U.S. Department of the Interior
National Park Service
Natural Resource Stewardship and Science Directorate
Geologic Resources Division

Katmai National Park and Preserve and Alagnak Wild River

GRI Ancillary Map Information Document

Produced to accompany the Geologic Resources Inventory (GRI) Digital Geologic Data for Katmai National Park and Preserve and Alagnak Wild River

katm_geology.pdf

Version: 9/7/2016

Geologic Resources Inventory Map Document for Katmai National Park and Preserve and Alagnak Wild River

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Geologic Resources Inventory Map Document

Katmai National Park and Preserve and Alagnak Wild River, Alaska

Document to Accompany Digital Geologic-GIS Data

katm_geology.pdf

Version: 9/7/2016

This document has been developed to accompany the digital geologic-GIS data developed by the Geologic Resources Inventory (GRI) program for Katmai National Park and Preserve and Alagnak Wild River, Alaska (KATM).

Attempts have been made to reproduce all aspects of the original source products, including the geologic units and their descriptions, geologic cross sections, the geologic report, references and all other pertinent images and information contained in the original publication.

This document contains the following information:

1) **About the NPS Geologic Resources Inventory Program** – A brief summary of the Geologic Resources Inventory (GRI) Program and its products. Included are web links to the GRI GIS data model, and to the GRI products page where digital geologic-GIS datasets, scoping reports and geology reports are available for download. In addition, web links to the NPS Data Store and GRI program home page, as well as contact information for the GRI coordinator, are also present.

2) **GRI Digital Maps and Source Citations** – A listing of all GRI digital geologic-GIS maps produced for this project along with sources used in their completion. In addition, a brief explanation of how each source map was used is provided.

3) **Map Unit Listing** – A listing of all geologic map units present on maps for this project, generally listed from youngest to oldest.

4) **Map Unit Descriptions** – Descriptions for all geologic map units. If a unit is present on multiple source maps the unit is listed with its source geologic unit symbol, unit name and unit age followed by the unit's description for each source map.

5) **Geologic Cross Sections** – Geologic cross section graphics with source geologic cross section abbreviation.

6) **Ancillary Source Map Information** – Additional source map information presented by source map.

For each source map this may include a stratigraphic column, index map, map legend and/or map notes.

7) **GRI Digital Data Credits** – GRI digital geologic-GIS data and ancillary map information document production credits.

For information about using GRI digital geologic-GIS data contact:

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About the NPS Geologic Resources Inventory Program

Background

Recognizing the interrelationships between the physical (geology, air, and water) and biological (plants and animals) components of the earth is vital to understanding, managing, and protecting natural resources. The Geologic Resources Inventory (GRI) helps make this connection by providing information on the role of geology and geologic resource management in parks.

Geologic resources for management consideration include both the processes that act upon the Earth and the features formed as a result of these processes. Geologic processes include: erosion and sedimentation; seismic, volcanic, and geothermal activity; glaciation, rockfalls, landslides, and shoreline change. Geologic features include mountains, canyons, natural arches and bridges, minerals, rocks, fossils, cave and karst systems, beaches, dunes, glaciers, volcanoes, and faults.

The Geologic Resources Inventory aims to raise awareness of geology and the role it plays in the environment, and to provide natural resource managers and staff, park planners, interpreters, researchers, and other NPS personnel with information that can help them make informed management decisions.

The GRI team, working closely with the Colorado State University (CSU) Department of Geosciences and a variety of other partners, provides more than 270 parks with a geologic scoping meeting, digital geologic-GIS map data, and a park-specific geologic report.

Products

Scoping Meetings: These park-specific meetings bring together local geologic experts and park staff to inventory and review available geologic data and discuss geologic resource management issues. A summary document is prepared for each meeting that identifies a plan to provide digital map data for the park.

Digital Geologic Maps: Digital geologic maps reproduce all aspects of traditional paper maps, including notes, legend, and cross sections. Bedrock, surficial, and special purpose maps such as coastal or geologic hazard maps may be used by the GRI to create digital Geographic Information Systems (GIS) data and meet park needs. These digital GIS data allow geologic information to be easily viewed and analyzed in conjunction with a wide range of other resource management information data.

For detailed information regarding GIS parameters such as data attribute field definitions, attribute field codes, value definitions, and rules that govern relationships found in the data, refer to the NPS Geology-GIS Data Model document available at: http://science.nature.nps.gov/im/inventory/geology/GeologyGISDataModel.cfm

Geologic Reports: Park-specific geologic reports identify geologic resource management issues as well as features and processes that are important to park ecosystems. In addition, these reports present a brief geologic history of the park and address specific properties of geologic units present in the park.

For a complete listing of Geologic Resource Inventory products and direct links to the download site visit the GRI publications webpage http://www.nature.nps.gov/geology/inventory/gre_publications.cfm

GRI geologic-GIS data is also available online at the NPS Data Store Search Application: http://irma.nps.gov/App/Reference/Search. To find GRI data for a specific park or parks select the appropriate park

(s), enter “GRI” as a Search Text term, and then select the Search Button.

For more information about the Geologic Resources Inventory Program visit the GRI webpage: http://www.nature.nps.gov/geology/inventory, or contact:

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The Geologic Resources Inventory (GRI) program is funded by the National Park Service (NPS) Inventory and Monitoring (I&M) Division.

GRI Digital Maps and Source Map Citations

The GRI digital geologic-GIS map for Katmai National Park and Preserve and Alagnak Wild River, Alaska (KATM):

GRI Digital Geologic Map of Katmai National Park and Preserve, Alagnak Wild River, and vicinity, Alaska (*GRI MapCode KATM*)
was compiled from the following sources:

Data produced for the GRI by the USGS Alaska Science Center

Wilson, F.H., 2009, Digital Geology for Katmai National Park and Preserve, Alagnak Wild River and Vicinity, Alaska: U.S. Geological Survey, unpublished digital data, scale 1:250,000. (Geology of Katmai and Alagnak). (*GRI Source Map ID 75244*).

Several attribute fields present in the USGS Alaska Science source GIS data were retained in the GRI digital geologic-GIS data to provide users with the ability to relate GIS data back to the USGS Alaska Science Center source digital data. To view source publications used in the creation of this dataset refer to the Source Map References section of this document and visit the USGS Alaska Science Center at: http://alaska.usgs.gov/ to obtain USGS Alaska Science source GIS data files.

The above source data is the primary mapping source used for the geologic map of Katmai National Park and Preserve, and Alagnak Wild River. Source datasets referenced below were included to provide a more complete representation of the geology in and around Katmai National Park and Preserve, and Alagnak Wild River.

Data extracted from Alaska Resource Data Files (ARDF)

Hawley, C.C., 2004, Alaska Resource Data File - Iliamna Quadrangle, Alaska: U.S. Geological Survey, Open-File Report OF-2004-1057, scale 1:250,000. (*GRI Source Map ID 75243*).

Pilcher, S.H., 1999, Alaska Resource Data File - Afognak Quadrangle, Alaska: U.S. Geological Survey, Open-File Report OF-99-40, scale 1:250,000. (*GRI Source Map ID 2700*).

Pilcher, S.H., 1999, Alaska Resource Data File - Karluk Quadrangle, Alaska: U.S. Geological Survey, Open-File Report OF-99-42, scale 1:250,000. (*GRI Source Map ID 2701*).

Wilson, F.H., Church, S.E., and Bickerstaff, D.P., 2006, Alaska Resource Data File - Mount Katmai Quadrangle, Alaska: U.S. Geological Survey, Open-File Report OF-2006-1022, scale 1:250,000. (*GRI Source Map ID 75242*).

Additional map data included to provide a more complete map product

Cameron, C.E., and Nye, C.J., 2014, Preliminary Database of Quaternary Vents in Alaska: Alaska Division of Geological & Geophysical Surveys, Miscellaneous Publication MP 153. (*GRI Source Map ID 76069*).

Detterman, R. L., and Reed, B. L., 1980, Stratigraphy, Structure, and Economic Geology of the Iliamna Quadrangle, Alaska: U.S. Geological Survey Bulletin 1368-B, scale 1:250,000. (*GRI Source Map ID 3573*).

Only vents and plugs were extracted from the above publication.

Global Volcanism Program, 2013, Volcanoes of the World, v. 4.5.0, Venzke, E. (ed.): Smithsonian Institution, Downloaded January 2016, http://volcano.si.edu/. (*GRI Source Map ID 76070*).

Hults, C., 2016, Surficial Geology of the Southeast Part of the Dillingham Quadrangle, Alaska: National Park Service, Unpublished digital data, scale 1:250,000. (*GRI Source Map ID 76071*)

Additional information pertaining to each source map is also presented in the GRI Source Map Information (KATMMAP) table included with the GRI geology-GIS data.

Map Unit List

The geologic units present in the digital geologic-GIS data produced for Katmai National Park and Preserve and Alagnak Wild River, Alaska (KATM) are listed below. Units are listed with their assigned unit symbol and unit name (e.g., Qa - Alluvial deposits). Units are listed from youngest to oldest. Information about each geologic unit is also presented in the GRI Geologic Unit Information (KATMUNIT) table included with the GRI geology-GIS data.

