Map Unit Properties Table: War in the Pacific National Historical Park

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Age	Map Unit (Symbol)	Geologic Description	Geologic Issues	Geologic Features and Processes	Geologic History
QUATERNARY (Recent)	Artificial fill (Qaf)	Unit **Qaf** may include features such as extensive waste dumps, areas of extensive infilling, breakwaters, levees, and dams. Fill material may vary, but is typically unsorted masses of rock, sand, and even recycled road material. Erosion resistance is moderate. **Qaf** underlies the park visitor center near Apra Harbor. *Siegrist et al. (2007) mapping updates: More areas of **Qaf** have been recognized or developed since 1964.	*Adjacent Development and Disturbed Areas*—Landfills may be sources of contaminants. *Relative Sea Level Rise and Coastal Vulnerability*—Subject to inundation and infrastructure impacts as sea level rises. *Visitor Center Stability*—The park's visitor center, built upon artificial fill, has noted settling issues. *Storm Damage*—Subject to inundation and infrastructure damage during storms. *Seismicity and Tsunamis*—Strong earthquake could compromise park infrastructure, particularly along coastal areas underlain by unconsolidated beach, alluvium, or fill deposits. **Qaf** experienced liquefaction during 1993 earthquake. Subject to inundation during tsunamis.	*Connections Between Geology and Park Stories*—Historic military features may have been constructed on **Qaf**.	These features are primarily of World War II or post war vintage. Depending on the era of installation, unit **Qaf** may record historical land-use practices on Guam.
	Beach deposits (Qrb) Merizo Limestone (Qrm) Alluvium (Qal)	Unit **Qrb** contains sand and coarser gravel in beach areas, particularly in the intertidal zone between low and high water levels. Patches of limestone fragments transported from submerged, offshore coral reefs and older limestone deposits are also present in this unit. **Qrb** generally occurs 5–10 m (15–30 ft) above sea level. This dynamic area of the landscape is susceptible to rapid change (particularly erosion and/or deposition) during storms, sea-level rise, and human-induced processes. **Qrm** is reef limestone; it occurs offshore in layers 1–2 m (2–5 ft) thick. This unit caps modern reef flats and platforms eroded into basalt at sea level. Unit **Qal** contains 9–30-m- (30–100-ft-)thick clay deposits associated with streams and rivers, as well as muck and clay deposited in marshy, estuarine areas along Guam's western coast. Very fine-grained clay may also collect in natural depressions or sinks within older limestone units. Erosion resistance is low to moderate for these units. Unconsolidated beach deposits and alluvium have low resistance **Qrb** and **Qal** are mapped within the Asan Beach and Agat units. **Qal** is mapped within the Asan Inland and Piti Guns units. *Siegrist et al. (2007) mapping updates: New unit "Reefs" added to the Recent map units.	*Mass Wasting*—Susceptible to mass wasting, particularly when saturated with water or exposed on slopes. *Relative Sea Level Rise and Coastal Vulnerability*—Subject to inundation and infrastructure impacts as sea level rises. *Storm Damage*—Coastal areas subject to inundation during storms. *Seismicity and Tsunamis*—Strong earthquake could compromise park infrastructure, particularly along coastal areas underlain by unconsolidated beach, alluvium, or fill deposits. Coastal areas subject to inundation during tsunamis.	*Karst Features*—Epikarst and/or karren cover exposed surfaces of **Qrm**. Discharge features (seeps and springs) in beach, reef, and inland limestones. *Coastal Features*—**Qrb**: Coralline, sandy beaches flank much of the park's coastline. **Qrm**: Reef limestones fringe southwest areas of island, outside of the park. *Paleontological Resources*—Modern marine remains and fragments of fossils possible in limestone-clast deposits; modern reef species in **Qrm**. Crustacean fossils (12 species of crabs) may wash up on **Qrb**. Fossil shrimp, barnacles, mollusks, corals, and ray teeth have been collected on Guam's beaches. *Plate Tectonic Processes*—Uplift (as well as sea level change) has left **Qrm** exposed. *Connections Between Geology and Park Stories*—**Qrb** may contain cultural resources associated with the military history of the island that wash up on shore.	Unit **Qrb** is among the most dynamic units at the park. **Qrm** is part of the active reef environment fringing the island, locally capping the Mariana reef rocks at sea level. This unit demonstrates how reef limestone forms, and is only exposed in the intertidal and sea-spray zones. **Qal** forms along streams and rivers, recording the evolution of Guam's fluvial environment. **Qal** is common in the Agat Unit. "Satin-stones" (after Stroup 1940) may wash up in **Qal** and/or **Qrb** and are polishable as semi-precious gemstones.

