U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

MISCELLANEOUS FIELD STUDIES
MAP MF-2144-E
PAMPHLET

# Mineral Resource Assessment of the Chandler Lake Quadrangle, Alaska

By

S.E. Church, J.S. Kelley, and Diedra Bohn

## EXECUTIVE SUMMARY

Interpretation of the results from extensive regional reconnaissance studies of the geology, stratigraphy, and geochemistry of the Chandler Lake quadrangle, northern Brooks Range, Alaska, and site-specific evaluations of mineralized areas conducted by the U.S. Bureau of Mines indicate that the mineral potential of the Chandler Lake quadrangle is low. There is no surface or geophysical expression indicating the presence of plutons and there is no indication that any of the mineral deposit types associated with plutons are present in the study area. The geologic characteristics and the structural evolution of the sedimentary basins suggests that rocks in the quadrangle are permissive for several mineral deposit types; however, detailed geochemical sampling and lead-isotopic evaluation of permissive areas where geochemical anomalies were found indicate that the probability of the presence of undiscovered mineral resources in the Chandler Lake quadrangle is low.

- We estimate that there is less than a five-percent probability that one or more sediment-hosted copper or sandstone-hosted lead-zinc deposits occur within the lower Paleozoic clastic rocks in the Chandler Lake quadrangle.
- We estimate that there is less than a five-percent probability that one or more SEDEX zinc-lead or bedded barite deposits exist in the permissive deep-water facies of the Mississippian Lisburne Group in the southern part of the Chandler Lake quadrangle.
- On the basis of detailed studies carried out by the U.S. Bureau of Mines (Kurtak and others, 1995), we conclude that there is a fifty-percent probability of the presence of one or more undiscovered phosphate deposits in the rocks of the permissive black shale and chert facies of the Mississippian Lisburne Group platform carbonates. There is only a limited potential, less than a five-percent probability, for one or more undiscovered phosphate deposits in the phosphatic rocks of the Shublik Formation in the Chandler Lake quadrangle.
- Because of the low barite grades in the rocks of the Permian Siksikpuk Formation, we estimate that there is less than a five-percent chance that one or more bedded barite deposits is present in these rocks in the Chandler Lake quadrangle.
- Within the Chandler Lake quadrangle, the relatively thin nature of the pebble shale and the low grade of manganese in clastic-dominated sections indicates that there is a limited potential for

sedimentary manganese deposits in rocks deposited in the Cretaceous basin. We have not observed any manganese carbonate facies that supplant the clastic sedimentary facies in the Chandler Lake quadrangle that would indicate areas where manganese might accumulate in sufficient grade to constitute a sedimentary manganese deposit. The U.S. Bureau of Mines reported several isolated localities of manganiferous siderite in the Cobblestone Creek area. We are unable to make a probability estimate of the occurrence of this deposit type in the rocks in the Chandler Lake quadrangle.

- Scattered gold anomalies in the northern part of the quadrangle represent the detrital transport of fine-grained gold in a deltaic environment. We have not delineated permissive areas for gold-placer deposits in the northern part of the Chandler Lake quadrangle.
- Although the geologic conditions are permissive, the geochemical data indicate that the area of the Chandler Lake quadrangle underlain by Cretaceous sedimentary rocks is not favorable for the occurrence of sandstone-hosted uranium deposits.
- Although the geologic conditions are permissive for the occurrence of concealed carbonate-hosted lead-zinc deposits in the Mississippian platform carbonate rocks, the absence of evidence of large-scale fluid flow, the presence of the Kayak Shale (which would serve as an aquiclude) and the absence of adequate source rocks from which to leach metals in the region indicates that the geologic conditions for the formation of carbonate-hosted lead-zinc deposits are not favorable.
- There may be potential for fault-controlled base-metal mineralization in the Cobblestone Creek study area, but our reconnaissance studies, as well as a detailed study of the Cobblestone Creek area by the Arctic Slope Regional Corporation, failed to find any evidence of this type of mineral deposit in this part of the quadrangle (Barnwell and others, 1989).
- There are sufficient quantities of sand and gravel resources available to fulfill any projected future needs by the local residents in the quadrangle.
- Extensive deposits of clean platform carbonates provide a future resource needed for the manufacture of cement; however, there is no local demand for, or infrastructure to support, such an industry in northern Alaska.

## INTRODUCTION

The Secretary of the Interior is required by the Alaska National Interest Lands Conservation Act (ANILCA, section 1010, Public Law 96-487, 1980) to survey Federal Lands in Alaska to determine their oil, gas, and mineral resources. As a part of this effort, the U.S. Geological Survey evaluates known and undiscovered resources in Alaska and these studies are made available to the public and to the President and the Congress. This report presents our evaluation of the mineral resources of the Chandler Lake 1° x 3° quadrangle, north-central Alaska, on the basis of the geological, geophysical, mineralogical, and geochemical data collected by the U. S. Geological Survey, site-specific investigations of mineralized areas by the U.S. Bureau of Mines, and the data collected in the quadrangle during the Department of Energy National Uranium Resource Evaluation (NURE) program during the mid-1970's.

Tracts of land that have potential for mineral deposits are delineated on the accompanying maps. Our mineral resource assessment was made using the data collected during our studies and set in the context of the environment in which specific mineral-deposit types form (Cox and Singer, 1986), the interpreted geologic framework (Kelley, 1990), and the recently completed U.S. Bureau of Mines mineral investigation report of the Colville mining district (Kurtak and others, 1995).

Geophysical data (U.S. Geological Survey, 1983) were used to assess the presence of possible buried plutons in the quadrangle. Geochemical reports of the NURE data from the Chandler Lake quadrangle (Los Alamos National Laboratory [LANL], 1982), as well as U.S. Geological Survey geochemical reports by Barton and others (1982), Sutley and others, (1984), Erlich and others (1988), Barnwell and others (1989), Kelley, Barton, and others (1993), and Kelley and Sutley (1993) that were prepared for subareas within the quadrangle using subsets of samples from the stream-sediment data base also have been used in this assessment. Kelley, Sutley, and Frisken (1993) presented an analysis of the geochemistry and mineralogy of the nonmagnetic heavy-mineral concentrate samples collected in subareas within the quadrangle; these data were used to define sulfide-mineral suites within the mineral resource tracts.

There are no active mines or prospects in the quadrangle. A map (fig. 1, on map sheet) of mineral occurrences in the Colville mining district shows many of the localities discussed in this report. Duttweiler (1986) presented a discussion of several geochemical anomalies from work in the Chandler Lake study area. Patton and Matzko (1959) described five localities in the Chandler Lake quadrangle where phosphate may constitute a mineral resource (Cobb and others, 1981); additional areas within the Chandler Lake quadrangle were examined by the U.S. Bureau of Mines (Kurtak and others, 1995) and the U.S. Geological Survey in this report.

The mineral-resource assessment of the Chandler Lake quadrangle used the assessment approach outlined by Singer (1975). Comparison of the geology of the study area with the geologic constraints provided by published descriptive mineral-deposit models limited the types of mineral deposits considered in the study. We also make the tacit assumption that the geology of areas covered by glacial deposits (Hamilton, 1979), especially in the northern half of the quadrangle is similar to that of areas where the rocks are exposed. Mineral-deposit types present elsewhere in the Brooks Range (see the summary of Alaskan mineral deposits in *Economic Geology*, 1986, v. 81, No. 7, pp. 1583-1794), as well as those mineral deposits present in rocks of equivalent age from the adjacent Philip Smith Mountains (Menzie and others, 1985) and Wiseman quadrangles (Bliss and others, 1988) were carefully evaluated during preparation of this report. Criteria used to delineate individual land tracts than may have mineral potential are presented in the discussion that follows and are summarized in table 1. For some deposit types, an estimate was made of the number of deposits that might be found within tracts defined in the quadrangle. These estimates, used in conjunction with the tonnage and grade models published in Cox and Singer (1986), provide the most explicit estimate of the undiscovered mineral resources of the quadrangle.

## LOCATION, LAND OWNERSHIP, AND ACCESS

The Chandler Lake quadrangle lies in the north-central Brooks Range, Alaska and includes an area of about 14,000 km$^2$ (5,400 mi$^2$). The southern quadrangle boundary is lat 68°00'N. and between about 1 and 25 km south of the continental divide of the Endicott Mountains. The northern quadrangle boundary is lat 69°00' N. and lies between about 55 and 80 km north of the Brooks Range mountain front. The eastern and western boundaries, long 150°00' and 153°00' W., roughly parallel the Itkillik and Chandler Rivers.

The National Park Service, the State of Alaska, and the Bureau of Land Management are the administrators of public land. The Nunamiut Village Corporation, the Arctic Slope Regional Corporation, and individuals are private land holders in the Chandler Lake quadrangle. The National Park Service administers the mountainous area in the southern part of the quadrangle as part of Gates of the Arctic National Park and Preserve, with the exception of inholdings belonging to the Nunamiut Village Corporation of Anaktuvuk Pass, the Arctic Slope Regional Corporation headquartered in Barrow, Alaska, and Native allotments belonging mostly to individuals living in Anaktuvuk Pass. The Bureau of Land Management, the Arctic Slope Regional Corporation, and the State of Alaska own or administer the land north of the range front, except for a small area in the east-central part of the quadrangle that is part of Gates of the Arctic National Park.

Access to the Chandler Lake quadrangle is limited. The only village in the quadrangle, Anaktuvuk Pass, has scheduled air service from Fairbanks and Barrow, Alaska. The remainder of the quadrangle is accessible by short-takeoff-and-landing airplane, float plane, and helicopter. Ground travel in the quadrangle is limited to foot or all-terrane vehicle where permitted; there are no roads or trails in the quadrangle, except in the immediate vicinity of Anaktuvuk Pass. Some of the rivers are navigable during the summer months. Permission to carry out geological investigations in the quadrangle must be obtained from government agencies, corporations, or individual land holders.

## GEOGRAPHIC SETTING

The Chandler Lake quadrangle transects the Brooks Range province, the southern Arctic foothills, and the northern Arctic foothills (fig. 2). Wahrhaftig (1965) defined these three physiographic provinces, which extend from Cape Lisburne on the Bering Sea east to the northeastern Brooks Range.

The southern Chandler Lake quadrangle encompasses part of the Endicott Mountains and continental divide in the central Brooks Range. This part of the quadrangle consists of steep, glacially sculptured

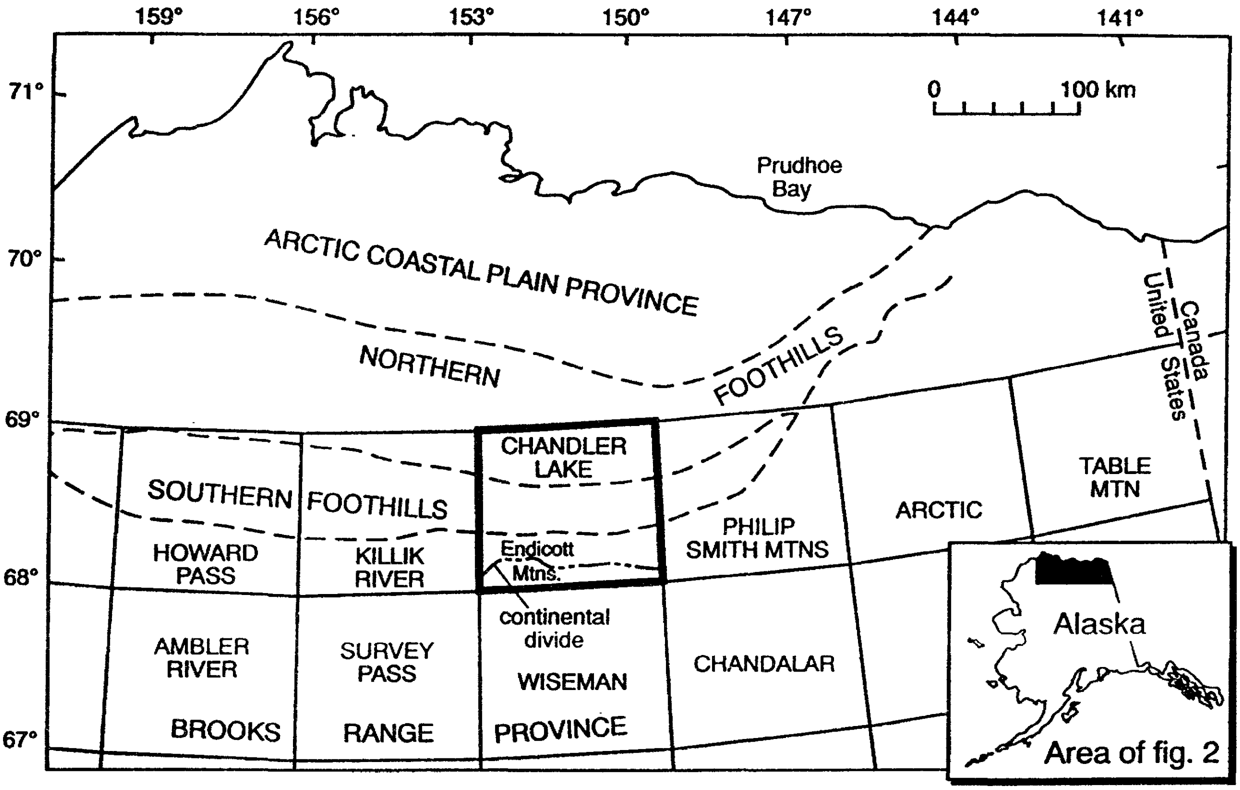


Figure 2. Index map of the Brooks Range, Alaska, showing the physiographic provinces, place names, and quadrangles discussed in text.

and generally barren topography that stands in marked and abrupt contrast to the adjacent southern Arctic foothills. Elevations range from 7,600 feet (2,356 m) to 2,000 feet (600 m) above sea level. Relief of adjacent landforms is up 4,500 feet (1,395 m) over distances as short as 3 miles (4.8 km). Vegetation is relatively sparse and generally limited to alpine grasses and low shrubs.

The central part of the Chandler Lake quadrangle transects the southern Arctic foothills. Terrain in the southern Arctic foothills is characterized by scattered hills and discontinuous trends of hills with up to 1,500 feet (465 m) of relief. Moraines and outwash fans are the characteristic landforms (Hamilton, 1979). Most hills are irregular, moderately steep, and partially tundra mantled, especially lower slopes.

The northern part of the Chandler Lake quadrangle encompasses part of the northern Arctic foothills. Topography in the northern Arctic foothills consists of sparsely vegetated linear ridges and broad, open tundra-covered valleys. Small stands of black willow are present in the stream valleys. Ridges are narrow, west-northwest to west-southwest trending, and underlain by sandstone. Narrow, laterally continuous anticlines generally form ridges. Broad synclinal troughs characterized by shallow dips and central circular depressions lie between ridges.

*Acknowledgments.*--We thank Roger Siglin, National Park Service, for his assistance and support in granting us access to the Gates of the Arctic National Park to conduct this study. We also thank officials of the Nunamiut Corporation, the Arctic Slope Regional Corporation, and the Bureau of Land Management for access to lands under their jurisdiction in the quadrangle. The Arctic Slope Regional Corporation, Alaska Division of Oil and Gas, the Alaska Division of Geological and Geophysical Surveys, and Chevron, U.S.A. provided data and field support during the study; without their support and scientific interaction, this study could not have been completed.

Table 1. Summary of mineral resource data used in the Chandler Lake mineral resource assessment
[Abbreviations for rock units from list of map units; tonnages given in millions of metric tons (mmt) or grams per metric ton (g/mt). See map for outlines of mineral resource tracts.]

| Mineral resource tract | Map units with permissive lithologies | Mineral deposit type | Occurrences in Chandler Lake quadrangle | Sites of interest in the Chandler Lake quadrangle (USBM data from Kurtak and others, in press) | Summary of mineral occurrences in Colville mining district | Grades and tonnages of deposits in Colville mining district | Grades and tonnages of ore in mineral deposits (range is from 0.1 to 0.9; median value) | Reference for grade and tonnage data |
|---|---|---|---|---|---|---|---|---|
| A | Clastic rock units (Dh, Dhw, Dhs, Dkn, Dkln, MDku, and Mk?) | Sediment-hosted copper | none | 1-6 | | none | 1.5 to 330 mmt; 22 mmt 1.0 to 4.5 percent copper | Mosier and others (1986) |
| | | Sandstone-hosted lead-zinc | none | | One occurrence in SW Philip Smith Mtns. (Loren Young, writ. comm., 1991) | none | 0.47 to 62 mmt; 5.4 mmt 0.89 to 5.2 percent lead <.025 to 3.0 percent zinc | Mosier (1986c) |
| B | Deep water facies of Lisburne Group (Maw, Mawc) | SEDEX zinc-lead | none | | Many deposits and occurrences—see fig. 1 | Red Dog: 85 mmt; 17.1 percent zinc, 5.0 percent lead, 82 g/mt silver (Nokleberg and others, 1987) Lik: 25 mmt; 8.8 percent zinc, 3.0 percent lead, 34 g/mt silver (Nokleberg and others, 1987) | 1.7 to 130 mmt, 15 mmt 2.4 to 13 percent zinc 1.0 to 7.7 percent lead <1.0 to 160 g/mt silver | Menzie and Mosier (1986) |
| | | Bedded barite | none | | Many deposits and occurrences—see fig. 1 | <1 to 30 mmt of bedded barite (Barnes and others, 1982; Kelley and others, 1993) | .12 to 28 mmt; 1.8 mmt 64 to 96 percent barite | Orris (1986b) |
| C | Platform carbonate of Lisburne Group (Maw) | MVT lead-zinc Appalachian zinc | none | | One possible deposit in SW Philip Smith Mtns. quadrangle (Detra, 1977; Dutro, 1978) | none estimated | 2.2 to 540 mmt; 35 mmt 1.4 to 12 percent zinc <0.1 to 3.6 percent lead | Mosier and Briskey (1986) |
| | | Warm-current phosphate | Kiruktagiak River | No resources estimated, 9.7 m section averaged 5.2 percent $P_2O_5$; 70 cm section averaged 20.6 percent $P_2O_5$ | Several deposits and occurrences—see fig. 1 | Phosphate has been reported as mineral resource; no previous estimates of grade and tonnage have been reported (see Patton and Matzko, 1959) | 46 to 3,500 mmt; 400 mmt 20 to 29 percent $P_2O_5$ | Mosier (1986d) |

Table 1. Summary of mineral resource data used in the Chandler Lake mineral resource assessment—Continued

| Mineral resource tract | Map units with permissive lithologies | Mineral Deposit Type | Occurrences in Chandler Lake quadrangle and others, in press) | Sites of interest in the Chandler Lake quadrangle (USBM data from Kurtak mining district | Summary of mineral occurrences in Colville mining district | Grades and tonnages of deposits in Colville | Grades and tonnages of ore in mineral deposits (range is from 0.1 to 0.9; median value) | Reference for grade and tonnage data |
|---|---|---|---|---|---|---|---|---|
| | | | Monotis Creek | No resources estimated, 6.7 m section average 23 percent $P_2O_5$; 60 cm section contains up to 30 percent $P_2O_5$. USBM recommends drilling program to evaluate resource | | | | |
| | | | Skimo Creek East | 12.1 m section of oolitic phosphate averaged 7.2 percent $P_2O_5$; 30 cm section averaged 23.7 percent $P_2O_5$ 14.2 mmt 6.7 percent $P_2O_5$ | | | | |
| | | | Skimo Creek West | 11 m section of oolitic phosphate averaged 5.7 percent $P_2O_5$; 30 cm section averaged 22.5 percent $P_2O_5$ USBM recommends drilling program to evaluate resource | | | | |
| | | | Tiglukpuk Creek | 10.5 m section of oolitic phosphate averaged 7.2 percent $P_2O_5$; 70 cm section averaged 23 percent $P_2O_5$ USBM recommends drilling program to evaluate resource | | | | |
| D | Phosphatic black shales in the Otuk and Shublik Fm. (undivided) (JTOS) | Upwelling phosphate | | | | none | 26 to 4,200 mmt; 330 mmt 15 to 32 percent P2O5 | Mosier (1986a) |
| E | Permian Siksikpuk Fm. (Ps) | Bedded barite | none | | none | none | 0.12 to 28 mmt; 1.8 mmt 64 to 96 percent barite | Orris (1986b) |

## GEOLOGIC SUMMARY

### REGIONAL GEOLOGIC SETTING

The Chandler Lake quadrangle lies in the Brooks Range fold-and-thrust belt that extends the entire breadth of northern Alaska. Rocks of the fold-and-thrust belt underlie the Brooks Range, southern Arctic foothills, and northern Arctic foothills, and extends from Cape Lisburne on the Chukchi Sea across Arctic Alaska to Canada. The North Slope foreland basin, which is comprised largely of Cretaceous rocks and is the foreland basin to the Brooks Range fold-and-thrust belt, underlies the northern Arctic foothills and the Arctic Coastal plain. The following summary is based on extensive previous geologic studies and references in Kelley (1990).