Cenozoic Era

Quaternary Period
Qg - Glacier
Qs - Surficial deposits
Qtf - Tidal flat deposits
Qa - Alluvial deposits
Qb - Beach deposits
Qes - Estruarine deposits
Qaf - Alluvial fan deposits
Qc - Colluvium
Qsf - Solifluction deposits
Qls - Landslide deposits
Qt - Alluvial terrace deposits
Qac - Abandoned channel deposits
Ql - Lacustrine deposits
Qsw - Swamp deposits
Qmt - Marine terrace deposits
Qd - Eolian deposits
Qm - Moraines and other glacial deposits
Qsg - Superglacial drift
Qrg - Rock glacier deposits
Qhg - Glacial deposits of Holocene glaciations
Qho - Outwash deposits of Holocene glaciations
Qv - Volcanic rocks
Qhv - Younger volcanic rocks
Qhvd - Younger volcanic rocks, domes
Qpd - Pyroclastic and debris-flow deposits
Qva - East Point Formation, andesite and low-silica dacite
Qafd - Ash-flow and ash-fall deposits
Qvd - Dacitic to rhyolitic domes
QTv - Older volcanic rocks
Qblu - Brooks Lake Glaciation, drift, undivided
Qblik - Brooks Lake Glaciation, drift of Iliuk Advance, drift deposits
Qbld - Brooks Lake Glaciation, drumlin field deposits
Qblo - Brooks Lake Glaciation, drift and outwash deposits, undivided
Qbln - Brooks Lake Glaciation, drift of Newhalen Advance, drift deposits
Qblil - Brooks Lake Glaciation, drift of Iliamna Stade, drift deposits
Qblk - Brooks Lake Glaciation, drift of Kvichak Advance, drift deposits
Qgl - Glaciolacustrine deposits
Qglf - Glaciolacustrine fan deposits
Qmh - Mak Hill Glaciation, drift deposits
Qmhg - Mak Hill Glaiciation, Kulakeklek Stade, drift, ground moraine
Qmho - Mak Hill Glaciation, outwash deposits

Qjhd - Johnson Hill drift, drift deposits
Qjho - Older outwash deposits

Tertiary Period
Tglu - Gibraltar Lake Tuff, upper member
Tgll - Gibraltar Lake Tuff, lower member
Tab - Volcanic rocks of Barrier Range
Td - Dikes
Tiu - Intrusive rocks, undivided
Tgd - Intrusive rocks, granodiorite
Ti - Granitic intrusive rocks
Th - Hemlock Conglomerate
Togd - Granodiorite
Toqd - Quartz diorite
Tvr - Volcanic rocks, undivided tuff
Tm - Meshik Volcanics
Tmbf - Meshik Volcanics, basalt flows
Tvm - Andesitic and dacitic rocks of the Meshik volcanic arc
Tvc - Pyroclastic deposits of the Meshik volcanic arc
Tc - Copper Lake Formation

Cenozoic and Mesozoic Eras

Tertiary and/or Cretaceous Periods
TKgd - Granodiorite

Mesozoic and Paleozoic Eras

Cretaceous Period
Ksr - Sedimentary rocks
Kk - Kaguyak Formation
Kp - Pedmar Formation
Khe - Herendeen Formation
Kst - Staniukovich Formation
Kqm - Quartz monzonite

Jurassic? to Permian? Periods
JPk - Kakhonak(?) Complex

Jurassic Period
Jn - Naknek Formation
Jnk - Naknek Formation, Katolinat Conglomerate Member
Jnc - Naknek Formation, Chisik Conglomerate Member
Jni - Naknek Formation, Indecision Creek Sandstone Member
Jns - Naknek Formation, Snug Harbor Siltstone Member
Jnn - Naknek Formation, Northeast Creek Sandstone Member
Jgr - Granite
Jgd - Granodiorite
Jqd - Tonalite and quartz diorite
Jgb - Diorite and gabbro
Js - Shelikof Formation
Jtk - Talkeetna Formation

Triassic Period
TRk - Kamishak Formation
TRku - Kamishak Formation, Ursus Member
TRkm - Kamishak Formation, middle member
TRc - Cottonwood Bay Greenstone

Map Unit Descriptions

Descriptions of all geologic map units, generally listed from youngest to oldest, are presented below.

Qg - Glacier (Quaternary)

No description is provided for Qg (Glacier). (*GRI Source Map ID 75244)* (Geology of Katmai and Alagnak).

Qs - Surficial deposits (Quaternary)

Ranges from coarse, subangular rock fragments to fine sand and silt in grainsize; locally includes considerable amounts of pumice near volcanic centers. As mapped, unit locally incorporates deposits of fluvial, colluvial, glacial outwash, lacustrine, estuarine, swamp, and eolian origin, in addition to minor areas of other Quaternary surficial units. Large areas are covered by organic-rich silt deposits. Unit locally includes extensive redeposited pumice and ash initially deposited during 1912 Novarupta (Katmai) eruption. Eolian deposits form dunes 10 to 20 m high that are composed largely of sand and pumice. (*GRI Source Map ID 75244)* (Geology of Katmai and Alagnak).

Qtf - Tidal flat deposits (Holocene)

Well-sorted, stratified silt and some sand and local gravel deposited in shallow embayments. Sub-tidal. (*GRI Source Map ID 75244)* (Geology of Katmai and Alagnak).

Qa - Alluvial deposits (Quaternary)

Varies from poorly sorted and crudely stratified deposits of coarse angular fragments near valley heads to well-sorted and stratified deposits of sand and gravel in lowlands. Locally includes boulders where streams have cut through glacial moraines. Unit includes both active and vegetated inactive deposits; unit may include older outwash and (or) terrace deposits too small to show separately. (*GRI Source Map ID 75244)* (Geology of Katmai and Alagnak).

Qb - Beach deposits (Quaternary)

Moderately well sorted, locally stratified deposits of sand and gravel. Beach deposits on Bristol Bay coastline are chiefly sand derived from adjacent glacial deposits, whereas those along Shelikov Strait are chiefly sandy gravel or gravel derived from local bedrock. Beaches along Katmai and Dakavak Bays include abundant pumice from the 1912 Novarupta eruption. Includes the more prominent beaches formed during late Pleistocene high stands of glacial Lake Naknek. (*GRI Source Map ID 75244)* (Geology of Katmai and Alagnak).

Qes - Estruarine deposits (Quaternary)

Dark-gray silt and clay commonly laminated with interbeds of fine sand; locally rich in organic material. Extensively developed around Ugashik Bay where the deposits extend from the high tide line to as much as 2 m above high tide. (*GRI Source Map ID 75244)* (Geology of Katmai and Alagnak).

Qaf - Alluvial fan deposits (Quaternary)

Vary from coarse, poorly sorted blocks at head of fan to stratified deposits of moderately well sorted and well-rounded pebbles and boulders near margin of fan. Unit includes small, steep-sided alpine fans, commonly inactive, of mixed alluvial and colluvial origin, as well as larger active fans that grade into alluvium. (*GRI Source Map ID 75244)* (Geology of Katmai and Alagnak).

Qc - Colluvium (Quaternary)

Sheets, fans, and cones of angular frost-riven rock fragments accumulate on steep slopes in mountainous regions. Most commonly formed in areas of granitic rock. Rubble covers flat to gently rounded hilltops and upland surfaces that stand above the limit of Late Wisconsin glaciation. Areas where rubble has developed are underlain by a variety of rock types, but are most commonly granitic or Tertiary volcanic rocks. (*GRI Source Map ID 75244)* (Geology of Katmai and Alagnak).

Qsf - Solifluction deposits (Quaternary)

Silt and (or) organic deposits mixed with coarse angular blocks of bedrock or with material derived from underlying glacial deposits. Unsorted to locally poorly stratified. Found low on valley walls and mountain slopes as thin sheet-like deposits. (*GRI Source Map ID 75244)* (Geology of Katmai and Alagnak).

Qls - Landslide deposits (Quaternary)

Landslide deposits ranging from non-sorted, non-stratifed, coarse angular rubble forming lobes, to large discrete blocks that resemble undisturbed bedrock. (*GRI Source Map ID 75244)* (Geology of Katmai and Alagnak).

Qt - Alluvial terrace deposits (Quaternary)

Crudely stratified deposits of gravel and sand having level or gently sloping upper surfaces form terraces found along virtually all streams in the quadrangle. Many streams show a complex series of multiple terraces and the deposits that form the terraces are locally more than 100 feet thick. Consist mainly of poorly stratified, well-round pebbles and cobbles having interbeds and lenses of sand and silt. (*GRI Source Map ID 75244)* (Geology of Katmai and Alagnak).

Qac - Abandoned channel deposits (Quaternary)

Broad channels incised into moraines of the Brook Lake Glaciation containing stratified and graded deposits of silt, sand, and gravel. Most channel occupied by under-fit streams, locally no streams are present. Channels reflect drainage during maximum melting of the glaciers. Position of abandoned channels suggest numerous occurrences of stream piracy as well as shift channels in response to changing base level. (*GRI Source Map ID 75244)* (Geology of Katmai and Alagnak).

Ql - Lacustrine deposits (Quaternary)

Include (1) organic silt and fine sand in small inter-moraine basins, (2) silty fine sand in broad inter-moraine flats, and (3) silty sand, sandy gravel, and lag boulders on terraces that are typically bounded by wave-cut scarps bordering Naknek and Becharof Lakes. Includes lake terrace deposits from Detterman and Reed, 1973. (*GRI Source Map ID 75244)* (Geology of Katmai and Alagnak).

Qsw - Swamp deposits (Quaternary)

Dark-brown organic accumulation of woody and peaty material mixed with silt and fine sand. Sedge and sphagnum peat are both present. Measured thicknesses are about 2 feet but deposits are probably much thicker than has been observed. (*GRI Source Map ID 75244)* (Geology of Katmai and Alagnak).

Qmt - Marine terrace deposits (Quaternary)

Marine terrace deposits. Stratified and moderately well sorted sand and gravel deposits that form nearly level plains that end locally at prominent wave-cut scarps. Terraces occur at 15 to 18 m elevation along Bristol Bay and between 40 and 45 m elevation along Pacific Ocean. (*GRI Source Map ID 75244)* (Geology of Katmai and Alagnak).