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Age	Map Unit (Symbol)		Geologic Description	Geologic Issues	Geologic Features and Processes	Geologic History
TERTIARY-QUATERNARY (Pliocene-Pleistocene)	Mariana Limestone	Reef facies (QTmr)	**QTmr**, a subunit of the Mariana Limestone, consists of porous, cavernous, white limestone that formed in a coral reef environment. Few bedding structures or depositional surfaces are visible in exposures. Corals preserved in this unit remain oriented in the direction of growth, indicating that this unit has not been disturbed much since its formation. Surrounding the fossil corals of **QTmr** is a matrix of encrusting calcareous (containing calcium carbonate) fossil algae. Erosion resistance is moderate. **QTmr** is mapped within the Asan Beach unit.	*Relative Sea Level Rise and Coastal Vulnerability*—Subject to inundation and infrastructure impacts as sea level rises. *Adjacent Development and Disturbed Areas*—Groundwater Withdrawal and Contamination: **Tbl** and Mariana Limestone units host Northern Guam Lens Aquifer. *Mass Wasting*—Areas with steep slopes susceptible to mass wasting. *Seismicity and Tsunamis*—Coastal areas mapped as **QTma** or **QTmr** within park are subject to inundation during tsunamis. Pago-Adelup Fault cuts **QTma**. *Storm Damage*—Coastal areas subject to inundation during storms. *Radon Potential*—Soils developed on **QTmr** or **QTma** may contain radium.	*Karst Features*—"Macabre" karst features noted in Asan Inland unit (mapped as **QTma**, **Ta**, **Tal**). Epikarst may be present. Karren covers many exposed surfaces and form in part from grazing and boring by marine organisms. Caves are particularly well developed in southern Guam. Rare pit caves are documented in Mariana Limestone. Discharge features (springs) present in limestone plateaus (**QTma**, **Ta**, **Tam**) of Mt. Alifan and Asan units. *Limestone Forests*—Particularly well developed at Asan Beach and Fonte Plateau units. **QTma** is mapped in those units. Limestone forests on **QTma** may also be present at Agat Beach and Asan Inland units. *Paleontological Resources*—Units contain fossilized corals (*Acropora*, *Seriatopora*, *Porites*, and *Favia*) and algae; mollusk (pelecypods *Ostrea* and *Tridacna*, and gastropod *Turritella*) casts and molds; sea urchins; and foraminifera. The Mariana Limestone contains seven known species of foraminifera, including *Operculina*, *Marginopora*, *Amphistegina*, *Gypsina*, and *Cycloclypeus*. *Connections Between Geology and Park Stories*—Cliffs of the Mariana Limestone probably figured prominently in the military history of the island. "Coral limestone" from this unit may have provided building material for island fortifications and other cultural sites, including Japanese Emplacement and 1961 Mabini Memorial. Natural caves and man-made cavities figured prominently in the military history of the park.	The Mariana Limestone formation records the conditions present across a broad, Pleistocene- and Pliocene-aged coral reef/lagoon system. As such, it contains a record of past sea level and paleoclimate. It has an unconformable contact with the underlying rocks, indicating a period of erosion or nondeposition prior to the establishment of the reef adjacent to Guam. The Mariana Limestone is the most fossiliferous and extensive formation on Guam, comprising up to 75% of the exposed limestone on the island. Depositional environments recorded in the various facies of the Mariana Limestone include reefs and lagoons
		Detrital facies (QTmd)	Mariana Limestone subunit **QTmd** ranges in texture from well-cemented to loose and friable, and ranges in grain size from coarse- to fine-grained. Like **QTmr**, **QTmd** is generally porous; however, unlike **QTmr**, **QTmd** formed in a lagoon environment. Erosion resistance is moderate.			