The fold-and-thrust belt comprises thrust faults and folds that formed in response to compressive tectonics during Mesozoic and Cenozoic time (Brosgé and others, 1979; Kelley and Brosgé, 1995). The fold-and-thrust belt contains north-transported thrust sheets made up of imbricate thrust fault blocks and north- to northeast-vergent folds. Fractures, most of which are filled with quartz and calcite, are widely distributed. Some of these fracture sets also contain some sulfide minerals.

Different bedrock assemblages crop out in the Endicott Mountains, southern Arctic foothills, and northern Arctic foothills. Mostly upper Paleozoic, resistant-weathering rocks crop out in the Endicott Mountains. Mostly Mesozoic, structurally complex, and heterolithic rocks comprise the southern Arctic foothills. Although older strata crop out locally, most strata that crop out in the northern Arctic foothills were deposited in the North Slope foreland basin during Cretaceous time and were subsequently involved in folding and thrusting (Detterman and others, 1963; Bird and Molenaar, 1992; Kelley and Brosgé, 1995).

The aeromagnetic survey of the quadrangle (U.S. Geological Survey, 1983) shows a south-sloping, uneven magnetic basement 4,500 to 6,000 m beneath the Arctic foothills upon which the sedimentary rocks were deposited. There are no magnetic anomalies in either the Arctic foothills or the Brooks Range that are indicative of concealed plutons within 1 km of the surface (D.L. Campbell, written commun., 1987). These data indicate both a west-sloping continuation of the magnetic basement in the Philip Smith Mountains quadrangle and south-sloping continuation of the magnetic basement under the Arctic coastal plain of the Arctic foothills (Cady, 1978).

### ENDICOTT MOUNTAINS

Upper Devonian to Lower Cretaceous strata crop out in the Endicott Mountains (Brosgé and others, 1979; Kelley, 1988, 1990). Mississippian platform carbonate rocks and Upper Devonian chert-quartz sandstone crop out extensively in the southern Chandler Lake quadrangle. Upper Devonian shale, Mississippian shale, and Permian clastic rocks are less extensively exposed. Triassic to Cretaceous strata are mostly eroded away; remaining outcrops are areally restricted and poorly exposed.

Upper Devonian to Mississippian strata underlying the Endicott Mountains in the Chandler Lake quadrangle include deep and shallow marine clastic, transitional marine clastic, sub- to supra-tidal shelf carbonate, transitional marine clastic, and nonmarine clastic strata (Patton and Tailleur, 1964; Brosgé and others, 1979; Kelley, 1988, 1990). The Late Devonian Hunt Fork Shale (Brosgé and others, 1979) is the oldest unit recognized in the Chandler Lake quadrangle; it consists of marine shale, argillite, weakly metamorphosed mudstone, siltstone, and fine- to medium-grained and mostly turbidite sandstone. The wacke member, which includes turbidites, overlies the shale member of the Hunt Fork Shale. The marine (but locally nonmarine) Late Devonian Noatak Sandstone overlies the Hunt Fork Shale and is mostly fine to very coarse grained, conglomeratic, calcite and ferruginous cemented, quartzose, and cherty (Nilsen and Moore, 1984). The Kanayut Conglomerate of Late Devonian and Early Mississippian(?) age overlies the Noatak Sandstone and principally consists of fluvial sandstone and conglomerate mostly composed of chert and quartz (Anderson, 1987). The Kanayut Conglomerate locally interfingers with the Noatak Sandstone where present and depositionally overlies the Hunt Fork Shale where the Noatak Sandstone is absent (Brosgé and others, 1979; Nilsen and others, 1981). The Early Mississippian Kayak Shale (Brosgé and others, 1979) comprises marine dark gray carbonaceous shale, mudstone, siltstone, light-gray bioclastic limestone, and depositionally overlies the Kanayut Conglomerate; locally, the Kayak Shale includes volcanic rocks (Reiser and others, 1979; Kelley, 1988, 1990). The Lisburne Group of Mississippian age overlies the Kayak Shale and is predominantly platform carbonate consisting of mostly light-gray limestone and dolostone, but includes carbonaceous shale, chert, and phosphate-bearing shale, and shaly limestone (Armstrong and others, 1976; Armstrong and Mamet, 1977a, 1977b, 1978, 1989; Mull and others, 1982; Kelley, 1988, 1990; Kelley and Brosgé, 1995). Isolated outcrops of the Lisburne Group in the southwestern Chandler Lake quadrangle are predominantly dark-gray massive chert (Kelley, 1988, 1990; Nelson and Csejtey, 1990).

Permian strata in the Endicott Mountains include a variety of lithologies in scattered and discontinuous bodies (Kelley, 1988, 1990). The Permian Siksikpuk Formation crops out along the range front and in scattered and isolated localities south of the range front (Mull and others, 1982). Strata in the Permian Sadlerochit Group crop out in the southeastern part of the quadrangle (Kelley, 1988, 1990; Kelley and Brosgé, 1995). The Siksikpuk Formation that is present along the range front and in most of the isolated outcrops in the range is mostly barite-bearing mudstone, siltstone, chert, and limestone (Siok, 1985; Adams, 1991; Kelley and Brosgé, 1995). In contrast to the Siksikpuk Formation present along the range front, the Siksikpuk Formation in the southwestern part of the quadrangle is mostly light- to dark-gray marine siltstone and shale that is typically hard, siliceous, rhythmically bedded, possesses a conchoidal fracture, and probably grades to ribbon chert (Adams, 1991; Kelley and Brosgé, 1995). The Sadlerochit Group consists of fossiliferous marine mudstone and siltstone and forms in isolated outcrops in the southeastern part of the Chandler Lake quadrangle (Kelley 1988, 1990; Kelley and Brosgé, 1995).

Triassic and Jurassic marine strata in the Endicott Mountains of the Chandler Lake quadrangle depositionally overlie the Permian Siksikpuk Formation. The Triassic and Jurassic Otuk Formation (Mull and others, 1982) and the Triassic Shublik Formation (Patton and Tailleur, 1964) crop out along the range front (Bodnar, 1984, 1989; Kelley, 1988, 1990; Kelley and Brosgé, in press). The Otuk Formation, which crops out in isolated areas in the southwestern part of the quadrangle and discontinuously along the range front, comprises dark-gray shale, dark-gray rhythmically and thin-bedded chert, rhythmically bedded yellowish-gray weathering limestone, and organic shale. The Shublik Formation comprises dark-gray phosphatic shale and limestone that crops out east of the Anaktuvuk River. Only the Otuk Formation is present in the southwestern part of the quadrangle, where it is especially cherty.

Lower Cretaceous strata in the Endicott Mountains of the Chandler Lake quadrangle form isolated outcrops in the southwestern part of the quadrangle. The strata depositionally overlie the Otuk Formation and consist of very fossiliferous marine shale and mudstone that is typically iron-stained (Kelley, 1988, 1990; Kelley and Brosgé, 1995).

## SOUTHERN ARCTIC FOOTHILLS

The Arctic foothills assemblage of Kelley (1990) and Lower Cretaceous sandstones and conglomerates crop out in the southern Arctic foothills. The Arctic foothills assemblage contains rocks of Early Cretaceous to Mississippian age and extensively underlies the southern Arctic foothills. The assemblage comprises (1) Early Cretaceous fossiliferous shaly limestone, (2) Late Jurassic(?) and Early Cretaceous sandstone, shale, and conglomerate, (3) Jurassic mafic igneous rocks, (4) Permian and Triassic radiolarian ribbon chert, (5) Mississippian and Pennsylvanian(?) limestone and feldspathic sandstone (Patton and Tailleur, 1964; Kelley, 1988, 1990), (6) marble of unknown age, and (7) melange rocks. The assemblage is poorly exposed and structurally complex. Outcrops are generally isolated rubble hills and mounds in otherwise tundra-mantled terrain. The Arctic foothills assemblage structurally overlies Mississippian to Cretaceous strata that crop out to the south in the Endicott Mountains.

Lower Cretaceous sandstone and conglomerate of the Fortress Mountain Formation overlie the Arctic foothills assemblage (Kelley, 1988, 1990). West of the Anaktuvuk River, rocks of the Fortress Mountain Formation crop out in basin-shaped synclines where massive-weathering conglomerate and sandstone beds form circular to ellipsoidal patterns in map view (Kelley, 1990). East of the Anaktuvuk River, the Fortress Mountain Formation is present in imbricate fault blocks that form southeast-trending ridges (Kelley, 1990). The formation is heterolithic and contains framework clasts mostly derived from the Arctic foothills assemblage and rocks exposed in the Endicott Mountains. West of the Anaktuvuk River, the formation contains both nonmarine and marine rocks (Crowder, 1987; Molenaar and others, 1988; Kelley, 1988, 1990). East of the Anaktuvuk River, the formation consists of presumably marine sandstone and conglomeratic sandstone turbidites (Kelley, 1988, 1990).

## NORTHERN ARCTIC FOOTHILLS

Strata that range in age from Triassic to Late Cretaceous crop out in the northern Arctic foothills (Detterman and others, 1963; Kelley 1988, 1990; Kelley and Brosgé, 1995). Lower and Upper Cretaceous sandstone and shale are the principal rocks types that underlie the northern Arctic foothills; however, Triassic and Lower Cretaceous strata crop out locally in the south easternmost part of the northern Arctic foothills in the Chandler Lake quadrangle.

Triassic strata of the Shublik Formation are overlain by Lower Cretaceous fossiliferous shaly limestone in the south easternmost part of the northern Arctic foothills in the Chandler Lake quadrangle (Kelley, 1988, 1990). Lower Cretaceous ferrugineous- and manganiferous-weathering shale containing scattered pebbles and granules of mostly chert and mafic igneous rock overlie Lower Cretaceous fossiliferous shaly limestone. The Early Cretaceous Torok Formation, which includes sandstone bodies mapped as the Cobblestone sandstone unit, overlies the pebble-bearing shale.

Resistant-weathering Lower Cretaceous sandstone in the Tuktu and Grandstand Formations and Killik Tongue of the Chandler Formation form the prominent ridges of the Northern Foothills Province. Less resistant sandstone and shale in the Niakogan Tongue of the Chandler Formation and the Ninuluk Formation form the broad areas between ridges. The rocks of the Seabee, Prince Creek, and Schrader Bluff Formations of Late Cretaceous age form basin-like structural depressions between ridges, especially in the northern part of the province. Lower Cretaceous and recessive-weathering shale in the Torok Formation forms linear central depressions along the crests of ridges in the southeastern part of the province. Shale and turbidite sandstone mapped as the Cobblestone sandstone unit in the lower part of the Torok Formation crop out locally along the southern boundary of the northern Arctic foothills.

## MINERAL DEPOSIT MODELS

Evaluation of the geology of the Chandler Lake quadrangle and known mineral occurrences in northern Alaska indicated that he study area should be evaluated for seven sedimentary and diagenetic mineral-deposit types described in Cox and Singer (1986). The absence of intrusive rocks in the study area, and the absence of aeromagnetic anomalies (U.S. Geological Survey, 1983) that might indicate the presence of buried intrusions within one km of the surface eliminated deposits associated directly with igneous activity from consideration. Four sedimentary mineral-deposit types are present in rocks of the Brooks Range (see fig. 1 on map sheet for deposit localities).

1) Sedimentary-exhalative zinc-lead deposits (mineral-deposit model 31a, Briskey, 1986a; referred to in this report as SEDEX Zn-Pb) are found west of the study area as stratabound deposits in rocks of Mississippian age, and in breccia zones that we interpret as feeder-veins that occur in rocks ranging in age from Devonian and Mississippian (Tailleur and others, 1977; Mayfield and others, 1979, Lange and others, 1985; Moore and others, 1986; Duttweiler, 1987; Young, 1989; Kurtak and others, 1995; Kelley and Mull, 1995), as well as in Devonian rocks on the Canadian Cordillera (MacIntyre, 1983; Goodfellow and Jonasson, 1986).

2) Bedded barite occurrences (mineral-deposit model 31b, Orris, 1986a), which may, or may not be associated with the above stratabound deposits occur in the western Brooks Range (for example, bedded barite associated with the Red Dog deposit or the Nimiuktuk barite deposit described by Mayfield and others, 1979). Kelley, Tailleur, and others (1993) summarize the recent work on bedded barite in the Brooks Range; the reader is referred to this report for deposit descriptions and grade and tonnage estimates.

3) Carbonate-hosted lead-zinc (Appalachian zinc and MVT Pb-Zn; mineral-deposit models 32b and 32a, Briskey, 1986b, 1986d) may be present in the Philip Smith Mountains quadrangle just east of the study area described by Detra (1977) and Dutro (1978).

4) Phosphate deposits (mineral-deposit models 34c and 34d, Mosier, 1986a,b) and occurrences have been described from the study area by Patton and Matzko (1959). Recent site-specific investigations on the phosphate occurrences by Kurtak and others (1995) has also been incorporated into this mineral resource assessment.

Three additional types of sediment-hosted deposits were also evaluated on the basis of the geology of the study area even though the occurrence of resources of this type were less likely.

1) Sediment-hosted volcanogenic massive sulfide deposits (mineral-deposit models 24b and 28a, Cox, 1986a; Singer, 1986),

2) Sediment-hosted copper, sandstone-hosted lead-zinc, and sedimentary manganese deposits (mineral-deposit models 30b, 30a, and 34b; Cox, 1986b; Briskey, 1986c; Cannon and Force, 1986, respectively), and

3) Sandstone-hosted uranium deposits (mineral-deposit model 30c, Turner-Peterson and Hodges 1986).

Recent work by the U.S. Bureau of Mines in the Colville mining district (Kurtak and others, 1995) has provided an excellent summary of the mineral deposits, occurrences, and mineralized areas. The grade and tonnage data for several important deposits are summarized in table 1. These data form the background for the estimates of the probability of occurrence of mineral resources in the Chandler Lake quadrangle.

## MINERAL RESOURCE ASSESSMENT

### SEDIMENT-HOSTED COPPER AND SANDSTONE-HOSTED LEAD-ZINC DEPOSITS

The fluvial and marine clastic rocks of the Hunt Fork Shale, the Noatak Sandstone, and the Kanayut Conglomerate, which range from Late Devonian to Early Mississippian in age, define mineral-resource tract A. The Mississippian Kayak Shale, some outcrops of which are too small to be shown at the map scale, is the youngest stratigraphic unit included in tract A. Sulfide-bearing concretions in the Kayak Shale may be the cause of many on the geochemical anomalies present in the tract. Kurtak and others (1995) discussed several of these localities in the Chandler Lake quadrangle and did not consider them to be a mineral resource. We will not consider them further in this report. The Paleozoic clastic rocks are potential host rocks for sediment-hosted copper and sandstone-hosted lead-zinc deposits. One sandstone-hosted lead occurrence has been recognized in the headwaters of the Atigun River in the southwestern part of the Philip Smith Mountains quadrangle (L.E. Young, written commun., 1991; table 2). These deposits form by transport of metal-rich chloride brines into clastic sediments, usually red beds, in equatorial regions. Rose

(1976) discussed the geochemical processes of metal transport and deposition for the formation of sediment-hosted copper deposits in terms of Eh-pH diagrams. Chloride brines leach base-metals (Cu, Co, Pb, Zn, Ag) from source beds transporting the metals in the hydrothermal chloride brines. Precipitation of metals from this solution occurs when it encounters reducing conditions that may be caused by the presence of organic matter, $H_2S$, pyrite, or variable oxidation states of iron in red bed sandstones. Similar fluid transport and deposition models have been evaluated for lead and zinc in carbonate host rocks (for example, Anderson, 1983).

Geochemical anomalies from tract A are usually single-element anomalies of Mn, Cu, Pb, and Zn from localities underlain by the wacke member of the Hunt Fork Shale or the Kanayut Conglomerate where they are hematite-stained. Kelley, Barton, and others (1993) subdivided the geochemical anomalies in this tract into three areas (b-d) for discussion.

In the southeastern part of tract A (area b: T. 16 S., R. 4 E. to R. 9 E.), stream-sediment samples commonly contain anomalous concentrations of Cu, Pb, As, Co, and Cr (Kelley, Barton, and others, 1993). Anomalous concentrations of Pb, Zn, Co, and Ni, and less commonly Cu, Ag, and As are also present in nonmagnetic heavy-mineral-concentrate samples. Light yellow sphalerite (an iron-poor variety) is common, and barite, pyrite, galena, chalcopyrite and arsenopyrite were found in samples collected at one or more localities (Kelley, Sutley, and Frisken, 1993).

Geochemical anomalies were also found in clastic rocks from the Thibodeaux Mountain area south of Inikaklik Creek (site 4). The Noatak Sandstone in this area is coarser grained, highly iron-stained, contains granules of ironstone, and has sedimentary structures that may be described as indicative of a nonmarine facies of the Noatak Sandstone, although extensive thrusting in the area (Kelley and Bohn, 1988) precluded definitive mapping of this facies during this study. Duttweiler (1986) described numerous small quartz-calcite veins in the Thibodeaux Mountain area that contain siderite and limonite after siderite. Nonmagnetic heavy-mineral-concentrate samples commonly contain anomalous concentrations of Pb, Zn, Co, and Ni, and less commonly Cu, Cr, and Ag; pyrite, sphalerite, and galena were also identified in these samples (Kelley, Sutley, and Frisken, 1993).

Anomalous concentrations of manganese, lead, and zinc are present in stream-sediment samples from the area near the headwaters of Grizzly Creek (site 7; Kelley, Barton, and others, 1993). Nonmagnetic heavy-mineral-concentrate samples contain anomalous concentrations of Cu, Pb, Zn, Ag, As, Co, and Ni, and contain barite, pyrite, sphalerite, and galena (Kelley, Sutley, and Frisken, 1993). Numerous small quartz-calcite veins are also present in the area (Duttweiler, 1986).

In the central part of tract A, on either side of Inukpasugruk Creek (area c: T. 16 S., R. 1 E. to R. 3 E.), anomalous concentrations of Mn, Ba, Mo, Zn, Pb, Ag, As, Cd, Cu, Ni, Cr, and Co were found in stream sediments (Kelley, Barton, and others, 1993). Anomalous concentrations of nickel and cobalt were detected in the nonmagnetic heavy-mineral-concentrate samples; pyrite was common, and barite, sphalerite, chalcopyrite, and galena were found in one or two samples (Kelley, Sutley, and Frisken, 1993). Metal concentrations in rock samples were low and generally not anomalous (table 3, Kelley, Barton, and others, 1993, sites 3 and 5).

Clastic rocks from the southwestern part of tract A (area d: T. 16 S., R. 2 W. to R. 5 W.) have anomalous concentrations of Zn, Cu, Pb, As, Ni, Co, Cd, and Cr (Kelley, Barton, and others, 1993). No nonmagnetic heavy-mineral-concentrate samples are available from this area (Kelley, Sutley, and Frisken, 1993).

The geochemical anomalies in tract A do not indicate the presence of a sediment-hosted copper or sandstone-hosted lead-zinc deposit. Critical features of each of the mineral deposit models appear to be lacking. Sediment-hosted copper deposits (model 30b, Cox, 1986b) are associated with epicontinental basins formed near the equator in red bed clastic sequences. Sandstone-hosted lead-zinc deposits (Briskey, 1986c) are associated with marine fluvial sandstone sequences in an area draining deeply weathered granitic source terranes. Although the depositional model for the Devonian clastic sequence is somewhat favorable and base-metal content of the Hunt Fork Shale is high (Dutro, 1978), source rocks that might be expected to contain base metals, such as basaltic rocks weathering to release copper or cratonic granites weathering to release lead and zinc, are not recognized in the Brooks Range. Furthermore, there is no independent evidence of the presence of large-scale fluid flow to form ore deposits or of the presence of hydrothermal dolomite in the carbonate sequence, although our assessment of the presence of hydrothermal dolomite should be considered cursory. Areas delineated by geochemical methods within tract A have low grades and small tonnages, and plot well below the grade-tonnage curves for these deposit types (Mosier, 1986c; Mosier and others, 1986). Tract A has a very limited potential for sandstone-hosted copper and lead-zinc deposits; we estimate that there is less than a five-percent probability that one or more sediment-hosted copper or sandstone-hosted lead-zinc deposits occur within tract A.

The geochemical anomalies in tract A are most likely the result of late diagenetic processes, such as the formation of the sulfide minerals in the concretions in the Kayak Shale (Kurtak and others, 1995) or metamorphic processes that have not resulted in a base-metal mineral deposit. Kelley, Barton, and others (1993) suggest that the geochemical anomalies in stream-sediment samples from tract A are primarily the result of high background values in the unmineralized wacke member of the Hunt Fork Shale. Analyses of chip samples from the Hunt Fork Shale (Dutro, 1978) also support this conclusion.

