology of northwestern Alaska, but their description of the Cosmos Hills was based largely on that of Smith and Eakin (1911). They showed that rocks previously referred to as greenstone included intrusive serpentinite as well as extrusive rocks now referred to as metabasalt and metatuff.

Reed (1932) described in detail many of the placer mining operations in the Cosmos Hills, including those on Dahl, Lynx and California Creeks in the Shungnak D-2 quadrangle. Mining on those creeks began about 1898, 1912, and 1918, respectively.

Heide, Wright, and Rutledge (1949) discussed sampling and mapping of several asbestos-bearing serpentinite bodies in the Cosmos Hills, including a large one at Asbestos Mountain near the southern edge of the Ambler River quadrangle. [Note: The name Asbestos Mountain on the Shungnak D-2 quadrangle actually applies to a prominent peak immediately north of this area.] The serpentinite body at Asbestos Mountain was interpreted as a C-shaped stock extending south to the mouth of Stockley Creek in the Shungnak quadrangle, as shown by Coats (1943). Heide, Wright, and Rutledge (1949, fig 4) also showed a sheet-like body of serpentinite beneath metaconglomerate at the north face of Inerevuk Mountain, and the authors inferred an unconformity beneath the serpentinite.

Read and Lehner (1959) compiled a geologic map of the Cosmos Hills for Bear Creek Mining Company. The original map and report are confidential company property. The report, therefore, has not been read by the present writer. However, simplified versions of their map were included in reports by Runnells (1963, 1969). He and Chadwick (1960) discussed the general interpretation of stratigraphy and structure presented by Read and Lehner. The following summary of work by Read and Lehner is taken from those discussions.

Read and Lehner showed the general distribution of major lithologies in the Cosmos Hills, and recognized two stratigraphic series. Their lower series of Paleozoic age consisted of a thick sequence of pelitic rocks, greenschists, and greenstone overlain by more than 2,000 feet of limestone and dolomite, including the copper-bearing strata at Bornite. Their upper series of Mesozoic(?) age consisted of a thick sequence of pelitic rocks and metabasalt overlain unconformably by metaconglomerate, graywacke, and siltstone. The gross regional structure shown on the map was a breached, doubly plunging anticline or dome trending west northwest, locally modified by minor cross folds and high-angle faults. Granite and garnetiferous muscovite schist mapped near the Kogoluktuk River were interpreted as basement rocks occupying a horst nearly two miles wide, which was bounded by north-trending faults inferred along the relatively straight sides of the glaciated river valley. All high-angle faults in the Cosmos Hills were thought to be characterized by displacements of not more than a few hundred feet. The original map, however, showed two low-angle overthrust faults inferred by Lehner in the western part of the Cosmos Hills above and below serpentinite, which underlies metaconglomerate.

Chadwick (1960) discussed the geologic setting and mineralization of the copper deposit at Bornite. The main primary copper minerals are chalcopyrite, bornite, and chalcocite, which are found in dolomitic reef breccia. He emphasized the stratigraphic control of the deposit, the low metamorphic grade of rocks in the vicinity, and the lack of strong hydrothermal alteration. He concluded that the deposit is of low-temperature hydrothermal origin. He postulated migration of copper from mafic lava flows or sills to the more permeable reef breccia during a late stage of regional metamorphism, and visualized mineralization as a more or less post-metamorphism process. He also mentioned that the magnetic expression of the serpentinite at Asbestos Mountain suggests a sill-like form rather than the stock inferred by previous authors.

Runnells (1963) made a detailed study of mineralization at Bornite and discussed vertical as well as lateral zoning of sulfides. He showed that abundant pyrite associated with the copper minerals is partly sedimentary in origin. On the basis of sulfur isotope studies, he concluded that the primary copper minerals and part of the pyrite are of low-temperature, magmatic, hydrothermal origin. He postulated that the copper may have come from chloritized gabbro exposed about two miles southeast of Bornite. He interpreted the gabbro and copper mineralization as post-metamorphism in age. He also reported that spectrographic analyses of serpentinte from the Cosmos Hills indicate a composition similar to that of dunite. Much of the work by Runnells (1963) also was discussed by Lutz (1963) and by Runnells (1969). In the latter paper, the author emphasized the epigenetic origin of the copper deposit, but stated that its source is unknown.

Berg and Cobb (1967) emphasized the uncertainty about the origin of copper minerals at Bornite. They stressed two main possibilities. (1) The copper was derived from nearby stratified rocks, became mobilized during regional metamorphism, and migrated to permeable dolomite breccia. (2) The copper was derived from a concealed magmatic source and was deposited from hydrothermal solutions. The first possibility implies a modified syngenetic origin. The second implies an epigenetic origin.

Patton, Miller, and Tailleur (1968) prepared a reconnaissance geologic map of the Shungnak quadrangle and the southern part of the Ambler River quadrangle. This map shows the generalized geology of the Cosmos Hills at scale 1:250,000 (1 inch = 4 miles). It was especially useful in planning the Division's field work. The explanation includes the latest available paleontological and radiometric data concerning the geologic ages of rocks in the Cosmos Hills, which range in age from Middle Devonian or older to Late Cretaceous. The authors showed that the granite near the Kogoluktuk River is Early Cretaceous in age, intruded the adjacent pelitic strata, and metamorphosed them to garnetiferous schists. This discovery revealed a previously unknown possible source for mineralizing hydrothermal solutions. The authors assigned a Jurassic(?) age to metavolcanic rocks that overlie fossiliferous dolomitic limestone of Middle Devonian age. The Jurassic(?) age is questionable, however, because the map suggests that the metavolcanic rocks contain, or are interlayered with, unfaulted lenses of fossiliferous limestone of Devonian age. The map also shows several high-angle faults in the Cosmos Hills, but does not show low-angle overthrust faults.

Surficial geology and glaciation in and near the Cosmos Hills were discussed by Fernald (1964) who mapped an old moraine along the flanks of the Cosmos Hills, generally below 800 feet altitude, and a younger one in the valley of the Kogoluktuk River. Reed (1932) inferred glaciation in the valleys of Dahl and California Creeks, but no clearcut evidence of valley glaciation there was noted during the recent mapping.

S T R A T I G R A P H Y

Four main stratigraphic formations were recognized in the course of the recent mapping. Three are known or thought to be Paleozoic in age and have undergone progressive regional metamorphism of low to moderate grade. The fourth is Cretaceous in age and has undergone low-grade dynamic metamorphism. In general, the Paleozoic strata are exposed in the central part of the Cosmos Hills and are nearly surrounded by the Cretaceous strata (fig 1). This sequence of metamorphosed rocks, however, is complicated further by doming near intrusive granite, high-angle faulting, and low-angle overthrust faulting, which are discussed under the heading "Structure."

PALEOZOIC ROCKS

Phyllitic schist and related rocks (Pzs, Pzc, Pzt, Pzg)

The lowest stratigraphic formation consists of weakly to moderately metamorphosed pelitic, calcareous, and volcanic strata. It includes a predominant graywacke-bearing, phyllitic schist unit (Pzs), small units of chrystalline limestone (Pzc), and small to large units of greenschist and greenstone of probable metavolcanic origin (Pzt, Pzg). In some outcrops, these rocks are all intimately interlayered or interbedded. The formation underlies as much as 25 square miles in the north-central part of the Shungnak quadrangle, and is more than 5,000 feet thick.

Phyllitic schist (Pzs) -- Thinly bedded, graywacke-bearing phyllite and schist underlie at least 20 square miles in the mapped area. Beds less than one inch to more than one foot thick are obvious in many outcrops and reflect mainly variations in the amount of muscovite and quartz present in the rock matrix. Foliation commonly parallels bedding.

Typical pelitic rocks such as phyllite and muscovite schist are characteristic of this unit. The rocks consist mainly of muscovite, albite, and quartz, with small amounts of chlorite and carbonate. Garnet and biotite are present in beds of appropriate composition and metamorphic grade, but biotite is not plentiful. The abundance of muscovite and albite in the rocks indicates a high K and Na content, and the comparatively small amount of chlorite and biotite in them indicates a low Mg and Fe content. Accessory minerals are sphene, tourmaline, apatite, ziosite, clinozoisite, rutile, hematite, pyrite, and pyrrhotite. Pyrrhotite is most obvious in quartz-rich schist exposed in the bed of California Creek immediately east of massive greenstone (Pzg). The mineral there forms numerous lenses as much as 5 mm long parallel to bedding and foliation.

The pelitic rocks are characterized by abundant carbon and a gradual but conspicuous increase in metamorphic grade toward intrusive granite (Kg). Phyllite exposed on the west bank of Dahl Creek in the SE 1/4 sec. 10, T. 18 N., R. 9 E. (from the Kateel River reference point) contains enough carbon to blacken the hands and clothing of those handling the rock. The phyllite there contains neither garnet nor albite porphyroblasts, but both are abundant in beds of appropriate composition east of the Dahl Creek drainage basin. Thus, near the Kogoluktuk River and its tributaries, the predominant rock is fine- to medium-grained muscovite schist containing either garnet or albite porphyroblasts 1-10 mm in diameter, or both. In general, albite is much more abundant than garnet. Most of the albite porphyroblasts contain enough carbon to make them nearly black, and they strongly resemble ferromagnesian minerals such as hornblende, except for a lack of prismatic cleavage and crystal habit. Both kinds of porphyroblast increase in size and abundance toward the granite, and can be used as indicators of proximity to such rock during exploration.

The quartz content of the phyllite and schist varies widely. In some places, matrix quartz is so abundant that the rock becomes metagraywacke or impure quartzite, which forms distinct beds 1-6 inches thick. The quartz-rich rock commonly is carbonaceous, dark, tough, slabby, and breaks with a nearly conchoidal fracture. It is most conspicuous in prominent outcrops on the west side of the Kogoluktuk River about 1/2-1 mile from granite (Kg). However, thinly bedded, noncarbonaceous, nearly white quartzite crops out near the center of sec. 11, T. 18 N., R. 10 E., where it is associated with noncarbonaceous actinolite schist. Secondary quartz in the form of veins, lenses and pods also is abundant in the phyllite and schist.

Crystalline limestone (Pzc) -- Impure crystalline limestone and marble (pzc) form widely scattered beds from less than 1 foot to as much as 150 feet thick within the predominant phyllite and schist. The typical limestone effervesces quickly in dilute hydrochloric acid, and apparently consists mainly of calcite. It also contains minor muscovite, quartz, and tremolite or actinolite, especially where thin and moderately metamorphosed. Some of the limestone contains accessory pyrite. Many of the limestone bodies are too small to show on the geologic map. The largest, however, extends for more than two miles across the heads of valleys occupied by Glacier and Radio Creeks, and continues northward into the Ambler River quadrangle.