		Molluscan facies (QTmm)	Subunit **QTmm** is a lagoonal limestone occurring in white to tan, fine-grained exposures. **QTmm** contains abundant casts and molds of mollusks. Erosion resistance is moderate.			
		Forereef facies (QTmf)	Subunit **QTmf** consists of friable, white limestone featuring obvious bedding surfaces that formed as carbonate sands were deposited in the forereef area and later were cemented together with carbonates precipitated from solution. Erosion resistance is moderate.			
		Agana Argillaceous Member (QTma)	**QTma** contains tan to brown limestone with textures ranging from coarse, with limestone clasts clearly visible to the naked eye, to finer-grained areas with no discernable grains. **QTma** contains abundant clay, typically settling into pockets and cavities and present as lenses atop the rest of the unit. Some exposures of the Mariana Limestone are cliffs up to 150 m (500 ft) in height. Erosion resistance is moderate. **QTma** is mapped within the Asan Beach, Asan Inland, and Agat units.			

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Age	Map Unit (Symbol)	Geologic Description	Geologic Issues	Geologic Features and Processes	Geologic History
TERTIARY (Miocene-Pliocene)	Alifan Limestone (Tal) Talisay Member (Tt)	Unit **Tal** consists of pale pink, buff, or white limestone with localized exposures that are red, yellow, or brown. Some portions near the base of the unit are argillaceous, meaning they contain significant amounts of clay. The unit appears massive, meaning that bedding features are not obvious, and limestone textures range from coarse (individual grains are obvious to the naked eye) to fine-grained. A subunit of **Tal**, **Tt** is yellow, green, and red clay with lenses of 1) coarse conglomerate (large clasts in a clay matrix), 2) gray to green marl, and 3) limestone. These lenses range in thickness from 1 to 9 m (2 to 30 ft). Erosion resistance is moderate for these units. **Tal** is mapped within the Asan Beach, Asan Inland, Fonte Plateau, Agat, and Mt. Alifan units. *Siegrist et al. (2007) mapping updates: **Tt** is now assigned to the Oligocene as a separate unit.	*Terrestrial Erosion and Coastal Sedimentation*—Erosion of upland areas within park (and across the island) may be sources of sediment. *Relative Sea Level Rise and Coastal Vulnerability*—Subject to inundation and infrastructure impacts as sea level rises. *Adjacent Development and Disturbed Areas*—Off-Road Vehicle Use: ORV use in upland areas may lead to erosion and unvegetated areas, particularly in Mt. Chachao/Mt. Tenjo unit. *Storm Damage*—Coastal areas subject to inundation during storms. *Seismicity and Tsunamis*—Coastal areas subject to inundation during tsunamis. Pago-Adelup Fault cuts **Tal**. *Mass Wasting*—Areas with steep slopes susceptible to mass wasting. *Radon Potential*—Soils developed on **Tal** may contain radium.	*Karst Features*—"Macabre" karst features noted in Asan Inland unit (mapped as **QTma**, **Ta**, **Tal**). Large, closed depressions form in **Tal**. Epikarst may be present. Karren covers many exposed surfaces. Caves are particularly well developed in southern Guam. Traversable stream caves noted in **Tal**. *Limestone Forests*—Particularly well developed at Asan Beach and Fonte Plateau units. **Tal** is mapped in those units. Limestone forests on **Tal** are also present at Mt. Alifan unit and potentially at Asan Inland unit. *Paleontological Resources*—**Tal** contains remains of corals (*Porites* and *Acropora*) as well as singular calcite tubes formed by burrowing worms or gastropods. Marl within **Tt** contains stick-like *Porites* and *Acropora*. The Alifan Limestone contains 19 known species of foraminifera (most commonly *Rotalia atjehensis*) and/or calcareous algae. *Connections Between Geology and Park Stories*— "Coral limestone" from this unit may have provided building material for island fortifications and other cultural sites, including Japanese Emplacement and 1961 Mabini Memorial. Limestone quarry within Fonte Plateau unit likely targeted Tal. Natural caves and man-made cavities figured prominently in the military history of the park.	**Tt** unconformably overlies the Umatac (**Tuf**, **Tum**, **Tub**, and **Tud**) and Alutom (**Ta** and **Tam**) formations, indicating a period of nondeposition or erosion. **Tt** locally overlies **Tb**. The Alifan Limestone is exposed in the highest peaks of Guam. The Alifan Limestone is the remnant of a one extensive Miocene reef, recording reef-wall, lagoonal, and off-reef shallow-water depositional environments.