Qd - Eolian deposits (Quaternary)

Fine-to medium-grained sand or, in Valley of Ten Thousand Smokes, ash-and lapilli-sized pumice that typically forms longitudinal dunes. Found mainly along beaches and stream terraces or adjacent to ash-flow deposits. Include both stabilized and active deposits. (*GRI Source Map ID 75244)* (Geology of Katmai and Alagnak).

Qm - Moraines and other glacial deposits (Quaternary)

Moraines and other glacial deposits. Poorly sorted, non-stratified, glacial drift that forms end, lateral, and ground moraines. Locally includes moderately well sorted and stratified ice-contact and outwash deposits. (*GRI Source Map ID 75244)* (Geology of Katmai and Alagnak).

Qsg - Superglacial drift (Holocene)

Consists of unsorted boulder to fine-grained debris on the surface of modern glaciers. (*GRI Source Map ID 75244)* (Geology of Katmai and Alagnak).

Qrg - Rock glacier deposits (Quaternary)

Unsorted deposits of coarse angular rock debris having a lobate form, arcuate surface ridges, and a steep front and sides. Present in higher mountain elevations at foot of steep bedrock slopes,typically in cirques having at least a partial northerly exposure. Deposits are commonly separated from cirque headwall by tens to hundreds of meters, implying former presence of a small glacier. Rock glaciers are uncommon in the Iliamna quadrangle. Those present are all apparently inactive and have crescent-like ridges and furrows bowing downslope and commonly have deep conical thaw pits and longitudinal ridges on the surface. All mapped rock glaciers have a distinct wall of debris facing upslope, with a pit between the rock glaciers and the cirque headwall. All are small, no more than one half mile in length in small cirques. No identifiable Tunnel Stade moraines are associated with these features, suggesting there may not have been enough ice during the Tunnel Stade to form a true glacier. (*GRI Source Map ID 75244)* (Geology of Katmai and Alagnak).

Qhg - Glacial deposits of Holocene glaciations (Holocene)

Deposits represent an event beginning about 4,500 to 4,800 years BP and continuing until about 200 years BP. Modern glaciers are remnants from this advance. Restricted to higher parts of mountains

along Cook Inlet. (*GRI Source Map ID 75244)* (Geology of Katmai and Alagnak).

Qho - Outwash deposits of Holocene glaciations (Holocene)

Poorly to moderately well sorted sand and gravel forming plains in front of moraines of neoglacial drift deposits or terraces as much as 6 m high along streams that originate in modern glaciers. (*GRI Source Map ID 75244)* (Geology of Katmai and Alagnak).

Qv - Volcanic rocks (Quaternary)

Andesite, dacite, and leucobasalt lava flows, volcanic breccia, lahar deposits, and debris-flow deposits. Lava flows and clasts in other volcanic deposits of unit are porphyritic, typically glassy, gray to black, and commonly vesicular. Andesite is overwhelmingly dominant composition and probably constitutes 60 percent or more of rocks. Includes basalt of Black Point, Arch Point Basalt, and Dushkin Basalt (Kennedy and Waldron, 1955), and Frosty Peak Volcanics (Waldron, 1961). Also includes lava flows, breccias, and older pyroclastic deposits of Yantarni Volcano (Riehle and others, 1987). Unit typically forms volcanic edifices; it also forms isolated outcrops that cap ridges, providing a good example of topography reversal caused by erosion. Individual flows are locally as thick as 30 m and are laterally continuous over large areas. Unit also includes basaltic, basaltic andesite, and dacite parasitic cinder and spatter cones. Cones are commonly 30 to 300 m high, are steep sided, and have small crater at top. Rocks at Mount Veniaminof are mainly basaltic andesite, whereas those at Aniakchak Crater are mainly dacite (T.P. Miller, oral commun., 1990). Basaltic scoria cones occur at three separate locations in the Mount Katmai 1:250,000-scale quadrangle (Riehle and others, 1993). Rocks are highly scoriaceous to vitrophyric, ranging in size from cinder-size fragments to 1-m-long bombs (Detterman and others, 1981b; T.P. Miller, oral commun., 1991). Primarily located in vicinity of Mount Veniaminof, Aniakchak Crater, in Mount Katmai area, and on Unimak Island. (*GRI Source Map ID 75244)* (Geology of Katmai and Alagnak).

Qhv - Younger volcanic rocks (Holocene)

Crudely stratified lava flows, breccia, and tuff chiefly of andesitic composition, but locally including lava flows of dacitic composition and air-fall deposits of rhyolitic to andesitic composition at head of Valley of Ten Thousand Smokes. May also include some domes. (*GRI Source Map ID 75244)* (Geology of Katmai and Alagnak).

Qhvd - Younger volcanic rocks, domes (Holocene)

Domes of probable Holocene age at Snowy Mountain, at Mount Cerberus and Falling Mountain near Novarupta dome at head of the Valley of Ten Thousand Smokes, and at Kaguyak Crater are dacitic in composition, whereas Novarupta dome is rhyolitic. An unnamed dome or tuya of probable Pleistocene age about 5 km northeast of Kaguyak Crater is of unknown composition. (*GRI Source Map ID 75244)* (Geology of Katmai and Alagnak).

Qpd - Pyroclastic and debris-flow deposits (Holocene and late Pleistocene?)

Dacite and rhyolite ash-flow tuff and debris-flow, block-and-ash-flow, explosion debris, and air-fall deposits. Mapped near Pavlof Volcano, Mount Dana, Kupreanof Volcano and other nearby unnamed volcanoes (Wilson, 1989), Mount Veniaminof (Detterman and others, 1981b), Aniakchak Crater (Miller and Smith, 1977), Ugashik Caldera (Detterman, Wilson, and others, 1987), and Valley of Ten Thousand Smokes (Riehle and others, 1987 and 1993). Pyroclastic deposits typically are composed of pumice and scoria bombs and subordinate lithic fragments in a matrix of fine to coarse ash, pumice, and lithic

material (Miller and Smith, 1977, p. 174). Miller and Smith (1977) reported that composition ranges from basaltic andesite to rhyolite, although most are dacite. Valley of Thousand Smokes is well known for its compositionally zoned rhyolite to andesite ash flows erupted in 1912 (see, for example, Hildreth, 1983). Hildreth (1987) estimated composition of lavas from 1912 Katmai eruption to have been roughly 54 to 59 percent rhyolite, 35 to 43 percent dacite, and 3 to 5 percent andesite. (*GRI Source Map ID 75244)* (Geology of Katmai and Alagnak).

Qva - East Point Formation, andesite and low-silica dacite (Quaternary)

Light- to dark-gray, holocrystalline to vitrophyric, porphyritic; common phenocrysts include plagioclase, orthopyroxene, hornblende, quartz, and magnetite; rare olivine and clinopyroxene. Locally includes interlayered units of tuff and volcanic rubble. Individual flow units to 50 m thick, commonly columnar jointed. (*GRI Source Map ID 75244)* (Geology of Katmai and Alagnak).

Qafd - Ash-flow and ash-fall deposits (Quaternary)

Nonsorted, variably indurated deposits of ash, vitrophyre blocks, and (or) pumiceous lapilli. Mapped in Valley of Ten Thousand Smokes and at Kaguyak Crater. (*GRI Source Map ID 75244)* (Geology of Katmai and Alagnak).

Qvd - Dacitic to rhyolitic domes (Quaternary)

Dacite at Snowy Mountain, Mount Cerberus, Falling Mountain, and at Kaguyak Crater and rhyolite at Novarupta. (*GRI Source Map ID 75244)* (Geology of Katmai and Alagnak).

QTv - Older volcanic rocks (Quaternary and Pliocene?)

Andesite and basalt lava flows, sills, and plugs. These primarily extrusive rocks typically cap ridges and include massive lava flows, agglomerate, and lahar deposits. Includes basalt flows of Mount Simeon of Waldron (1961). (*GRI Source Map ID 75244)* (Geology of Katmai and Alagnak).

Qblu - Brooks Lake Glaciation, drift, undivided (Pleistocene)

Moraines and other glacial deposits. Poorly sorted, nonstratified, glacial drift that forms end, lateral, and ground moraines. Locally includes moderately well sorted and stratified ice-contact and outwash deposits. Broadly distributed glacial deposits; generally assigned to individual late Wisconsin advances. (*GRI Source Map ID 75244)* (Geology of Katmai and Alagnak).

Qblik - Brooks Lake Glaciation, drift of Iliuk Advance, drift deposits (Pleistocene)

Little modified, showing fresh knob-and-kettle topography. Contains a less heterogeneous assemblage of rock types than older moraines, indicating localized sources. Ice-polished and striated erratics are common on surface of the moraines. Well-preserved lobate end moraines can be followed for many miles; recessional moraines are less preserved, being partially covered by glaciofluvial deposits. Kettle ponds are for most part undrained and retain the irregular shapes left by melting ice blocks. Vegetational cover varies widely, but is not a criteria for determining age of a moraines; it is more a function of climatic zones. Some of the youngest moraines are locally heavily forested, whereas the oldest moraines at comparable elevations may be only tundra covered. These end moraines extend no more than 10 to 20 miles beyond their source cirques, yet are about the same distance behind

Newhalen end moraines. Many cirques have been little modified by Holocene glaciations; locally one recessional moraine is mapped; others may have been covered by Holocene readvances. (*GRI Source Map ID 75244)* (Geology of Katmai and Alagnak).