Greenschist (Pzt) -- Noncarbonaceous, porphyroblastic actinolite schist (greenschist) is well exposed and apparently abundant in sec. 11, T. 18 N., R. 10 E. Numerous needle-like crystals of actinolite give the rock a characteristic greenish-gray color and satiny luster. It also contains numerous porphyroblasts of white to creamy albite 1-5 mm in diameter. These crystals contain many tiny inclusions of other minerals, but differ from the black albite porphyroblasts described above by lacking carbon. The rock also contains chlorite, muscovite, quartz, epidote, and minor biotite and carbonate. Accessory minerals are sphene, apatite, pyrite, and magnetite.

The actinolite schist is interpreted here as metatuff, but the map unit is generalized. This rock is intimately interlayered or interbedded with phyllitic schist, metagraywacke, and minor impure quartzite. Beds range from less than one inch to more than one foot thick. The interbedding of pelitic rocks and actinolite schist is believed to reflect contemporaneous deposition of mud and volcanic ash, respectively.

Greenstone (Pzg) -- Tough, massive greenstone, with subordinate greenschist similar to that described above, forms large bodies near Harry and California Creeks. Each of them underlies an area of approximately two square miles, characterized by numerous subangular boulders of greenstone as much as 10 feet in diameter. Several small bodies of similar rock also crop out within the main area occupied by phyllite and schist. The typical greenstone consists mainly of green hornblende or actinolite, epidote, chlorite, albite, and quartz. Garnets 1-10 mm in diameter are abundant in the main body near California Creek, where the metamorphic grade of the rock is moderately high for this area. In contrast, near Harry Creek, where the metamorphic grade is lower, garnet has been observed only as numerous tiny crystals in unusually heavy, thinly bedded, impure quartzite within the greenstone in the SW 1/4, sec. 1, T. 18 N., R. 9 E. In some places, the greenstone also contains small amounts of carbonate and muscovite. Accessory minerals are sphene, pyrite, hematite, and magnetite.

The main bodies of greenstone appear to be tabular like stratigraphic units, and the rock is intepreted here as metatuff perhaps interbedded with metabasalt. Although it is possible that the massive greenstone is intrusive and sill-like, the evidence at hand favors a volcanic origin. In thin section, at least part of the quartz in this rock forms thin lenses and layers parallel to foliation, suggesting relict bedding. Furthermore, in several places the main bodies of greenstone contain interlayered metasedimentary rocks. North of California Creek, for example, the greenstone contains layers of quartz-muscovite schist several feet thick. Likewise, near the head of Harry Creek, the greenstone contains equally thick layers of impure crystalline limestone with minor tremolite-muscovite schist near intrusive serpentinite, in addition to the garnetiferous quartzite described above. The two largest bodies of greenstone also appear to be parts of a single formerly continuous stratigraphic unit 600 to 1,000 feet thick separated by erosion and faulting.

Geologic age -- The age of this formation is uncertain, but is believed to be Paleozoic. No fossils were found in it during or before 1968. However, it underlies a thick fossiliferous dolomitic limestone of known Middle Devonian age, parts of which are lithologically similar to the limestone (Pzc) described above. Thus the rocks beneath the dolomitic limestone (Pzd) probably are not younger than Middle Devonian. On the other hand, the marked change in predominant lithology between the two formations reflects a change in the environment of deposition, and it is possible that the phyllitic schist and related rocks are pre-Middle Devonian in age. The age of this formation, therefore, is reported here as Middle Devonian or older.

Dolomitic limestone (Pzd)

Distribution -- Weakly metamorphosed dolomitic limestone underlies more than two square miles west of Dahl Creek, and is especially well exposed in prominent ridges and cliffs in secs. 3 and 4, T. 18 N., R. 9 E. Much of sec. 10 also is underlain by this rock, but concentrations of limestone rubble are more numerous there than outcrops. In that section, the limestone forms a heavily wooded, nearly triangular ridge immediately west of the upper placer workings along Dahl Creek (see photograph on cover). Near Wesley Creek, the formation is unexposed in this quadrangle, but is inferred on the basis of bedding attitudes found in good outcrops immediately north of the area. The formation also underlies as much as 20 square miles in the Ambler River quadrangle, and contains copper-bearing dolomitic reef breccia at Bornite.

Lithology -- The predominant rock of this formation in the Shungnak quadrangle is thinly bedded limestone, but small amounts of dolomite also are present. Beds commonly are from 2 mm to 6 inches thick. Extremely thin beds, showing distinct mineral lineatio were found in several places, especially in the lower part of the formation. These beds produce abundant platy rubble. Minor dolomite breccia also was seen in the middle or upper part in the SW 1/4 of sec. 3, but no copper minerals were found. A sample of the typical breccia consists of medium-light-gray dolomite fragments 1-15 mm in diameter set in a medium-dark-gray carbonate matrix. A sample of the typical limestone shows alternating gray and white beds a few millimeters thick. In thin section, the white beds are completely recrystallized, but adjacent gray beds containing widely disseminated dusty opaque inclusions are not. The inclusions probably are carbonaceous material similar to anthraxolite described by Runnells (1965). A petroliferous odor is characteristic of parts of this formation, and is especially strong in the SW 1/4 of sec. 3 on rainy days. Fragments of white to pale-bluish-gray calcite apparently derived from veins were seen near the east end of the main limestone ridge in sec. 3. In the Ambler River quadrangle, the formation also contains interbedded phyllite.

Attitude and thickness -- The map indicates that the limestone strikes generally northwest, dips about 25° SW, and is more than 1,500 feet thick. Local variations in strike and dip suggest possible folding and (or) faulting within the formation, but such variations also might be due, in part, to slumping during sedimentation or to recent frost action. Chaotic bedding attitudes attributed to slumping and high initial dips in a reef environment are common in this formation near Bornite, and its thickness there exceeds 2,000 feet.

Geologic age -- A Middle Devonian age for this limestone has been established on the basis of fossils collected in the Ambler River quadrangle (Patton, Miller, and Tailleur, 1968). No fossils were found in the formation in the Shungnak quadrangle in 1968.

Metabasalt and related rocks (Pzp, Pzv, Pzl, Pza)

A thick formation of metavolcanic and metasedimentary rocks of low metamorphic grade is exposed in a belt as much as 1/2 mile wide bounded by two low-angle overthrust faults along the southern and eastern sides of the mapped area. Rocks of this belt overlie the Middle Devonian dolomitic limestone (Pzd) and apparently surround the rocks of Paleozoic age described above (fig 1). The stratigraphic sequence within the belt includes a lower phyllitic member (Pzp) and a predominant upper metavolcanic member (Pzv). The upper member contains lenses of limestone (Pzl) and agglomerate (Pza). The lower member contains undifferentiated limestone and metvolcanic rocks. Metavolcanic rocks of this formation also are exposed at the eastern edge of the Shungnak D-2 quadrangle, and extend eastward for many miles (Patton, Miller, and Tailleur, 1968). The total thickness of the formation is uncertain, but the upper member is at least 1,500 feet thick near Ferguson Peak.

Lower phyllitic member (Pzp) -- The lower member consists mainly of interbedded phyllite, metagraywacke, and metatuff. In this quadrangle, the rocks are exposed intermittently from the northern face of Inerevuk Mountain to the west side of Dahl Creek. Metatuff composed largely of chlorite, actinolite, and epidote is most abundant near the creek, and forms numerous beds from 1 mm to several inches thick. This rock is interbedded with carbonaceous phyllite composed mainly of muscovite, albite, and quartz. At the northern face of Inerevuk Mountain, tough, slabby, quartz-rich rock interpreted here as metagraywacke is locally abundant. In that vicinity, Heide, Wright, and Rutledge (1949, fig 4) showed a limestone layer 60-75 feet thick interbedded with quartz-muscovite rocks and minor chlorite-actinolite schist now interpreted as parts of this member. The rocks they described, however, are mainly in the adjacent Ambler River quadrangle. Patton, Miller, and Tailleur (1968) also showed lenses of metavolcanic rocks and limestone in phyllite now interpreted as part of this member west of Shungnak Mountain and northeast of Bornite, respectively.

Upper metavolcanic member (Pzv) -- The upper member consists mainly of metabasalt and metatuff, but also contains moderate amounts of interbedded phyllite and metagraywacke, and small lenses of limestone. Massive metabasalt is most abundant near the heads of California and Canyon Creeks, and is associated with subordinate fragmental metavolcanic rock. The metabasalt contains abundant plagioclase, epidote, and chlorite, and exhibits a relict diabasic texture in thin section. It also contains numerous amygdules as much as 2 mm in diameter filled with chlorite. Well-bedded metatuff composed of actinolite, epidote, chlorite, and albite is abundant throughout the member along the southern edge of the mapped area. It is especially well exposed on a prominent peak about two miles northeast of the Dahl Creek airstrip. This peak was named Stout Mountain by Read and Lehner (1959). The metatuff there is interbedded with phyllite composed mainly of muscovite, quartz, albite and probable very fine-grained biotite. Some of the interbedded metatuff and phyllite at Stout Mountain strongly resemble rocks of the lower member (Pzp) exposed just west of Dahl Creek. Accessory minerals in the metavolcanic rocks are sphene, rutile, hematite, and magnetite. At a prominent knob near the center of the SW 1/4 sec. 22, T. 18 N., R. 10 E., the metavolcanic rocks contain enough microscopic magnetite to deflect a compass needle.

Agglomerate (Pza) -- Fragmental rock interpreted here as metamorphosed agglomerate or intraformational volcanic conglomerate crops out near the center of sec. 12, T. 18 N., R. 10 E. This rock is characterized by an extremely rough weathered surface on which numerous unstretched subangular fragments of metabasalt as much as 10 inches in diameter stand out above the surrounding fine-grained matrix. The fragments are lithologically similar to underlying amygdaloidal metabasalt. The matrix is metatuff or metasedimentary rock derived from metavolcanic rock. The agglomerate or conglomerate is overlain by greenschist in the southern part of sec. 12, and appears to be part of a conformable sequence of predominantly metavolcanic strata (Pzv). Fragmental metavolcanic rock also is associated with metabasalt in the NE 1/4 sec. 1, T. 18 N., R. 10 E., but is not differentiated on the geologic map.

Limestone (Pzl) -- Thinly bedded limestone is interlayered with the metavolcanic strata (Pzv) in many places along the southern side of the mapped area. The limestone forms lenses from less than 1 foot to as much as 30 feet thick, which commonly parallel bedding and foliation in adjacent metatuff. The largest known lens is in the NE 1/4 sec. 14, T. 18 N., R. 9 E., near the summit of Stout Mountain. On the southern side of the mountain, this limestone contains a layer of greenish-gray metatuff approximately 20 feet long and as much as 1 1/2 feet thick, which parallels bedding in the limestone (fig 3). The field relations indicate contemporaneous deposition of limestone and tuff.