	Janum Formation (Tj) Barrigada Limestone (Tbl)	**Tj** consists of white to tan limestone with obvious bedding structures and abundant fossil remains. In northern Guam, **Tj** directly overlies **Tb** and displays an unconformable (erosional) contact with overlying Mariana Limestone (**QTam**). Lenticular (lens-like) beds of **Tj** interlayer with **Tbl**, which is a coarse-grained, white limestone. **Tbl** contains more abundant and varied fossil remains than **Tj**, including corals and mollusks. **Tbl** exceeds 165 m (540 ft) in thickness and appears massive in exposures (lacking obvious bedding structures). Textures within the unit range from well-cemented to friable. In northern Guam, **Tbl** is unconformable with the overlying Mariana Limestone (**QTam**), but further south, the contact changes to a more continuous, upward-grading relationship. Erosion resistance is moderate for these units.	*Mass Wasting*—Areas with steep slopes susceptible to mass wasting. *Adjacent Development and Disturbed Areas*—Groundwater Withdrawal and Contamination: **Tbl** and Tm units host Northern Guam Lens Aquifer. Vegetation quickly colonizes disturbed surfaces of **Tbl**.	*Karst Features*—Epikarst may be present. Caves are particularly well developed in southern Guam. *Paleontological Resources*—**Tj** contains abundant globigerinid foraminifera (a planktonic genus with walls of radial calcite crystals). **Tbl** contains foraminifera (*Operculina*, *Gypsina*, and *Cycloclypeus*), coral, and mollusks. **Tbl** contains nine known species of foraminifera and/or calcareous algae. *Connections Between Geology and Park Stories*— "Coral limestone" from this unit may have provided building material for island fortifications and other cultural sites, including Japanese Emplacement and 1961 Mabini Memorial. Natural caves and man-made cavities figured prominently in the military history of the park.	These units record the Miocene to Pliocene transition in the development of Guam, and the subsequent period of erosion and/or nondeposition is reflected in the unconformable contact with **QTam**. **Tbl** was named after Barrigada Hill in northern Guam. **Tbl** and **Tj** formed in a deep-water environment on the flank of the volcanic highlands.
TERTIARY (Miocene)	Bonya Limestone (Tb)	Unit **Tb** contains nearly pure limestone in exposures up to 21 m (70 ft) thick. Some portions of the unit are argillaceous, meaning they contain significant amounts of clay. In southern Guam, **Tb** displays obvious bedding features and is coarse-grained and sandy, whereas in northern Guam, closer to the park area, bedding features are less obvious and the limestone is much finer-grained (described as massive and compact). Exposures of **Tb** can be up to 37 m (120 ft) thick. Erosion resistance is moderate.	*Mass Wasting*—Areas with steep slopes susceptible to mass wasting.	*Karst Features*—Low porosity compared to younger limestones. Large, closed depressions form in **Tb**. Epikarst and runnels may be present on exposed surfaces. Caves are particularly well developed in southern Guam. Traversable stream caves are noted in **Tb**. *Paleontological Resources*—Contains 13 known species of foraminifera and/or calcareous algae. *Connections Between Geology and Park Stories*—Natural caves and man-made cavities figured prominently in the military history of the park.	**Tb** records a longstanding carbonate platform system that persisted after volcanism on Guam had largely stopped during the Miocene. It was deposited in off-reef environments in moderately deep water and is among the few limestones of Guam to be diagenetically mature, having been covered until recent uplift of Guam exposed it in a meteoric environment.