Qbld - Brooks Lake Glaciation, drumlin field deposits (Pleistocene)

Formed of unsorted till of Brooks Lake age in elongate, roughly elliptical hills as much as 1.5 km long and 50 m high. Found mainly in Kejulik River valley and Bellim Bay area of Becharof Lake, where orientation indicates ice flow was southwest towards Becharof Lake. A small drumlin field lies west of Ugashik Lake. Stream erosion reveals some drumlins cored by bedrock in the Kejulik River valley. (*GRI Source Map ID 75244)* (Geology of Katmai and Alagnak).

Qblo - Brooks Lake Glaciation, drift and outwash deposits, undivided (Pleistocene)

Glaciofluvial deposits bordering moraine fronts of the Kvichak and Iliamna advances, commonly 1.5 to 2 miles wide and many miles long. Thought to be so extensive because of protracted stillstands of the glacial advances. Deposits form great plains, dipping 25 to 50 feet per miles and showing shallow braided channels scars due to rapidly shifting streams. Pitted outwash border the moraines where outwash cover ice blocks and ultimately melted out, leaving depressions as much as 50 feet deep. At west end of Iliamna lake, outwash is 65 feet thick, composed of alternating layers of silt and gravel and containing lenses of cobbles. A well-developed kame terrace extends along south side of Kvichak moraine west from Kukaklek Lake. It is 300 to 800 feet wide and the inner (ice) margin is a scrap 25-50 feet high. Outwash locally mantles morainal deposits of the Mak Hill and older Brooks Lake advances. (*GRI Source Map ID 75244)* (Geology of Katmai and Alagnak).

Qbln - Brooks Lake Glaciation, drift of Newhalen Advance, drift deposits (Pleistocene)

Little modified, showing fresh knob-and-kettle topography. Contains a less heterogeneous assemblage of rock types than older moraines, indicating localized sources. Ice-polished and striated erratics are common on surface of the moraines. Well-preserved lobate end moraines can be followed for many miles; recessional moraines are less preserved, being partially covered by glaciofluvial deposits. Kettle ponds are for most part undrained and retain the irregular shapes left by melting ice blocks. Some of the youngest moraines are locally heavily forested, whereas the oldest moraines at comparable elevations may be only tundra covered. Apparently a large gap in time occurred between the older Iliamna stade and the Newhalen advance. The Newhalen advance was an alpine advance where for the most part, individual glaciers did not coalesce. The alpine glaciers extended no more than 20 to 30 miles from their source areas; at least 3 recessional moraines have been identified, best developed along Lower Tazimina Lake in the north and Moraine Creek in the south. (*GRI Source Map ID 75244)* (Geology of Katmai and Alagnak).

Qblil - Brooks Lake Glaciation, drift of Iliamna Stade, drift deposits (Pleistocene)

Little modified, showing fresher knob-and-kettle topography than Kvichak moraines. Contains a heterogeneous assemblage of rock types indicating multiple sources of tributary glaciers. Ice-polished and striated erratics are common on surface of the moraines. Well-preserved lobate end moraines can be followed for many miles; recessional moraines are less preserved, being partially covered by glaciofluvial deposits. Kettle ponds are for most part undrained and retain the irregular shapes left by melting ice blocks, locally loess and vegetation are infilling the kettles. Some of the youngest moraines

are locally heavily forested, whereas the oldest moraines at comparable elevations may be only tundra covered. These end moraines lie 20 to 60 miles beyond the Newhalen end moraines and a complex system of recessional moraines indicate at least three major stillstands. (*GRI Source Map ID 75244)* (Geology of Katmai and Alagnak).

Qblk - Brooks Lake Glaciation, drift of Kvichak Advance, drift deposits (Pleistocene)

Little modified, showing fresh knob-and-kettle topography. Contains a less heterogeneous assemblage of rock types than older moraines, indicating localized sources. Ice-polished and striated erratics are common on surface of the moraines. Well-preserved lobate end moraines can be followed for many miles; recessional moraines are less preserved, being partially covered by glaciofluvial deposits. Kettle ponds are for most part undrained and retain the irregular shapes left by melting ice blocks. Vegetational cover varies widely, but is not a criteria for determining age of a moraines; it is more a function of climatic zones. Some of the youngest moraines are locally heavily forested, whereas the oldest moraines at comparable elevations may be only tundra covered. These end moraines extend no more than 10 to 20 miles beyond their source cirques, yet are about the same distance behind Newhalen end moraines. Many cirques have been little modified by Holocene glaciations; locally one recessional moraine is mapped; others may have been covered by Holocene readvances. (*GRI Source Map ID 75244)* (Geology of Katmai and Alagnak).

Qgl - Glaciolacustrine deposits (Pleistocene)

These deposits are almost entirely silt- and clay-size, though locally sand and pebbles occur near ground moraine exposures. Silt and clay is light-gray to tan, locally laminated and as much as 20-50 feet thick. Upper layers are rich in organic material. Lenses of interstitial ice are present and relict permafrost (periglacial) features are common. Proglacial lake deposits have a characteristic topographic expression, nearly flat and covered by myriad small ponds, remnants of larger ponds and the intervening areas covered by quaking bogs. (*GRI Source Map ID 75244)* (Geology of Katmai and Alagnak).

Qglf - Glaciolacustrine fan deposits (Pleistocene)

Deposits of gravel, sand and silt, these are the result of streams draining into ancestral Lake Iliamna. Typically deltaic and consist of stratified layers of cobbles, pebbles, sand, silt, and glacial lake clay. Mostly associated with outwash of the Kvichak and Iliamna stades. Are at two levels, coarser ones are at the higher level, generally above 200 feet and larger, being 2 to 4 miles long and as wide in a triangular shape. Deltas of lower set are commonly narrow and more linear, up to 4 miles long and rarely more than 1/4 to 1/2 mile wide; these tend to be 100 to 150 feet in elevation and most sand and silt. (*GRI Source Map ID 75244)* (Geology of Katmai and Alagnak).

Qmh - Mak Hill Glaciation, drift deposits (Pleistocene)

Till and stratified ice-contact deposits, forming discontinuous ridges of arcuate and lobate end moraines of much as 30 km in front of outer limit of Kvichak advance (Qblk). Clasts are moderately to highly weathered. Constructional topography is subdued and has been modified by mass movements, deposition of as much as 2 m of loess, infilling of kettle ponds, and thermokarst activity. (*GRI Source Map ID 75244)* (Geology of Katmai and Alagnak).

Qmhg - Mak Hill Glaiciation, Kulakeklek Stade, drift, ground moraine (Pleistocene)

Mak Hill Glaiciation, drift, ground moraine. Along Stuyahok River, only unmodified remnants of formerly extensive deposits. Unsorted nature indicates they were formed under a moving glacier. (*GRI Source Map ID 75244)* (Geology of Katmai and Alagnak).

Qmho - Mak Hill Glaciation, outwash deposits (Pleistocene)

Gently sloping plain graded to end moraine of Kulakeklek stade. Mass wasting and loess obliterate anastomosing stream pattern and pitted surface of younger outwash. Consists largely of gravel and minor silt and sand. (*GRI Source Map ID 75244)* (Geology of Katmai and Alagnak).

Qjhd - Johnson Hill drift, drift deposits (Pleistocene)

Till and stratified ice-contact deposits, forming subdued ridges of highly modified end moraines along the Bristol Bay coast. Ridges are rounded and kettles partly in filled by loess and organic deposits. Deposits are buried by or merge with, those of older outwash deposits. (*GRI Source Map ID 75244)* (Geology of Katmai and Alagnak).

Qjho - Older outwash deposits (Pleistocene)

Poorly to moderately well sorted and stratified sand and gravel deposits. Comprise sloping plains in front of moraines of Johnston Hill drift or are found as irregularly shaped areas adjacent to morainal ridges of Johnston Hill drift and Mak Hill drift. Moderately to highly modified by stream dissection, thermokarst activity, and loess deposition. Locally overlain by lake deposits, particularly north of the Naknek River, which are not mapped separately. (*GRI Source Map ID 75244)* (Geology of Katmai and Alagnak).

Tglu - Gibraltar Lake Tuff, upper member (Tertiary, Pliocene?)

Light-gray to white crystal ash-flow tuff. Maximum thickness of 152 to 182 meters. (*GRI Source Map ID 75244)* (Geology of Katmai and Alagnak).

Tgll - Gibraltar Lake Tuff, lower member (Tertiary, Pliocene? to Oligocene?)

Light- to medium-gray and tan rhyolitic crystal and lithic welded tuff and local interbedded porphyritic rhyolite flows. (*GRI Source Map ID 75244)* (Geology of Katmai and Alagnak).

Tab - Volcanic rocks of Barrier Range (Late Tertiary, early Pliocene to late Oligocene)

Breccia, lava flows, sills, and local pyroclastic and epiclastic tuff, southeast of active part of Aleutian Arc. (*GRI Source Map ID 75244)* (Geology of Katmai and Alagnak).

Td - Dikes (Tertiary)

Dikes from 1 to 20 m wide, mainly found southeast of Bruin Bay Fault and having a northwest trend. Many cut rocks as young as units Th (Hemlock Conglomerate) and Tab (Volcanic Rocks of Barrier Range), implying a late Tertiary or Quaternary age. Some are porphyritic and have quartz and

potassium feldspar in groundmass; others have partially altered phenocrysts of plagioclase and pyroxene and (or) hornblende in chloritized groundmass. (*GRI Source Map ID 75244)* (Geology of Katmai and Alagnak).