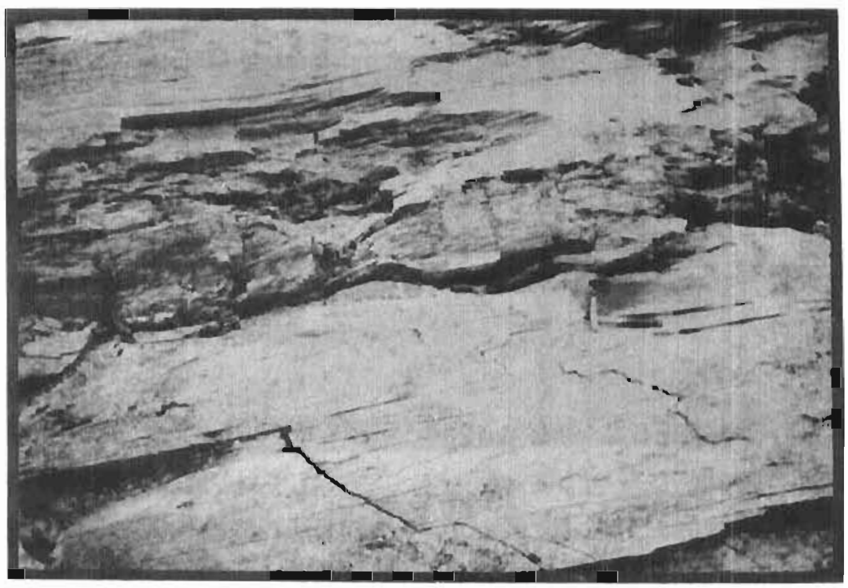

Figure 3
Metatuff interbedded with bioclastic limestone near the summit of Stout Mountain. Hammer lies on bioclastic limestone

The limestone (Pzl) is at least partly bioclastic. At Stout Mountain, limestone adjacent to the metatuff lens described above consists mainly of calcite, but contains numerous microscopic grains of clastic quartz and macroscopic grains of dark-gray clastic calcite as much as 2 mm in diameter. In thin section, some of the dark-gray clastic grains were recognized as distinct fragments of crinoids replaced by calcite. Much larger fragments of crinoids (fig 4) were found in similar limestone float in the southeast corner of sec. 22, T. 18 N., R. 10 E. The float there apparently was derived from a small body of bioclastic limestone exposed about 1,000 feet west northwest of the summit of Ferguson Peak. Fragments of crinoid stems from the Ferguson Peak locality are as much as 1/4 inch in diameter and 1/2 inch long.

Geologic age -- The age of this formation is uncertain but most likely is Early Paleozoic. The lower phyllitic member (Pzp) is believed to be a continuation of a narrow strip of rocks that Patton, Miller, and Tailleur (1968) mapped as phyllite of Paleozoic age immediately above Middle Devonian limestone in the western and northern parts of the Cosmos Hills. The upper metavolcanic member (Pzv) is known to be part of a stratigraphic unit they mapped as mafic volcanic rocks of Jurassic(?) age, in which they also mapped unfaulted lenses of fossiliferous limestone of Middle Devonian age. At least one such lens near the Mauneluk River about 12 miles east of the Shungnak D-2 quadrangle contains phaceloids (rugose corals) of possible Devonian age. The presence of crinoid stems in similar limestone lenses interbedded with metavolcanic rocks of this formation in the Shungnak quadrangle also suggests that the strata are Devonian in age. J. T. Dutro, Jr. (written communication, April 1969) suggested that the age of this formation could be reported tentatively as probably Early Paleozoic, possibly Devonian. The evidence at hand suggests that the pelitic and metavolcanic rocks of this formation may be grossly equivalent to pelitic and metavolcanic rocks that underlie the Middle Devonian limestone (Pzd).

Figure 4
Crinoid fragments in bioclastic limestone from Ferguson Peak. The specimen has been etched slightly with weak hydrochloric acid. Approximately natural size.

CRETACEOUS ROCKS

Metaconglomerate and related rocks (Ks, Kp, Kc)

The highest stratigraphic formation in the mapped area consists of a predominant conglomeratic sandstone and slate unit (Ks), phyllite (Kp), and slaty conglomerate (Kc). The rocks have undergone pervasive shearing and low-grade dynamic metamorphism, which distinguish them from underlying strata. Other distinguishing features include an abundance of coarse clastic material and a lack of limestone. The formation underlies approximately 30 square miles in the Shungnak D-2 quadrangle and large areas near Cosmos and Bismark Mountains (fig 1). The thickness of these strata is unknown, but probably is at least 1,000 feet in the mapped area.

Conglomeratic sandstone and slate (Ks) -- The conglomeratic sandstone and slate unit is well exposed on mountain summits and flanks along the southern and eastern sides of the mapped area, but severe frost action has reduced many outcrops to concentrations of slabby boulders 1-20 feet in diameter. The map unit consists of interbedded metaconglomerate, metasandstone, metagraywacke, and phyllite or slate. Beds 1-6 feet thick are common. Fine-grained rocks exhibiting typically slaty cleavage were observed mainly south of an east-trending fault south of Ferguson Peak. Phyllite, metagraywacke, and metasandstone are widespread, but are especially abundant east of the Kogoluktuk River. Metaconglomerate also is widespread, but is most abundant west of the river. Common minerals in all of these rocks include quartz, muscovite, chlorite, biotite, and feldspar. Most cobbles and pebbles in the metaconglomerate are white quartz (fig 5), but pebbles of quartz-rich schist and gneiss also are present. No limestone pebbles or cobbles were seen. The largest clastic fragment found in the metaconglomerate was a quartz boulder 6 x 8 x 15 inches near Wesley Creek. Alinement of stretched cobbles, pebbles, and grains in these sheared rocks gives them a conspicuous lineation, which commonly trends northeast. Recognition of this feature is helpful in mapping, because it enables the mapper to distinguish between outcrops and frost-heaved debris.

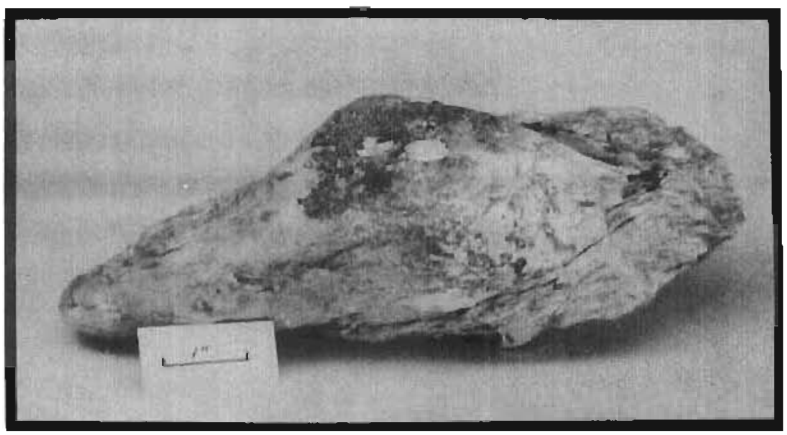

Figure 5
Stretched quartz cobble in foliated and lineated Metaconglomerate from the NW 1/4 sec. 15, T. 18 N., R. 9 E., near Dahl Creek.

Phyllite (Kp) -- Phyllite was mapped separately east of Wesley Creek primarily to emphasize the northeast trend of bedding where well-foliated metaconglomerate predominates. Bedding and foliation there are parallel. In thin section, the phyllite is composed mainly of muscovite, quartz, and probable feldspar. The rock also contains scattered porphyroblasts of chlorite as much as 0.2 mm in diameter oblique to foliation and bedding. Carbon is present, but is less abundant than carbon in phyllite of Paleozoic age exposed near Dahl Creek.

Slaty metaconglomerate (Kc) -- Highly sheared metaconglomerate characterized by extremely stretched and flattened pebbles and cobbles of greenschist (fig 6) is well exposed at the summit of Ferguson Peak, and in the north-central part of sec. 12, T. 18 N., R. 10 E. Similar rock is exposed near the east edge of the Shungnak D-2 quadrangle and at the south end of a prominent ridge west of Kollioksak Lake (figs 7 and 8). At Ferguson Peak and Kollioksak Lake, the metaconglomerate is interbedded with sheared slate or phyllite. At Kollioksak Lake, these rocks conformably underlie conglomeratic sandstone and slate (Ks), and appear to constitute part of a basal member of the entire formation. The greenschist fragments in the metaconglomerate presumably could have been derived by erosion from underlying metavolcanic rocks (Pzv). However, the metaconglomerate and related rocks there are separated from underlying metavolcanic rocks by a low-angle overthrust fault (fig 8), and an erosional unconformity between the formations cannot be proved. Similarly, at Ferguson Peak, sheated metaconglomerate (Kc) overlies relatively unsheared greenschist and fossiliferous limestone of probable Paleozoic age (Pzv, Pzl), and the contact between the two formations is interpreted as a low-angle overthrust fault rather than a simple unconformity. The faulting is discussed further under the heading "Structure."

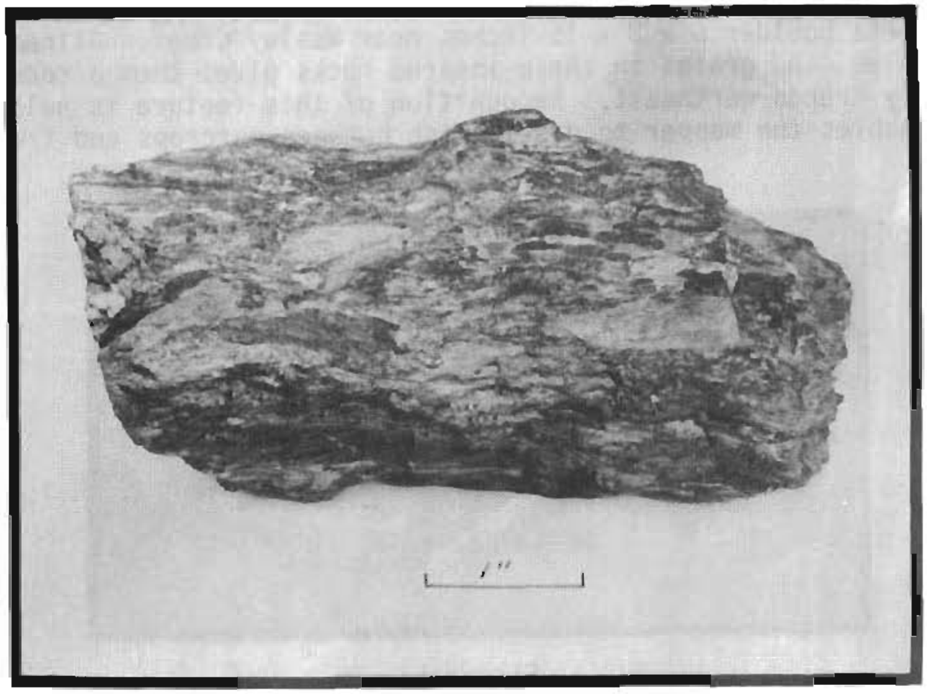

Figure 6
Sheared slaty metaconglomerate (Kc) from the NW 1/4 sec. 12, T. 18 N., R. 10 E., near the head of California Creek. Light gray patches visible on the upper surface of the specimen in this photograph are stretched pebbles of greenschist set in a grayish-red, hematitic, slaty matrix.