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Age	Map Unit (Symbol)		Geologic Description	Geologic Issues	Geologic Features and Processes	Geologic History
TERTIARY (Miocene)	Umatac Formation	Dandan Flow Member (Tud)	**Tud** consists of about 15 m (50 ft) of basalt lava flows with large, visible crystals occurring in a finer grained matrix, separated from the underlying Tub subunit by a 3-m-thick (10-ft-thick) flow breccia (described under **Tub**). Erosion resistance is moderately high.	*Mass Wasting*—Areas with steep slopes susceptible to mass wasting. *Terrestrial Erosion and Coastal Sedimentation*—Erosion of upland areas within park (and across the island) may be sources of sediment. *Mass Wasting*—Areas with steep slopes susceptible to mass wasting. *Storm Damage*—Coastal areas subject to inundation during storms. *Seismicity and Tsunamis*—Coastal areas are subject to inundation during tsunamis.	*Karst Features*—Low porosity compared to younger limestones. Epikarst and runnels may be present on exposed surfaces of **Tum**. Caves are particularly well developed in southern Guam. *Paleontological Resources*—Primarily foraminifera and other marine invertebrates in limestones. **Tum** contains coral reef fossils, globigerinid foraminifera (a planktonic genus with walls of radial calcite crystals), and algae. Tum contains 36 known species of foraminifera and/or calcareous algae. Basalt flows may contain tree molds. Lava tubes and caves may preserve fossils such as avian bones and other Neogene and younger remains. *Plate Tectonic Processes*—Volcanoes that formed **Tud**, **Tub**, and **Tuf** were fueled by a subduction zone. **Tuf** represent the early phases of island-building volcanism. *Connections Between Geology and Park Stories*—"Coral limestone" from this unit may have provided building material for island fortifications and other cultural sites, including Japanese Emplacement and 1961 Mabini Memorial. Natural caves and man-made cavities figured prominently in the military history of the park.	Subunits within the Umatac Formation have complex relationships. **Tum** occurs in part as lenses within **Tuf**. **Tub** rests atop **Tuf** near Umatac and interfingers with **Tud** on the eastern slopes of Mount Almagosa. **Tud** lavas flowed atop **Tub**. These complex interrelationships formed in a longstanding system of intermittent volcanism and coral reef development. Volcanic activity deposited the basalt flows, pyroclastic deposits, and ash deposits. Volcanism must have had longstanding periods of quiescence to allow a carbonate, coral reef complex (**Tum**) to form between flows (**Tuf**).
		Bolanos Pyroclastic Member (Tub)	Subunit **Tub** consists of basal layers of reworked coarse-grained volcanic conglomerate and breccia—differentiated by the roundness of the clasts contained within a finer grained matrix. Breccia has angular clasts, in this case formed during explosive volcanic eruptions whereas in conglomerates, the clasts are more rounded indicating they were weathered and/or transported some distance prior to becoming incorporated into the matrix. **Tub** contains fragments of **Tum**. Upper layers contain mixed sandstone and finer grained shale with some minor layers of conglomerate. The maximum thickness of **Tub** is about230 m (750 ft). Erosion resistance is moderate.			
		Maemong Limestone Member (Tum)	**Tum** is predominantly limestone that formed in a reef environment. The coral remains are still in their growth positions. In south Guam, Tum contains very coarse, conglomeratic lenses that grade into calcareous (contain calcium carbonate) layers of mixed volcanic ash and limestone. The maximum thickness of **Tum** is 80 m (260 ft). Erosion resistance is moderate.			