At several of these localities, clastic rocks commonly contain interstitial sulfide minerals. Furthermore, numerous small quartz-calcite veins containing small amounts of pyrite, sphalerite(?), galena, and possibly other sulfide minerals were observed in rock samples collected from drainage basins in tract A. However, these small quartz-calcite veins also cross-cut younger rocks. Sulfide minerals from both the interstitial sulfides and cross-cutting veins are interpreted to be responsible for many of the scattered base-metal geochemical anomalies, particularly those from the heavy-mineral-concentrate samples (Kelley, Sutley, and Frisken, 1993).

Lead-isotope data (table 2) of various samples from the Chandler Lake quadrangle provide insight into the processes that caused these geochemical anomalies. The SEDEX Zn-Pb mineralization has a very uniform lead-isotopic signature (fig. 3), as indicated by the analytical results from 44 samples of this type of mineralization from throughout the western Brooks Range (Church, Gray, and others, 1987; Gaccetta and Church, 1989; R.B. Vaughn and S.E. Church, unpub. data, 1994). In marked contrast, the lead-isotopic compositions of sulfide minerals forming the interstitial cement © in the Kanayut Conglomerate and the wacke member of the Hunt Fork Shale (sites 1-6) from tract A are highly variable (table 2) and support the hypothesis that the lead in these sulfide minerals is most likely either leached from the sedimentary rocks by hydrothermal brines after diagenesis or, in the case of the sample from site 5, of possible detrital origin. These data differ from the lead-isotopic signature obtained from samples of the cross-cutting quartz-calcite veins in the Chandler Lake (sites 7 and 8, O) and Killik River (●) quadrangles (Gaccetta and Church, 1989) formed during the deformation responsible for the fold-and-thrust belt. A sample from the Atigun River locality (S), a sandstone-hosted lead occurrence in the southwestern part of the Philip Smith Mountains quadrangle (table 2) has a lead-isotopic composition that is less radiogenic and isotopically distinct from the SEDEX Zn-Pb deposits of the western Brooks Range, indicating that a different ore-forming process was responsible for the formation of the sandstone-hosted lead deposit. Analyses of galena samples (P) from the carbonate-hosted lead-zinc deposit in the southwest corner if the Philip Smith Mountains quadrangle are shown for comparison with the other deposit types. The data obtained from samples collected at site 6 in barite float (I) in the Itkillik River West area (Kurtak and others, 1995) is a very close match to the Atigun River sandstone-hosted lead occurrence (S) in the Philip Smith Mountains and similar to the lead-isotopic values from sulfide cement recovered from the Kanayut Conglomerate at site 2. The relatively low lead-isotope ratios from these three sites indicate that the event responsible for the cementation probably occurred during diagenesis rather than at some later time.

Analyses of the lead from nonmagnetic heavy-mineral concentrates collected from the Killik River quadrangle (□) indicate that lead anomalies in drainage basins located in that quadrangle have at least two sources: one reflecting the lead-isotopic signature of the SEDEX Zn-Pb mineralization, and a second reflecting the variable lead-isotopic composition of galena from the quartz-calcite veins formed during the Jurassic thrusting event. Only a few nonmagnetic heavy-mineral concentrates collected in the Chandler lake quadrangle were available for lead-isotope analysis. The lead-isotopic data from all three of those samples (sites 9-11, table 2 and fig. 3, ■) indicate that the anomalies are probably from the quartz-calcite veins formed during the Jurassic thrusting event, although we can not rule out contributions from the concretions from the Kayak Shale if the samples from site 12 (table 2) and from the Killik River quadrangle are representative (Gaccetta and Church, 1989).

## SEDEX Zn-Pb DEPOSITS

SEDEX Zn-Pb and associated bedded barite deposits occur in euxinic facies rocks formed in marine epicratonic embayments and intracratonic basins (Briskey, 1986a; Orris, 1986a). Tract B includes the three outcrops of deep water black chert of the Alapah and Wachmuth Limestones undivided (Maw) in the southern part of the Chandler Lake quadrangle, including the cherty rocks (Mawc) in the Ekokpuk Creek area. These strata (Mawc) had previously been correlated with the black shale lithofacies that hosts the SEDEX Zn-Pb deposits in the western Brooks Range (Moore and others, 1986; Young, 1989). Since unit Mawc in tract B is exposed only in a small klippe, basin relationships are obscure. Stream-sediment samples from this area contain anomalous concentrations of Mn, Ba, Zn, Pb, and Cu (Kelley, Barton, and others, 1993). No results from nonmagnetic heavy-mineral-concentrates are available from tract B (Kelley, Sutley, and Frisken, 1993). Chip samples collected throughout the entire thickness of the stratigraphic section exposed on Ekokpuk Creek (data in table 3 in Kelley, Barton, and others, 1993) did not reveal any stratiform sulfides in the section sampled (section X on the map). High concentrations of barium were found in some samples of chert but they rarely contained anomalous concentrations of zinc or other metals. The maximum concentration of zinc detected in the chip samples was 200 ppm in a sample of black chert. We found no surface expression of stratiform or breccia zone sulfides indicating the presence of SEDEX Zn-Pb mineralization in tract B. Barite concretions as large as 7.5 cm in diameter were found in the Permian Siksikpuk Formation in tract B in the Ekokpuk Creek area.

Although geochemically and geologically permissive, there is little evidence to indicate that tract B has potential for undiscovered SEDEX Zn-Pb or bedded barite resources. The black chert lithofacies of the Alapah and Wachmuth Limestones (Kelley, 199?; Nelson and Csejtey, 1990) may be similar to those of the Kuna

Table 2. Lead-isotopic data collected in samples from the Chandler Lake quadrangle, Alaska

| Locality | Site no. | Sample no. | Latitude | Longitude | $^{206}Pb/^{204}Pb$ | $^{207}Pb/^{204}Pb$ | $^{208}Pb/^{204}Pb$ | Host[1] rock | Texture[2] | Form[3] | Mineralogy[4] | Age[5] | Analyst[6] or reference |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Kayanut Conglomerate | 1 | 80TN-12 | 68°18'30" | 150°51'15" | 18.582 | 15.708 | 39.078 | cong-hstd | dissem | cement | py | D | 3 |
| Kayanut Conglomerate | 2 | 80TN-22A | 68°19'25" | 150°58'55" | 18.259 | 15.624 | 38.811 | cong-hstd | dissem | cement | py | D | 3 |
| Kayak Shale | 2 | 80TN-22B | 68°19'25" | 150°58'55" | 18.398 | 15.619 | 38.765 | sd-hstd | dissem | cement | py | M | 3 |
| Three River Mtn. | 3 | 84CL444R | 68°04'30" | 151°39'22" | 18.753 | 15.627 | 38.870 | cong-hstd | dissem | cement | py | D | 1 |
| Thibideaux Mtn. | 4 | 84CL401R | 68°17'31" | 150°08'00" | 18.433 | 15.617 | 38.547 | sd-hstd | dissem | cement | py | D | 3 |
| Inukpasugruk Cr. | 5 | 84AKD430R | 68°05'00" | 151°49'35" | 17.929 | 15.529 | 37.750 | cong-hstd | dissem | cement | py, cp | D | 3 |
| Itkillik River West | 6 | CMD-4553 | 68°13'28" | 150°30'05" | 18.293 | 15.567 | 38.307 | sd-hstd (float) | massive | vein(?) | bar, gn | D | 4 |
| Itkillik River | 7 | CL848R | 68°14'45" | 150°24'05" | 18.586 | 15.610 | 38.628 | sd-hstd | crs-cuting | qz/cal vein | gn | D | 1 |
| Grizzly Cr. | 8 | CL784R1 | 68°05'38" | 150°43'13" | 18.658 | 15.622 | 38.638 | shear zn | crs-cuting | qz/cal vein | gn, cal | M | 1 |
| Grizzly Cr. | 8 | CL784R2 | 68°05'38" | 150°43'13" | 18.716 | 15.629 | 38.614 | shear zn | crs-cuting | qz/cal vein | gn, cal | M | 2 |
| | 9 | CL-589H | 68°35'02" | 152°54'08" | 18.939 | 15.588 | 38.400 | sediment | | HMC | py | | 3 |
| | 10 | CL-590H | 68°37'11" | 152°51'53" | 18.527 | 15.538 | 38.297 | sediment | | HMC | py | | 3 |
| | 11 | CL-662H | 68°12'06" | 150°28'06" | 18.503 | 15.581 | 38.393 | sediment | | HMC | py | | 3 |
| Cockedhat Mountain | 12 | CMD-4768 | 68°07'47" | 150°42'50" | 18.637 | 15.596 | 38.477 | sd-hstd | | concretion | qz, cal, py, bar, sl, gn | M | 4 |
| Atigun River | | PS-219 | 68°12'50" | 149°41'30" | 18.312 | 15.564 | 38.265 | cong-hstd | dissem | cement | gn | D | 3 |

1 Host rock: cong-hstd, conglomerate hosted; sd-hstd, sediment hosted; sediment, sample from active sediment load in stream drainage.
2 Texture: dissem, disseminated mineral grains; crs-cuting, vein cuts across stratigraphy.
3 Form: HMC, heavy-mineral concentrate from stream sediments (Kelley and ohters, 1993); qz, cal; see Mineralogy below.
4 Mineralogy: py, pyrite; cp, chalcopyrite; gn, galena; sl, sphalerite; cal, calcite; bar, barite; qz, quartz.
5 Age (stratigraphic age of host rock): D, Devonian; M, Mississippian.
6 Analyst or reference: 1, M.H. Delevaux, analyst (Church and others, 1987, p. 10-11 ); 2, J.D. Gaccetta, analyst (Gaccetta and Church, 1989, p. 8-9); 3, R.B. Vaughn, analyst; 4, Chempet Research Corp., data provided by J.M. Kurtak, U.S. Bureau of Mines, published with permission.

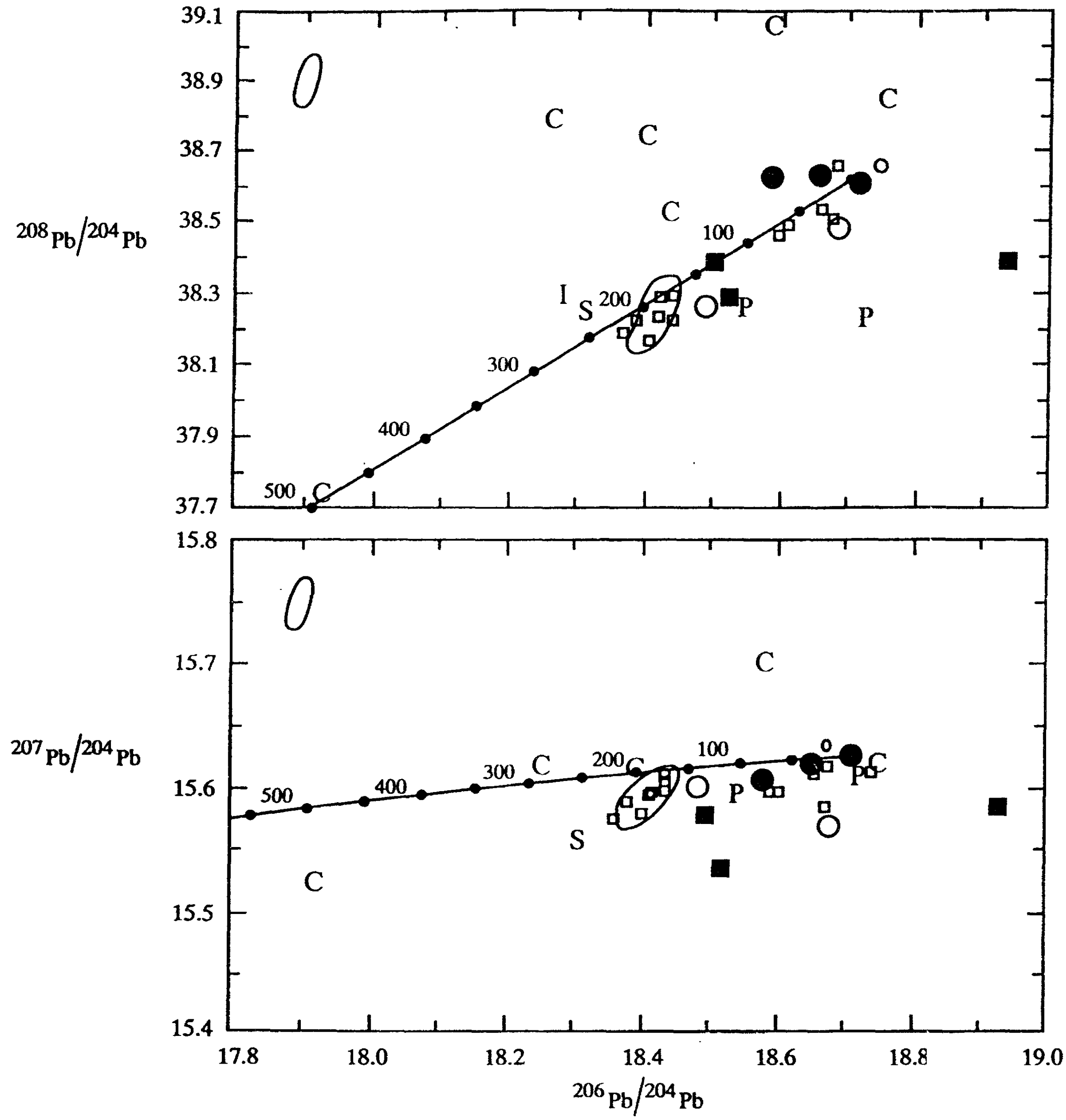


Figure 3. Plot of lead-isotopic data from analyzed samples collected from the Chandler Lake quadrangle (table 2) compared with data from deposits in the Brooks Range. C, data from samples of sulfide cement from heavy-mineral separates of clastic lower Paleozoic rocks; I, data from a sample of galena from the Itkillik River West occurrence; S, data from a sample from the sandstone-hosted lead occurrence from Atigun River; P, data from samples from the galena-sphalerite deposit located in the southwestern part of the Philip Smith Mountains quadrangle (Detra, 1977); data from galena separates from quartz-calcite veins from the Chandler Lake (●) and the Killik River (O) quadrangles; data from nonmagnetic heavy-mineral-concentrates from the Chandler Lake (■) and the Killik River (□) quadrangles. These lead-isotopic data contrast greatly with the uniform lead-isotopic composition of the SEDEX Zn-Pb deposits of the western Brooks Range shown in the small elliptical field that plots below the Stacey-Kramers (1975) growth curve. An error ellipse is shown in the upper left corner of the lead-isotope diagrams.

Formation; however, where SEDEX Zn-Pb deposits occur in the Kuna Formation in the western Brooks Range, the lithofacies is dominated by black shale (Moore and others, 1986, fig. 4). Substantial bedded barite resources are directly associated with the SEDEX Zn-Pb deposits in the Kuna Formation (Young, 1989), whereas in tract B, the barite in the stream sediments may come predominately from the Permian Siksikpuk Formation. Barite lenses in the Siksikpuk Formation are ubiquitous in the Brooks Range and are not associated with SEDEX Zn-Pb deposits elsewhere in the Siksikpuk Formation strata. And finally, given the limited exposure of about 3 $mi^2$ (8 $km^2$) of these facies in erosional remnants, there is a very small area for the occurrence of SEDEX Zn-Pb or bedded barite deposits in tract B. We conclude that there is less than a five-percent probability that one or more SEDEX Zn-Pb or bedded barite deposits exist within tract B.

## CARBONATE-HOSTED LEAD-ZINC DEPOSITS

Carbonate rocks of the Mississippian platform facies are plausible hosts for lead-zinc deposits in both karst and stratigraphic traps (models 32b and 32a, Briskey, 1986b, 1986d). In order for these types of deposits to form, there must have been a mechanism to focus fluid flow such as a stratigraphic pinchout on a topographic high or a weathering event during which karst topography formed traps, followed by a high fluid-flow event from a source basin containing red beds, and a source of chloride-rich brines.

Dutro (1978) described a small carbonate-hosted lead-zinc occurrence in karsts(?) in the Devonian part of the Skagit Limestone from an area that was a pre-Frasnian structural high in the western part of the Philip Smith quadrangle (Detra, 1977; Menzie and others, 1985). This occurrence fits the deposit description for carbonate-hosted lead-zinc deposits and demonstrates that topographic highs did exist in this part of the Brooks Range. However, the Skagit Limestone, which is the host for this deposit, is not present in the Chandler Lake quadrangle.

Five large, discontinuous blocks of Lisburne platform carbonate rock comprise tract C (labeled C1-C5 on the map). These Mississippian platform carbonate rocks have characteristics of potential host rocks for carbonate-hosted lead-zinc deposits. Several geologic features of the area limit the potential for formation of these deposits in the Lisburne Group platform carbonate rocks. The Early Mississippian Kayak Shale, lies stratigraphically between the clastic metal-rich sediments of the Hunt Fork Shale and the Mississippian carbonate rocks, and forms a barrier to regional fluid flow. Source beds for metals, for example, the black phosphatic shale section described below, are present in rocks of the Lisburne Group. However, it is problematic whether post Mississippian porosity existed in the clastic rocks. The lead-isotope signatures from sites 2, 6, and Atigun River argue that earlier hydrothermal fluids had already cemented the Devonian clastic section so it may not have been an aquifer in post Mississippian time. Although adequate host and source rocks are present and the Devonian clastic rocks may have served as an aquifer if porosity still existed in post Mississippian time, there is no compelling evidence for an aquifer in the stratigraphic section that would allow for large fluid-flow systems that might form a carbonate-hosted lead-zinc deposit of either type (model 32a or 32b; Briskey, 1986d, 1986b) unless fluid flow is focused by basement highs in areas where flow paths may have been created by extensive faulting or thrusting in an area overlain by carbonate rocks.

Geochemical anomalies are sparse within tract C; however, both the frequency and density of geochemical anomalies increase in drainage basins where thrust faults are more abundant (for example, in tract C5). Kelley, Sutley, and Frisken (1993) discussed strong base-metal correlations defined by the geochemical data from the nonmagnetic heavy-mineral-concentrate samples in area C5. They observed Co-Cu-Ni-Zn-Pb anomalies in drainage basins underlain by carbonate rocks and identified sphalerite, barite, and galena in the concentrate samples. These anomalies are possibly best explained by the presence of trace amounts of base-metal-bearing sulfides that originated in the quartz-carbonate veins formed during the Jurassic thrusting event discussed by Barnwell and others (1989) in and north of tract C5. The high fluid-flow regime, as indicated by the extensive manganese anomaly in the south Cobblestone Creek area, is attributed to fluid flow through the Cobblestone sandstone unit (Barnwell and others, 1989). The aeromagnetic data indicate that this area overlies a basement magnetic high (U.S. Geological Survey, 198?; Cady, 1978). We conclude that there is a limited potential for a concealed, carbonate-hosted lead-zinc deposit in the Paleozoic carbonate rocks; however, more detailed studies of the paleohydrology would be required before we could make a probabalistic estimate of the occurrence of one or more deposits in tract C. In addition, the presence of Ba, Zn, Pb, Ag, and As anomalies indicate that there may also be potential for fault-controlled base-metal mineralization in the rocks of the Cobblestone Creek study area in and immediately north of tract C5 (Barnwell and others, 1989).

## PHOSPHATE RESOURCES

Warm-current-type phosphate deposits form by the upwelling of oceanic currents along structural lows or at the mouths of rivers or estuaries, causing the deposition of phosphate in warm latitudes (Mosier, 1986a). Patton and Matzko (1959) summarized work on phosphate resources in the Brooks Range. They discussed several localities within the phosphatic section of the Lisburne Group west of Shainin Lake where trimmed grab samples were analyzed for $P_2O_5$ content. Phosphate rock within the Mississippian Lisburne Group (tract C) is confined to the black shale and chert facies of the Alapah Limestone, which is indicative of deposition in shelf or euxinic basin environments (Armstrong and Mamet, 1977b).

In order to evaluate the phosphate resources of the Chandler Lake quadrangle, we collected chip samples throughout the entire thickness of the phosphatic section of the Lisburne Group at several localities (sites ANW-1 and ANW-2 in the Killik River quadrangle to the west, and sites 82A-2, and 82A-3 in the Chandler Lake quadrangle; see map for sample localities). The samples were analyzed using both spectrographic methods (Grimes and Marranzino, 1968) and ICP-AES methods (Church, Mosier, and Motooka, 1987). All chemical data are reported from sampled intervals measured in feet (table 3); some data are from high-graded grab samples from specific intervals within the measured section. Patton and Matzko (1959) found the highest $P_2O_5$ values in the measured section at Tiglukpuk Creek (TC on the map), where the section averaged 8 percent $P_2O_5$ over a 36 foot (11 m) interval and a zone near the top of the section averaged 21 percent $P_2O_5$ over a 4.5 foot (1.4 m) interval. In this study, the average $P_2O_5$ content of channel samples collected throughout the entire thickness of the phosphate-bearing sections of the Lisburne Group (see table 3) are well below the median ore grade of 24 percent $P_2O_5$ (Mosier, 1986d).

