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ECOLOGICAL SUBSECTIONS OF BERING LAND BRIDGE NATIONAL PRESERVE

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LANDSCAPE-LEVEL MAPPING OF ECOLOGICAL UNITS FOR THE BERING LAND BRIDGE NATIONAL PRESERVE

Final Report

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INTRODUCTION

An ecological land classification is essential to evaluating land resources and refining management strategies for specific areas. More specifically, a landscape-level stratification can be used to more efficiently allocate inventory and monitoring efforts, to improve land cover classifications developed from remote sensing, to partition ecological information for analysis of ecological relationships and development of predictive models, and to improve recommendations for ecological restoration. Accordingly, the National Park Service (NPS) has decided to use landscape-level maps as the basis for stratifying their biological inventories to ensure that their field sampling is distributed across the entire range of environmental gradients.

An ecological land classification involves the organization of ecosystem components at various scales based on the recognition that ecological factors operate within a hierarchy of differing spatial and temporal scales (Rowe 1961, Wiken and Ironside 1977, O'Neil et al., 1986, ECOMAP 1993, Klijn and Udo de Haes 1994, Bailey 1996). This hierarchical linkage reveals that smaller-scale features, such as vegetation, are nested within larger-scale components, such as climate and physiography. Climatic factors, particularly temperature and precipitation, typically account for the largest amount of variation in ecosystem structure and function globally (Walter 1979). Physiography, or broad-scale landforms, with a characteristic substrate, surface shape, and relief, are the terrain conditions that control the spatial arrangement and rate of geomorphic processes. These processes, in turn, affect material and energy flows and, ultimately, ecosystem development (Swanson et al. 1988, Bailey 1996). These large-scale "state" factors (climate, physiography, geology) can be used as differentiating criteria for delineating sections (physiographic regions with similar geology and regional climate) and subsections (more narrowly defined geology with repeating associations of geomorphic units)(ECOMAP, 1993).

NPS in Alaska currently is undertaking landscape-level mapping at the subsection level of the National Hierarchical Framework (ECOMAP 1993) for all its parks in Alaska. Landscape- level maps already have been produced for the Yukon-Charley Rivers National Preserve (Swanson 1999), and Katmai National Park and Preserve (Shepard 2000). Outside of the park system, similar landscape-level mapping in Alaska has been done for the central arctic coastal plain (Jorgenson et al. 1997), and for Fort Wainwright (Jorgenson et al. 1999) and Fort Greely (Jorgenson et al. 2000) in central Alaska.

This paper presents the results of the mapping of sections and subsections for the Bering Land Bridge National Preserve (BELA), a 2.8 million acre preserve in western Alaska (Figure 1) that was set aside to preserve the natural and cultural heritage of the Beringian landscape, which represents the cross-roads to the Americas. Specific objectives of this study were to: 1) compile existing information to identify differences in landscape patterns and processes across the study area, 2) classify landscape units using standardized differentiating criteria, 3) map ecological units at the section and subsection levels, 4) conduct a field reconnaissance to evaluate the preliminary map and collect photographs of each unit, 5) to develop representative toposequences of ecosystem patterns within selected subsections to illustrate the relationships among landscape components within the diverse regions, and 6) compare land cover classes mapped by Markon and Wesser (1997) among subsections to evaluate how well the subsection map partitions ecological characteristics.

METHODS

DATA COMPILATION AND GEOREFERENCING

Data compilation involved reviewing existing field studies for relevant information on the characteristics of the various landscape components, compiling information on the distribution of the various components from hard copy maps, and integrating digital-map data into a georeferenced GIS database. While the focus of the data compilation was on collecting information on topography (DEM), geology (bedrock and surficial geology), and hydrology (waterbodies and drainage networks), detailed information on soil-vegetation relationships also was included. The regional information on topography, geology, and hydrology was essential for classification and boundary delineation. Information from localized field studies was useful for evaluating how well the ecological units partitioned differences in soils and vegetation among units and for developing representative toposequences that illustrate differences among map units. Soil profiles were adapted from field descriptions by Holowaychuk and Smeck (1979), Van Patten (1990), Höfle and Ping (1996), and Höfle et al. (1998).