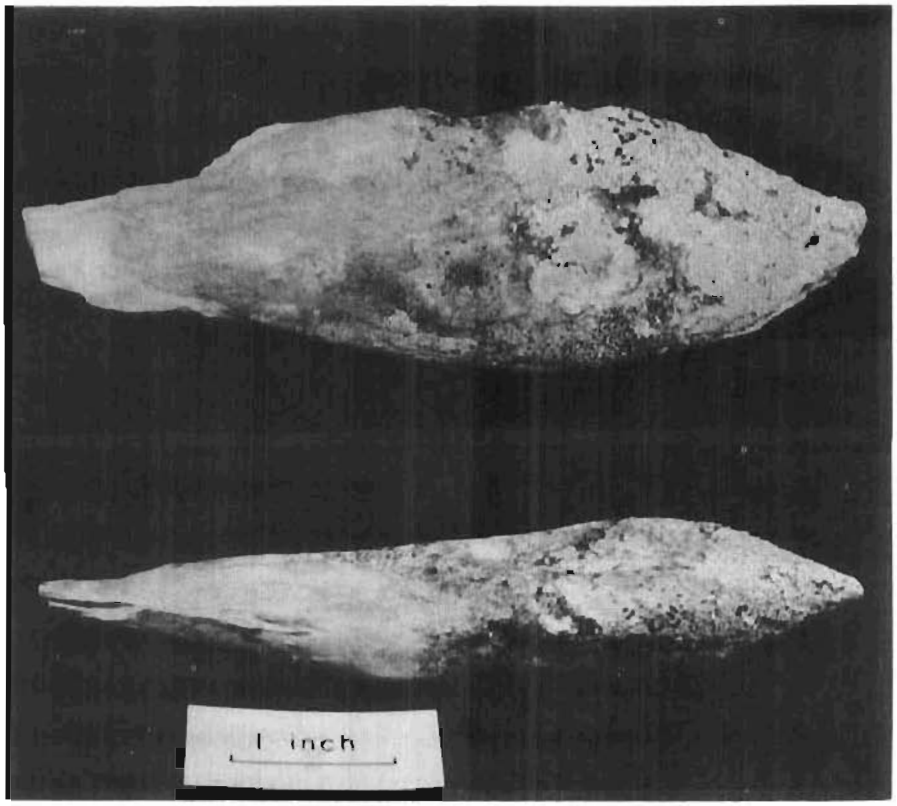

Figure 7
Two views of a stretched and flattened pebble from slaty metaconglomerate exposed west of Kollioksak Lake. Right end faced southwest in the outcrop from which this pebble came.

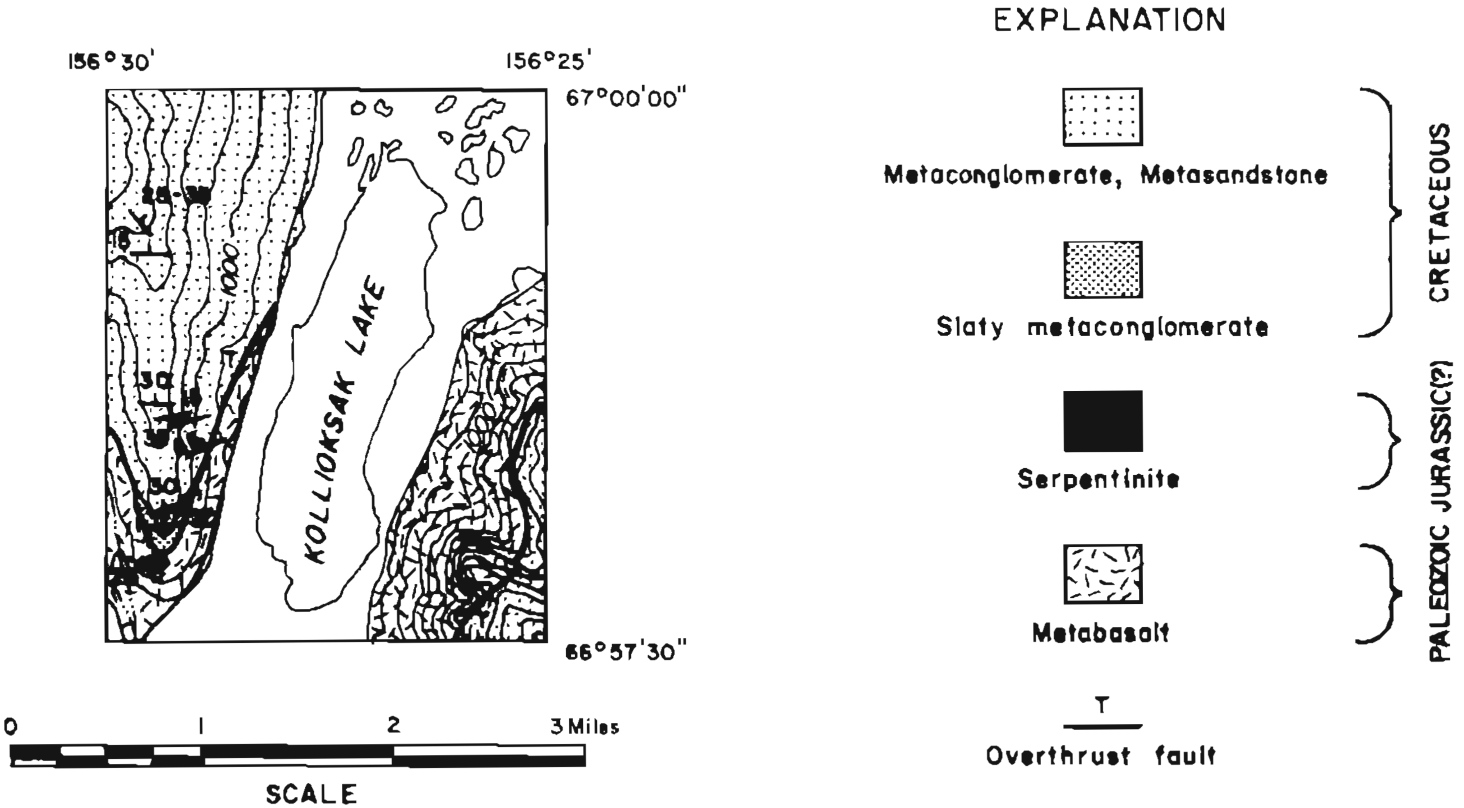

Figure 8

Reconnaissance geologic map of the Kollioksak Lake area showing an overthrust fault beneath Cretaceous rocks. Geology west of the lake was mapped by C. E. Fritts, 1968. Geology east of the lake was modified from Patton, Miller and Tailleur (1968).

Geologic age -- A Late Cretaceous age was assigned to the metaconglomerate and related rocks of the Cosmos Hills by Patton, Miller, and Tailleur (1968) on the basis of correlation with similar rocks exposed in the Baird Mountains and Selawik quadrangles west of Kobuk. The conglomeratic strata in those quadrangles contain tuffaceous beds dated by potassium-argon methods. The authors also correlated the slaty conglomerate (Kc) of the Kollioksak Lake area with similar but fossiliferous rock of probable Early Cretaceous age mapped by Patton and Miller (1968) in the Selawik quadrangle. In the present report, an Early to Late Cretaceous age is assigned to the conglomeratic rocks of the Cosmos Hills, because unit Kc appears to be overlain conformably by unit Ks west of Kollioksak Lake (fig 3).

I N T R U S I V E   R O C K S

JURASSIC(?) ROCKS

Serpentinite (Js)

Distribution and size -- Serpentinite forms numerous, lenticular, generally sill-like bodies intrusive into strata of known and probable Paleozoic ages. West of the Kogoluktuk River, this rock intrudes at least two formations. East of the river, however, it apparently intrudes only unit Pzv. The largest serpentinite body in the mapped area is exposed about one mile west of Ferguson Peak. The rock there forms a sill-like sheet as much as 400 feet thick, which crops out intermittently along strike for at least 5,000 feet.

The four small bodies of serpentinite shown on the map near the confluence of Stockley and Dahl Creeks formerly were included in the stock inferred at Asbestos Mountain by Coats (1943). At least two of the lenses mapped on opposite sides of Dahl Creek at the north edge of the Shungnak quadrangle appear to be parts of a gently dipping sheet through which the creek has cut. The serpentinite exposed near Stockley Creek may have been part of that sheet. The westernmost of the four bodies also might be part of that sheet, but is thought to be a separate pod occupying a slightly higher stratigraphic position. Serpentinite exposed at the summit of Asbestos Mountain just north of the Shungnak quadrangle is interpreted here as another larger tabular body which caps the mountain.

Lithology -- The serpentinite has undergone shearing and brecciation as well as complete metamorphism. Shearing in this rock is most intense along the north and east faces of Inerevuk Mountain. The lenticular body mapped in sec. 10, T. 18 N., R. 9 E., for example, exhibits breccia fragments 1/4 inch to 6 inches in diameter. The surface of that body is littered with hundreds of well foliated serpentinite chips of comparable size. This lens also contains layers of relatively unsheared serpentinite as much as 5 feet thick and 15 feet long, which are approximately parallel to foliation. One outcrop on the northeast side of the lens exhibits a face which dips 30° SW, perhaps parallel or nearly parallel to an overthrust fault mapped nearby. Slickensides there show striations plunging down dip.

Where least sheared, the typical serpentinite is composed largely of antigorite. Crystals of this mineral commonly are less than 0.2 mm in diameter. Near Wesley Creek, some samples of serpentinite exhibit textures which suggest that the rock formed by complete alteration of fine-grained dunite. Other samples contain antigorite crystals as much as 3 mm in diameter set in a matrix composed mainly of very fine-grained antigorite. Magnetite is a common accessory mineral, and is abundant enough in some places to deflect a compass needle. Other accessory minerals are pyrite and chromite.