The U.S. Bureau of Mines has just completed a systematic evaluation of the phosphate resources in the Chandler Lake quadrangle (Kurtak and others, 1995, data summarized in table 1). They investigated five areas: Kiruktagiak River (KR), Monotis Creek (MC), Skimo Creek East (SE), Skimo Creek West (SW), and Tiglukpuk Creek (TC). At these sites, stratigraphic sections were measured and sampled. Resource estimates were made for the Skimo-Tiglukpuk Creek area where the best continuity of phosphatic beds were found. At Skimo Creek, a sequence containing interbedded phosphatic shale, phosphate rock, and limestone measured 11.2 m in thickness. Chip samples collected across this entire sequence averaged 6.79 percent phosphate. At Monotis Creek, a 6.7 m-thick, less continuous sequence averages 23.0 percent phosphate (Kurtak and others, 1995). The phosphate resources in the Chandler Lake quadrangle may be larger than reported because the phosphatic section may be somewhat continuous between the two localities on Tiglukpuk and Skimo Creeks (fig. 1).

Analysis of stream sediments for phosphorous content (Erlich and others, 1988) indicates that most of the phosphatic rock in the Chandler Lake quadrangle is in or near tracts C1 and C2. Low phosphorous concentrations in the stream sediments confirm the field observations reported in Patton and Matzko (1959) that no phosphate rock had been found east of Shainin Lake. This observation was confirmed during this study at site 82A-3 where the phosphatic part of the section has been removed by faulting. Geochemical results obtained from our measured sections (see table 3 and 4) indicate areas within the phosphatic section that contain high uranium, vanadium, and other trace-metal contents that would affect mineral processing of the ore. A 45 kg bulk sample from the Kiruktagiak River occurrence was analyzed by the U.S. Bureau of Mines. It contained sixty percent fluorapatite and forty percent intergrown calcite. Trace amounts of quartz, pyrite, and sphalerite were also reported (Kurtak and others, 1995). A milling test indicated that ninety-four percent of the phosphate could be recovered in the plus-325 mesh material.

Minimum ore grades for phosphate deposits of this type are about 20.0 percent $P_2O_5$; the median grade is 24.0 percent $P_2O_5$ for deposits of 400 million tonnes of ore (Mosier, 1986d). In the measured sections sampled by the U.S. Geological Survey during this study, beds are not continuous over a distance of about 600 m, so estimates of tonnage of phosphate rock were not made. Higher phosphorous values were obtained from stream-sediment samples collected from other drainage basins within tracts C1 and C2, but time did not permit us to do a detailed evaluation of the phosphate resources in these areas. We conclude that tract C2 has a definite potential for undiscovered phosphate deposits. In view of the abundance of phosphate resources in the U.S. (Manheim and others, 1980; Fantel and others, 1984) and the relatively low proven grade of the phosphate rock of the Lisburne Group demonstrated by the U.S. Bureau of Mines study (Kurtak and others, 1995), we conclude that there is a 50-percent probability that one or more phosphate deposits may be present in the rocks of the Lisburne Group in the Chandler Lake quadrangle.

The phosphate-rich strata of the Otuk and Shublik Formations (tract D) have also been evaluated for upwelling-type phosphate deposits (model 34d, Mosier 1986a). We collected channel samples at three localities (ADB-1, ADB-3, and ADB-5) during our study. (Sites are shown on the map and the analytical data are in table 4; the locality of sample ADB-3 plots in the Permian Siksikpuk Formation because the outcrop of the Shublik Formation is exposed in a cliff bank along Welcome Creek in the fault zone and is too small to show at this map scale.) The $P_2O_5$ values are well below ore grades (compare data in table 4 with ore grades in table 1). Assuming that these data are representative, we conclude that there is less than a five-percent chance that one or more phosphate deposits occur in rocks of the Shublik Formation in the Chandler Lake quadrangle.

## BEDDED BARITE IN THE PERMIAN SIKSIKPUK FORMATION

Bedded barite deposits form in epicratonic marine embayments and restricted basins (model 31b, Orris, 1986a). Kelley, Tailleur, and others (1993) recently reported new bedded barite resources in the Howard Pass quadrangle in rocks of Mississippian age (see table 1 and fig. 1). Barite anomalies have been found in the stream-sediment samples collected from drainage basins underlain by rocks in the Siksikpuk Formation (Kelley, Barton, and others, 1993). The outcrop pattern of the Siksikpuk Formation is designated as tract E. Siok (1985) described the occurrence of barite crystals, nodules, and veins in measured sections of the Siksikpuk Formation, in the Chandler Lake quadrangle (sites A and B). Barite constitutes a minor component of the Siksikpuk Formation ranging from less than 2 to nearly 10 percent by volume. In a measured section on Tiglukpuk Creek (B), barite exceeds 30 percent in one grab sample; barite veins crosscut the bedding and also occur as discrete crystals within mudstone, indicating that the environment may have produced bulk minable deposits. Siok (1985, p. 108) concluded that, on the basis of faunal evidence, deposition of the barite-bearing portion of the Siksikpuk Formation occurred in a neritic environment at water depths of less than 200 m. Siok (1985) concluded that the potential for the presence of barite resources in rocks of the Siksikpuk Formation is low. The cutoff ore grade for bedded barite deposits exceeds 50-percent barite; the median grade contains 88-percent barite and the median tonnage of bedded barite deposits is 1.8 million tons (Orris, 1986b). Nowhere in the study area does the barite content and grade of the Siksikpuk Formation approach these tonnages. We estimate that there is less than a five-percent chance that one or more bedded barite deposits occur within rocks of the Siksikpuk Formation in the Chandler Lake quadrangle.

## VOLCANOGENIC MASSIVE SULFIDE DEPOSITS

Volcanogenic massive sulfide deposits of both the Besshi type (model 24b, Cox, 1986a) and the Kuroko type (model 28a, Singer, 1986) were briefly evaluated for this study. Many small hypabassal mafic intrusions and scattered occurrences of basaltic pillow lavas have been mapped in the Arctic Foothills assemblage (Patton and Tailleur, 1964; Kelley, 1990). Patton and Tailleur (1964) described most of these occurrences as mafic sills that have been altered predominantly to chlorite. They constrained the age of the igneous rocks to latest Jurassic on the basis of geologic relationships. No sulfides were found in any outcrops of these mafic sills. Outcrops of these units are too small to be shown accurately at map scale, but they are shown schematically within the Arctic Foothills assemblage (KMaf) by an asterisk (*). The area underlain by the Arctic Foothills assemblage contains isolated sites where the stream sediments contain anomalous concentrations of Co, Cr, As, and Zn (Kelley, Barton, and others, 1993). Isolated anomalies of Mn, Ba, As, Zn and Cu are present and persistent in the ICP-aqua-regia-leachate data (Erlich and others, 1988). Anomalous concentrations of Cu, Pb, Ag, Zn, Ba, Cr, and Ni are present and isolated Co and As anomalies were found in the nonmagnetic heavy-mineral-concentrate samples. Pyrite, chalcopyrite, arsenopyrite, sphalerite, and barite were also identified in these samples (area 1 in Kelley, Sutley, and Frisken, 1993). Although there are some geochemical anomalies that can be ascribed to these outcrops, the geologic setting does not fit critical tectonic characteristics of either the Kuroko or Besshi-type mineral-deposit models. The basaltic dikes and sills are not part of a spreading back-arc or rift basin (model 24b, Cox, 1986a) or an active volcanic arc (model 28a, Singer, 1986). Most of the field observations indicate that the volcanic rocks are dikes or sills that contain few if any sulfide minerals. We conclude that the Arctic Foothills assemblage is not permissive for the occurrence of volcanic massive sulfide deposits.

## SEDIMENTARY MANGANESE DEPOSITS

Sedimentary manganese deposits form around rims of anoxic basins during phases of transgression (Cannon and Force, 1986). High concentrations of iron and manganese were found in samples of the pebble shale unit (Barnwell and others, 1989) of the Torok Formation. Prominent coatings of pyrolusite, psilomelane(?), and hematite are present in the pebble-bearing shale, siltstone, and fine-grained sandstone in the Cobblestone Creek area. Kurtak and others (1995) also investigated the area for manganese resources (fig. 1) and confirmed the high manganese values in the Cobblestone Creek area reported by Barnwell and others (1989). Analysis of one bulk sample gave 4.8 percent manganese; grab samples collected at regularly spaced intervals across the mineralized zones contained from 1.3 to 11.7 percent manganese. The primary mineral in the bulk sample was siderite. Kurtak and others (1995) speculated that the manganese was substituting for iron in the siderite. Analyses of stream-sediment samples collected from drainage basins from the Cobblestone Creek area underlain by the Torok Formation, the Cobblestone sandstone unit, and the Fortress Mountain Formation contain anomalous concentrations of manganese (Kelley, Barton, and others, 1993; Kelley and Sutley, 1993). The highest concentration of manganese reported from rocks exceeds 2 percent (Barnwell and others, 1989) and the concentration of manganese in stream-sediment samples from this area exceed 6 percent (LANL, 1982). We interpret these data to indicate that the basin conditions are permissive for the formation of sedimentary manganese deposits (Cannon and Force, 1986; Force and Maynard, 1991).

Sedimentary manganese deposits have an established minimum grade of 10 percent and a median grade of 31 percent manganese, and a median tonnage is 7.3 million tonnes of ore (Mosier, 1986e). Within the Chandler Lake quadrangle, the relatively thin nature of the pebble-bearing shale and the low grade of manganese in clastic-dominated sections indicates that the Cretaceous basin has limited potential for sedimentary manganese resources. However, because we have not observed any manganese carbonate facies supplanting the clastic sedimentary facies in the Chandler Lake quadrangle, which would indicate areas where manganese might accumulate to sufficient grade to form a deposit (Force and others, 1991; Force and Maynard, 1991), we concluded that a permissive tract could not be delineated for sedimentary manganese deposits in the Chandler Lake quadrangle and no estimate of the number of undiscovered deposits was made.

## SANDSTONE-HOSTED URANIUM DEPOSITS IN THE CRETACEOUS NANUSHUK GROUP

Sandstone-hosted or roll-front uranium deposits are formed during diagenesis by groundwater leaching uranium from the source rocks and redepositing and concentrating uranium at sites where reducing conditions are found in the sedimentary rocks (model 30c, Turner-Peterson and Hodges, 1986). Huffman (1985) summarized the suitability of the Lower and Upper Cretaceous rocks of the Nanushuk Group in northern Alaska (fig. 2) for undiscovered sediment-hosted uranium deposits. Within the study area, the Nanushuk Group, which consists of Lower and Upper Cretaceous rocks above the Torok Formation and below the Seabee Formation, underlie much of the southern and northern Arctic foothills belts. The Nanushuk Group includes the rocks of the Tuktu, Grand Stand, Chandler, and Ninuluk Formations. They are gently folded, contain abundant plant debris and pyrite, and are gray to green in color, indicating the presence of reduced material that would cause precipitation of uranium from groundwater. The rocks of the upper part of the Nanushuk Group as well as the rocks of the overlying formations contain beds of bentonite and may be source rocks for uranium. The phosphatic black shales of the Triassic Shublik Formation also contain as much as 80 ppm uranium and may also be uranium source rocks (Brosgé and Reiser, 1976, table 1; table 4 of this report).

The uranium potential of the study area was evaluated using data from the NURE sampling within the quadrangle (LANL, 1982), as well as the results summarized by Huffman (1985). The maximum concentration of uranium measured in both lake and stream samples collected from the study area was 5.7 ppm; the mean value was 2.6 ppm. Low concentrations of uranium were also inferred by Huffman (1985) on the basis of radiometric studies of the Nanushuk Group, which included many sites in the Chandler Lake quadrangle. Factor analysis of these data (LANL, 1982) shows that uranium correlates with a factor representing detrital minerals such as zircon and magnetite. Kelley and Sutley (1993) argue that uranium correlates with both a shale and a sandstone lithologic factor. They present a plot of the uranium-to-thorium ratio to show where areas of high uranium and high uranium-thorium ratios correspond to these two lithologic factors and demonstrate that the variation of uranium and the uranium-thorium ratio are explained by the presence of detrital uranium-bearing minerals in the sedimentary rocks. Two small areas that are underlain by rocks of the Chandler and Ninuluk Formations have high uranium-thorium ratios and contain more than 3.4 ppm uranium (Kelley and Sutley, 1993). Both of these sites lie in the prodelta facies of the Umiat delta complex (see fig. 26, p. 62-63, Huffman and others, 1985), within that part of the formation that Huffman (1985; oral commun., 1991) suggests has the highest potential for undiscovered sandstone-hosted uranium deposits. However, samples collected from these localities do not contain anomalously high concentrations of copper or vanadium, two elements that behave similarly in this depositional environment (Turner-Peterson and Hodges, 1986) and the concentration of uranium is not high for these deposit types (A.C. Huffman, Jr., oral commun., 1991). We conclude that, although the geologic conditions are permissive, the geochemical data indicate that the area of the Chandler Lake quadrangle underlain by Cretaceous sedimentary rocks is not favorable for the occurrence of sandstone-hosted uranium deposits and no mineral-resource tract is delineated.

## PLACER GOLD

Scattered gold anomalies were found in stream-sediment samples from the northern part of the Chandler Lake quadrangle (plate 3, Kelley and Sutley, 1993) in the area that contains rocks of the Colville and Nanushuk Groups. The Colville Group includes rocks of the Seabee, Prince Creek, and Schrader Bluff Formations, whereas the Nanushuk Group includes the rocks of the Tuktu, Grand Stand, Chandler, and Ninuluk Formations. The area also contains extensive mapped and unmapped Quaternary deposits (Hamilton, 1979; Kelley, 1990). Of the 58 stream-sediment samples from the northern part of the Chandler Lake quadrangle collected by the U.S. Geological Survey, 8 samples contain detectable gold (0.5 to 1.28 ppm; Erlich and others, 1988) whereas only three of the 420 NURE stream-sediment samples contained detectable gold (0.44 to 1.28 ppm; LANL, 1982). Although the samples were not collected from the same localities, gold anomalies generally were found in the same area (Kelley and Sutley, 1993, plate 3). In contrast, of the 193 NURE lake-sediment samples, 14 contained gold at detectable concentrations ranging from 0.34 to 1.73 ppm. Examination of the distribution of gold in NURE samples from Alaska (LANL, 1983, plate 16) shows that the gold anomalies from the northern part of the Brooks Range are dominated by gold in lake-sediment samples. The scattered gold anomalies in the northern part of the quadrangle may be the result of isolated gold placer deposition in a deltaic environment (Huffman and others, 1985), but these gold anomalies may also represent a sample-media bias. Studies by Barnwell and others (1989) indicated that there are no gold placer resources in this area. We have not delineated a tract for gold-placer deposits (Yeend, 1986, model 39a) because the gold is very fine grained (that is, no gold anomalies were found in the nonmagnetic heavy-mineral-concentrate samples, Erlich and others, 1988) and because there are no known or indicated source areas for gold.

## SAND AND GRAVEL RESOURCES

Sand and gravel resources are abundant in the glacial and alluvial deposits within the study area. Large quantities of sand and gravel were produced from the Philip Smith Mountains quadrangle (Menzie and others, 1985) for use in construction of the Trans-Alaska pipeline system. Sand and gravel resources present within the study area are sufficient to meet local needs for the foreseeable future. No tracts showing sand and gravel resources are delineated; however, tracts for sand and gravel resources can readily be defined on the basis of the surficial geologic map of the study area (Hamilton, 1979).

## LIMESTONE RESOURCES

Analyses of samples of limestone from the Mississippian Lisburne Group collected in the Philip Smith Mountains quadrangle (Menzie and others, 1985) indicated limestone resources for the manufacture of cement. No new analytical work was done on the platform carbonate rocks of the Lisburne Group (tract C) during this study; however, the platform carbonate rocks (Maw) constitute a resource for limestone that could be used in the production of cement if the transportation infrastructure is developed and the market demand were present.

# REFERENCES CITED


Adams, K.E., 1991, Permian sedimentation in the northcentral Brooks Range, Alaska--Implications for tectonic reconstructions: M.S. thesis, Fairbanks, University of Alaska, 122 p.

Anderson, A.V., 1987, Provenance and petrofacies, Upper Devonian sandstones, Philip Smith Mountains and Arctic quadrangles, Brooks Range, Alaska: M.S. thesis, Tucson, University of Arizona, 113 p.

Anderson, G.M., 1983, Some geochemical aspects of sulfide precipitation in carbonate rocks, *in* Kisvarsanyi, Geza, Grant, S.K., Pratt, W.P., and Koenig, J.W., eds., International Conference on Mississippi Valley type lead-zinc deposits, Proceedings, Rolla, Missouri, October,1982, University of Missouri at Rolla, p. 61-76.

Armstrong, A.K., and Mamet, B.L., 1977a, Carboniferous microfacies, microfossils, and corals, Lisburne Group Arctic Alaska: U.S. Geological Survey Professional Paper 849, 144 p.

_____ 1977b, Mississippian microfacies of the Lisburne Group, Endicott Mountains, arctic Alaska, *in* Blean, K.M., ed., The United States Geological Survey in Alaska: Accomplishments during 1976: U.S. Geological Survey Circular 751-B, p. B18-B19.

_____ 1978, Mississippian microfacies of the Lisburne Group, Endicott Mountains, arctic Alaska, *in* Stelck, C.R., and Chatterton, B.D.E., eds., Western and arctic Canadian biostratigraphy: Geological Association of Canada Special Paper 18, p. 333-394.

_____ 1989, Stratigraphy of the Lisburne Group in the central Brooks Range, *in* Mull, C.G. and Adams, K.E., eds., Dalton Highway, Yukon River to Prudhoe Bay, Alaska: Division of Geological and Geophysical Surveys Guidebook No. 7, v. 2, p. 253-265.

Armstrong, A.K., Mamet, B.L., Brosgé, W.P., and Reiser, H.N., 1976, Carboniferous section and unconformity at Mount Doonerak, Brooks Range, Alaska: American Association of Petroleum Geologists Bulletin, v. 60, p. 962-972.

Barnes, D.F., Mayfield, C.F., Morin, R.L., and Brynn, Sean, 1982, Gravity measurements useful in the preliminary evaluation of the Nimiuktuk barite deposit, Alaska: Economic Geology, v. 77, p. 185-189.

Barnwell, C.E., Simpson, Steven, and Church, S.E., 1989, Analytical results and sample locality maps of stream-sediment and rock samples from the Cobblestone Creek area, southeastern Chandler Lake quadrangle, Alaska: U.S. Geological Survey Open-File Report 89-540, 26 p. scale 1:8,240.

Barton, H.N., Odland, S.K., O'Leary, R.M., and Day, G.W., 1982, Geochemical data for the Killik River and Chandler Lake quadrangles, Alaska: U.S. Geological Survey Open-File Report 82-1026, 53 p., scale 1:250,000.

Bird, K.J., and Molenaar, C.M., 1992, The north slope foreland basin, Alaska *in* MacQueen, R.W., and Leckie, D.A., eds., Foreland basins and fold belts, American Association of Petroleum Geologists Memoir 55, p. 363-393.

Bliss, J.D., Brosgé, W.P., Dillon, J.T., Dutro, J.T., Jr., Cathrall, J.B., and Cady, J.W., 1988, Mineral resource assessment of the Wiseman 1° x 3° quadrangle, Alaska: U.S. Geological Survey Open-File Report 88-533, 84 p., scale 1:250,000.

Bodnar, D.A., 1984, Stratigraphy, age, depositional environments, and hydrocarbon source rock evaluation of the Otuk formation, north-central Brooks Range, Alaska; M.S. thesis, Fairbanks, University of Alaska, 232 p.

_____ 1989, Stratigraphy of the Otuk Formation and a Cretaceous coquinoid limestone and shale unit, northcentral Brooks Range, *in* Mull, C.G., and Adams, K.E., eds., Dalton Highway, Yukon River to Prudhoe Bay, Alaska: Division of Geological and Geophysical Surveys Guide Book No. 7, v. 2, p. 277-284.

Briskey, J.A., 1986a, Descriptive model of sedimentary exhalative Zn-Pb, *in* Cox, D.P., and Singer, D.A., eds., Mineral Deposit Models: U.S. Geological Survey Bulletin 1693, p. 211-212.

_____ 1986b, Descriptive model of Appalachian Zn, *in* Cox, D.P., and Singer, D.A., eds., Mineral Deposit Models: U.S. Geological Survey Bulletin 1693, p. 222-223.