Tiu - Intrusive rocks, undivided (Tertiary)

Small, typically hypabyssal dikes, sills, and stocks of andesite, quartz diorite, or diorite containing phenocrysts of pyroxene or hornblende in fine-grained groundmass. No potassium-argon ages are available for these rocks; unit may include rocks of other Tertiary intrusive rock units. (*GRI Source Map ID 75244)* (Geology of Katmai and Alagnak).

Tgd - Intrusive rocks, granodiorite (Pliocene and late Miocene)

Fine- to medium-grained granodiorite and quartz diorite, includes volcanic necks, sills, and dikes. (*GRI Source Map ID 75244)* (Geology of Katmai and Alagnak).

Ti - Granitic intrusive rocks (Pliocene and late Miocene)

Medium- to coarse-grained, equigranular, granodiorite to quartz diorite plutons and stocks containing hornblende, biotite, and pyroxene as mafic minerals and typically are surrounded by well-developed hornfels zones and sporadic hydrothermal alteration in country rocks. Intrusive bodies are typically located along Pacific coast and include, but are not limited to, large plutons at Cape Douglas. Potassium-argon ages range from 9.43+/-0.26 to 3.21+/-0.14 Ma (Wilson and others, 1981; F.H. Wilson and Nora Shew, unpublished data, 1990; Wilson and Shew, 1992). (*GRI Source Map ID 75244)* (Geology of Katmai and Alagnak).

Th - Hemlock Conglomerate (late Oligocene)

Originally described by Calderwood and Fackler (1972) and Adkison (1975) for exposures in Cook Inlet area. Magoon and others (1976a, b) applied this name to rocks in northern part of Mount Katmai 1:250,000-scale quadrangle and correlated thicker section there with type Hemlock Conglomerate. Detterman and others (1996) described reference section about 560 m thick of Hemlock Conglomerate in Mount Katmai 1:250,000-scale quadrangle that is composed primarily of fluvial sandstone and conglomerate that contain interbeds of siltstone, shale, and coal. Chert, quartz, and granitic and metasedimentary rocks form most of clasts in conglomerate; volcanic rocks are small but significant proportion of clasts. Minor tuff is present; however, erosion of underlying Mesozoic rocks is probably main source for Hemlock Conglomerate. In most areas, unit unconformably overlies Kaguyak Formation; in a few localities, it unconformably overlies Naknek Formation. At Cape Douglas, it disconformably overlies Copper Lake Formation. Megaflora fossils of broadleaf deciduous plants and evergreen needles suggest late Oligocene age (J.A. Wolfe, written commun., 1988, in Detterman and others, 1996). (*GRI Source Map ID 75244)* (Geology of Katmai and Alagnak).

Togd - Granodiorite (Oligocene)

Riehle and others (1993) describe these rocks as light-gray to gray-green, medium-grained equigranular to marginally porphyritic rocks having subhedral plagioclase and (or) hornblende phenocrysts. Biotite is subequal to clinopyroxene or hornblende and secondary epidote and chlorite are common. Average color index is 18. Modal quartz rarely exceeds 25 percent, and unit includes samples that marginally classify as quartz monzodiorite, quartz diorite, or uncommonly, tonalite. Found in northern part of Mount Katmai 1:250,000-scale quadrangle. (*GRI Source Map ID 75244)* (Geology of Katmai and Alagnak).

Toqd - Quartz diorite (Oligocene)

Riehle and others (1993) describe these rocks as gray, medium-grained equigranular rocks consisting chiefly of plagioclase, pyroxene, and quartz and having accessory hornblende in excess of biotite. Average color index is 23. Modal quartz content varies widely, and rocks composing unit include tonalite and monzonite (Riehle and others, 1987). Found in northern part of Mount Katmai 1:250,000-scale quadrangle. (*GRI Source Map ID 75244)* (Geology of Katmai and Alagnak).

Tvr - Volcanic rocks, undivided tuff (Tertiary, Oligocene and older)

Gray, green, and purple bedded lithic, crystal, and vitric tuff; light-gray to tan welded crystal and lithic tuff most common. (*GRI Source Map ID 75244)* (Geology of Katmai and Alagnak).

Tm - Meshik Volcanics (early Oligocene and late Eocene)

Originally named Meshik Formation by Knappen (1929, p. 198-201) for exposures along Meshik River and near Meshik Lake in Chignik 1:250,000-scale quadrangle. Detterman and others (1996) have renamed unit Meshik Volcanics and have included measured section from Gulf Oil Co. Unit No. 1 drillhole, located near Port Heiden (see Chignik D-3 1:63,360-scale quadrangle). This drillhole penetrated almost 1,765 m of Meshik before reaching total depth, still within Meshik (Brockway and others, 1975). Drillhole section contains considerably more tuff than do outcrop exposures of Meshik Volcanics. Potassium-argon ages on multiple samples of Meshik Volcanics range from about 25 Ma to about 42 Ma (Wilson and others, 1981; DuBois and others, 1987; F.H. Wilson and Nora Shew, unpub. data, 1990; Wilson and Shew, 1992); vast majority of age determinations are between 30 and 40 Ma. Megafauna fossil collections from Meshik are rare; however, existing collections are Eocene and Oligocene in age. As mapped, unit includes informally defined Popof volcanic rocks of Wilson and others (1995), and volcanic rocks of equivalent age, composition, and stratigraphic position mapped by Riehle and others (1993) as units Tvb and Tvm in Mount Katmai and Naknek 1:250,000-scale quadrangles. (*GRI Source Map ID 75244)* (Geology of Katmai and Alagnak).

Tmbf - Meshik Volcanics, basalt flows (early Oligocene and late Eocene)

Originally named Meshik Formation by Knappen (1929, p. 198-201) for exposures along Meshik River and near Meshik Lake in Chignik 1:250,000-scale quadrangle. Detterman and others (1996) have renamed unit Meshik Volcanics and have included measured section from Gulf Oil Co. Unit No. 1 drillhole, located near Port Heiden (see Chignik D-3 1:63,360-scale quadrangle). This drillhole penetrated almost 1,765 m of Meshik before reaching total depth, still within Meshik (Brockway and others, 1975). Drillhole section contains considerably more tuff than do outcrop exposures of Meshik Volcanics. Potassium-argon ages on multiple samples of Meshik Volcanics range from about 25 Ma to about 42 Ma (Wilson and others, 1981; DuBois and others, 1987; F.H. Wilson and Nora Shew, unpub. data, 1990; Wilson and Shew, 1992); vast majority of age determinations are between 30 and 40 Ma. Megafauna fossil collections from Meshik are rare; however, existing collections are Eocene and Oligocene in age. As mapped, unit includes informally defined Popof volcanic rocks of Wilson and others (1995), and volcanic rocks of equivalent age, composition, and stratigraphic position mapped by Riehle and others (1993) as units Tvb and Tvm in Mount Katmai and Naknek 1:250,000-scale quadrangles.

This unit has the same lithologic description as the preceding unit (Tm - Meshik Volcanics). Lithologic table data provided along with source map data differentiates this unit from unit Tm by having basalt flow characteristics. (*GRI Source Map ID 75244)* (Geology of Katmai and Alagnak).

Tvm - Andesitic and dacitic rocks of the Meshik volcanic arc (Tertiary, early Oligocene and Eocene)

Compact, highly porpyritic lavas of andesitic and dacitic flows and breccias having abundant plagioclase and pyroxene (+/- hornblende) phenocrysts. (*GRI Source Map ID 75244)* (Geology of Katmai and Alagnak).

Tvc - Pyroclastic deposits of the Meshik volcanic arc (Tertiary, early Oligocene and Eocene)

Volcanic rubble and breccia, including some agglomerate; may include deposits of lahars. (*GRI Source Map ID 75244)* (Geology of Katmai and Alagnak).

Tc - Copper Lake Formation (early Eocene and Paleocene?)

Named by Detterman and Reed (1980) for exposures in Iliamna 1:250,000-scale quadrangle directly north of map area, name "Copper Lake Formation" also was applied to rocks in Mount Katmai area by Riehle and others (1987; see also Riehle and others, 1993). Detterman and others (1996) described 1,025-m-thick section in Mount Katmai area (see secs. 16 and 21, T. 14 S., R. 25 W., Afognak D-5 1:63,360-scale quadrangle); formation there consists of thick pebble-cobble conglomerate in its uppermost and lowermost parts and contains sandstone and siltstone in its middle part. In measured section, conglomerate intervals are massive and have clasts that are mixture of volcanic, granitic, and metamorphic rocks in subequal proportions. Sandstone and siltstone intervals of measured section vary from thin bedded to massive and are typically dark to medium gray; they are fine to medium grained lower in section and become medium to coarse grained toward top. More fine grained clastic parts of formation contain considerable carbonaceous debris and minor coaly material. In map area, Copper Lake Formation, like Tolstoi Formation, was derived from erosion of Mesozoic source area and is non-marine. In Mount Katmai and Iliamna areas (north of map area), this source area was underlain by Alaska-Aleutian Range batholith (Reed and Lanphere, 1973) and associated Mesozoic sedimentary and metamorphic rocks. North of map area, Copper Lake undergoes transition from rocks of Mesozoic provenance to fresh volcanic clasts of probably Tertiary age (Detterman and Reed, 1980, p. B47). Age of Copper Lake is not well constrained; sparse megaflora in type section in Iliamna area and abundant megaflora in map area are restricted to sandstone and siltstone intervals that are present in middle part of unit (Detterman and others, 1996). Detterman and others (1996) consider age of Copper Lake to be Paleocene(?) and early Eocene. Upper and lower contacts of Copper Lake Formation are disconformities with Hemlock Conglomerate and Kaguyak Formation, respectively. Unit also includes, only for map display purposes, rocks mapped by Riehle and others (1987) as their unit Ts, Tertiary sedimentary rocks (Riehle and others, 1987, unit Tu, and Riehle and others, 1993, unit Ts). (*GRI Source Map ID 75244)* (Geology of Katmai and Alagnak).