Several of the more interesting or unusual minerals found in the mapped area are associated with the serpentinite. Many outcrops exhibit tiny veinlets of tremolite 1-2 mm wide. Seams of chrysotile as much as three inches wide have been reported near Dahl Creek at the north edge of the Shungnak quadrangle (Coats, 1943, p 2, 3). The serpentinite in sec. 10 also displays seams which contain fibrous serpentine crystals as much as eight inches long. Float derived from serpentinite exposed near the head of Harry Creek includes talc, coarse dolomite crystals, and tremolite schist which contains small lenses of vivid green chromium-bearing muscovite. Green boulders currently recovered from Dahl Creek placer deposits for sale as jade also were derived from the serpentinite. Anderson (1945, p 17) reported the presence of nickel in a hand sample of intermixed antigorite and chrysotile collected from serpentinite exposed near the mouth of Stockley Creek, but the amount of nickel in the rock is believed to be very small.

Geologic age -- The age of the serpentinite is uncertain. On the basis of field evidence, it can be described only as post-Middle Devonian, pre-Cretaceous. The serpentinite intrudes a sequence of Paleozoic strata including rocks of Middle Devonian age, but is not known to intrude strata of Cretaceous age. Patton, Miller, and Tailleur (1968) tentatively assigned a Jurassic(?) age to this rock on the basis of correlation with a mafic igneous complex exposed in the Christian quadrangle about 300 miles east of the Cosmos Hills. That complex consists mainly of gabbro, diabase, basalt, and diorite, but also includes interbanded leucogabbro, anorthosite, pyroxenite, and peridotite (Reiser, Lanphere, and Brosge, 1966, p 69-70). Potassium-argon dating of hornblende suggests an Early or Middle Jurassic age for the complex (idem., p 71). The serpentinite of the Cosmos Hills presumably could be related to pyroxenite and peridotite of this complex.

CRETACEOUS ROCKS

Granite (Kg)

Distribution and size -- Gneissic granite forms a pluton as much as 1 3/4 miles in diameter near the Kogoluktuk River. The granite is well exposed along the river and on ridges near Radio and Lynx Creeks. Schist crops out in several places along the northern side of the pluton, providing good control for placement of the granite-schist contact there. Along the southern side, however, outcrops of granite and schist are as much as one mile apart. Thus the nearly circular outline of the pluton shown on the map is generalized, and merely indicates the minimum area underlain by granite. Small unmapped bodies of granitic rock most likely related to the pluton were found near marble and limestone in the western part of sec. 11, T. 18 N., R. 10 E., and near garnetiferous schist in the SE 1/4 sec. 12, T. 18 N., R. 9 E. Minor gneissic granite float also was found on the south bank of Glacier Creek in the SW 1/4 sec. 7, T. 18 N., R. 10 E.

Lithology -- The granite consists mainly of albite, microcline, quartz, and muscovite. Biotite is much less abundant. The microcline forms numerous crystalloblasts 1/2 to 3/4 inch long. Some are smeared out parallel to well developed foliation. Deformation of these crystals presumably occurred during a late stage of the emplacement and metamorphism. Accessory minerals are sphene, carbonate, and zircon. Garnets 1-5 mm in diameter are present in some outcrops adjacent to schist. The granite is cut by minor aplite dikes and sills, which are oblique and parallel to foliation, respectively.

Lithologies at the northernmost outcrops of the granite on the Kogoluktuk River clearly indicate that this rock intrudes the adjacent schist (Pzs). The granite there contains inclusions of garnetiferous muscovite schist similar to the host rock. The granite also contains distinct muscovite- and garnet-rich layers, which represent partly assimilated schist. Some layers contain stubby crystals as much as 3 mm in diameter, which resemble albite porphyroblasts characteristic of the intruded schist (Pzs). Small, nearly round albite crystals also are characteristic of granite gneiss found near marble east of Lynx Creek.

The granite of the pluton is characterized by excellent joints from a few inches to several tens of feet apart. Outcrops along the Kogoluktuk River show at least two kinds. Gently dipping joints are nearly parallel to foliation. Others are nearly vertical. Joint blocks as much as 25 feet in diameter are numerous, especially on ridges underlain by granite bedrock near Radio and Lynx Creeks (fig 9). Similar blocks have been distributed along the river downstream from the southernmost outcrops, most likely during episodes of high run-off in Pleistocene time.

Figure 9
Joint blocks in granite gneiss near Lynx Creek.
Kelty pack shows scale.

Geologic age -- An Early Cretaceous age was assigned tentatively to this granite by Patton, Miller, and Tailleur (1968) on the basis of potassium-argon dating of hornblende from associated soda aplite. Hornblende has not been observed by the writer in thin sections of granitic rock from this area. Nevertheless, an Early Cretaceous age is compatible with available field evidence, and therefore is accepted. Field relations merely indicate that the granite cannot be older than Middle Devonian, because it intruded, deformed, and metamorphosed a stratigraphic sequence that includes rocks of Middle Devonian age. The granite presumably is not younger than Early Cretaceous, because it is part of a folded, faulted, and metamorphosed sequence over which strata of Early to Late Cretaceous age have been thrust.

S T R U C T U R E

The principal geologic structures recognized in the course of the recent mapping are a dome near the Kogoluktuk River, a horst which includes the dome, and a window which includes both of those structures. Other structural features include high-angle faults of two distinct ages, low-angle overthrust faults, minor folds, crenulations, and widespread lineation.

DOME NEAR INTRUSIVE GRANITE

The dome near the Kogoluktuk River consists of several thousand feet of phyllitic schist and related rocks (Pzs, Pzc, Pzg) which dip outward away from intrusive granite (Kg). The structure is shown on section B-B' (fig 2). The large bodies of greenstone (Pzg) mapped near Harry and California Creeks are the youngest of the domed strata exposed in the Shungnak D-2 quadrangle. The distribution of these rocks in relation to the granite is slightly asymmetrical, but doming apparently accompanied emplacement of the granite.

HORST AND EARLY HIGH-ANGLE FAULTS

A major horst containing the domed strata is bounded by two north-trending, high-angle faults of large displacement approximately six miles apart. The western one, here called the Dahl Creek fault, accounts for the abrupt eastward termination of dolomitic limestone (Pzd) and westward termination of greenstone (Pzg) near Dahl Creek. This fault is believed to extend northward into the Ambler River quadrangle and to account for the eastward termination of dolomitic limestone near the confluence of Riley and Ryan Creeks in that area. The eastern fault, here called the Lynx Creek fault, accounts for marked changes in bedding attitudes and topography near the head of Lynx Creek and for the abrupt eastward termination of garnetiferous greenstone (Pzg) near California Creek. Phyllite and greenschist east of the Lynx Creek fault are not garnetiferous. The horst is shown on section B-B' (fig 2).

Rocks in the horst apparently have been upthrown more than 1,500 feet. Displacement on the Dahl Creek fault is at least 1,500 feet, because the dolomitic limestone (Pzd) is completely missing east of Dahl Creek. Displacement on the Lynx Creek fault is at least 1,000 feet, because the garnetiferous greenstone (Pzg) is completely missing east of this fracture. In view of the differences in bedding attitudes and metamorphic grade on opposite sides of the Lynx Creek fault, however, it is likely that displacement along that fracture is much greater than 1,000 feet.

The rocks inside the horst also have been faulted as well as domed. A nearly straight, west-trending, high-angle fault of moderate to large throw forms the southern boundary of greenstone (Pzg) mapped near Harry Creek. Rocks north of that fault are inferred to be upthrown, because they are more metamorphosed than adjacent rocks to the south. Throw is inferred to be at least 500 feet, because the greenstone does not crop out along Wye Creek. Another fault of small to moderate throw is inferred along the west side of the greenstone (Pzg) mapped near California Creek, because the greenstone-schist contact there is nearly straight. Displacement along that fault may be less than 500 feet.

The Dahl Creek and Lynx Creek faults and others that offset rocks within the horst all appear to be parts of a rectilinear system of early high-angle faults. High-angle faults of similar trend were mapped by Patton, Miller, and Tailleur (1968) near Aurora Mountain in the Ambler River quadrangle (fig 1). None of the faults of this system is known to offset low-angle overthrust faults in the Cosmos Hills. The early fractures, therefore, are believed to have formed during an episode of block faulting which post-dates granite emplacement, doming, and regional metamorphism, but pre-dates low-angle overthrust faulting.

COSMOS HILLS WINDOW AND LOW-ANGLE OVERTHRUST FAULTS

The most important geologic structure in the Cosmos Hills is a window about 20 miles long and 5 to 8 miles wide, which is referred to here as the Cosmos Hills window (fig 1). This structure is bounded by two major low-angle overthrust faults characterized by displacements measured in miles. These faults were mapped primarily on the basis of field evidence found in 1968 in the Shungnak D-2 quadrangle and the Kollioksak Lake area (figs 2 and 8). They were extended into the Ambler River quadrangle (fig 1) on the basis of aerial reconnaissance and reinterpretation of field relations mapped by Read and Lehner (1959) and Patton, Miller, and Tailleur (1968). The upper overthrust fault underlies allochthonous metaconglomerate and related rocks of Cretaceous age. In the western part of the Cosmos Hills, this fault is in the approximate position of one inferred by Lehner between metaconglomerate and serpentinite. The lower overthrust fault, first recognized in 1968, overlies autochthonous dolomitic limestone of Middle Devonian age. The lower fault accounts for the westward thinning of the dolomitic limestone in the Cosmos Hills.

Field evidence for the overthrust faults is indisputable in the Shungnak D-2 quadrangle. Evidence for the lower fault consists of (1) a conspicuous discordance in bedding between units Pzv and Pzs near Stout Mountain, and (2) a marked difference in metamorphic grade between units Pzg and Pzv near Ferguson Peak. Evidence for the upper overthrust fault consists of (1) a conspicuous discordance in bedding between unit Ks and units Pzp and Pzv from Inerevuk Mountain to Ferguson Peak, (2) a marked difference in the degree of internal shearing in unit Ks compared to units Pzv and Pzl at Stout Mountain and Ferguson Peak, and (3) an obvious discordance between metaconglomerate and underlying metavolcanic rocks west of Kollioksak Lake (fig 8). The metaconglomerate west of the lake dips northward into the fault contact between the two formations.

The direction of movement along the lower overthrust fault is uncertain, but is believed to have been toward the north northeast. No indisputable evidence of such movement has been found in the Shungnak quadrangle. However, the Cosmos Hills trend west-northwest approximately parallel to the regional trend of the adjacent part of the Brooks Range, which is known to contain west-northwest-trending thrust faults (king, 1967). The components of stress which produced those faults, as well as the range itself, presumably were oriented approximately perpendicular to the range. In other words, at least some of the rocks of the Brooks Range and foothills, including the Cosmos Hills, have been thrust toward the north northeast.