_____ 1986c, Descriptive model of sandstone-hosted Pb-Zn, *in* Cox, D.P., and Singer, D.A., eds., Mineral Deposit Models: U.S. Geological Survey Bulletin 1693, p. 201-202.

_____ 1986d, Descriptive model of southeast Missouri Pb-Zn, *in* Cox, D.P., and Singer, D.A., eds., Mineral Deposit Models: U.S. Geological Survey Bulletin 1693, p. 220-221.

Brosgé, W.P., and Reiser, H.N., 1976, Preliminary geologic and mineral resource maps (excluding petroleum), Arctic National Wildlife Range, Alaska: U.S. Geological Survey Open-File Report 76-539, scale 1:500,000.

Brosgé, W.P., Reiser, H.N., Dutro, J.T., Jr., and Nilsen, T.H., 1979, Geologic map of Devonian rocks in parts of the Chandler Lake and Killik River quadrangles, Alaska: U.S. Geological Survey Open-File Report 79-1224, scale 1:200,000.

Cady, J.W., 1978, Aeromagnetic map and interpretation of the Philip Smith Mountains quadrangle, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-879-E, scale 1:250,000.

Cannon, W.F., and Force, E.R., 1986, Descriptive model of sedimentary Mn, *in* Cox, D.P., and Singer, D.A., eds., Mineral Deposit Models: U.S. Geological Survey Bulletin 1693, p. 231.

Church, S.E., Delevaux, M.H., and Gray, J.E., 1987, Pb-isotope data base for sulfides from Alaska, 1987: U.S. Geological Survey Open-File Report 87-259, 44 p.

Church, S.E., Gray, J.E., Delevaux, M.H., and LeHuray, A.P., 1987, Pb-isotope signatures of Devonian-Mississippian massive sulfide deposits in Alaska and their significance to mineral exploration, *in* Elliott, I.L., and Smee, B.W., eds., GEOEXPO/86, Exploration in the North American Cordillera, May 12-14, 1986, Vancouver, Canada: Association of Exploration Geochemists, p. 132-141.

Church, S.E., Mosier, E.L., and Motooka, J.M., 1987, Mineralogical basis for the interpretation of multi-element (ICP-AES), oxalic acid, and aqua regia partial digestions of stream sediments for reconnaissance geochemistry: Journal of Geochemical Exploration, v. 29, p. 207-233.

Cobb, E.H., Mayfield, C.F., and Brosgé, W.P., 1981, Summaries of data and lists of references to metallic and selected nonmetallic mineral occurrences in eleven quadrangles in Northern Alaska: U.S. Geological Survey Open-File Report 75-628 [supplement], p. 10-11.

Cox, D.P., 1986a, Descriptive model of Besshi massive sulfide, *in* Cox, D.P., and Singer, D.A., eds., Mineral Deposit Models: U.S. Geological Survey Bulletin 1693, p. 136.

_____ 1986b, Descriptive model of sediment-hosted Cu, *in* Cox, D.P., and Singer, D.A., eds., Mineral Deposit Models: U.S. Geological Survey Bulletin 1693, p. 205.

Cox, D.P., and Singer, D.A., eds., 1986, Mineral Deposit Models: U.S. Geological Survey Bulletin 1693, 379 p.

Crowder, R.K., 1987, Cretaceous basin to shelf transition in northern Alaska--deposition of the Fortress Mountain Formation, *in* Tailleur, I.L., and Weimer, Paul, eds., Alaskan North Slope geology, Fieldtrip Guidebook 50, Society of Economic Paleontologists and Mineralogists, p. 449-458.

Detra, D.E., 1977, Delineation of an anomalous lead-zinc area in the Philip Smith Mountains A-2 quadrangle, Alaska: U.S. Geological Survey Open-File Report 77-223, 11 p.

Detterman, R.L., Bickel, R.S., and Gryc, George, 1963, Geology of the Chandler River region, Alaska: U.S. Geological Survey Professional Paper 303-E, 323 p.

Dutro, J.T., Jr., 1978, Potential strata-bound lead-zinc mineralization, Philip Smith Mountains quadrangle, Alaska, *in* Johnson, K.M., ed., The United States Geological Survey in Alaska--Accomplishments during 1977: U.S. Geological Survey Circular 772-B, p. 9-11.

Duttweiler, K.A., 1986, Sulfide occurrences in the Itkillik River region, southeast Chandler Lake quadrangle, Brooks Range, *in* Bartsch-Winkler, Susan, and Reed, K.M., eds., Geologic studies in Alaska by the U.S. Geological Survey during 1985: U.S. Geological Survey Circular 978, p. 10-13.

_____ 1987, Use of factor analysis in locating base metal mineralization in the Killik River quadrangle, Alaska, *in* Hamilton, T.D., and Galloway, J.P., eds., Geologic studies in Alaska by the U.S. Geological Survey during 1986: U.S. Geological Survey Circular 998, p. 27-30.

Erlich, Olga, Motooka, J.M., Church, S.E., Bailey, E.A., Arbogast, B.F., and Willson, W.R., 1988, Analytical data and sample locality map for aqua-regia leachates of stream sediments analyzed by ICP, and emission spectrographic results for both stream sediments and panned concentrates collected in 1985 from the Chandler Lake quadrangle, Alaska: U.S. Geological Survey Open-File Report 88-530, 38 p., scale 1:250,000.

Fantel, R.J., Anstett, T.F., Peterson, G.R., Porter, K.E., and Sullivan, D.E., 1984, Phosphate rock availability--world, a minerals availability program appraisal: U.S. Bureau of Mines Information Circular 8989, 65 p.

Force, E.R. and Maynard, J.B., 1991, Manganese: Syngenetic deposits on the margins of anoxic basins, *in* Force, E.R., Eidel, J.J., and Maynard, J.B., eds., Sedimentary and diagenetic mineral deposits--A basin analysis approach to exploration: Reviews in Economic Geology, v. 5, p.147-157.

Force, E.R., Eidel, J.J., and Maynard, J.B., eds., 1991, Sedimentary and diagenetic mineral deposits--A basin analysis approach of exploration: Reviews in Economic Geology, v. 5, 216 p.

Gaccetta, J.D., and Church, S.E., 1989, Lead isotope data base for sulfide occurrences from Alaska, December, 1989: U.S. Geological Survey Open-File Report 89-688, 60 p.

Grimes, D.J., and Marranzino, A.P., 1968, Direct-current arc and alternating-current spark emission spectrographic field methods for the semiquantitative analysis of geologic materials: U.S. Geological Survey Circular 591, 6 p.

Goodfellow, W.D., and Jonasson, I.R., 1986, Environment of formation of the Howard Pass (XY) Zn-Pb deposit, Selwyn Basin, Yukon, *in* Morin, J.A., ed., Mineral Deposits of Northern Cordillera: Canadian Institute of Mining and Metallurgy Special Volume 37, p. 19-50.

Hamilton, T.D., 1979, Surfical geologic map of the Chandler Lake quadrangle, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-1121, scale 1:250,000.

Huffman, A.C., Jr., 1985, Uranium potential of the Cretaceous Nanushuk Group, North Slope, Alaska, *in* Huffman, A.C., Jr., ed., Geology of the Nanushuk Group and related rocks, North Slope Alaska: U.S. Geological Survey Bulletin 1614, p. 121-129.

Huffman, A.C., Jr., Ahlbrandt, T.S., Pasternack, Ira, Stricker, G.D., and Fox, J.E., 1985, Depositional and sedimentologic factors affecting the reservoir potential of the Cretaceous Nanushuk Group, central North Slope, Alaska, *in* Huffman, A.C., Jr., ed., Geology of the Nanushuk Group and related rocks, North Slope Alaska: U.S. Geological Survey Bulletin 1614, pp. 61-74.

Kelley, J.S., 1988, Preliminary geologic map of the Chandler Lake quadrangle, Alaska: U.S. Geological Survey Open-File Report 88-42, 2 sheets, scale 1:125,000.

_____ 1990, Generalized geologic map of the Chandler Lake quadrangle, north-central Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-2144-A, 19 p., scale 1:250,000.

Kelley, J.S., and Bohn, Diedra, 1988, Decollements in the Endicott Mountains allochthon, north-central Brooks Range, *in* Galloway, J.P., and Hamilton, T.D., eds., Geological studies in Alaska by the U.S. Geological Survey during 1987: U.S. Geological Survey Circular 1016, p. 44-47.

Kelley, J.S., and Brosgé, W.P., 1995, Geologic framework of a transect in the central Brooks Range and Arctic foothills, and correlation with basins under the Arctic Coastal Plain, an alternative to the Endicott Mountain allochthon, northern Alaska: Bulletin of the American Association of Petroleum Geologists, v. 79, p. 1087-1116.

Kelley, J.S., Tailleur, I.L., Morin, R.L., Reed, K.M., Harris, A.G., Schmidt, J.M., Brown, F.M., and , J.M., 1993, Barite deposits in the Howard Pass quadrangle and possible relations to barite elsewhere in the northwestern Brooks Range, Alaska: U.S. Geological Survey Open-File Report 93-215, p. 1-13.

Kelley, K.D., and Mull, C.G., 1995, Map showing areas of potential for mineral resources in the Killik River 1° x 3° quadrangle, Brooks Range, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-2225-A, scale 1:250,000.

Kelley, K.D., and Sutley, S.J., 1993, Maps showing geochemistry of sediment samples from the northern part of the Chandler Lake quadrangle, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-2144-D, scale 1:250,000.

Kelley, K.D., Barton, H.N., Sutley, S.J., and O'Leary, R.M., 1993, Maps showing geochemistry of sediment samples from the southern part of the Chandler Lake quadrangle, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-2144-C, scale 1:250,000.

Kelley, K.D., Sutley, S.J., and Frisken, J.G, 1993, Maps showing geochemistry and mineralogy of non-magnetic heavy-mineral-concentrate samples from the southern part of the Chandler Lake quadrangle, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-2144-B, scale 1:250,000.

Kurtak, J.M., Hicks, R.W., Werdon, M.B., Meyer, M.P., and Mull, C.G., 1995, Mineral investigations in the Colville mining district and southern national petroleum reserve in Alaska: U.S. Bureau of Mines Open-File Report 8-95, 217 p.

Lange, I.M., Nokleberg, W.J., Plahuta, J.T., Krouse, H.R., and Doe, B.R., 1985, Geologic setting, petrology, and geochemistry of stratiform sphalerite-galena-barite deposits, Red Dog Creek, and Drenchwater Creek areas, northwestern Brooks Range, Alaska: Economic Geology, v. 80, p. 1896-1926.

Los Alamos National Laboratory, 1982, Uranium hydrogeochemical and stream sediment reconnaissance of the Chandler Lake NTMS quadrangle, Alaska: U.S. Department of Energy Open-File Report GJBX-49(82), 89 p., 8 plates, scale 1:250,000.

_____ 1983, The Geochemical Atlas of Alaska: U.S. Department of Energy, Los Alamos National Laboratory Open-File Report GJBX-32(83), 57 p., 6 plates, scale 1:6,000,000.

MacIntyre, D.G., 1983, Geology and stratiform barite-sulfide deposits of the Gataga District, northeast British Columbia, *in* Sangster, D.F., ed., Sediment-hosted stratiform lead-zinc deposits: Canadian Mineralogical Association Short Course Handbook 9, v. 8, p.85-119.

Manheim, F.T., Pratt, R.M., and McFarlin, P.F., 1980, Composition and origin of phosphorite deposits of the Blake Plateau, Society of Economic Paleontologists and Mineralogists Special Publication No. 29, p. 117-137.

Mayfield, C.F., Cutis, S.M., Ellersieck, I.R., and Tailleur, I.L., 1979, Reconnaissance geology of the Ginny Creek zinc-lead-silver and Nimiuktuk barite deposits, northwestern Brooks Range, Alaska: U.S. Geological Survey Open-File Report 79-1092, 21 p., 2 plates, scale 1:250,000.

Menzie, W.D., and Mosier, D.L., 1986, Grade and tonnage model of sedimentary exhalative Zn-Pb, *in* Cox, D.P., and Singer, D.A., eds., Mineral Deposit Models: U.S. Geological Survey Bulletin 1693, p. 212-215.

Menzie, W.D., Reiser, H.N., Brosgé, W.P., and Detterman, R.L., 1985, Map showing distribution of mineral resources (excepting oil and gas) in the Philip Smith Mountains quadrangle, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-879-C, scale 1:250,000.

Meyer, M.P., 1994, Analytical results from U.S. Bureau of Mines investigations in the Colville mining district, Alaska: U.S. Bureau of Mines Open-File Report 34-94, 137 p.

Molenaar, C.M., Egbert, R.M., and Krystinik, L.F., 1988, Depositional facies, petrography, and reservoir potential of the Fortress Mountain Formation (Lower Cretaceous), central North Slope, Alaska, *in* Gryc, George, ed., Geology and exploration of the National Petroleum Reserve in Alaska, 1974 to 1982: U.S. Geological Survey Professional Paper 1399, p. 257-280.

Moore, D.W., Young, L.E., Modene, J.S., and Plahuta, J.T., 1986, Geologic setting and genesis of the Red Dog zinc-lead-silver deposit, western Brooks Range, Alaska: Economic Geology, v. 81, p. 1696-1727.

Mosier, D.L., 1986a, Descriptive model of upwelling type phosphate deposits, *in* Cox, D.P., and Singer, D.A., eds., Mineral Deposit Models: U.S. Geological Survey Bulletin 1693, p. 234.

_____ 1986b, Descriptive model of warm-current type phosphate deposits, *in* Cox, D.P., and Singer, D.A., eds., Mineral Deposit Models: U.S. Geological Survey Bulletin 1693, p. 237.

_____ 1986c, Grade and tonnage model of sandstone-hosted Pb-Zn, *in* Cox, D.P., and Singer, D.A., eds., Mineral Deposit Models: U.S. Geologic al Survey Bulletin 1693, p. 202-204.

_____ 1986d, Grade and tonnage model of warm-current type phosphate deposits, *in* Cox, D.P., and Singer, D.A., eds., Mineral Deposit Models: U.S. Geological Survey Bulletin 1693, p. 237-238.

_____ 1986e, Grade and tonnage model sedimentary Mn, *in* Cox, D.P., and Singer, D.A., eds., Mineral Deposit Models: U.S. Geological Survey Bulletin 1693, p. 231-233.

Mosier, D.L. and Briskey, J.A., 1986, Grade and tonnage model of southeast Missouri Pb-Zn and Appalachian Zn deposits, *in* Cox, D.P., and Singer, D.A., eds., Mineral Deposit Models: U.S. Geological Survey Bulletin 1693, p. 224-226.

Mosier, D.L., Singer, D.A., and Cox, D.P., 1986, Grade and tonnage model of sediment-hosted Cu, *in* Cox, D.P., and Singer, D.A., eds., Mineral Deposit Models: U.S. Geological Survey Bulletin 1693, p. 206-208.

Mull, C.G, Tailleur, I.L., Mayfield, C.F., Ellersieck, Inyo, and Cutis, S.M., 1982, New Upper Paleozoic and Lower Mesozoic stratigraphic units, central and western Brooks Range, Alaska: American Association of Petroleum Geologists Bulletin, v. 66, p. 348-362.

Nelson, W.H., and Csejtey, Béla, Jr., 1990, Stratigraphy and structure of the Ekokpuk Creek area, north-central Brooks Range, Alaska: U.S. Geological Survey Bulletin 1849, 8 p.

Nilsen, T.H., Brosgé, W.P., Dutro, J.T., Jr., and Moore, T.E., 1981, Depositional model for the fluvial Upper Devonian Kanayut Conglomerate, Brooks Range, Alaska, *in* Albert, N.R.D., and Hudson, Travis, eds., The United States Geological Survey in Alaska--Accomplishments during 1979; U.S. Geological Survey Circular 823-B, p. B20-21.

Nilsen, T.H., and Moore, T.E., 1984, Stratigraphic nomenclature for the Upper Devonian and Lower Mississippian(?) Kanayut Conglomerate, Brooks Range, Alaska: U.S. Geological Survey Bulletin 1529-A, 64 p.

Nokleberg, W.J., Bundtzen, T.K., Berg, H.C., Brew, D.A., Grybeck, Donald, Robinson, M.S., Smith, T.E., and Yeend, Warren, 1987, Significant metalliferous lode deposits and placer districts of Alaska: U.S. Geological Bulletin 1786, 104 p.

Orris, G.J., 1986a, Descriptive model of bedded barite, *in* Cox, D.P., and Singer, D.A., eds., Mineral Deposit Models: U.S. Geological Survey Bulletin 1693, p. 216.

_____ 1986b, Grade and tonnage model of bedded barite, *in* Cox, D.P., and Singer, D.A., eds., Mineral Deposit Models: U.S. Geological Survey Bulletin 1693, p. 216-218.

Patton, W.W., Jr., and Matzko, J.J., 1959, Phosphate deposits in northern Alaska, U.S. Geological Survey Professional Paper 302-A, 1-16.

_____ 1964, Geology of the Killik-Itkillik region, Alaska: U.S. Geological Survey Professional Paper 303-G, p. 409-500.

Reiser, H.R., Brosgé, W.P., Dutro, J.T., Jr., and Detterman, R.L., 1979, Upper Paleozoic volcanic rocks in the eastern and central Brooks Range, *in* Johnson, K.M., and Williams, J.R., eds., The United States Geological Survey in Alaska--Accomplishments during 1978: U.S. Geological Survey Circular 804-B, p. 25-27.

Rose, A.W., 1976, The effect of cuprous chloride complexes in the origin of red-bed copper and related deposits: Economic Geology, v. 71, p. 1036-1048.

Singer, D.A., 1975, Mineral resource models and the Alaska Mineral Resource Assessment Program, *in* Vogely, W.A., ed., Mineral material modeling: Washington, D.C., John Hopkins University Press, p. 370-382.

_____ 1986, Descriptive model of Kuroko massive sulfide, *in* Cox, D.P., and Singer, D.A., eds., Mineral Deposit Models: U.S. Geological Survey Bulletin 1693, p. 189-190.

Siok, J.P., III, 1985, Geologic history of the Siksikpuk Formation on the Endicott Mountains and Picnic Creek allochthons, north central Brooks Range, Alaska: Fairbanks, University of Alaska, M.S. thesis, 253 p., 13 charts.

Stacey, J.S., and Kramers, J.D., 1975, Approximation of terrestrial lead isotope evolution by a two-stage model: Earth and Planetary Science Letters, v. 26, p. 207-221.

Sutley, S.J., Duttweiler, K.A., and Hopkins, R.T., 1984, Analytical results and sample locality map of stream-sediment and panned-concentrate samples from the Chandler Lake quadrangle: U.S. Geological survey Open-File Report 84-412, 30 p.

Tailleur, I.L., Ellersieck, Inyo, and Mayfield, C.F., 1977, Mineral resources of the western Brooks Range, *in* Blean, K.M., ed., The United States Geological Survey in Alaska--Accomplishments during 1976: U.S. Geological Survey Circular 751-B, p. 24-25.

Turner-Peterson, C.E., and Hodges, C.A., 1986, Descriptive model of sandstone U, *in* Cox, D.P., and Singer, D.A., eds., Mineral Deposit Models: U.S. Geological Survey Bulletin 1693, p. 209-210.

U.S. Geological Survey, 1983, Aeromagnetic map of the Killik River and Chandler Lake 1° x 3° quadrangles, Alaska: U.S. Geological Survey Open-File Report 83-607, scale 1:250,000.

Wahrhaftig, Clyde, 1965, Physiographic divisions of Alaska: U.S. Geological Survey Professional Paper 482, 52 p., 6 plates.

Yeend, W.E., 1986, Descriptive model of placer Au-PGE, *in* Cox, D.P., and Singer, D.A., eds., Mineral Deposit Models: U.S. Geological Survey Bulletin 1693, p. 261.

Young, L.E., 1989, Geology and genesis of the Red Dog deposit, western Brooks Range, Alaska: Canadian Institute of Mining and Metallurgical Bulletin, v. 82, p. 57-67.