The literature review incorporated information on a diverse set of landscape components, including climate, oceangraphy, tectonics and physiography, bedrock geology, geomorphology (surficial geology and periglacial processes), soils, vegetation, and paleoecology. Relevant observations of each landscape component were extracted from the literature and entered into an *Excel* database. This database included information on subsection location, landscape component (e.g., geology, soils, vegetation), class (e.g., limestone, Pergelic Cryaquept, sedge-Dryas tundra), position on landscape or relationship to other component (e.g., well-drained soil on upper slope), author, page number, and notations of other pertinent facts. Nomenclature for classes of the various landscape components followed names used by the individual authors for geology, the engineering geology mapping classification system for geomorphic units (ADGGS 1983), the U.S. soil classification system used at the time of each study for soils, and the Alaska Vegetation Classification (Viereck et al. 1992) for vegetation types. The database was used to develop descriptions of the various subsections by sorting information by subsection and landscape component.

Most of the literature we reviewed already was listed in a natural resource bibliography developed for the BELA (ANHP 1992). Geologic information was obtained from studies by Sainsbury (1967), Sainsbury (1972), Hudson (1977), Till et al. (1986), Hopkins (1988), Kaufman et al. (1986), Till and Dumoulin (1994), and Begé et al. (1996). Geomorphic information was obtained from Hopkins (1949), Hopkins and Sigafoos (1950), Hopkins (1973), Holowaychuk and Smeck (1979), Hopkins (1982), Swanson et al. (1985), Kaufman (1986), Hopkins (1988), Jordan (1988), Kidd (1990), Kaufman et al. (1991), Heiser and Hopkins (1995), Mason et al. (1995), Höfle and Ping

(1996), and Mason et al. (1997). Soils information was obtained from Racine (1977), Holowaychuk and Smeck (1979), Van Patten (1990), Höfle and Ping (1996), and Höfle et al. (1998). Vegetation information was obtained from Hanson (1953), Colinvaux (1964), Racine (1977), Racine and Anderson (1979), Racine (1980), Wright (1981), Racine et al. (1983), Swanson et al. (1985), Racine et al. (1987), Harris (1988), Suter et al. (1990), Welp and Sowl (1990), Markon and Wesser (1997), and Höfle et al. (1998). Paleoecology information was obtained from Colinvaux (1964), Matthews (1974), Elias et al. (1992), and Hamilton and Brigham-Grette (1991). The study sites from which the data were obtained were georeferenced by subsection to facilitate access of information geographically. The number of observations by author and landscape component are provided in Appendix Table 1.

Most digital map data were provided by the NPS in GIS databases on CD-ROM. The databases included data at various scales and from a variety of sources including: an ecoregion map of Alaska (1:2.5 million scale, Nowacki et al., in press), digital elevation models developed from 1:250,000 scale USGS quadrangles, digital raster graphics of the USGS quadrangle maps (1:250,000 and 1:63,360), hydrography from USGS maps (1:63,360 scale), park, preserve, and wilderness boundaries (1:63,360 scale), bedrock geology (1:2,500,000 scale, Beikman et al. 1980), soils (Van Patten 1990), and ecological units from a reindeer range survey (Swanson et al. 1985). Finally, a digital land cover map has been produced for the BELA (Markon and Wesser 1997), and this was used after development of the subsection map to evaluate how well the units partitioned land cover classes.

CLASSIFICATION

While every map unit is unique, differentiation of landscape-level units requires explicit definition of the criteria used, in order to improve the objectivity of the classification and delineation and to facilitate consensus among users, each with their own perception of how to differentiate ecological patterns and processes. Following the ECOMAP (1993) framework, sections were defined as physiographic units with similar geology and regional climate that have repeating associations of a limited set of closely related geomorphic deposits. Subsections provide further partitioning of geomorphic or lithologic variability, such as differentiating between alkaline carbonate rocks and acidic granite. To reduce geologic complexity and to deal with the high interspersion of rock types, bedrock types were aggregated into groups that have similar effects on soil development (Appendix Table 2). Floodplains were given special consideration and were mapped as "detailed subsections"; these units were lumped with the adjacent subsection at the subsection level.