A northeasterly direction of movement of rocks that overlie the upper overthrust fault in the Cosmos Hills is indicated clearly by field evidence in the Shungnak quadrangle. Lineation and stretched pebbles in metaconglomerate and related rocks (Ks and Kc) consistently strike northeast. Many of the pebbles are so strongly deformed that they resemble flattened cigars (fig 7). They also display striations or slickensides which trend northeast. This kind of deformation can be explained only by shearing in a northeasterly direction.

The evidence at hand suggests that the metaconglomerate and related rocks were thrust northeastward against and across a buttress of older more consolidated rocks, and that they became sheared, dynamically metamorphosed, and crenulated in the process. The metaconglomerate and related rocks are most deformed along the south-southwestern side of the Cosmos Hills (Patton, Miller, and Tailleur, 1968). This suggests that gentle arching of the Cosmos Hills area along a west-northwest-trending axis occurred sometime after initial overthrust faulting of the metavolcanic rocks (Pzv) but before overthrust faulting of the Cretaceous strata (Ks) was completed. The presence of pervasive shearing in this formation and the absence of such shearing in underlying strata strongly suggests that the Cretaceous strata were poorly consolidated when thrusting began. As thrusting and shearing continued, however, the formation became recrystallized to rocks such as metaconglomerate and phyllite. Under continued stress, the three isolated patches of extremely deformed metaconglomerate (Kc) mapped in the Shungnak D-2 quadrangle apparently were overridden by the main part of the formation (Ks). During a late stage of the thrusting and dynamic metamorphism, crenulations oriented north-northwest nearly perpendicular to the direction of thrusting developed in slaty metaconglomerate (Kc) at Ferguson Peak (fig 10). Crenulations have not been observed in this formation elsewhere in the mapped area. Their presence at Ferguson Peak and the irregular course of the upper overthrust fault on the map there suggest that the thrust itself has been slightly folded in that area. However, an alternative interpretation of structure there is discussed under the heading "Late High-Angle Faults."

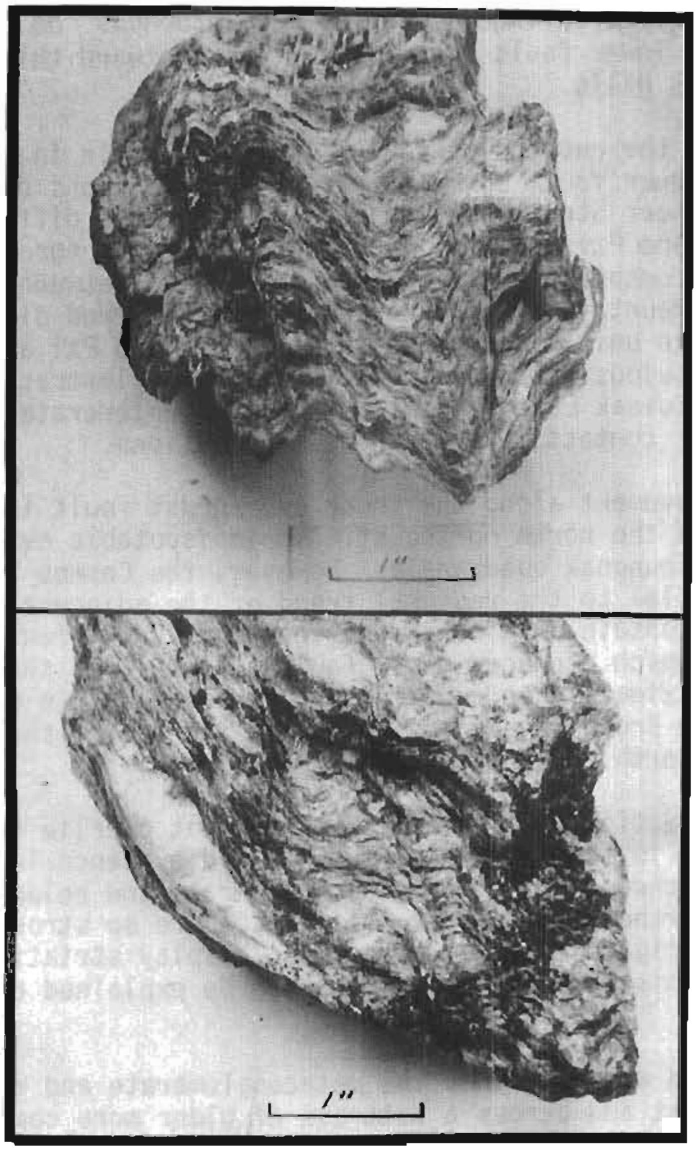

Figure 10
Crenulated slaty metaconglomerate (Kc) from the south side of the summit of Ferguson Peak. Two views show opposite ends of the same sample. The light gray lens about two inches long is a stretched pebble. Other pebbles are so severaly deformed they are difficult to recognize.

The amount of displacement on the lower overthrust fault is uncertain, but is believed to be very large. Field relations in the Cosmos Hills suggest a minimum displacement of eight miles along this fault, because metabasalt and related rocks (Pzv, Pzp, etc.) apparently have been thrust across the entire Cosmos Hills window area. Patton, Miller, and Tailleur (1968) have shown that the northern limit of the metavolcanic rocks (their Jv unit) is approximately six miles north northeast of Bornite, and that the formation extends along the entire southern flank of the Brooks Range in the Ambler River quadrangle. The northern limit of the metavolcanic rocks is about 12 miles from the southern edge of the Cosmos Hills window. The possibility that the northern edge of the metavolcanic rocks actually is the leading edge of the lower thrust plate now recognized in the Cosmos Hills recently was discussed with I. L. Tailleur (oral communication, April, 1969). If so, it is possible that displacement on the lower overthrust fault is at least 12 miles.

The amount of displacement on the upper overthrust fault also is believed to be large, but is more difficult to determine. If the slaty metaconglomerate (Kc) in the Shungnak quadrangle is equivalent to similar rocks known to be 4,500 feet thick in the Selawik quadrangle, as suggested by Patton, Miller, and Tailleur (1968), it seems likely that several thousand feet of strata have been removed by thrusting along this fault. Large displacement also is suggested by the fact that bedding in the main metaconglomerate (Ks) in the Shungnak quadrangle commonly dips more steeply than the underlying overthrust fault. Patton, Miller, and Tailleur (1968) have shown that the metaconglomerate and related rocks now placed in the upper thrust plate probably extended as far north as the middle of the Ambler Lowland (fig 1), although part of the formation has been eroded from that area. The field relations suggest that displacement along the upper overthrust fault most likely was at least four miles and possibly much more.

LATE HIGH-ANGLE FAULTS

Several late high-angle faults cut the low-angle overthrust faults as well as rocks of Paleozoic to Cretaceous age. These high-angle fractures are believed to be post-Cretaceous in age. Two north-trending faults in the eastern part of the map area are characterized by throws of several thousand feet. An east-trending fault mapped south of Ferguson Peak accounts for a conspicuous break in topography in an area underlain mainly by Cretaceous metaconglomerate and related rocks. In the field, the general appearance of the metaconglomerate and related rocks on opposite sides of this fault is different. The rocks south of the fault exhibit distinct slaty cleavage and are less sheared than rocks to the north. Throw along this fault, therefore, is believed to be several hundred feet or more.

In sec. 15, T. 18 N., R. 9 E., Dahl Creek occupies a steep-sided gorge or canyon, which is directly in line with the Dahl Creek fault. The position and straightness of the canyon suggest that the Dahl Creek fault may have been active again in post-Cretaceous time and that it cut the Cretaceous metaconglomerate along the canyon. If so, displacement must have been very slight, because it does not appear to have offset the two major overthrust faults mapped there.

The north-northeast-trending portion of the upper overthrust fault mapped about 1000 feet east of the summit of Ferguson Peak may reflect an unmapped high-angle fault. Such a fracture presumably could extend north-northeastward toward the center of sec. 23, T. 18 N., R. 10 E., and could offset both low-angle overthrust faults mapped in that section. If so, it would appear that rocks east of the high-angle fault have been downthrown several hundred feet. This would be reasonable if it could be shown that the lower overthrust fault is south rather than north of the small body of serpentinite mapped near Juanita Creek. Such an interpretation is difficult to prove, however, because of a lack of outcrops.

MINOR FOLDS AND CRENULATIONS

Minor folds and crenulations were observed in many places, but were mapped only where especially obvious or abundant. Small anticlines were mapped in greenstone near the head of Harry Creek and in metaconglomerate on Inerevuk Mountain. These folds are as much as 10 feet wide and 4 feet high. Greenstone north of Harry Creek also displays tight chevron folds as much as a few inches high on the flanks of broad folds as much as 5 feet high (fig 11). Similar chevron folds and crenulations were observed in phyllite near Dahl and Wonder Creeks, and in schist on the west side of the Kogoluktuk River north of the granite pluton. The significance of these folds is uncertain. Some may have formed during granite emplacement and regional metamorphism. Others, especially those which involve Cretaceous strata, presumably formed during the episode of dynamic metamorphism that accompanied overthrust faulting.

Figure 11
Folded metatuff (greenstone) near the center of sec. 2, T. 18 N., R. 9 E., north of Harry Creek. Small chevron folds are superimposed on the flanks of broader folds.

METAMORPHISM

A detailed discussion of metamorphism is beyond the scope of this report, but tw main kinds are recognized. An early episode of progressive regional metamorphism accompanied emplacement of granite in Early Cretaceous time. Rocks metamorphosed at that time are mainly in the greenschist facies. The highest grade metamorphic index minerals are garnet and biotite. However, some of the muscovite schist and amphibole-bearing rocks closest to the granite resemble rocks characteristic of the lower part of the amphibolite facies. A later episode of dynamic metamorphism accompanied overthrust faulting of strata as young as Late Cretaceous. Rocks affected by that metamorphism are primarily in the lower part of the greenschist facies. Most muscovite is completely recrystallized, and in some places the rocks contain biotite which appears to be new.

Slight retrograde metamorphism also has affected some of the rocks in the area. Retrograde changes such as the partial alteration of garnet and biotite to chlorite are typical.

Glaucophane-bearing rocks have been found north of the Shungnak quadrangle (I. L. Tailleur and R. B. Forbes, oral cummunication, 1969), but have not been observed by the writer in this area. Glaucophane forms under conditions of high pressure but low temperature. Such conditions presumably existed in and near the Cosmos Hills during the episode of dynamic metamorphism in Late Cretaceous or post-Cretaceous time. The relationship between this metamorphism and the glaucophane, however, is uncertain.

GEOLOGIC HISTORY

The geologic history of the Cosmos Hills, excluding mineralization at Bornite, is summarized as follows:

1. Precambrian and Early Paleozoic events for which no evidence is exposed here.

2. Deposition of thousands of feet of marine pelitic and fossiliferous carbonate sediments, including more than 2,000 feet of dolomitic limestone of Middle Devonian age. Contemporaneous volcanic activity, with much interlayering of pelitic and volcanic strata and minor fossiliferous limestone of probable Early Paleozoic (possible Devonian) age.