TKgd - Granodiorite (Tertiary and (or) Cretaceous)

Light-colored intrusive rocks, granodiorite. (*GRI Source Map ID 75244)* (Geology of Katmai and Alagnak).

Ksr - Sedimentary rocks (Cretaceous)

Massive, olive-brown, locally cross-bedded and channeled sandstone. Occurs only on northwest shore of Hallo Bay; 12-15 thick. Highly carbonaceous. (*GRI Source Map ID 75244)* (Geology of Katmai and Alagnak).

Kk - Kaguyak Formation (Late Cretaceous; Maestrichtian and Campanian)

Named by Keller and Reiser (1959) for rocks exposed near abandoned village of Kaguyak in Afognak C-6 1:63,360-scale quadrangle. Detterman and Miller (1985) remeasured and described type section that begins at mouth of Swikshak River and continues westward in cliffs for approximately 5 km. Measured thickness is more than 1,200 m of dark-gray to pale-brown, typically thin bedded shale, siltstone, and fine grained sandstone. Proportion of sandstone in unit increases up-section. Load and flute casts are common; in upper part of unit, graywacke is graded with numerous rip-up clasts. Overall depositional environment of formation is near mid-fan within multi-channeled system; however, uppermost part of unit may have been deposited in upper-fan regime (Detterman and others, 1996). In general, fossils are sparse; however, in lower part of unit they are locally abundant. Ammonites are most common and may range in size to as much as 1-m-across. Fossils allow age assignment of latest Campanian and early Maestrichtian for Kaguyak. Kaguyak unconformably overlies rocks as young as Early Cretaceous; upper contact is unconformity with Copper Lake Formation. (*GRI Source Map ID 75244)* (Geology of Katmai and Alagnak).

Kp - Pedmar Formation (Early Cretaceous; Albian)

Named by Detterman and others (1996) for thin (82 m) sequence of thick-bedded, fine- to medium-grained, gray to olive-gray sandstone exposed along coast of Katmai Bay near Mount Pedmar in Mount Katmai A-3 1:63,360-scale quadrangle. Carbonaceous debris is present throughout, and pebbles as large as 4 cm in diameter are found in tabular crossbedded sandstone in middle part of formation. Clasts are typically quartz; volcanic clasts are conspicuously absent. Two poorly exposed siltstone and shale intervals are present in upper part of formation; siltstone is much more common in a measured section east of Ikagluik Creek, 42 km north of type section in Mount Katmai B-3 1:63,360-scale quadrangle. Abundant ammonite and Aucellina sp. fossils help to establish well-controlled Albian age for formation. Upper contact of formation is disconformity with overlying by Kaguyak Formation. In type section, lower contact is fault that juxtaposes Pedmar and Naknek Formations. At Ikagluik Creek section, formation disconformably overlies Herendeen Formation. (*GRI Source Map ID 75244)* (Geology of Katmai and Alagnak).

Khe - Herendeen Formation (Early Cretaceous; Barremian and Hauterivian)

Originally named Herendeen Limestone by Atwood (1911, p. 39) for exposures along east shore of Herendeen Bay, north of Mine Harbor; renamed Herendeen Formation by Detterman and others (1996), who designate a 270-m-thick reference section in hills southwest of Hot Spring on Port Moller (sec. 14, T. 50 S., R. 73 W., Port Moller D-2 1:63,360-scale quadrangle). Originally described as limestone, rocks of formation are actually an unusually uniform calc-arenaceous sandstone. Rocks are thin bedded, medium grained, and dusky yellow to pale yellowish brown on freshly broken surfaces and weather to conspicuous light gray. They have distinct platy fracture upon weathering and strong petroliferous odor when freshly broken. Inoceramus fragments form major component of formation, although complete specimens have only been found in the Mount Katmai area. A belemnite similar to Acroteuthis sp. A (Jones and Detterman, 1966) was found in rocks of formation just east of Staniukovich Mountain between Port Moller and Herendeen Bay. Ammonite fossils and other collections from Herendeen in Mount Katmai area allow an age assignment of Hauterivian and Barremian for formation (J. W. Miller, written commun., 1983-85; Detterman and others, 1996). Herendeen conformably overlies Staniukovich Formation (Kst) and is unconformably overlain by Chignik (Kc) and Pedmar (Kp) Formations. (*GRI Source Map ID 75244)* (Geology of Katmai and Alagnak).

Kst - Staniukovich Formation (Early Cretaceous; Valanginian and Berriasian)

Originally named Staniukovich Shale by Atwood (1911, p. 25, 38) for exposures on Staniukovich Mountain. Burk (1965; see also, Imlay and Detterman, 1973, and Detterman and others, 1981a) changed name to Staniukovich Formation and included within unit a variety of rocks of latest Jurassic and Early Cretaceous age; however, Detterman and others (1996) stratigraphically restrict formation to original usage of Atwood (1911), and, as so restricted, its age is Early Cretaceous. Type section (Atwood, 1911), in sec. 30, T. 50 S., R. 73 W., Port Moller D-2 1:63,360-scale quadrangle, is composed of 246 m of light-olive-gray siltstone containing two light-olive-brown sandstone intervals, overlain by shaly olive-gray siltstone containing numerous calcareous nodules and concretions (Detterman and others, 1996). Upper part of formation erodes readily and, therefore, is typically not well exposed; additionally, it contains few age-diagnostic fossils, whereas lower part has abundant megafauna fossils, particularly pelecypod Buchia, which indicates Berriasian and Valanginian age (J.W. Miller, written commun., 1982-88; Detterman and others, 1996). Upper and lower contacts of Staniukovich are conformable with Herendeen (Khe) and Naknek (Jn) Formations, respectively. (*GRI Source Map ID 75244)* (Geology of Katmai and Alagnak).

Kqm - Quartz monzonite (Late Cretaceous)

Massive, coarse-grained light-gray porphyritic quartz monzonite. (*GRI Source Map ID 75244)* (Geology of Katmai and Alagnak).

JPk - Kakhonak(?) Complex (Late Jurassic? to Permian?)

Name introduced by Detterman and Reed (1980) for heterogeneous assemblage of metamorphic rocks exposed in Iliamna 1:250,000-scale quadrangle north of map area. In map area, metamorphic rocks of unknown age exposed west of Bruin Bay fault north of Becharof Lake are tentatively correlated with Kakhonak Complex (Detterman and others, 1996). Rocks are mainly preserved as roof pendants in Alaska-Aleutian Range batholith, but some outcrops are found in areas surrounded by surficial deposits. Includes metalimestone, quartzite, greenstone and other metavolcanic rocks, and schist. Most are weakly metamorphosed, greenschist-facies rocks in which relict bedding is often discernable. Minimum age of enclosing batholith is about 155 Ma, which places upper age limit of early Late Jurassic on metamorphic rocks. Lithology of rocks indicates that protoliths were similar to Permian limestone and rocks of Kamishak and Talkeetna Formations exposed at Puale Bay and on nearby islands. (*GRI Source Map ID 75244)* (Geology of Katmai and Alagnak).

Jn - Naknek Formation (Late Jurassic; Tithonian to Oxfordian)

Originally named Naknek Series by Spurr (1900, p. 169-171, 179, 181) for exposures at Naknek Lake. Detterman and others (1996; see also, Detterman and Hartsock, 1966; Martin and Katz, 1912) have subdivided unit into five members on Alaska Peninsula. Megafossils, particularly pelecypod Buchia (Detterman and Reed, 1980, p. B38; J.W. Miller, written communs., 1982-88), are common, and fauna, which also includes ammonites, indicate age range of Oxfordian to late Tithonian (Late Jurassic). Naknek is conformable with overlying Staniukovich Formation (Kst) and unconformably overlies Middle Jurassic Shelikof Formation (Js). Alaska-Aleutian Range batholith was main source of sedimentary debris for Naknek Formation, which on faunal evidence ranges in age from about 138 to 155 Ma; hence, uplift and erosion of batholith occurred shortly after emplacement. (*GRI Source Map ID 75244)* (Geology of Katmai and Alagnak).

Jnk - Naknek Formation, Katolinat Conglomerate Member (Late Jurassic; Tithonian)

Type section designated by Detterman and others (1996) is on unnamed mountain on northeast shore of Grosvenor Lake (secs. 33 and 34, T. 17 S., R. 35 W., Mount Katmai C-4 1:63,360-scale quadrangle). Thick (about 450 m) pebble-boulder conglomerate and minor amounts of greenish-gray to yellowish-green sandstone containing abundant quartz, chert, and granitic and metamorphic rock clasts. Restricted to northern part of Alaska Peninsula, it is, in part, lateral facies equivalent of upper part of Indecision Creek Sandstone Member. Lower contact is gradational with Indecision Creek Sandstone Member. Upper contact is unconformity with overlying Early Cretaceous Herendeen Formation. (*GRI Source Map ID 75244)* (Geology of Katmai and Alagnak).

Jnc - Naknek Formation, Chisik Conglomerate Member (Late Jurassic; Oxfordian)

Limited to northern half of map area, reference section is located 6.5 km south of Becharof Lake (secs. 26 and 27, T. 30 S., R. 43 W., Ugashik C-1 1:63,360-scale quadrangle) is composed of 614 m of massive to thick-bedded conglomerate and interbedded, crossbedded, clean quartzose sandstone. Clasts range in size from maximum of 120 cm at bottom to 15 cm at top. Clast composition is 30 percent granitic rocks, 30 percent quartzite, 20 percent metavolcanic rocks, 10 percent schist, and 10 percent chert and quartz. Clasts are well-rounded and commonly decrease in size stratigraphically upward within each lithic interval of member. Lower contact is unconformity with Shelikof Formation; upper contact is conformable and gradational with Northeast Creek Sandstone Member. (*GRI Source Map ID 75244)* (Geology of Katmai and Alagnak).