To ensure consistency in NPS's statewide effort, mapping investigators for other park units convened a workshop in Anchorage on 26 Sept. 2000 to develop a consensus on mapping criteria (Page Spencer, pers. comm.). At this meeting, consensus was developed to differentiate coastal (salt-affected) ecosystems and floodplain ecosystems, but not to differentiate alpine ecosystems. Alpine ecosystems are problematic because they are part of a continuous toposequence, are difficult to define in arctic environments, and are highly patchy and disjunct on mountain tops, which is a pattern that is inconsistent with the principle of broad regionalization.

MAPPING

To provide a common base map for co-registration of map information and boundary delineation, the Landsat TM imagery that was used by the land-cover mapping project (Markon and Wesser 1997) was used for this project, and its existing georectification was maintained. During mapping, 1:63,000 scale, color-infrared, aerial photography occasionally was used to better evaluate topographic and geomorphic differences among units.

Boundary delineation initially was done on hard copy prints (1:250,000 scale) of the Landsat TM image. The maps were digizited and rectified to the image using a series of ground control points. After initial digitizing, lines were revised by on-screen digitizing over the backdrop of the Landsat TM image. While map layers representing data on topography (USGS DEM in Figure 2) and geology (Beikman 1980 in Figure 3, and Till et al. 1986) were referred to during mapping, the terrain characteristics evident on the Landsat Image provided the primary control for boundary delineation. Mapping extended beyond the park boundaries where necessary to close polygons. Polygon size for the subsections was 10's to 100's of km^2 following ECOMAP (1993). The map was produced as a seamless ArcInfo coverage for BELA in Alaska Albers with NAD27 datum. Attributes included for each polygon included park_code (e.g., BELA), section (name), subsection (name), subseccode (subsection code), Det_SS (detailed subsection name), Det_sscode (detalied subsection code), physiograp (physiography), geology, and whether the unit was inside or outside the park boundaries (in_out).

FIELD RECONNAISSANCE

A field reconnaissance was conducted on 19–22 August 2000 to familiarize myself with the landscape, to acquire large-scale photography of subsections for reference and presentation, and to evaluate preliminary concepts of landscape units and landscape relationships. Oblique aerial photography was obtained for all subsections, although poor weather reduced photo-quality. Based on observations from the field reconnaissance, the preliminary map was revised by combining several subsections that had similar characteristics. In addition, individual floodplain units that were initially mapped separately were combined as a single disjunct subsection within each encompassing section.

RESULTS AND DISCUSSION

LITERATURE REVIEW AND SYNTHESIS OF FACTORS AFFECTING LANDSCAPE EVOLUTION

The structure and function of ecosystems largely are regulated along energy, moisture, nutrient, salinity, and disturbance gradients, and these gradients are affected by climate, oceanography, tectonic effects on physiography, and parent material as controlled by bedrock geology and geomorpholoy (Swanson et al. 1988, ECOMAP 1993, Bailey 1996). Thus, ecosystem components can be viewed as state factors that affect ecological organization (Jenny 1941, Van Cleve et al. 1990, Vitousek 1994, Bailey 1996). Accordingly, information on the various landscape components compiled from literature relavent to BELA are synthesized below to help evaluate the importance of the various factors in controlling the ecological patterns evident in the study area.

CLIMATE

The present climate in NW Alaska has short summers lasting only June through August, and long winters. Based on long-term climatic data (WRCC 2000), the mean annual air temperature is -3.2°C for Nome (1949-1999), -5.8°C for Kotzebue (1949–1999), and -6.0°C for Wales (1949–1999). Mean annual precipitation is 408 mm for Nome, 240 mm for Kotzebue, and 291 mm for Wales. Approximately half of the precipitation falls during July, August, and September. These data reveal moderately strong temperature and precipitation gradients across BELA. In addition, there presumably is a strong elevational gradient resulting from the adiabatic lapse rate, although no data have been collected in the area to quantify the gradient. Limited data from Racine (1979) indicate that air temperatures during the summer are colder in coastal areas compared to inland areas.