		Facpi Volcanic Member (Tuf)	Subunit **Tuf** of the Umatac Formation consists of 275 m (900 ft) of pillow basalts formed as lava extruded from the earth underwater at its base. Upon cooling and contraction of the molten rock, columnar joints formed regular patterns within the flows. These flows are in turn cut by linear dikes of basalt that trend at an angle to the flows. The upper 150 m (500 ft) of **Tuf** contains interlayered lava flows, shale, and sandstone with lenses of the limestone of Tum, locally. Erosion resistance is moderately high. **Tuf** is mapped within the Mt. Alifan unit. *Siegrist et al. (2007) mapping updates: Maemong Limestone is a stand-alone unit—Maemong Limestone formation (**Tm**). There is a lumped Umatac Formation undifferentiated unit (**Tu**). Two new units were assigned to the Umatac Formation: Schroeder flow member (**Tus**), and the Geus River Member (**Tug**). **Tug** is now Oligocene in age. **Tuf** is now an Eocene, stand-alone unit—Facpi formation (**Tf**). According to Siegrist et al. (2007), the Facpi formation is now the oldest recognized rock unit on Guam.			

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Age	Map Unit (Symbol)		Geologic Description	Geologic Issues	Geologic Features and Processes	Geologic History
TERTIARY (Eocene-Oligocene)	Alutom Formation	Alutom Formation (Ta)	**Ta** consists of 1) gray, green, and brown shale and sandstone; 2) lenses of limestone; 3) breccia conglomerate formed during explosive volcanism (pyroclastic ejections of lava) that also contains limestone fragments; 4) interbedded lava flows. These units display obvious bedding structures, and textures within the layers range from fine- to coarse-grained (individual clasts easily discernable with the naked eye). Volcanic breccia forms near the center of an explosive eruption, where pre-existing rocks are shattered and mixed with fresh volcanic lava and ash from the eruption. **Ta** contains significant amounts of volcanic ash (tuffaceous) and exceeds 610 m (2000 ft) in thickness. Erosion resistance is moderate to moderately high for lava flows. **Ta** is mapped within the Asan Beach, Asan Inland, Piti Guns, Mt Chachao/Mt. Tenjo, Agat, and Mt. Alifan units.	*Terrestrial Erosion and Coastal Sedimentation*—Erosion of upland areas within park (and across the island) may be sources of sediment. *Adjacent Development and Disturbed Areas*—Off-Road Vehicle Use: ORV use in upland areas may lead to erosion and unvegetated areas, particularly in Mt. Chachao/Mt. Tenjo unit. *Mass Wasting*—Areas with steep slopes susceptible to mass wasting. *Seismicity and Tsunamis*—Pago-Adelup Fault cuts **Tal**. *Radon Potential*—Soils developed on **Ta** may contain radium.	*Karst Features*—"Macabre" karst features noted in Asan Inland unit (mapped as **QTma**, **Ta**, **Tal**). Epikarst may be present on exposed limestone. Caves are particularly well developed in southern Guam. Discharge features (springs) present in limestone plateaus (**QTma**, **Ta**, **Tam**) of Mt. Alifan and Asan units. *Limestone Forests*—Particularly well developed at Asan Beach and Fonte Plateau units. **Ta** is mapped in those units. Limestone forests on **Ta** may also be present at Asan Inland unit. *Paleontological Resources*—Primarily forminifera. The Alutom Formation contains 14 known species of foraminifera, the most common species of which are *Bolivinopsis* sp., *Nonion maoricum*, *Bolivina choctawansis*, *Angulogerina vicksburgensis*, and *Angulogerina cooperensis*. Other marine invertebrates may be present. Basalt flows may contain tree molds. Lava tubes and caves may preserve fossils such as avian bones and other Paleogene and younger remains. *Plate Tectonic Processes*—Volcanic breccias of **Ta** resulted from explosive volcanic eruptions. *Connections Between Geology and Park Stories*—Natural caves and man-made cavities figured prominently in the military history of the island.	Units record early volcanism and associated marine conditions present during the Oligocene and Eocene, and are the oldest units that appear in the digital geologic map data for Guam. **Ta** is named for Mt. Alutom in southern Guam
		Mahlac Member (Tam)	Subunit **Tam** is a buff to tan or yellow-tan, calcareous (contains calcium carbonate) shale. The shale occurs in highly laminated layers that are crumbly in texture. **Tam** has a maximum known thickness of 60 m (200 ft). Erosion resistance is moderate. **Tam** is mapped within the Mt. Alifan unit.			