Jni - Naknek Formation, Indecision Creek Sandstone Member (Late Jurassic; Tithonian and Kimmeridgian)

First recognized by Keller and Reiser (1959); designated as informal member of Naknek Formation by Detterman and Reed (1980); and formally named and described by Detterman and others (1996). Detterman and others (1996) designated an approximately 870-m-thick type section on east-facing slope of unnamed mountain near Mount Chiginagak (see secs. 35 and 36, T. 35 S., R. 49 W., Seward Meridian, Ugashik A-4 1:63,360-scale quadrangle). Consists of medium-gray, fine- to medium-grained arkosic sandstone and siltstone. It is thin bedded to massive; where bedded, it is locally crossbedded. Fresh biotite and hornblende are minor, but important, components of sandstone, as they are interpreted to indicate first-cycle erosion from Alaska-Aleutian Range batholith. Indecision Creek Sandstone Member is abundantly fossiliferous; however, fossils are restricted almost exclusively to pelecypods of genus Buchia. Depositional environment is shallow-water shelf to inner neritic (Detterman and others, 1996). Its lower contact is conformable and slightly gradational with Snug Harbor Siltstone Member. Upper contact is unconformity with overlying Late Cretaceous or Tertiary strata except where conformably and gradationally overlain by Staniukovich Formation or, in Mount Katmai region, Katolinat Conglomerate Member. Indecision Creek Sandstone Member is most widely exposed member of Naknek Formation and occurs throughout the Alaska Peninsula. (*GRI Source Map ID 75244)* (Geology of Katmai and Alagnak).

Jns - Naknek Formation, Snug Harbor Siltstone Member (Late Jurassic; Kimmeridgian and Oxfordian)

Originally described by Kirschner and Minard (1949) and named by Detterman and Hartsock (1966) for exposures in Iniskin Peninsula area of Cook Inlet. Detterman and others (1996) established reference section on Northeast Creek in sec. 27, T. 37 S., R. 51 W., in Sutwik Island D-5 1:63,360-scale

quadrangle. Reference section consists of more than 638 m of dark-yellowish-brown and dark-gray, thin-bedded siltstone and minor amounts of thin- to medium-bedded olive-gray sandstone. Limestone nodules are locally abundant, and limestone beds are present in some siltstone intervals. It is lowest abundantly fossiliferous member of Naknek; main fossils present are of genus Buchia. Depositional environment was interpreted by Detterman and others (1996) to have been moderately deep water, well below wave base and above carbonate compensation depth, in a basin that had restricted circulation. Both upper and lower contacts of unit are gradational with Indecision Creek Sandstone and Northeast Creek Sandstone Members, respectively. (*GRI Source Map ID 75244)* (Geology of Katmai and Alagnak).

Jnn - Naknek Formation, Northeast Creek Sandstone Member (Late Jurassic; Oxfordian)

Named and described by Detterman and others (1996) for exposures along Northeast Creek in Sutwik Island D-5 1:63,360-scale quadrangle (sec. 34, T. 37 S., R. 51 W., Seward Meridian). Type section consists of 624 m of fine- to coarse-grained, light-brownish-gray arkosic sandstone and minor amounts of olive-gray to dark-gray, thin-bedded siltstone in lower part of section. Sandstone is typically thick bedded and crossbedded and contains magnetite laminae and thin beds of conglomerate. Fossils are uncommon in unit although carbonaceous debris is common locally. Depositional environment is mainly nonmarine. Some sand beds are channeled with lag gravel at bases of channels. Crossbedding is mostly high-angle and variable directional eolian type, some is small-scale, tabular crossbedding with clay drapes characteristic of point bar deposits (Detterman and others, 1996). Lower contact is conformable on underlying Chisik Conglomerate Member and is placed where thick sandstone replaces conglomerate in section. Upper contact is sharp and conformable with overlying Snug Harbor Siltstone Member. At this contact, depositional environment shifts from mainly nonmarine to marine; position of contact varies temporally depending on local conditions. (*GRI Source Map ID 75244)* (Geology of Katmai and Alagnak).

Jgr - Granite (Late? and Middle Jurassic)

Light-gray, medium-grained equigranular or fine-grained porphyritic rocks. Average color index is 8 and biotite equals or exceeds hornblende. Rounded quartz grains weather prominently from the rock and, where elliptical, define a foliation (Riehle and others, 1993). Generally found between Becharof and Naknek Lakes in Mount Katmai and Naknek 1:250,000-scale quadrangle. (*GRI Source Map ID 75244)* (Geology of Katmai and Alagnak).

Jgd - Granodiorite (Late? and Middle Jurassic)

Fine- to coarse-grained, gray, hornblende-biotite granodiorite. In Naknek Lake area, color index averages 16; either hornblende or biotite can be dominant mafic phase. Modal quartz comprises 22-44 percent of the rock, in excess of that found in unit Tgd (Riehle and others, 1993). Generally is found in vicinity of Naknek Lake in Mount Katmai 1:250,000-scale quadrangle; however, southernmost outcrop of this unit of Alaska-Aleutian Range batholith is mapped on an unnamed island on south side of Becharof Lake in Ugashik 1:250,000-scale quadrangle. (*GRI Source Map ID 75244)* (Geology of Katmai and Alagnak).

Jqd - Tonalite and quartz diorite (Middle and Early Jurassic)

Medium-grained, gray equigranular rocks. Average color index of tonalite is 28, of quartz diorite is 37. Either clinopyroxene or hornblende is the dominant mafic (mineral) and biotite is an accessory. Inclusions of fine-grained mafic rocks or of porphyroaphanitic volcanics (rocks) are common. Both a foliation and a layering commonly occur together (Riehle and others, 1993). Generally found north of

Naknek Lake in Mount Katmai 1:250,000-scale quadrangle. (*GRI Source Map ID 75244)* (Geology of Katmai and Alagnak).

Jgb - Diorite and gabbro (Middle and Early Jurassic)

Small bodies of dark gray, diabasic- and gabbroic-textured rocks having either or both of two pyroxenes and hornblende. In some, hornblende is secondary; others are hornfels in which biotite and muscovite have partly replaced hornblende and clinopyroxene. (*GRI Source Map ID 75244)* (Geology of Katmai and Alagnak).

Js - Shelikof Formation (Middle Jurassic; Callovian)

Named by Capps (1923) for exposures at Cold (now named Puale) Bay along the northwest shore of Shelikof Strait. Type section designated by Allaway and others (1984) is 1,402 m of volcaniclastic sedimentary rocks along northeast shore of Puale Bay (see sec. 19 , T. 28 S., R. 37 W. to sec. 9, T. 28 S., R. 38 W., Karluk C-4, C-5, and D-5 1:63,360-scale quadrangles). Allaway and others (1984) also designated 1,524-m-thick principal reference section at Wide Bay along ridge southwest of Big Creek (see sec. 5, T. 31 S., R. 43 W., Ugashik C-1 to sec. 3, T. 32 S., R. 43 W., Ugashik B-1 1:63,360-scale quadrangles). Another reference section 823 m thick was designated by Allaway and others (1984) at Wide Bay along ridge southwest of Alai Creek, between sec. 13, T. 33 S., R. 46 W. and sec. 19, T. 33 S., R. 45 W., Ugashik B-2 1:63,360-scale quadrangle. Lower part of type section is mainly thick-bedded to massive, dusky-yellowish-green graywacke and conglomerate, and minor amounts of siltstone, whereas upper part is mainly volcanic sandstone interbedded with massive and laminated brownish-gray siltstone containing calcareous sandstone clasts. Many lithic intervals in upper part of section have a fining-upward sequence from conglomerate to sandstone or sandstone to siltstone (Allaway and others, 1984). Owing to rapid lateral facies changes, informal subdivisions of Capps (1923) have been found impractical for mapping and have been abandoned. Shelikof is interpreted to have been deposited in a deep- to shallow-water environment (Detterman and others, 1996). Megafauna are locally abundant in Shelikof, although, in general, formation is unfossiliferous. Vast majority of fossils collected from formation are ammonites of Callovian age; however, a few specimens suggest a Bathonian(?) age for some rocks (Allaway and others, 1984, p. A23; Detterman and others, 1985, and 1996). Contact with underlying Kialagvik Formation is considered conformable (see Detterman and others, 1996). Upper contact of Shelikof with Naknek Formation is an unconformity. Shelikof is lithologically and faunally correlative with Paveloff Siltstone Member of Chinitna Formation (Detterman and Hartsock, 1966) of Cook Inlet region (Detterman and others, 1996). (*GRI Source Map ID 75244)* (Geology of Katmai and Alagnak).