Because of cold temperatures, the area is included within the Arctic biome, and vegetation over most of the area is dominated by graminoid, low and dwarf shrub, moss, and lichen lifeforms. Temperatures are even colder in alpine areas and they frequently are barren and support only a sparse cover of lichens, mosses, and a limited number of vascular species. In contrast, spruce forests are common in the southern lowland areas of the park where temperatures are warmer.

Differences in precipitation also have a large effect on soils. In the northern area with more arid conditions, the reduced precipitation presumably reduces leaching of cations for the soils and reduces acidification. In contrast, increased precipitation in the southern portion along with increased precipitation with elevation probably enhances leaching and acidification.

Climate conditions also have varied considerably over time. Stable isotope analysis of ice cores from Greenland and Antarctica reveal numerous large, rapid shifts in climate during the Pleistocene (Bradley 1999). These changes have resulted in multiple episodes of glaciation, sea- level fluctuations, and loess deposition associated with glaciation (Hopkins 1982), and have been documented by numerous geomorphic and paleoecological studies in the Bering Land Bridge area (Collinvaux 1964, Matthews 1974, McColloch and Hopkins 1966, Hopkins 1967a, Hopkins 1982, Elias et al. 1992, Hamilton and Brigham-Grette 1991, Mann and Hamilton 1995). During the late Pleistocene, buried calcareous paleosols in northern BELA indicate that the climate was cold and dry around 16,000–19,000 years ago and loess deposition was heavy (Höfle and Ping 1996). During the early Holocene, white spruce remains, ice-wedge casts, and buried soils indicate that the climate was much warmer 8,300–10,000 years ago (McColloch and Hopkins 1966). Historical records and analyses of proxy indicators indicate that temperatures were substantially colder during the Little Ice age (ending around 1850) and that temperatures during the last decade were the warmest in the last 400 years (Overpeck et al. 1997).

OCEANOGRAPHY

The western coast of the BELA abuts the Bering Straits and the southern margin of the Chucki Sea, a rectangular embayment of the Arctic Ocean. At Shishmaref, mean high tides reach 0.8 m, while the highest tidal debris is only 1.0 m above mean sea level (amsl) (Naidu and Gardner 1988). At Cape Espenberg, storm debris extends to 2.3 m amsl (Mason et al. 1997). Current direction and thus sediment transport is northward along the coast. During winter, drifting pack and shorefast ice covers the entire Chucki Sea for 7–8 months. Sea depths extend to only ~80 m in the Bering Straits.

Large changes in sea level, however, have accompanied the climatic changes described above. During maximum glaciation in the late Pleistocene (□18,000 years before present [ybp]) sea levels were lowered to □100 m below current sea level. This lowering exposed a broad land bridge across the Bering continental shelf (Hopkins 1967). By ~11,000 ybp the land bridge was inundated and the migration corridor for plants and animals, including humans, was closed (Elias et al. 1992). Sea level reached nearly its present level (within 2–3 m) around 5,000 ybp (Mason et al. 1995), and sediment transport and storm events have contributed to the development of extensive barrier islands, spits, and beach ridge complexes along the Bering Straits (McCullough 1967, Jordan 1988, Mason and Jordan 1991, Mason et al. 1997).

Sea level also has been much higher in the past, and marine transgressions during the Pleistocene have created the broad coastal plain across the northern portion of the Seward Peninsula. The Pelukian transgression during the last interglacial (isotope stage 5e) occurred □125,000 ybp and left beach ridge deposits that outcrop at elevations of 8–10 m above mean sea level (Sainsbury 1967, Hamilton and Bringham-Grette 1991, Brigham-Grette and Hopkins 1995). The Pelukian trangression is recorded by a well-defined wave-cut scarp and marine terrace that can be traced along much of the coast of the northern Bering Sea and southern Chucki Sea (Sainsbury 1967, Hopkins 1973). During the middle Pleistocene, two marine transgressions, the Kotzebuan (□175,000 ybp) and Einahnuhtan (□225,000 ybp) have been described, although their sea-level history has been difficult to reconstruct (Hopkins 1967b, Hopkins 1973). Sea level during the later transgression reached a maximum elevation of □35 m. Marine trangressions during the Pliocene may have been as high as 70 m (Brigham-Grette and Carter 1992). These transgressions left marine beach and coastal deposits of silt, sand,

and gravel across the coastal plain. Ancient barrier bars are occasionally evident, comprised of well-sorted sand forming linear ridges (Till et al. 1986).