3. Late Paleozoic and Early Mesozoic events for which no evidence is exposed here. Inferred deep burial of the Devonian strata.

4. Beginning of uplift and erosion along the Brooks Range geanticline in Jurassic time (Payne, 1955). Emplacement of ultramafic igneous rocks of Jurassic(?) age now represented by serpentinite.

5. Emplacement of granite of Early Cretaceous age now exposed near the Kogoluktuk River. Contemporaneous doming and regional metamorphism.

6. Block faulting in late- or post-Early Cretaceous time, with formation of a horst six miles wide containing the granite and domed schist. Continued uplift and erosion along the Brooks Range geanticline.

7. Deposition of thousands of feet of conglomerate, sandstone, and mudstone of Earl to Late Cretaceous age derived, in part, from rocks of Paleozoic age.

8. Deformation in Late Cretaceous and (or) post-Cretaceous time, including the following events:

   a. Folding and (or) tilting and faulting of Upper Cretaceous strata.

   b. Overthrust faulting from the south-southwest, which placed volcanic and pelitic rocks of probable Early Paleozoic age over folded and block-faulted rocks of Devonian to Early Cretaceous age.

   c. Possible gentle arching along an axis trending west northwest in the vicinity of the Cosmos Hills.

   d. Continued or renewed stress from the southwest, with overthrust faulting of previously deformed Upper Cretaceous strata against and across a buttress of previously deformed Paleozoic strata in the vicinity of the Cosmos Hills. Contemporaneous dynamic metamorphism, including pervasive shearing and stretching of pebbles and cobbles, and local crenulation of stretched-pebble conglomerate, especially at Ferguson Peak. Contemporaneous internal deformation of Upper Cretaceous strata, with local overriding of interbedded conglomerate, sandstone, and phyllite across patches of basal(?) slaty conglomerate (Kc). Possible gentle folding of the overthrust faults in the vicinity of Ferguson Peak.

9. High-angle faulting of both thrust plates and underlying rocks.

10. Erosion which produced the present Cosmos Hills window. This erosion included glaciation in Pleistocene time, especially along the valley of the Kogoluktuk River.

E C O N O M I C   G E O L O G Y

The principal minerals of economic value recovered from the Shungnak D-2 quadrangle are gold and jade. A little prospecting for asbestos has been done, but no commercial deposits have been found in this area. Asbestos has been mined briefly, however, in the adjacent Ambler River quadrangle.

GOLD

Gold prospecting and placer mining in the Cosmos Hills began more than 70 years ago. Grinnell (1901) described the activities of prospectors along the Kowak [Kobuk] and Kogoluktuk Rivers during the gold rush of 1898 and the mass exodus of most of those men in 1899. A few prospectors who remained in the Cosmos Hills were successful on the Shungnak River and Dahl Creek, but only four claims were active on those streams by 1905 (Brooks, 1906, p 8). By 1909, Dahl Creek was the largest producer in the Shungnak mining district (Brooks and others, 1910, p 46). [Note: the name Shungnak apparently was derived from Ashigonak, the Eskimo word for a prominent "green-stone mountain" now known as Jade Mountain, which is about 30 miles northwest of Kobuk (Cantwell, 1884, p 57). Maps and reports concerning the Shungnak mining district published prior to 1931 referred to the present village of Kobuk as Shungnak. The Kobuk post office was established in 1928. The present village of Shungnak is approximately seven miles west of Kobuk (fig 1).]

Dahl Creek

Two main placer deposits along Dahl Creek were worked intermittently for gold from 1898 to 1961. They are separated by a narrow, boulder-filled canyon, which extends from the SW 1/4, SE 1/4, sec. 10, T. 18 N., R. 9 E., to the center of the SW 1/4 sec. 15. The upper deposit reaches approximately one mile from the head of the canyon to the SE 1/4 sec. 3. The lower deposit reaches about one-half mile from the mouth of the canyon to the north end of an abandoned air strip in sec. 21.

The upper and lower placer deposits occupy different environments of deposition. The upper one is underlain by bedrock, which acted as natural riffles. This deposit occupies a large, unglaciated valley and is fed by several important tributary streams. The gradient of Dahl Creek there is approximately 150 feet per mile. Gravel laid down along that creek is 5 to 25 feet thick, and gold was concentrated near the base of the gravel. In contrast, the lower placer deposit is underlain by glacial drift of Pleistocene age, which was described by Fernald (1964). Gold in the lower placer was found mainly on false bedrock strata commonly less than 10 feet beneath the surface (Smith and Eakin, 1911, p 292-294). Shafts sunk 25 to 80 feet through till penetrated barren gravel and failed to reach bedrock (Reed, 1932, p 31-36). The lower placer deposit does not occupy a large valley and is fed only by Dahl Creek. The local stream gradient there, however, is comparable to that in the upper placer area. The lower placer deposit cannot be older than Pleistocene. The upper placer deposit is believed to be mainly, if not entirely, Pleistocene in age.

The upper placer deposit on Dahl Creek was the richest. Gold was most abundant near the mouth of Wye Creek, where the underlying bedrock is phyllite cut by quartz veins one inch to four feet thick. Most of the gold recovered was fine-grained and angular to subangular, and some was even spongy (Smith and Eakin, 1911, p 293). Wire gold was rare. The angularity and sponginess of the gold indicated that it had not traveled far. Several large nuggets also were found in that area. The biggest was found in 1911 and weighed nearly three pounds. It was valued at about $600, with gold worth approximately $16.50 per troy ounce. Brooks (1912, p 42) described that nugget as a large, thin, subangular slab of gold to which no quartz was attached. Smith and Eakin (idem.), however, described a fairly well worn, 4-ounce nugget to which a considerable amount of greasy-looking, milky quartz was attached. The presence of quartz on this nugget and the presence of specks of free gold in quartz veins of the district led to the conclusion that the gold was derived from auriferous quartz veins close to the upper placer deposit on Dahl Creek.

The lower placer deposit was not as rich as the upper one mainly because of location. The lower placer is farther from the bedrock source. Furthermore, the boulder-filled canyon upstream from this deposit undoubtedly trapped a certain amount of detrital gold, which did not reach the lower placer. In general, the gold found in this placer was fine-grained, somewhat rounded and shot-like, largely because of the greater distance it traveled.

Other metallic minerals of interest found in the Dahl Creek placer concentrates include abundant magnetite, and subordinate chromite and native silver. The magnetite undoubtedly was derived from serpentinite and metavolcanic rocks in the vicinity of Dahl Creek, which contain abundant accessory magnetite. Smith and Eakin (idem.) reported chromite boulders as much as one foot in diameter, which most likely were derived from serpentinite. They also described and analyzed nuggets of native silver as much as one inch in diameter, the source of which is unknown. The authors emphasized the lack of garnet in the concentrates, which clearly reflects the low metamorphic grade of rocks in the source area.

Mining methods on Dahl Creek have varied. Spasmodic sluicing was done from 1898 to 1906, and systematic mining by sluicing began in 1907 (Brooks and others, 1909, p 59; 1925, p 51). Hydraulic mining was reported during the period 1922-1926 (Brooks and others, 1924, p 49; Smith and others, 1929, p 28). This work was done in the SE 1/4 sec. 3, T. 18 N., R. 9 E., where hydraulic mining equipment still can be seen. During the period 1927-1940, from one to four active claims on Dahl Creek were mentioned briefly in U. S. Geological Survey Bulletins concerning the mineral resources of Alaska, but hydraulic mining was not recorded. C. E. Stout (oral communication, 1968) reported that more hydraulic mining was done near the mouth of Wye Creek during the period 1938-1956. During the period 1954-1961, Stout reworked much of the better placer ground on Dahl Creek, and was most successful in the area underlain by phyllite near the mouth of Wye Creek. Numerous piles of gravel stripped by bulldozer at that time now are visible along Dahl Creek (see photograph on cover). Gold was recovered by sluicing and the use of mercury with copper plates.

Total gold production figures for the Dahl Creek placers have not been published. However, private records suggest that more than 300 ounces of gold per year were produced during certain favorable periods. It is possible, therefore, that the total production reached 20,000 ounces, but this estimate may be high.

California Creek

A gold-bearing placer deposit was discovered on California Creek in 1918 in a position comparable to that of the upper placer deposit of Dahl Creek. A narrow, boulder-filled canyon, which is cut into garnetiferous greenstone, extends across the eastern half of sec. 21 and the western half of sec. 22, T. 18 N., R. 10 E. The California Creek placer deposit reaches at least 3/4 of a mile from the head of that canyon eastward to the SW 1/4 sec. 14. This deposit occupies an unglaciated valley fed by several important tributary streams, which drain an area underlain mainly by phyllite and metavolcanic rocks. The phyllite is cut by numerous quartz veins. Gold in the placer deposit presumably was derived from those veins or similar ones removed by erosion. The age of this deposit is believed to be mainly Pleistocene like that of the upper placer deposit of Dahl Creek.

The California Creek deposit consists of gravel which is slightly coarser grained than that of the upper placer deposit on Dahl Creek. The coarser grain size is due partly to stream gradient and partly to proximity to resistant metavolcanic rocks. The local gradient of California Creek is approximately 200 feet per mile. The gravel contains numerous boulders as much as several feet in diameter derived from greenstone and greenschist exposed nearby. Gold was found mainly in the lower part of the gravel close to bedrock.

The California Creek placer deposit was mined intermittently from 1918 to 1940 (Cathcart, 1920, p 197; Smith, 1942, p 64). Early mining probably was done by sluicing, but hydraulic mining equipment was installed in 1922 (Brooks and others, 1924, p 49). By 1924, hydraulic mining on California Creek was considered the first large-scale mining operation in the Shungnak district, and by 1926, this operation was the largest producer in the district (Brooks and others, 1925, p 52; Smith and others, 1929, p 28). Flumes, mining equipment, and piles of stripped gravel still can be seen along the creek, but production records are not available. Total production probably did not exceed that of Dahl Creek (Guy Moyer, oral cummunication, 1968).

Lynx Creek

Small-scale mining of a placer deposit on Lynx Creek was done from 1912 at least until 1940 (Brooks and others, 1913, p 50; Smith, 1942, p 64). This deposit extends from the NE 1/4 sec. 9 to the southern part of sec. 3, T. 18 N., R. 10 E. The local stream gradient ranges from 240 to 370 feet per mile. The main workings were located where the stream gradient was relatively low in the NE 1/4 sec. 9 and NW 1/4 sec. 10. Reed (1932, p 47-48) reported smaller workings in two places in the southern part of sec. 3. The Lynx Creek placer deposit consists of a thin veneer of gravel lying on garnetiferous muscovite schist and related rocks, which are cut by quartz veins. Gold, presumably derived from quartz veins, was found mainly close to bedrock, which acted as natural riffles. Gold was recovered primarily by sluicing. Reed (idem.) reported that approximately half of the gold was small nuggets, and the rest was shot-like. No production figures have been published, but the deposit contained enough gold to support a 1- or 2-man mining operation for at least 28 years.