Table 3. Analytical data from phosphatic rocks collected from the Lisburne Group, Chandler Lake and Killik River quadrangles, Alaska
[N, not detected; <, detected but below the limit of determination shown; >, determined to be greater than the value shown; --, no data. Spectrographic data, "s," B.F. Arbogast, analyst; uranium data, Ted Roemer, analyst; ICP data, J.M. Motooka, analyst]

| Interval sampled | Mg-pct. s | Ca-pct. s | Fe-pct. s | Ti-pct. s | Mn-ppm s | B-ppm s | Be-ppm s | Sr-ppm s | Ba-ppm s | La-ppm s | Y-ppm s | Sc-ppm s | Zr-ppm s | U-ppm s |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Section ANW-1, lat 68° 23' 15" N., long. 154° 20' 00" W.** | | | | | | | | | | | | | | |
| 1 | 1.0 | <.05 | 2.0 | .300 | 100 | 200 | 2 | N | 1,500 | N | 30 | 15 | 200 | .35 |
| 27 | 7.0 | 15.00 | 1.5 | .020 | 1,000 | <10 | N | 1,000 | >5,000 | N | 15 | <5 | 10 | .75 |
| 0-28 | 1.5 | 1.00 | 3.0 | .200 | 200 | 200 | 1 | 300 | 5,000 | N | 30 | 15 | 200 | .45 |
| 29-63 | .5 | 1.50 | 1.5 | .200 | 200 | 200 | <1 | 500 | 2,000 | <20 | 30 | 10 | 100 | .45 |
| 64-80 | 1.5 | 7.00 | 3.0 | .300 | 1,000 | 200 | N | 500 | 5,000 | 50 | 100 | 20 | 100 | 1.40 |
| 80 | .3 | .50 | 1.5 | .150 | 200 | 150 | 2 | 100 | 1,500 | N | 70 | 10 | 100 | 3.30 |
| 81-109 | 1.0 | 1.00 | 2.0 | .300 | 200 | 200 | 1 | 200 | 5,000 | <20 | 50 | 15 | 200 | 1.10 |
| 110-148 | .5 | 10.00 | .5 | .100 | 50 | 100 | N | 300 | 3,000 | N | 30 | 5 | 50 | 1.30 |
| 140 | 1.0 | 10.00 | 1.5 | .100 | 100 | 150 | <1 | 700 | 1,500 | N | 20 | 5 | 50 | .55 |
| 149-202 | .7 | 10.00 | .5 | .070 | 100 | 100 | N | 300 | 2,000 | N | 30 | <5 | 50 | 1.10 |
| 203-250 | 1.0 | 15.00 | .5 | .150 | 500 | 100 | N | 700 | 3,000 | 20 | 50 | 10 | 200 | 1.70 |
| 251-298 | 1.0 | 15.00 | 1.5 | .200 | 500 | 200 | N | 500 | 3,000 | N | 50 | 10 | 200 | .70 |
| 299-356 | .2 | .20 | 1.0 | .100 | 70 | 200 | N | N | 2,000 | N | <10 | 5 | 100 | .45 |
| ls. ǀ 357 | .5 | 15.00 | .1 | .005 | 500 | N | N | 500 | 500 | N | <10 | N | 10 | .35 |
| shale ǀ – | 1.0 | 10.00 | 1.0 | .100 | 500 | 100 | N | 300 | 1,000 | N | 50 | 10 | 100 | .65 |
| chert ǀ 383 | .2 | 7.00 | .2 | .020 | 300 | 100 | N | 300 | 700 | N | 20 | <5 | 20 | .25 |
| **Section ANW-2, lat 68° 19' 30" N., long. 155° 40' 42" W.** | | | | | | | | | | | | | | |
| 0-15 | 5.0 | 5.00 | .5 | .050 | 100 | 70 | N | N | 200 | 100 | 100 | 5 | 20 | 5.90 |
| 6 | 5.0 | 10.00 | .3 | .020 | 100 | 30 | <1 | N | 300 | <20 | 100 | 5 | 10 | 3.10 |
| 18 | .2 | .50 | .2 | .010 | 20 | 70 | <1 | N | 200 | N | 50 | N | <10 | 2.40 |
| 16-57 | 2.0 | 5.00 | .2 | .020 | 70 | 50 | N | N | 200 | <20 | 100 | 5 | 20 | 5.90 |
| 58-72 | 5.0 | 10.00 | .3 | .020 | 200 | 50 | N | N | 200 | 50 | 100 | 5 | 20 | 2.90 |
| 72 | .5 | 1.00 | .2 | .010 | 100 | 100 | <1 | N | 300 | N | 50 | N | <10 | 2.90 |
| 73-153 | 2.0 | 5.00 | .3 | .050 | 50 | 70 | N | N | 300 | 50 | 50 | 5 | 20 | 3.00 |

Table 3. Analytical data from phosphatic rocks collected from the Lisburne Group, Chandler Lake and Killik River quadrangles, Alaska—continued

| Interval sampled | Mg–pct. s | Ca–pct. s | Fe–pct. s | Ti–pct. s | Mn–ppm s | B–ppm s | Be–ppm s | Sr–ppm s | Ba–ppm s | La–ppm s | Y–ppm s | Sc–ppm s | Zr–ppm s | U–ppm s |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Section 82A-2, lat 68° 22' 42" N., long. 152° 56' 42" W.** | | | | | | | | | | | | | | |
| 13-22 | 3.00 | 10 | 1.00 | .20 | 100 | 150 | N | 200 | 500 | 300 | 500 | 20 | 200 | 25.0 |
| 23 | .30 | 20 | .10 | .01 | 20 | <10 | N | 1,000 | 200 | 200 | 500 | 7 | 10 | 110.0 |
| 24 | .05 | 20 | .07 | .01 | 10 | 30 | N | 1,000 | 200 | 200 | 500 | 5 | 10 | 96.0 |
| 36 | 1.00 | 15 | 1.50 | .20 | 500 | 50 | N | 300 | 1,000 | 20 | 50 | 15 | 150 | 1.5 |
| 39 | 1.00 | 10 | 1.00 | .10 | 150 | 100 | 1 | 500 | 500 | 300 | 500 | 15 | 100 | 350.0 |
| 40 | 3.00 | 3 | 1.00 | .20 | 700 | 150 | <1 | <100 | 200 | <20 | 50 | 10 | 150 | 3.1 |
| 30-41 | .50 | 15 | 1.00 | .30 | 50 | 200 | N | 1,000 | 500 | 300 | 500 | 30 | 200 | 79.0 |
| 45 | .50 | 20 | .70 | .10 | 700 | 70 | N | 200 | 200 | <20 | 50 | 10 | 100 | 2.0 |
| 48 | .70 | 7 | 2.00 | .30 | 500 | 200 | 1 | 100 | 500 | 20 | 50 | 20 | 200 | 2.2 |
| 53 | .30 | 2 | 2.00 | .50 | 300 | 200 | 1 | <100 | 700 | 50 | 50 | 20 | 200 | 1.7 |
| 45-54 | .50 | 2 | 2.00 | .30 | 200 | 200 | <1 | <100 | 700 | 50 | 50 | 20 | 200 | 7.0 |
| 57 | .50 | 20 | .50 | .15 | 500 | 100 | <1 | 500 | 500 | 150 | 100 | 20 | 100 | 20.0 |
| 77 | .70 | 20 | .20 | .07 | 300 | <10 | N | 500 | 70 | 100 | 100 | 15 | 100 | 16.0 |
| 81 | .50 | 20 | .10 | .02 | 200 | N | N | 500 | <20 | <20 | 50 | 5 | 20 | 15.0 |
| 84 | .50 | 20 | .20 | .05 | 200 | 10 | N | 500 | 200 | <20 | 100 | 10 | 50 | 25.0 |
| 12-84 | 1.00 | 15 | 1.50 | .30 | 500 | 100 | N | 300 | 500 | 100 | 100 | 20 | 200 | 51.0 |
| 90 | .50 | 20 | .50 | .15 | 200 | 100 | <1 | 500 | 300 | <20 | 70 | 15 | 100 | 16.0 |
| 93 | .50 | 15 | .50 | .10 | 200 | 100 | <1 | 500 | 200 | <20 | 70 | 10 | 50 | 16.0 |
| 100 | .50 | 20 | .50 | .07 | 200 | 50 | <1 | 500 | 300 | <20 | 70 | 15 | 50 | 11.0 |
| 106 | 1.00 | 20 | 1.00 | .10 | 500 | 50 | <1 | 500 | 1,000 | N | 50 | 10 | 100 | 1.4 |
| 113 | .50 | 20 | .30 | .05 | 100 | 10 | N | 500 | 100 | N | 50 | 10 | 100 | 7.9 |
| 117 | .50 | 20 | 1.00 | .15 | 100 | 100 | <1 | 500 | 300 | 50 | 100 | 20 | 100 | 18.0 |
| 122 | .50 | 20 | .50 | .05 | 100 | <10 | N | 500 | 100 | <20 | 50 | 10 | 20 | 6.1 |
| 126 | .50 | 20 | .50 | .05 | 200 | 20 | N | 500 | 100 | 20 | 70 | 10 | 50 | 12.0 |
| 133 | .10 | 10 | .20 | .02 | 70 | 70 | N | 200 | 300 | N | 50 | <5 | 15 | 4.1 |
| 84-133 | 1.00 | 15 | .50 | .10 | 200 | 50 | N | 700 | 300 | 50 | 100 | 10 | 100 | .8 |
| **Section 82A-3, lat 68° 19' 30" N., long. 150° 17' 12" W.** | | | | | | | | | | | | | | |
| [illegible] | 3.00 | 20 | .10 | .02 | 20 | 20 | N | 500 | <20 | N | 20 | N | 10 | 2.3 |

Table 3. Analytical data from phosphatic rocks collected from the Lisburne Group, Chandler Lake and Killik River quadrangles, Alaska—continued

| Interval sampled | V-ppm s | Cr-ppm s | Co-ppm s | Ni-ppm s | Cu-ppm s | Zn-ppm s | Pb-ppm s | Mo-ppm s | Cd-ppm s | Ag-ppm s | Mg-ppm icp |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Section ANW-1, lat 68° 23' 15" N., long. 154° 20' 00" W.** | | | | | | | | | | | |
| 1 | 200 | 70 | 10 | 20 | 70 | N | <10 | N | N | <.5 | 3,600 |
| 27 | 15 | 20 | N | 15 | 5 | N | N | N | N | N | 92,000 |
| 0- 28 | 200 | 50 | 10 | 50 | 150 | N | 50 | N | N | <.5 | 24,000 |
| 29- 63 | 200 | 50 | 5 | 50 | 70 | N | 20 | N | N | 1.0 | 2,000 |
| 64- 80 | 200 | 100 | 50 | 200 | 100 | N | 50 | 10 | N | 2.0 | 5,100 |
| 80 | 200 | 100 | 5 | 100 | 70 | N | <10 | 5 | N | 2.0 | 1,000 |
| 81-109 | 300 | 200 | 10 | 100 | 100 | N | 30 | 15 | N | 2.0 | 2,700 |
| 110-148 | 100 | 70 | <5 | 20 | 20 | N | <10 | 5 | N | 1.0 | 3,000 |
| 140 | 100 | 50 | <5 | 50 | 10 | N | N | <5 | N | 1.0 | 2,400 |
| 149-202 | 50 | 50 | <5 | 20 | 20 | N | 20 | <5 | N | 1.0 | 3,500 |
| 203-250 | 50 | 50 | <5 | 20 | 10 | N | 10 | 10 | N | 1.0 | 3,000 |
| 251-298 | 100 | 100 | 10 | 70 | 20 | N | 30 | 10 | N | 1.5 | 2,300 |
| 299-356 | 100 | 20 | 5 | 20 | 20 | N | <10 | <5 | N | .5 | 290 |
| ls. ǀ 357 | 10 | 10 | N | <5 | <5 | N | N | N | N | <.5 | 2,500 |
| shale ǀ - | 100 | 100 | <5 | 50 | 15 | N | <10 | 5 | N | <.5 | 3,700 |
| chert ǀ 383 | 10 | 10 | <5 | 10 | <5 | N | <10 | N | N | <.5 | 1,200 |
| **Section ANW-2, lat 68° 19' 30" N., long. 155° 40' 42" W.** | | | | | | | | | | | |
| 0-15 | 100 | 200 | <5 | 100 | 50 | N | 20 | 20 | N | <.5 | 61,000 |
| 6 | 150 | 200 | N | 100 | 50 | <200 | N | 15 | N | 7.0 | 1,400 |
| 18 | 100 | 50 | N | 50 | 20 | N | N | 5 | N | 5.0 | 32,000 |
| 16-57 | 100 | 150 | <5 | 50 | 20 | N | <10 | 10 | N | <.5 | 48,000 |
| 58- 72 | 100 | 200 | <5 | 50 | 20 | N | <10 | 20 | N | <.5 | 40,000 |
| 72 | 50 | 70 | N | 50 | 20 | N | N | 5 | N | 2.0 | 4,700 |
| 73-153 | 100 | 100 | <5 | 50 | 20 | N | <10 | 10 | N | <.5 | 9,600 |

Table 3. Analytical data from phosphatic rocks collected from the Lisburne Group, Chandler Lake and Killik River quadrangles, Alaska—continued

| Interval sampled | V-ppm s | Cr-ppm s | Co-ppm s | Ni-ppm s | Cu-ppm s | Zn-ppm s | Pb-ppm s | Mo-ppm s | Cd-ppm s | Ag-ppm s | Mg-ppm icp |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Section 82A-2, lat 68° 22' 42" N., long. 152° 56' 42" W.** | | | | | | | | | | | |
| 13-22 | 1,500 | 200 | 5 | 500 | 100 | 1,000 | 50 | 100 | 50 | <.5 | 9,700 |
| 23 | 1,000 | 200 | N | 50 | 10 | <200 | <10 | 15 | 150 | N | 2,100 |
| 24 | 1,000 | 200 | N | 50 | 10 | <200 | <10 | 10 | 100 | N | 290 |
| 36 | 70 | 50 | 10 | 15 | 5 | N | 10 | <5 | N | N | 3,700 |
| 39 | 300 | 70 | 50 | 200 | 50 | 200 | 50 | 100 | N | 5.0 | 6,000 |
| 40 | 100 | 30 | 15 | 20 | 7 | N | 10 | 10 | N | N | 63,000 |
| 30-41 | 7,000 | 1,500 | 10 | 200 | 150 | 500 | 100 | 200 | 100 | 5.0 | 1,600 |
| 45 | 70 | 30 | 20 | 30 | 15 | N | <10 | 5 | N | N | 2,000 |
| 48 | 200 | 50 | 20 | 100 | 50 | N | 50 | N | N | N | 2,200 |
| 53 | 200 | 50 | 20 | 100 | 50 | N | 50 | N | N | <.5 | 1,100 |
| 45-54 | 200 | 70 | 50 | 100 | 50 | N | 50 | 10 | N | .5 | 1,100 |
| 57 | 100 | 70 | 10 | 70 | 20 | N | <10 | 50 | N | .5 | 2,400 |
| 77 | 50 | 70 | <5 | 50 | 10 | N | N | 20 | N | <.5 | 2,800 |
| 81 | 20 | 30 | N | 10 | 5 | N | N | 10 | N | N | 2,100 |
| 84 | 50 | 50 | N | 20 | 7 | N | N | 15 | N | <.5 | 2,200 |
| 12-84 | 200 | 100 | 20 | 100 | 50 | N | 20 | 20 | N | 1.5 | 2,900 |
| 90 | 100 | 70 | 5 | 50 | 20 | N | <10 | 20 | N | .5 | 2,500 |
| 93 | 50 | 50 | 5 | 50 | 20 | N | <10 | 20 | N | .5 | 2,100 |
| 100 | 50 | 30 | N | 50 | 30 | N | N | 15 | N | <.5 | 1,500 |
| 106 | 50 | 20 | 5 | 10 | 5 | N | 10 | N | N | N | 2,500 |
| 113 | 20 | 20 | N | 10 | 5 | N | N | 10 | N | <.5 | 2,400 |
| 117 | 100 | 50 | 10 | 70 | 30 | N | N | 20 | N | .5 | 1,700 |
| 122 | 20 | 20 | N | 10 | 5 | N | N | <5 | N | <.5 | 1,900 |
| 126 | 50 | 50 | N | 30 | 10 | N | N | 20 | N | <.5 | 1,400 |
| 133 | 20 | 15 | N | 20 | 10 | N | N | 10 | N | <.5 | 580 |
| 84-133 | 50 | 50 | <5 | 20 | 10 | N | 10 | 10 | N | 1.0 | 1,600 |
| **Section 82A-3, lat 68° 19' 30" N., long. 150° 17'12" W.** | | | | | | | | | | | |
| 0-200 | 20 | 20 | N | 10 | <5 | N | <10 | 10 | N | N | -- |

Table 3. Analytical data from phosphatic rocks collected from the Lisburne Group, Chandler Lake and Killik River quadrangles, Alaska—continued

| Interval sampled | Ca-ppm icp | Al-ppm icp | Fe-ppm icp | Ti-ppm icp | Mn-ppm icp | P-ppm icp | $P_2O_5$ wt. % | Be-ppm icp | Sr-ppm icp | Ba-ppm icp | La-ppm icp | Ce-ppm icp | Y-ppm icp |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Section ANW-1, lat 68° 23' 15" N., long. 154° 20' 00" W.** | | | | | | | | | | | | | |
| 1 | 460 | 6,900 | 15,000 | 6.3 | 37 | 120 | 0.03 | 0.310 | 14.0 | 28.0 | N | N | N |
| 27 | 210,000 | 500 | 10,000 | 18.0 | 640 | 180 | .04 | .200 | 710.0 | 670.0 | N | N | 1.8 |
| 0-28 | 67,000 | 12,000 | 46,000 | 18.0 | 370 | 330 | .08 | .570 | 230.0 | 3.0 | N | N | N |
| 29-63 | 36,000 | 2,300 | 9,400 | 5.2 | 130 | 160 | .04 | .140 | 160.0 | 13.0 | N | N | 5.5 |
| 64-80 | 63,000 | 2,700 | 12,000 | 5.4 | 300 | 180 | .04 | .220 | 190.0 | 10.0 | 6.1 | 4.6 | 15.0 |
| 80 | 3,500 | 2,300 | 9,300 | 2.9 | 81 | 1,100 | .25 | .310 | 22.0 | 7.7 | 7.8 | 14.0 | 18.0 |
| 81-109 | 15,000 | 1,600 | 8,800 | 4.5 | 65 | 290 | .07 | .180 | 50.0 | 13.0 | 9.3 | 14.0 | 12.0 |
| 110-148 | 170,000 | 710 | 3,600 | 8.7 | 37 | 220 | .05 | .110 | 190.0 | 30.0 | N | N | 7.1 |
| 140 | 72,000 | 490 | 3,600 | 3.8 | 36 | 93 | .02 | .058 | 170.0 | 25.0 | N | N | 3.5 |
| 149-202 | 130,000 | 600 | 3,100 | 6.5 | 60 | 140 | .03 | .079 | 160.0 | 40.0 | N | N | 6.1 |
| 203-250 | 110,000 | 850 | 3,500 | 6.5 | 120 | 740 | .17 | .079 | 190.0 | 59.0 | 5.1 | N | 11.0 |
| 251-298 | 100,000 | 1,200 | 5,400 | 6.1 | 110 | 120 | .03 | .110 | 160.0 | 31.0 | 4.1 | N | 6.8 |
| 299-356 | 850 | 970 | 3,700 | 5.7 | 57 | 34 | .01 | .059 | 13.0 | 21.0 | N | N | .44 |
| ls. \| 357 | 310,000 | 280 | 490 | 17.0 | 260 | 90 | .02 | .090 | 280.0 | 170.0 | 6.5 | N | 2.6 |
| shale \| - | 82,000 | 1,100 | 5,100 | 6.6 | 300 | 190 | .04 | .100 | 180.0 | 55.0 | N | N | 9.2 |
| chert \| 383 | 26,000 | 210 | 940 | 2.5 | 90 | 45 | .01 | N | 82.0 | 78.0 | N | N | 2.2 |
| **Section ANW-2, lat 68° 19' 30" N., long. 155° 40' 42" W.** | | | | | | | | | | | | | |
| 0-15 | 120,000 | 850 | 1,500 | 15.0 | 81 | 3,800 | .87 | .250 | 71.0 | 83.0 | 31.0 | N | 52.0 |
| 6 | 4,900 | 260 | 890 | 3.1 | 14 | 1,100 | .25 | .045 | 9.7 | 29.0 | 7.0 | N | 13.0 |
| 18 | 67,000 | 520 | 1,200 | 12.0 | 47 | 2,500 | .57 | .140 | 43.0 | 66.0 | 19.0 | N | 31.0 |
| 16-57 | 93,000 | 720 | 1,400 | 11.0 | 91 | 3,100 | .71 | .200 | 67.0 | 56.0 | 22.0 | N | 39.0 |
| 58-72 | 73,000 | 500 | 730 | 11.0 | 52 | 1,500 | .34 | .140 | 40.0 | 52.0 | 11.0 | N | 20.0 |
| 72 | 14,000 | 270 | 680 | 3.0 | 14 | 1,400 | .32 | .057 | 16.0 | 42.0 | 11.0 | N | 20.0 |
| 73-153 | 20,000 | 450 | 910 | 5.4 | 20 | 1,600 | .37 | .086 | 20.0 | 41.0 | 11.0 | N | 23.0 |