TECTONIC SETTING AND PHYSIOGRAPHY

The Seward Peninsula is within a moderately active seismic zone connected to the Brooks Range and is characterized as having a relatively thin crust, scattered Quaternary volcanism, and relatively high heat flow (Thenhaus et al. 1982). The coastal plain on the northern portion of the Seward Peninsula is a subsiding basin comprised of Cenozoic sediments several thousand meters thick that are crosscut by several east/west faults just south of Cape Espenberg (Tolson 1987). Little uplift or subsidence has occurred during the Holocene, however, and isostatic rebound is unlikely because the northern coastal plain was not glaciated during the Pleistocene.

The geologic structure and physiography of the region is dominated by thrust faulting of two different ages. Beginning probably in the mid-Cretaceous, Precambrian and Paleozoic rocks were thrust eastward creating north-trending folds (Sainsbury 1972). Later in the Cretaceous, unmetamorphosed rocks of the York Mountains moved northward into their present position. At the end of the Cretaceous, isolated blocks of granite intruded the thrust sheets and several normal faults developed. Tertiary tectonism is responsible for prominent, high-angle faulting.

BEDROCK GEOLOGY

The bedrock geology is highly complex and includes a wide variety of sedimentary, metamorphic, volcanic, and intrusive rocks (Sainsbury 1972, Hudson 1977, Beikman 1980, Till et al. 1986, Till and Dumoulin 1994). This complexity and interspersion of rock types provided a major challenge in differentiating subsections into broad homogenous units. Some of the principal differences among carbonate, felsic-intrusive, and volcanic rocks, and their influence on soil formation, are described below.

Carbonate or closely associated rocks, such as limestone, dolostone, marble, and calcareous schists are prevalent in the highland areas within the park. The greater age (Ordivician, Cambrian, Precambrian) and weathering of these rocks has resulted in a rounded slope morphology, and the carbonates associated with these rocks has resulted in strongly alkaline soils. The higher soil pH and abundance of Ca in the alkaline soils strongly reduces phosporus availability and phosphorus absorption and utilization by plants (Bohn et al. 1985). Alkaline soils also tend to be rich in humus, are often associated with more active cryoturbation, and tend to have deeper active layers (Ping et al. 1998).

Felsic intrusive igneous rocks occur in the Bendeleben and Darby Mountains and in other isolated locations, such as the upper Serpentine River and Inmachuk River areas. These granitic rocks are dominated by light-colored minerals, such as quartz, alkali feldspars (orthoclase), and muscovite mica, that are rich in aluminum silicates, with little to no calium, magnesium, and iron. The high aluminum and low calcium-magnesium content contributes to development of strongly acidic soils and high soluble aluminum concentrations. The elevated aluminum, in turn, can lead to plant growth problems because root growth can be stopped by Al concentrations as low as 1 mg/L (Bohn et al. 1985). Phosphorus is predominantly fixed as aluminum and iron phosphates in the acid soils but is still more available than in alkaline soils. To reduce aluminum toxicity, many plants generate organic acids such as tannins as chelating agents in the rhizosphere for protection (Rendig and Taylor 1989). Thus, ericaceous plants that are better adapted to these conditions tend to dominate.