Jtk - Talkeetna Formation (Early Jurassic)

Name introduced by Martin (1926) for series of greenstone and tuff deposits first described in Talkeetna Mountains of south-central Alaska by Paige and Knopf (1907). Detterman and Hartsock (1966) geographically extended unit into Cook Inlet area. Detterman and others (1983) further geographically extended unit to include 405 m of clastic sedimentary rocks and tuff exposed on northeast shore of Puale Bay. Stratigraphically and lithologically equivalent rocks have been encountered in drillholes as far southwest as vicinity of Cathedral River (AMOCO Cathedral River #1 drillhole) in southwest part of map area. In measured section at Puale Bay, described by Detterman and others (1996), Talkeetna Formation is composed of primarily of gray-green, coarse-grained tuffaceous sandstone, lesser amounts of green to red, massive coarse-grained tuff, and minor amounts of brownish-gray siltstone and gray to gray-brown limestone. At Puale Bay, formation records inner-neritic to sublittorial environment. Northeast of map area, formation has much higher proportion of volcanic rocks (Detterman and Hartsock, 1966). Age of unit, Early Jurassic (Hettangian and early Sinemurian), is based on abundant megafauna; however, this megafauna is present in great abundance in only a few horizons and may represent mass kills as a result of volcanic eruptions (Detterman and others, 1996). Contact of Talkeetna with underlying

Kamishak Formation is conformable and gradational; it is arbitrarily placed where clastic sedimentary rocks replace limestone as major constituents of rock sequence. Contact of Talkeetna with overlying Kialagvik Formation is structurally conformable; however, it is considered a disconformity, as rocks of late Sinemurian, Pliensbachian, and most of Toarcian Stages are missing. (*GRI Source Map ID 75244)* (Geology of Katmai and Alagnak).

TRk - Kamishak Formation (Late Triassic; Norian)

Originally named Kamishak Chert by Martin and Katz (1912) for rocks in vicinity of Bruin Bay, in Cook Inlet area. Kellum (1945; see also, Kirschner and Minard, 1949) changed name to Kamishak Formation for similar rocks at Puale Bay. Detterman and Reed (1980) divided unit into three members, in descending order, Ursus Member, middle member, and Bruin Limestone Member. In map area (see inset A, pl. 1), Triassic limestone strata was assigned to Bruin(?) Limestone Member of Kamishak Formation by Detterman and others (1996). Reference section of Kamishak was measured near Puale Bay by R.M. Egbert (U.S. Geological Survey, 1979, cited in Detterman and others, 1996, section in Karluk C-4 and C-5 1:63,360-scale quadrangles). Section consists of approximately 800 m of light- to brownish-gray, thin- to medium-bedded limestone, minor amounts of brownish-gray, calcareous siltstone and mudstone, and limestone conglomerate. An interval of brecciated and calcite-recemented basalt occurs near top of section, as does a volcanic breccia interval in lower part of the section. A 46-m-thick columnar-jointed basalt flow or sill from upper part of section has yielded a potassium-argon age of 197 ±12 Ma (Wilson and Shew, 1992); however, it remains to be determined whether basalt is sill from overlying Early Jurassic Talkeetna Formation or, alternatively, a flow from Kamishak that yields an analytically "minimum" age. Depositional environment of unit was shallow water and high energy; intervals of unit include both reefs and biohermal buildups. Fossils that have been found yield Norian age (Detterman and Reed, 1980; C.D. Blome, U.S. Geological Survey, oral commun., 1981). In map area, no lower contact is exposed. Upper contact is conformable and gradational with overlying Talkeetna Formation; Detterman and others (1996) arbitrarily placed contact at point where clastic sedimentary rocks replace limestone as major constituent of rock sequence. As Bruin Limestone Member is lowest member of Kamishak Formation, this contact indicates Bruin Limestone Member is time-transgressive unit. (*GRI Source Map ID 75244)* (Geology of Katmai and Alagnak).

TRku - Kamishak Formation, Ursus Member (Late Triassic; Norian)

Thin-bedded, light-gray limestone (locally dolomitic), and minor interbedded gray chert and porcellanite and minor tuff. Limestone is fine-grained biomicrite. Depositional environment was moderate to high-energy, shallow water. Unit cut by abundant dikes and sills related the Talkeetna Formation. (*GRI Source Map ID 75244)* (Geology of Katmai and Alagnak).

TRkm - Kamishak Formation, middle member (Late Triassic; Norian)

Thin- to medium-bedded, dark-gray to black limestone and calcilutite (locally dolomitic), and minor black chert and gray tuff. Limestone is fine-grained microsparite. Calcite is locally altered to chert, suggesting a deep-basin environment. Unit cut by abundant dikes and sills related the Talkeetna Formation. (*GRI Source Map ID 75244)* (Geology of Katmai and Alagnak).

TRc - Cottonwood Bay Greenstone (Late Triassic; Norian?)

Named by Detterman and Reed (1980) for sequence of dark-green to gray metavolcanic rocks exposed on west side of Cook Inlet. In map area, unit mapped only as roof pendants in Alaska-Aleutian Range batholith north of Becharof Lake, where it consists of weakly metamorphosed epidote-albite-actinolite assemblages that are suggestive of greenschist-facies metamorphism. Thickness may exceed 400 m;

however, contact relations with other stratigraphic units are not well understood. Some rocks locally included herein in Kakhonak(?) Complex (JPk) are Cottonwood Bay Greenstone. No isotopic age determinations exist for greenstone, but its close association with Kamishak Formation near Iliamna Bay northeast of map area suggests Late Triassic (Norian?) age. (*GRI Source Map ID 75244)* (Geology of Katmai and Alagnak).

Geology of Katmai and Alagnak

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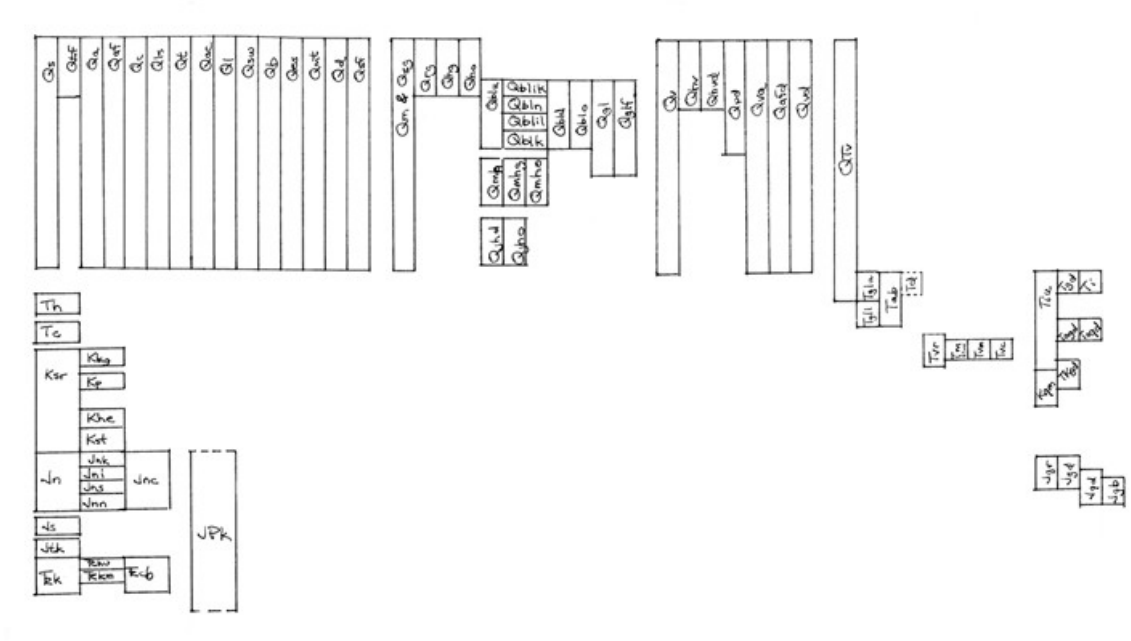
Correlation of Units

Correlation diagram is unpublished and drafted for the GRI by Ric Wilson (U.S. Geological Survey, Alaska Science Center). Correlation modified by James Chappell to match the GRI digital geologic-GIS data.



Map References

USGS geologic spatial data for the Alaska region maintains geologic source information as an attribute attached to each geologic feature. Although the GRI considers the USGS to the be mapping source for this project, sources used and referenced by the USGS have been preserved in the GRI GIS product. Geologic features in the GRI digital geologic-GIS data and the unit descriptions listed in this document have references to the sources listed here.

AF001	USGS 1:250,000-scale topo sheet
AF002	Riehle, J.R., Detterman, R.L., Yount, M.E., and Miller, J.W., 1993, Geologic map of the Mount Katmai quadrangle and adjacent parts of the Naknek and Afognak quadrangles, Alaska: U.S. Geological Survey, Miscellaneous Investigations Series Map I-2204, scale 1:250,000
AF006	Riehle, J.R., and Detterman, R.L., 1993, Quaternary geologic map of the Mount Katmai quadrangle and adjacent parts of the Naknek and Afognak quadrangles, Alaska: U.S. Geological Survey, Miscellaneous Investigations Series Map I-2032, scale 1:250,000

AF008 Wilson, F.H., Detterman, R.L., and DuBois, G.D., in press, Geologic framework of the Alaska Peninsula: U.S. Geological Survey Bulletin 1969-B and U.S. Geological Survey, Open-file Report 99-317 (digital)

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This document was developed and completed by James Chappell (Colorado State University) for the NPS Geologic Resources Division (GRD) Geologic Resources Inventory (GRI) Program. Quality control of this document by James Chappell (Colorado State University).

The information in this document was compiled from GRI source maps and intended to accompany the digital geologic-GIS map and other digital data for Katmai National Park and Preserve and Alagnak Wild River, Alaska (KATM) developed by James Chappell (Colorado State University) (see the GRI Digital Maps and Source Map Citations section of this document for all sources used by the GRI in the completion of this document and the related GRI digital geologic-GIS map).

GRI finalization by James Chappell (Colorado State University)

GRI program coordination and scoping provided by Bruce Heise and Tim Connors (NPS GRD, Lakewood, Colorado).