Table 3. Analytical data from phosphatic rocks collected from the Lisburne Group, Chandler Lake and Killik River quadrangles, Alaska—continued

| Interval sampled | Ca-ppm icp | Al-ppm icp | Fe-ppm icp | Ti-ppm icp | Mn-ppm icp | P-ppm icp | $P_2O_5$ wt. % | Be-ppm icp | Sr-ppm icp | Ba-ppm icp | La-ppm icp | Ce-ppm icp | Y-ppm icp |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Section 82A-2, lat 68° 22' 42" N., long. 152° 56' 42" W.** | | | | | | | | | | | | | |
| 13-22 | 51,000 | 3,300 | 7,000 | 52.0 | 43 | 11,000 | 2.5 | .420 | 70 | 30.0 | 65.0 | 18.0 | 120.0 |
| 23 | 290,000 | 1,200 | 710 | 37.0 | 19 | N | N | .520 | 640 | 44.0 | 79.0 | 6.9 | 150.0 |
| 24 | 190,000 | 560 | 300 | 22.0 | 6 | N | N | .290 | 390 | 49.0 | 56.0 | 5.5 | 110.0 |
| 36 | 210,000 | 1,400 | 8,800 | 11.0 | 230 | 350 | .08 | .150 | 120 | 11.0 | 8.9 | 9.7 | 15.0 |
| 39 | 79,000 | 4,500 | 10,000 | 100.0 | 73 | 46,000 | 10.5 | .640 | 130 | 7.5 | 73.0 | 80.0 | 140.0 |
| 40 | 130,000 | 2,300 | 12,000 | 9.4 | 400 | 560 | .13 | .240 | 53 | 18.0 | 12.0 | 6.5 | 22.0 |
| 30-41 | 130,000 | 10,000 | 7,600 | 87.0 | N | 35,000 | 8.0 | N | 290 | 170.0 | 57.0 | 16.0 | 110.0 |
| 45 | 220,000 | 1,100 | 4,600 | 9.9 | 280 | 120 | .03 | .130 | 110 | 39.0 | 6.4 | N | 7.6 |
| 48 | 70,000 | 2,300 | 10,000 | 6.7 | 170 | 250 | .06 | .190 | 44 | 6.1 | 5.5 | 7.8 | 8.8 |
| 53 | 44,000 | 2,300 | 13,000 | 3.9 | 140 | 290 | .07 | .180 | 34 | 5.1 | 5.9 | 9.2 | 6.6 |
| 45-54 | 25,000 | 2,100 | 8,900 | 2.7 | 110 | 710 | .16 | N | 21 | 23.0 | 6.0 | 12.0 | 14.0 |
| 57 | 230,000 | 1,300 | 3,100 | 18.0 | 180 | 1,900 | .44 | .160 | 190 | 35.0 | 22.0 | 5.7 | 44.0 |
| 77 | 280,000 | 680 | 1,900 | 16.0 | 150 | 1,100 | .25 | .110 | 240 | 37.0 | 18.0 | N | 33.0 |
| 81 | 310,000 | 340 | 570 | 16.0 | 92 | 350 | .08 | .099 | 320 | 20.0 | 13.0 | N | 15.0 |
| 84 | 280,000 | 770 | 1,500 | 17.0 | 100 | 1,500 | .34 | .120 | 230 | 71.0 | 16.0 | N | 31.0 |
| 12-84 | 120,000 | 5,500 | 6,000 | 26.0 | 77 | 12,000 | 2.7 | N | 120 | 130.0 | 23.0 | 4.5 | 49.0 |
| 90 | 200,000 | 1,000 | 3,100 | 12.0 | 72 | 480 | .11 | .120 | 180 | 31.0 | 10.0 | N | 19.0 |
| 93 | 200,000 | 1,300 | 3,300 | 11.0 | 68 | 580 | .13 | .130 | 170 | 39.0 | 9.7 | N | 20.0 |
| 100 | 230,000 | 630 | 1,400 | 13.0 | 91 | 460 | .11 | .082 | 150 | 64.0 | 12.0 | N | 19.0 |
| 106 | 240,000 | 950 | 4,000 | 12.0 | 160 | 220 | .05 | .130 | 180 | 27.0 | 4.5 | N | 7.4 |
| 113 | 310,000 | 700 | 1,900 | 18.0 | 100 | 410 | .09 | .110 | 240 | 38.0 | 14.0 | N | 16.0 |
| 117 | 230,000 | 1,500 | 4,000 | 14.0 | 83 | 810 | .19 | .150 | 230 | 38.0 | 17.0 | N | 31.0 |
| 122 | 270,000 | 770 | 2,600 | 13.0 | 72 | 260 | .06 | .110 | 220 | 61.0 | 11.0 | N | 17.0 |
| 126 | 230,000 | 630 | 1,800 | 13.0 | 65 | 460 | .11 | .084 | 190 | 35.0 | 12.0 | N | 19.0 |
| 133 | 94,000 | 470 | 1,400 | 6.9 | 38 | 750 | .17 | N | 86 | 120.0 | 7.3 | N | 15.0 |
| 84-133 | 220,000 | 920 | 2,800 | N | N | 410 | .09 | N | 140 | 98.0 | 3.7 | N | 15.0 |
| **Section 82A-3, lat 68° 19' 30" N., long. 150° 17'12" W.** | | | | | | | | | | | | | |
| 0-200 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |

Table 3. Analytical data from phosphatic rocks collected from the Lisburne Group, Chandler Lake and Killik River quadrangles, Alaska—continued

| Interval sampled | V-ppm icp | Cr-ppm icp | Co-ppm icp | Ni-ppm icp | Cu-ppm icp | Zn-ppm icp | Pb-ppm icp | As-ppm icp | Mo-ppm icp | Cd-ppm icp | Ag-ppm icp |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Section ANW-1, lat 68° 23' 15" N., long. 154° 20' 00" W.** | | | | | | | | | | | |
| 1 | 17.0 | <7.4 | N | 20.0 | 59.0 | 68 | 12 | N | N | N | N |
| 27 | 3.3 | N | N | 5.3 | 1.0 | 21 | N | N | N | N | N |
| 0-28 | 36.0 | N | N | 34.0 | 160.0 | 82 | 46 | N | N | N | N |
| 29-63 | 15.0 | N | N | 20.0 | 35.0 | 42 | N | <14.0 | N | N | N |
| 64-80 | 9.7 | N | N | 61.0 | 23.0 | 120 | N | <13.0 | N | N | N |
| 80 | 8.1 | 7.3 | N | 42.0 | 44.0 | 110 | N | 9.4 | N | N | N |
| 81-109 | 16.0 | <4.9 | N | 46.0 | 41.0 | 110 | N | 17.0 | N | N | N |
| 110-148 | 6.5 | N | N | 15.0 | 6.5 | 47 | N | N | N | 1.2 | N |
| 140 | 3.1 | N | N | 12.0 | 7.4 | 41 | N | N | N | .9 | N |
| 149-202 | 4.8 | N | N | 8.9 | 4.6 | 27 | N | N | N | N | N |
| 203-250 | 4.9 | N | N | 8.2 | 4.6 | 27 | N | N | N | N | N |
| 251-298 | 4.7 | N | N | 15.0 | 9.2 | 41 | N | N | N | N | N |
| 299-356 | 4.3 | N | N | 9.0 | 16.0 | 17 | N | N | N | N | N |
| ls. \| 357 | 1.3 | N | N | N | N | 8 | N | N | N | 1.5 | N |
| shale \| - | 6.0 | N | N | 20.0 | 9.4 | 50 | N | <8.5 | N | .9 | N |
| chert \| 383 | .7 | N | N | N | 1.7 | 10 | N | 15.0 | N | N | N |
| **Section ANW-2, lat 68° 19' 30" N., long. 155° 40' 42" W.** | | | | | | | | | | | |
| 0-15 | 46.0 | 120.0 | N | 61.0 | 21.0 | 160 | N | N | N | 1.8 | N |
| 6 | 12.0 | 17.0 | N | 33.0 | 11.0 | 75 | N | 8.5 | N | N | N |
| 18 | 30.0 | 57.0 | N | 52.0 | 17.0 | 150 | N | <15.0 | N | 1.6 | N |
| 16-57 | 50.0 | 110.0 | N | 53.0 | 19.0 | 150 | N | N | N | 2.0 | N |
| 58-72 | 25.0 | 62.0 | N | 21.0 | 8.3 | 48 | N | <14.0 | N | .8 | N |
| 72 | 7.9 | 15.0 | N | 22.0 | 10.0 | 57 | N | 16.0 | N | .8 | N |
| 73-153 | 23.0 | 50.0 | N | 29.0 | 11.0 | 60 | N | 19.0 | N | 1.3 | N |

Table 3. Analytical data from phosphatic rocks collected from the Lisburne Group, Chandler Lake and Killik River quadrangles, Alaska—continued

| Interval sampled | V-ppm icp | Cr-ppm icp | Co-ppm icp | Ni-ppm icp | Cu-ppm icp | Zn-ppm icp | Pb-ppm icp | As-ppm icp | Mo-ppm icp | Cd-ppm icp | Ag-ppm icp |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Section 82A-2, lat 68° 22' 42" N., long. 152° 56' 42" W.** | | | | | | | | | | | |
| 13-22 | 240.0 | 250.0 | N | 260.0 | 77.0 | 1,100 | N | 30.0 | 22.0 | 43 | 7.9 |
| 23 | 340.0 | 160.0 | N | 55.0 | 13.0 | 390 | N | <55.0 | 3.0 | 33 | N |
| 24 | 190.0 | 79.0 | N | 54.0 | 7.8 | 250 | N | 49.0 | N | 20 | N |
| 36 | 4.3 | N | N | 11.0 | 4.2 | 37 | N | N | N | .9 | N |
| 39 | 140.0 | 30.0 | 41.0 | 230.0 | 25.0 | 440 | 15.0 | <27.0 | 41.0 | 9.2 | 2.5 |
| 40 | 23.0 | 7.4 | N | 29.0 | 12.0 | 43 | N | N | N | N | N |
| 30-41 | 1,000.0 | 310.0 | 4.0 | 78.0 | 81.0 | 450 | 6.5 | 8.9 | 31.0 | 49 | 10 |
| 45 | 4.1 | N | N | 19.0 | 11.0 | 23 | N | N | N | .9 | N |
| 48 | 6.6 | N | N | 57.0 | 22.0 | 88 | 9.0 | <11.0 | N | N | N |
| 53 | 5.5 | N | N | 82.0 | 24.0 | 88 | 12.0 | <18.0 | N | N | N |
| 45-54 | 8.0 | 6.5 | 10.0 | 53.0 | 21.0 | 71 | 6.2 | 7.4 | 2.2 | .5 | N |
| 57 | 9.3 | 6.8 | N | 38.0 | 22.0 | 99 | N | N | 6.1 | 1.7 | N |
| 77 | 6.4 | N | N | 21.0 | 13.0 | 74 | N | N | N | 1.8 | N |
| 81 | 5.3 | N | N | N | 3.5 | 23 | N | N | N | 1.6 | N |
| 84 | 7.2 | N | N | 16.0 | 9.3 | 44 | N | N | N | 1.6 | N |
| 12-84 | 60.0 | 21.0 | 7.3 | 49.0 | 21.0 | 110 | N | 4.6 | 5.6 | 3.9 | .9 |
| 90 | 6.9 | N | N | 26.0 | 16.0 | 64 | N | N | 2.1 | 1.4 | N |
| 93 | 8.0 | N | N | 26.0 | 17.0 | 63 | N | N | 2.3 | 1.3 | N |
| 100 | 5.9 | 4.4 | N | 20.0 | 13.0 | 58 | N | N | N | 1.5 | N |
| 106 | 4.3 | N | N | 4.2 | 2.8 | 17 | N | N | N | 1.1 | N |
| 113 | 4.0 | N | N | 6.8 | 5.8 | 30 | N | N | N | 1.7 | N |
| 117 | 9.7 | 4.8 | N | 26.0 | 19.0 | 74 | N | N | 3.2 | 1.8 | N |
| 122 | 3.6 | N | N | 4.9 | 3.9 | 20 | N | N | N | 1.3 | N |
| 126 | 4.4 | N | N | 11.0 | 5.8 | 37 | N | N | N | 1.4 | N |
| 133 | 1.5 | N | N | 7.5 | 4.9 | 24 | N | N | N | N | N |
| 84-133 | 3.4 | 2.1 | 2.8 | 11.0 | 11.0 | 32 | N | N | N | N | N |
| **Section 82A-3, lat 68° 19' 30" N., long. 150° 17'12" W.** | | | | | | | | | | | |
| 0-200 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |

Table 4. Analytical data from phosphatic rocks collected from the Shublik Formation, Chandler Lake quadrangle, Alaska

[N, not detected; <, detected but below the limit of determination shown; >, determined to be greater than the value shown; --, no data. Spectrographic data, "s," B.F. Arbogast, analyst; uranium data, Ted Roemer, analyst; ICP data, J.M. Motooka, analyst]

| Interval sampled | Mg-pct. s | Ca-pct. s | Fe-pct. s | Ti-pct. s | Mn-ppm s | B-ppm s | Be-ppm s | Sr-ppm s | Ba-ppm s | La-ppm s | Y-ppm s | Sc-ppm s | Zr-ppm s | U-ppm |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Section ADB-1, lat 68° 23' 12" N., long. 150° 52' 05" W.** | | | | | | | | | | | | | | |
| 0-20 | 1.00 | .07 | 2.0 | .70 | 70 | 500 | 2.0 | 500 | >5,000 | 50 | 50 | 20 | 200 | 4.2 |
| 20-49 | 1.00 | 1.00 | 2.0 | .50 | 500 | 300 | 2.0 | 1,000 | >5,000 | 50 | 50 | 20 | 150 | 6.5 |
| 52-60 | 1.00 | .70 | 1.0 | .70 | 70 | 500 | 2.0 | 500 | >5,000 | 100 | 50 | 20 | 200 | 4.0 |
| 61-80 | 1.00 | 10.00 | 1.0 | .10 | 1,000 | 50 | N | 700 | 2,000 | 20 | 70 | 10 | 50 | 5.9 |
| 81-100 | .50 | 10.00 | 1.0 | .10 | 500 | 50 | <1.0 | 700 | 3,000 | <20 | 50 | 10 | 50 | 2.2 |
| 101-110 | .50 | 3.00 | 2.0 | .30 | 100 | 200 | 1.0 | 500 | 3,000 | <20 | 50 | 15 | 100 | 3.1 |
| 114 | .15 | 1.00 | .5 | .10 | 50 | 70 | <1.0 | 100 | 2,000 | N | 20 | 15 | 50 | 2.4 |
| 111-128 | 1.50 | 5.00 | 2.0 | .30 | 200 | 200 | <1.0 | 500 | 2,000 | <20 | 50 | 20 | 100 | 2.9 |
| 129-148 | .30 | 7.00 | .5 | .10 | 50 | 70 | <1.0 | 500 | 2,000 | <20 | 70 | 15 | 50 | 6.6 |
| 149-162 | .20 | 10.00 | .7 | .10 | 100 | 70 | N | 500 | 2,000 | <20 | 50 | 15 | 70 | 11.0 |
| 165 | .50 | 15.00 | .2 | .07 | 20 | 10 | N | 1,500 | 2,000 | 50 | 200 | 15 | 50 | 57.0 |
| 163-180 | .20 | 15.00 | .5 | .10 | 100 | 50 | N | 1,500 | 2,000 | 50 | 150 | 15 | 100 | 29.0 |
| 181-205 | 2.00 | 10.00 | .7 | .15 | 300 | 10 | N | 700 | 2,000 | N | 20 | 10 | 30 | 7.9 |
| 206-225 | 1.50 | 10.00 | 1.0 | .15 | 200 | 10 | N | 700 | >5,000 | N | 20 | 7 | 50 | 8.2 |
| 226-235 | .50 | 10.00 | 1.0 | .10 | 100 | 50 | N | 1,500 | >5,000 | 300 | 500 | 15 | 50 | 48.0 |
| **Section ADB-3, lat 68° 22' 30" N., long. 150° 48' 30" W.** | | | | | | | | | | | | | | |
| 0-10 | 1.50 | 10.00 | 1.5 | .20 | 500 | 100 | <1.0 | 1,000 | 5,000 | <20 | 50 | 10 | 70 | 6.5 |
| 0- 6 | .20 | 15.00 | 1.5 | .01 | 50 | N | N | 2,000 | >5,000 | 20 | 200 | 15 | 30 | 45.0 |
| 0-42 | 5.00 | 15.00 | 2.0 | .20 | 500 | 70 | <1.0 | 1,000 | 2,000 | 150 | 100 | 10 | 100 | 27.0 |
| 0-20 | 3.00 | 10.00 | 2.0 | .20 | 500 | 100 | <1.0 | 700 | 1,000 | <20 | 30 | 10 | 100 | 13.0 |
| 21-40 | 2.00 | 2.00 | 5.0 | .50 | 200 | 200 | 1.0 | 500 | 1,500 | 50 | 100 | 20 | 200 | 4.7 |
| 41-60 | 2.00 | 2.00 | 5.0 | .50 | 500 | 500 | 2.0 | 500 | 2,000 | 100 | 100 | 20 | 200 | 7.7 |

Table 4. Analytical data from phosphatic rocks collected from the Shublik Formation, Chandler Lake quadrangle, Alaska—continued

| Interval sampled | Mg-pct. s | Ca-pct. s | Fe-pct. s | Ti-pct. s | Mn-ppm s | B-ppm s | Be-ppm s | Sr-ppm s | Ba-ppm s | La-ppm s | Y-ppm s | Sc-ppm s | Zr-ppm s | U-ppm |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Section ADB-5, lat 68° 21' 18" N., long. 151° 52' 30" W.** | | | | | | | | | | | | | | |
| 0-20 | 1.50 | 1.00 | 3.0 | .30 | 1,000 | 150 | 1.0 | 200 | 1,500 | 20 | 30 | 10 | 150 | 5.4 |
| 21-40 | 1.00 | .30 | 5.0 | .50 | 200 | 200 | 1.0 | 100 | 1,500 | 30 | 30 | 15 | 200 | 1.5 |
| 41-60 | 1.00 | .70 | 1.0 | .20 | 1,000 | 150 | <1.0 | 200 | >5,000 | 20 | 30 | 10 | 100 | 4.1 |
| 61-80 | 2.00 | .70 | 2.0 | .50 | 500 | 200 | <1.0 | 100 | 2,000 | 50 | 50 | 15 | 200 | 5.9 |
| 81-100 | 2.00 | 1.00 | 1.5 | .30 | 700 | 200 | 1.0 | 150 | 2,000 | 50 | 50 | 15 | 200 | 2.5 |
| 101-120 | 1.00 | .70 | 3.0 | .30 | 2,000 | 200 | 1.0 | 200 | 2,000 | 50 | 50 | 15 | 150 | 2.1 |
| 121-140 | 1.00 | .50 | 3.0 | .20 | 1,000 | 200 | 1.0 | 200 | 2,000 | 50 | 50 | 15 | 150 | 4.3 |
| 141-160 | 2.00 | 1.00 | 3.0 | .20 | 1,000 | 200 | 1.0 | 200 | 3,000 | <20 | 50 | 15 | 150 | 3.2 |
| 161-180 | 2.00 | .70 | 3.0 | .20 | 500 | 200 | 1.0 | 200 | 3,000 | 20 | 50 | 15 | 150 | 2.0 |
| 181-200 | 1.00 | .70 | 2.0 | .20 | 100 | 150 | <1.0 | 200 | 3,000 | 20 | 50 | 15 | 100 | 2.4 |
| 201-220 | 1.00 | 1.00 | 2.0 | .20 | 200 | 150 | <1.0 | 300 | 3,000 | 30 | 50 | 15 | 100 | 4.1 |
| 221-240 | 1.50 | 2.00 | 2.0 | .20 | 300 | 200 | 1.0 | 1,000 | >5,000 | <20 | 100 | 15 | 100 | 6.6 |
| 241-260 | .50 | .50 | 2.0 | .20 | 100 | 200 | 1.5 | 200 | 5,000 | <20 | 50 | 15 | 100 | 2.7 |
| 261-280 | 1.50 | 1.00 | 2.0 | .20 | 200 | 200 | <1.0 | 200 | 5,000 | <20 | 50 | 15 | 100 | 3.7 |
| 281-300 | 2.00 | 10.00 | 1.0 | .10 | 200 | 100 | <1.0 | 700 | 5,000 | <20 | 50 | 15 | 100 | 15.0 |