JADE

The word jade in proper technical terminology refers to either jadeite or nephrite (American Geological Institute, 1957, p 157). Both minerals are hard, tough, and commonly green. They are used primarily for making jewelry and carved ornaments. Jadeite, a variety of pyroxene, is a sodium-aluminum silicate. Nephrite, a variety of amphibole, is a calcium-magnesium-iron silicate. Nephrite actually is compact, fine-grained tremolite or actinolite, but can be mistaken for bowenite, which is a moderately tough variety of serpentine (Ford, 1947, p 574, 675).

In western Arctic Alaska, true jade consists of nephrite. Jadeite has not been found in this region. Nephrite, however, was found during early exploration of Jade Mountain (Cantwell, 1884, p 57-60). Four samples from that locality were described and analyzed by Clarke and Merrill (1888). The analyses were republished by Smith (1913, p 155) and Smith and Mertie (1930, p 345). Nephrite also has been reported from Asbestos Mountain (Coats, 1943). At both localities, nephrite is associated with serpentinite. Because of this association, serpentinite and serpentine commonly are misidentified as jade.

Since 1958, green boulders derived from serpentinite have been recovered from placer tailings along Dahl Creek for sale as jade. These boulders are as much as several feet in diameter. Their composition and texture vary markedly. Some may contain nephrite, but many undoubtedly are composed largely of serpentine. Many of them are highly sheared, because the source rocks in this area have been involved in strong tectonic activity. The source rocks also have been subjected to severe frost action, which tends to enlarge previous fractures.

The current jade mining operation on Dahl Creek is confined mainly to the upper placer deposit. Boulders are moved with the aid of a small bulldozer. They are cut with a large diamond saw in the field to facilitate handling and to determine their internal composition, texture, and color. Highly sheared and fractured rock is undesirable, because it will not remain intact during grinding and polishing. Small seams and layers of relatively unsheared material, on the other hand, can be used to make cabochons. In 1968, the writer observed fibrous, chatoyant material from which very attractive cabochrons had been made. He also saw slabs of relatively unsheared, beautifully banded and mottled serpentine suitable for lapidary products such as bookends, pen holders, and other ornamental objects. Completely unsheared or unfractured material, however, is rare. The current price of the so-called jade in the field is $1 or more per pound, depending upon the quality of the material and the quantity available.

GEOCHEMISTRY

Geochemical work involved the collection and analysis of 124 samples of sediments from 10 main drainage basins inside the Cosmos Hills window. The distribution of samples is shown on figure 12 (in pocket). Sampling was confined to valleys tributary to Dahl Creek and the Kogoluktuk River, because detailed mapping of bedrock there provided the best possible control for interpretation of geochemical data. Most materials collected were grab samples of the finest-grained stream sediments available. However, appropriate stream sediments are difficult to find where stream gradients are steep or valleys are relatively dry. As a result, soils also were sampled where necessary, especially in the unnamed valley south southeast of Inerevuk Mountain. Atomic absorption analyses for four elements and spectrographic analyses for thirty elements were done by the U. S. Geological Survey in Anchorage, Alaska. The results of that work are listed in table 1 (in pocket). Elements are grouped according to common world-wide association. Values for bismuth, cadmium, antimony, tin, and tungsten are not reported, because those elements were not detected. Values for copper, lead, and zinc were obtained by both methods.

GOLD

Gold appears to be most abundant east of the Dahl Creek fault in this quadrangle. Atomic absorption analyses indicate a maximum of 0.9 ppm gold in a sample collected in the canyon of California Creek downstream from the site of an abandoned hydraulic mining operation. The gold in this sample probably was fine-grained detrital material. It may have been carried to the sample locality during a period of high run-off related to the mining operation, but could have been deposited during normal sedimentation. Values of 0.2 ppm found in samples from Lynx and Wye Creeks also probably indicate fine-grained detrital gold.

COPPER

Copper appears to be most abundant in greenstone and least abundant in dolomotic limestone in this area. Furthermore, copper is not abundant near the intrusive granite pluton exposed near the Kogoluktuk River. Atomic absorption analyses show generally low copper values along Lynx Creek and a few values as high as 100-110 ppm in the upper parts of Harry and Stockley Creeks. Spectrographic analyses show a single value of 200 ppm along Lynx Creek and several values of 100-150 ppm along Harry and Stockley Creeks. These data suggest that granite and adjacent strata are not enriched in copper. They also suggest that copper values are highest in sediments derived, in part, from greenstone. The data, however, merely reflect normal background values for copper in greenstone.

LEAD

Lead appears to be most abundant in dolomitic limestone in the mapped area. Atomic absorption analyses show a maximum lead value of 68 ppm in the upper part of the valley of an unnamed creek southeast of Inerevuk Mountain. This valley is underlain mainly by dolomitic limestone. The sample from which the high value was obtained consisted almost entirely of fine-grained gray sediment derived from dolomitic limestone. Other values of 44 and 46 ppm were obtained from samples collected in adjacent valleys, which are underlain, in part, by dolomitic limestone.

ZINC

Zinc appears to be most abundant near California and Wye Creeks and an unnamed creek east of Inerevuk Mountain. Atomic absorption analyses of samples from those creeks show zinc values of 180-200 ppm. Zinc appears to be least abundant in the vicinity of Lynx, Harry, and Stockley Creeks. The data suggest that greenstone and granite in this area do not contain appreciable quantities of zinc.

COBALT

Cobalt is most abundant in serpentinite. Values of 100-700 ppm were obtained from samples derived largely from serpentinite in an unnamed valley south southeast of Inerevuk Mountain. The upper two samples (map numbers 26 and 27) in that area were taken from soil immediately above serpentinite bedrock. The lower three samples (map numbers 28-30) were taken from valley sediments derived from serpentinite and adjacent rocks. A value of 100 ppm also was obtained from a sample collected in the unnamed valley east of Inerevuk Mountain. That sample is believed to have been derived, in part, from serpentinite, which forms small bodies near the head of the valley.

CHROMIUM

Chromium is most abundant in serpentinite. Values of 1500-5000 ppm were obtained from samples derived largely from serpentinite in the valley south southeast of Inerevuk Mountain. Values of 1500-3000 ppm also were obtained from samples collected in the valley east of Inerevuk Mountain. Those samples presumably were derived, in part, from small bodies of serpentinite.

NICKEL

Nickel is most abundant in serpentinite. Values of 1500 to much more than 5000 ppm were obtained from samples derived from serpentinite in the valley south southeast of Inerevuk Mountain. Values of 1000-1500 ppm also were obtained from samples collected in the unnamed valley east of Inerevuk Mountain. Those samples are believed to have been derived, in part, from small bodies of serpentinite.

OTHER ELEMENTS

Spectrographic analyses for other elements do not reveal concentrations of economic interest. The analyses for magnesium are interesting, however, as they show high values in sediments derived from limestone as well as serpentinite west of Dahl Creek. The data indicate clearly that the limestone is dolomitic. High values for calcium in that rock indicate an abundance of calcite.

CONCLUSIONS AND GUIDES TO PROSPECTING

The most important results of the recent work are as follows:

(1) Four main stratigraphic formations have been recognized. Three are Paleozoic in age. One is Cretaceous in age. Metavolcanic rocks previously thought to be Jurassic(?) in age are interbedded with crinoid-bearing limestone of probable Early Paleozoic (possible Devonian) age. The metavolcanic rocks, therefore, are Paleozoic rather than Jurassic(?) in age.

(2) The distribution of domed, porphyroblastic, albitic and garnetiferous rocks near an intrusive granite pluton of Early Cretaceous age has been mapped. Doming and progressive regional metamorphism are related to emplacement of the granite.

(3) High-angle block faulting and low-angle overthrust faulting are far more important than previously supposed. The high-angle faults are characterized by displacements of as much as 1500 feet. The low-angle faults are characterized by displacements of as much as 12 miles.

(4) The principal geologic structure in the Cosmos Hills is a window framed by allocthonous rocks displaced along two major overthrust faults. Metavolcanic and metasedimentary rocks of probable Early Paleozoic (possible Devonian) age have been thrust over dolomitic limestone of Middle Devonian age. Metasedimentary rocks of Cretaceous age have been thrust over the metavolcanic and metasedimentary rocks of probable Early Paleozoic age. Dynamic metamorphism of the Cretaceous strata accompanied the latest overthrust faulting.

(5) Another major structure is a horst six miles wide, which is inside the Cosmos Hills window. The horst includes the intrusive granite pluton and surrounding domed strata. The horst formed during an episode of block faulting after granite emplacement but before overthrust faulting.

(6) Late high-angle faults characterized by displacements of several hundred feet cut the overthrust faults.

(7) Concentrations of placer gold in this area were greatest where streams characterized by gradients of 150-200 feet per mile are underlain by weakly metamorphosed pelitic rocks cut by auriferous quartz veins. If lode gold deposits are present in the mapped area, they most likely will be found in environments like those near Wye and California Creeks, where nongarnetiferous phyllite is cut by quartz veins as much as four feet wide.

(8) Jade derived from serpentinite is most plentiful in the western part of the mapped area, where small bodies of serpentinite are most numerous. The largest body of serpentinite, however, is a northeast-trending, southeast-dipping, sill-like sheet exposed about one mile west of Ferguson Peak. It is possible that jade is present in colluvium on the northwest side of that sheet.

(9) The serpentinite also contains small amounts of asbestos. However, most of the rock is highly sheared as a result of strong tectonic activity. The shearing and small size of most of the serpentinite bodies makes it unlikely that the rock in this area contains asbestos deposits of economic interest. The large sill-like sheet near Ferguson Peak, however, might be worthy of further investigation.

(10) Geochemical data show that cobalt, chromium, and nickel are most abundant in serpentinite, which normally contains more of these elements than other rocks. The data do not indicate that the serpentinite constitutes an important source of cobalt, chromium, or nickel, but the largest body of serpentinite near Ferguson Peak has not been sampled thoroughly.

(11) The dolomitic limestone in the Shungnak D-2 quadrangle apparently does not contain quantities of copper of economic interest, even though the rock is brecciated in some places.

(12) No indisputable evidence has been found to relate copper mineralization to emplacement of intrusive granite or to mafic meta-igneous rocks in the Shungnak D-2 quadrangle. Geochemical data reveal no appreciable enrichment in copper near the granite. The highest copper values were obtained from stream sediments derived, in part, from greenstone (metatuff) of Middle Devonian or older age, but merely reflect normal background copper values for that kind of rock.

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