Table 4. Analytical data from phosphatic rocks collected from the Shublik Formation, Chandler Lake quadrangle, Alaska—continued

| Interval sampled | V-ppm s | Cr-ppm s | Co-ppm s | Ni-ppm s | Cu-ppm s | Zn-ppm s | Pb-ppm s | Mo-ppm s | Cd-ppm s | Ag-ppm s | Li-ppm icp | Na-ppm icp | K-ppm icp | Mg-ppm icp |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Section ADB-1, lat 68° 23' 12" N., long. 150° 52' 05" W.** | | | | | | | | | | | | | | |
| 0-20 | 700 | 200 | 5 | 50 | 100 | <200 | 50 | 50 | N | 2.0 | 2.10 | 330 | 2,000 | 950 |
| 20-49 | 500 | 200 | 10 | 50 | 100 | <200 | 30 | 50 | N | 2.0 | 1.70 | 290 | 1,900 | 2,600 |
| 52-60 | 700 | 200 | 5 | 100 | 100 | <200 | 70 | 50 | N | 2.0 | 2.20 | 250 | 2,200 | 850 |
| 61-80 | 50 | 100 | 5 | 20 | 20 | N | 20 | 5 | N | <.5 | .78 | 340 | 690 | 4,200 |
| 81-100 | 50 | 100 | <5 | 15 | 20 | N | 15 | <5 | N | <.5 | .60 | 330 | 640 | 2,800 |
| 101-110 | 200 | 150 | 10 | 50 | 100 | N | 20 | 10 | N | 1.0 | 1.20 | 260 | 1,400 | 2,900 |
| 114 | 150 | 100 | <5 | 50 | 100 | N | <10 | 10 | N | .5 | -- | 100 | 160 | 930 |
| 111-128 | 150 | 200 | 10 | 50 | 100 | N | 30 | 10 | N | 1.0 | 1.10 | 280 | 1,300 | 6,900 |
| 129-148 | 150 | 200 | <5 | 70 | 70 | N | <10 | 15 | N | 1.0 | 1.50 | 280 | 840 | 2,400 |
| 149-162 | 500 | 200 | <5 | 70 | 100 | N | 10 | 20 | N | 1.0 | 1.50 | 390 | 860 | 3,500 |
| 165 | 700 | 200 | N | 50 | 50 | N | <10 | 15 | N | 1.0 | 2.70 | 530 | 1,400 | 1,300 |
| 163-180 | 1,500 | 200 | <5 | 70 | 70 | N | 10 | 30 | N | 1.0 | 3.60 | 430 | 1,600 | 3,300 |
| 181-205 | 200 | 50 | 10 | 50 | 70 | N | 15 | 50 | N | .5 | -- | 390 | 470 | 12,000 |
| 206-225 | 200 | 70 | 10 | 50 | 70 | N | 15 | 50 | N | .5 | -- | 310 | 520 | 8,500 |
| 226-235 | 70 | 70 | N | 30 | 50 | N | 10 | 15 | N | <.5 | 1.20 | 640 | 1,000 | 1,500 |
| **Section ADB-3, lat 68° 22' 30" N., long. 150° 48' 30" W.** | | | | | | | | | | | | | | |
| 0-10 | 500 | 500 | 10 | 100 | 100 | N | 30 | 20 | N | 1.5 | 2.40 | 510 | 1,500 | 6,600 |
| 0- 6 | 100 | 50 | N | 15 | 10 | N | 10 | 10 | N | <.5 | -- | 1,300 | 450 | 830 |
| 0-42 | 200 | 200 | 7 | 70 | 50 | N | 20 | 10 | N | .5 | 4.10 | 480 | 2,200 | 27,000 |
| 0-20 | 200 | 300 | 10 | 100 | 100 | <200 | 20 | 10 | N | 1.0 | 1.90 | 280 | 1,300 | 27,000 |
| 21-40 | 300 | 200 | 30 | 150 | 150 | 200 | 70 | 20 | N | 1.0 | 3.70 | 260 | 2,800 | 11,000 |
| 41-60 | 300 | 200 | 30 | 150 | 150 | 500 | 100 | 10 | N | 1.5 | 3.20 | 270 | 2,800 | 7,900 |

Table 4. Analytical data from phosphatic rocks collected from the Shublik Formation, Chandler Lake quadrangle, Alaska—continued

| Interval sampled | V-ppm s | Cr-ppm s | Co-ppm s | Ni-ppm s | Cu-ppm s | Zn-ppm s | Pb-ppm s | Mo-ppm s | Cd-ppm s | Ag-ppm s | Li-ppm icp | Na-ppm icp | K-ppm icp | Mg-ppm icp |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Section ADB-5, lat 68° 21' 18" N., long. 151° 52' 30" W.** | | | | | | | | | | | | | | |
| 0-20 | 150 | 100 | 10 | 20 | 50 | N | 30 | 20 | N | N | 5.40 | 230 | 1,400 | 9,200 |
| 21-40 | 150 | 150 | 15 | 20 | 50 | N | 50 | 15 | N | N | 6.30 | 650 | 1,900 | 3,000 |
| 41-60 | 50 | 50 | 10 | 20 | 50 | N | 50 | 10 | N | <.5 | 4.40 | 240 | 1,300 | 6,500 |
| 61-80 | 200 | 200 | 30 | 100 | 100 | <200 | 70 | 50 | N | 2.0 | 9.60 | 250 | 2,200 | 9,900 |
| 81-100 | 200 | 100 | 20 | 70 | 100 | 300 | 70 | 30 | N | 2.0 | 10.00 | 180 | 2,000 | 10,000 |
| 101-120 | 100 | 100 | 50 | 50 | 70 | <200 | 50 | 15 | N | N | 9.50 | 260 | 2,600 | 5,500 |
| 121-140 | 200 | 150 | 30 | 50 | 100 | 500 | 70 | 15 | N | 1.0 | 8.60 | 240 | 1,900 | 6,800 |
| 141-160 | 300 | 100 | 30 | 50 | 100 | 500 | 50 | 20 | N | 1.5 | 11.00 | 290 | 2,100 | 10,000 |
| 161-180 | 200 | 100 | 30 | 100 | 100 | 200 | 50 | 20 | N | 1.0 | 5.80 | 370 | 2,000 | 9,100 |
| 181-200 | 100 | 100 | 30 | 70 | 100 | <200 | 50 | 20 | N | 1.0 | 4.20 | 410 | 1,600 | 4,700 |
| 201-220 | 200 | 150 | 15 | 50 | 70 | <200 | 20 | 20 | N | 2.0 | 1.90 | 270 | 1,300 | 4,700 |
| 221-240 | 100 | 200 | 15 | 50 | 70 | <200 | 20 | 10 | N | 2.0 | 1.00 | 280 | 1,400 | 4,700 |
| 241-260 | 200 | 300 | 15 | 100 | 100 | 200 | 20 | 20 | N | 2.0 | 1.10 | 200 | 1,400 | 1,200 |
| 261-280 | 200 | 300 | 15 | 100 | 100 | 200 | 30 | 30 | N | 1.5 | 1.10 | 390 | 1,700 | 7,900 |
| 281-300 | 700 | 200 | 10 | 100 | 100 | <200 | 20 | 100 | N | 1.5 | .65 | 440 | 720 | 10,000 |

Table 4. Analytical data from phosphatic rocks collected from the Shublik Formation, Chandler Lake quadrangle, Alaska—continued

| Interval sampled | Ca-ppm icp | Al-ppm icp | Fe-ppm icp | Ti-ppm icp | Mn-ppm icp | P-ppm icp | $P_2O_5$ wt. % | Be-ppm icp | Sr-ppm icp | Ba-ppm icp | La-ppm icp | Ce-ppm icp | Y-ppm icp |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Section ADB-1, lat 68° 23' 12" N., long. 150° 52' 05" W.** | | | | | | | | | | | | | |
| 0-20 | 2,900 | 3,100 | 13,000 | 4.3 | 54 | 290 | .07 | .45 | 110 | 120 | 1.00 | -- | 7.2 |
| 20-49 | 30,000 | 2,700 | 14,000 | 5.4 | 300 | 660 | .15 | .50 | 410 | 120 | 2.30 | -- | 12.0 |
| 52-60 | 17,000 | 2,700 | 13,000 | 4.9 | 63 | 930 | .21 | .45 | 200 | 100 | 3.30 | -- | 11.0 |
| 61-80 | 320,000 | 860 | 5,400 | 3.5 | 240 | 270 | .06 | <.13 | 420 | 130 | 4.80 | -- | 24.0 |
| 81-100 | 300,000 | 750 | 4,700 | 2.4 | 37 | 110 | .03 | <.12 | 380 | 480 | <2.30 | -- | 19.0 |
| 101-110 | 72,000 | 2,000 | 16,000 | 7.5 | 76 | 340 | .08 | .37 | 260 | 54 | 3.70 | -- | 16.0 |
| 114 | 8,000 | 360 | 2,500 | 3.6 | 71 | 46 | .01 | .09 | 48 | 290 | .97 | -- | 9.6 |
| 111-128 | 83,000 | 1,900 | 13,000 | 6.0 | 84 | 240 | .05 | .37 | 270 | 60 | 3.20 | -- | 12.0 |
| 129-148 | 120,000 | 1,600 | 4,400 | 15.0 | -- | 3,800 | .87 | .38 | 400 | 650 | 6.80 | -- | 26.0 |
| 149-162 | 220,000 | 1,500 | 3,700 | 8.0 | -- | 1,700 | .39 | .39 | 460 | 920 | 3.50 | -- | 18.0 |
| 165 | 310,000 | 2,600 | 1,300 | 34.0 | -- | 52,000 | 11.9 | .50 | 1,200 | 1,000 | 11.00 | -- | 68.0 |
| 163-180 | 270,000 | 3,200 | 2,700 | 41.0 | -- | 23,000 | 5.3 | .76 | 820 | 970 | 8.50 | -- | 53.0 |
| 181-205 | 250,000 | 570 | 5,200 | 1.3 | 29 | 130 | .03 | <.21 | 490 | 380 | -- | -- | 8.9 |
| 206-225 | 220,000 | 590 | 5,900 | 1.2 | -- | 140 | .03 | .24 | 430 | 180 | -- | -- | 10.0 |
| 226-235 | 180,000 | 2,100 | 4,000 | 24.0 | -- | 41,000 | 9.4 | .29 | 990 | 190 | 30.00 | 22.0 | 120.0 |
| **Section ADB-3, lat 68° 22' 30" N., long. 150° 48' 30" W.** | | | | | | | | | | | | | |
| 0-10 | 210,000 | 2,500 | 6,600 | 16.0 | -- | 6,500 | 1.5 | .44 | 570 | 59 | 3.40 | -- | 16.0 |
| 0- 6 | 350,000 | 1,400 | 9,500 | 10.0 | -- | 69,000 | 15.8 | <.25 | 1,200 | 96 | 4.60 | -- | 54.0 |
| 0-42 | 230,000 | 3,600 | 10,000 | 35.0 | 140 | 21,000 | 4.8 | .43 | 590 | 190 | 20.00 | <5.4 | 50.0 |
| 0-20 | 130,000 | 1,200 | 13,000 | 3.1 | 180 | 150 | .03 | .38 | 360 | 82 | 3.00 | -- | 6.8 |
| 21-40 | 27,000 | 3,600 | 29,000 | 6.4 | 180 | 600 | .14 | .61 | 230 | 48 | 9.70 | 12.0 | 27.0 |
| 41-60 | 23,000 | 4,200 | 23,000 | 7.9 | 180 | 1,800 | .41 | .58 | 210 | 59 | 13.00 | 17.0 | 38.0 |

Table 4. Analytical data from phosphatic rocks collected from the Shublik Formation, Chandler Lake quadrangle, Alaska—continued

| Interval sampled | Ca-ppm icp | Al-ppm icp | Fe-ppm icp | Ti-ppm icp | Mn-ppm icp | P-ppm icp | $P_2O_5$ wt. % | Be-ppm icp | Sr-ppm icp | Ba-ppm icp | La-ppm icp | Ce-ppm icp | Y-ppm icp |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Section ADB-5, lat 68° 21' 18" N., long. 151° 52' 30" W.** | | | | | | | | | | | | | |
| 0-20 | 22,000 | 4,900 | 24,000 | 13.0 | 750 | 210 | .05 | .36 | 110 | 34 | 2.60 | -- | 9.0 |
| 21-40 | 6,200 | 5,700 | 28,000 | 12.0 | 180 | 270 | .06 | .35 | 58 | 31 | 2.50 | 5.5 | 4.2 |
| 41-60 | 42,000 | 3,300 | 18,000 | 7.6 | 520 | 300 | .07 | .37 | 110 | 22 | 4.00 | 6.2 | 9.8 |
| 61-80 | 22,000 | 6,700 | 24,000 | 23.0 | 440 | 350 | .08 | .51 | 67 | 47 | 5.30 | 9.0 | 11.0 |
| 81-100 | 24,000 | 5,900 | 28,000 | 27.0 | 430 | 430 | .10 | .49 | 74 | 28 | 5.60 | 9.3 | 9.5 |
| 101-120 | 24,000 | 7,200 | 32,000 | 18.0 | 4,000 | 670 | .15 | .52 | 94 | 60 | 6.10 | 14.0 | 15.0 |
| 121-140 | 16,000 | 6,000 | 28,000 | 16.0 | 1,200 | 560 | .13 | .51 | 71 | 58 | 8.40 | 15.0 | 19.0 |
| 141-160 | 28,000 | 6,900 | 37,000 | 28.0 | 520 | 280 | .06 | .60 | 93 | 62 | 6.90 | 9.5 | 14.0 |
| 161-180 | 24,000 | 4,600 | 22,000 | 8.6 | 280 | 440 | .10 | .45 | 96 | 50 | 5.20 | 9.9 | 14.0 |
| 181-200 | 15,000 | 3,700 | 15,000 | 9.0 | 110 | 720 | .18 | .30 | 100 | 77 | 6.20 | 11.0 | 18.0 |
| 201-220 | 29,000 | 2,200 | 13,000 | 6.4 | 130 | 960 | .10 | .26 | 120 | 91 | 7.80 | 9.8 | 20.0 |
| 221-240 | 42,000 | 2,400 | 10,000 | 8.5 | 110 | 3,500 | .80 | .26 | 200 | 84 | 7.80 | 9.2 | 23.0 |
| 241-260 | 13,000 | 2,100 | 15,000 | 4.0 | 74 | 620 | .14 | .24 | 72 | 57 | 3.00 | -- | 10.0 |
| 261-280 | 37,000 | 2,600 | 19,000 | 7.1 | 160 | 190 | .04 | .34 | 130 | 110 | 3.50 | -- | 10.0 |
| 281-300 | 140,000 | 1,100 | 7,100 | 3.9 | 56 | 180 | .04 | .43 | 340 | 120 | 3.90 | -- | 15.0 |

Table 4. Analytical data from phosphatic rocks collected from the Shublik Formation, Chandler Lake quadrangle, Alaska—continued

| Interval sampled | V-ppm icp | Cr-ppm icp | Co-ppm icp | Ni-ppm icp | Cu-ppm icp | Zn-ppm icp | Pb-ppm icp | As-ppm icp | Mo-ppm icp | Cd-ppm icp | Ag-ppm icp |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Section ADB-1, lat 68° 23' 12" N., long. 150° 52' 05" W.** | | | | | | | | | | | |
| 0-20 | 130.0 | 78 | -- | 63 | 27 | 73 | 9.9 | 17.0 | 15.0 | -- | 1.00 |
| 20-49 | 110.0 | 44 | 4.1 | 47 | 43 | 120 | 9.2 | 17.0 | 14.0 | -- | .76 |
| 52-60 | 110.0 | 54 | 2.2 | 64 | 58 | 140 | 11.0 | 16.0 | 17.0 | -- | 1.10 |
| 61-80 | 12.0 | 31 | 3.6 | 19 | 17 | 38 | -- | -- | -- | -- | -- |
| 81-100 | 7.1 | 48 | 2.8 | 27 | 15 | 31 | -- | -- | -- | -- | -- |
| 101-110 | 15.0 | 27 | 4.9 | 38 | 52 | 88 | 8.3 | -- | 3.2 | -- | -- |
| 114 | 9.9 | 27 | -- | 22 | 45 | 65 | -- | -- | 3.1 | -- | -- |
| 111-128 | 14.0 | 27 | 4.0 | 25 | 35 | 55 | -- | -- | 2.9 | -- | -- |
| 129-148 | 48.0 | 68 | 2.2 | 34 | 53 | 78 | -- | -- | 5.3 | -- | -- |
| 149-162 | 140.0 | 57 | 2.4 | 34 | 49 | 120 | -- | -- | 6.1 | 1.50 | -- |
| 165 | 260.0 | 77 | 1.9 | 22 | 22 | 52 | -- | -- | 2.0 | -- | -- |
| 163-180 | 440.0 | 74 | 2.7 | 37 | 40 | 130 | -- | -- | 11.0 | 2.10 | -- |
| 181-205 | 58.0 | 16 | 4.2 | 29 | 42 | 39 | -- | -- | 15.0 | -- | -- |
| 206-225 | 53.0 | 16 | 4.5 | 25 | 46 | 36 | -- | -- | 13.0 | -- | -- |
| 226-235 | 25.0 | 38 | 2.0 | 15 | 23 | 40 | -- | -- | 2.0 | -- | -- |
| **Section ADB-3, lat 68° 22' 30" N., long. 150° 48' 30" W.** | | | | | | | | | | | |
| 0-10 | 100.0 | 70 | 3.4 | 37 | 34 | 130 | -- | -- | 3.8 | -- | -- |
| 0- 6 | 53.0 | 27 | 2.3 | 18 | 13 | 51 | -- | -- | -- | -- | -- |
| 0-42 | 72.0 | 65 | 3.6 | 36 | 27 | 100 | -- | -- | 2.1 | -- | -- |
| 0-20 | 44.0 | 43 | 4.4 | 49 | 46 | 170 | -- | 7.4 | 3.1 | -- | -- |
| 21-40 | 50.0 | 28 | 12.0 | 97 | 91 | 290 | 15.0 | 14.0 | 12.0 | N | -- |
| 41-60 | 26.0 | 26 | 12.0 | 93 | 77 | 390 | 20.0 | 13.0 | 3.3 | -- | -- |

Table 4. Analytical data from phosphatic rocks collected from the Shublik Formation, Chandler Lake quadrangle, Alaska—continued

| Interval sampled | V-ppm icp | Cr-ppm icp | Co-ppm icp | Ni-ppm icp | Cu-ppm icp | Zn-ppm icp | Pb-ppm icp | As-ppm icp | Mo-ppm icp | Cd-ppm icp | Ag-ppm icp |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Section ADB-5, lat 68° 21' 18" N., long. 151° 52' 30" W.** | | | | | | | | | | | |
| 0-20 | 19.0 | 20 | 5.3 | 19 | 30 | 47 | 10.0 | 12.0 | 11.0 | -- | -- |
| 21-40 | 17.0 | 21 | 6.7 | 23 | 22 | 48 | 12.0 | 13.0 | 5.7 | -- | -- |
| 41-60 | 13.0 | 21 | 8.0 | 31 | 28 | 75 | 9.6 | 11.0 | 5.0 | <.72 | -- |
| 61-80 | 46.0 | 50 | 11.0 | 68 | 62 | 200 | 11.0 | 22.0 | 12.0 | 3.40 | 1.30 |
| 81-100 | 48.0 | 30 | 12.0 | 67 | 48 | 250 | 12.0 | 28.0 | 16.0 | 3.90 | 1.30 |
| 101-120 | 19.0 | 32 | 18.0 | 54 | 41 | 120 | 14.0 | 12.0 | 4.2 | -- | -- |
| 121-140 | 39.0 | 35 | 12.0 | 45 | 72 | 270 | 17.0 | 15.0 | 5.1 | <2.20 | .62 |
| 141-160 | 65.0 | 39 | 11.0 | 47 | 89 | 330 | 12.0 | 23.0 | 10.0 | 4.40 | .77 |
| 161-180 | 32.0 | 35 | 9.9 | 71 | 84 | 210 | 11.0 | 12.0 | 4.8 | -- | -- |
| 181-200 | 23.0 | 31 | 9.3 | 55 | 72 | 110 | 10.0 | 7.2 | 6.7 | -- | -- |
| 201-220 | 24.0 | 32 | 5.0 | 43 | 42 | 130 | -- | 5.9 | 5.6 | -- | -- |
| 221-240 | 13.0 | 39 | 5.1 | 40 | 43 | 120 | -- | -- | 2.6 | -- | -- |
| 241-260 | 17.0 | 43 | 5.9 | 61 | 71 | 170 | 8.4 | 6.4 | 4.7 | <.63 | 1.10 |
| 261-280 | 33.0 | 43 | 7.7 | 71 | 69 | 210 | 8.5 | 10.0 | 11.0 | <1.10 | -- |
| 281-300 | 140.0 | 30 | 4.3 | 71 | 51 | 150 | -- | 11.0 | 30.0 | 3.40 | -- |