Volcanic rocks are prevalent in the Imuruk Plateau and around the Devil Mountain Lakes. The Imuruk Plateau basically was formed from basaltic lava flows of Tertiary and Quaternary age (Till et al. 1986). While the Tertiary flows are mostly covered by eolian silt and colluvium, the Lost Jim and Gosling lava flows of Quaternary age are mostly barren. Farther north, the shield volcanoes that form Devil Mountain occur at the northern limit of late Cenozoic volcanism in Alaska (Hopkins 1988). Explosive eruptions during the last 200,000 years has created a large region of basaltic ash, massive pyroclastic flows, and explosion breccia (Begét et al. 1996).

GEOMORPHOLOGY

Alluvial processes on narrow floodplains in the BELA have created one of the most dynamic landscapes subject to active erosional and depositional processes. Channel migration erodes and recycles surficial deposits, while deposition follows a predictable sequence from gravelly active channel deposits, to sandy active floodplains adjacent to the active channel, to peat-coverd loamy soils on the inactive floodplain (Jorgenson et al. 1998). During this sequence, ice-rich permafrost aggrades in the silty cover alluvium and greatly modifies the surface with ice-wedge polygons. In higher gradient streams in the mountains, bedrock control and heavy bedload result in confined headwater and gravelly braided floodplains. On lower gradient streams in the lowlands, sandy deposits with meandering morphology are dominant. The floodplains provide connectivity between regions, because water is a conduit for the movement of sediments and nutrients, as well as fish, invertebrates, and plant materials.

Eolian activity during dry, full glacial periods have deposited thick beds of eolian silt (loess) over much of the northern Seward Peninsula (Mathews 1974, Hopkins 1982). Near Imuruk Lake, eolian deposits up to 6-m thick have been observed (Holowaychuk and Smeck 1979). In contrast, late Pleistocene eolian deposits that occur on top of volcanic ash deposited ~17,500 ybp are only ~0.5 m thick (Holowaychuk and Smeck 1979). Much of the silt probably blew off glaciofluvial outwash plains associated with the Illinoian glaciation, which extended as far west as the terminal moraine now forming the Baldwin Peninsula (Matthews 1974). Loess accumulation during the Wisconsin glaciation (maximum at □18,000 ybp) probably was much less because outwash streams were blocked by the Baldwin Peninsula. Analysis of loess in northern BELA buried during the late Pleistocene (around 16,000–19,000 ybp) indicates it remained calcareous throughout the profile because the climate was cold and dry (Höfle and Ping 1996). While the frozen loess beneath the active layer of modern soils tends to remain alkaline, surface organic horizons usually are strongly acidic on the Imuruk Plateau and northern BELA (Holowaychuk and Smeck 1979, Höfle and Ping 1996), presumably due to leaching and paludification under a wetter climatic regime.

Glaciations during the middle to late Pleistocene covered the Bendeleben, Darby, western York, and Kiwalik mountains, but effects within BELA are limited (Matthews 1974, Hopkins et al. 1983, Kaufman and Hopkins 1986, Kaufman et al. 1991). The

Nome River glaciation (□280,000–580,000 ybp) extended into the Bendeleben Northern Foothills, but little is known about ecosystem development on the glacial deposits. The many cirque lakes present in the Bendeleben Mountains originated from this glacial activity.

Permafrost distribution is nearly continuous throughout the region because of low air temperatures (Brown et al. 1997) and is >100-m thick (Hopkins 1988). Permafrost in the lowlands generally is extremely ice-rich due to the thick loess deposits and long period of development, whereas upland areas underlain by bedrock have little ground ice as indicated by the lack of thermokarst features. Most of the massive ice that has accumulated in the lowlands appears to have developed during the mid-late Pleistocene and is in the form of massive ice sheets similar to the "paloma" described in Russia (Yuri Shur, pers. comm.). Ice-wedge development, which occurs in areas where mean annual air temperatures are <-6°C (Péwé 1975), during the Holocene also has contributed to this ice-rich premafrost. With the onset of a warmer and moister climate during the early Holocene, thermokarst of the ice-rich terrain has resulted in an abundance of thaw lakes (Heiser and Hopkins 1995). On the coastal plain, thaw basins are up to 25-m deep, indicating that the ground ice volume is extremely high (Hopkins and Kidd 1988, Kidd 1990). Collapse of permafrost into thaw lakes, and subsequent aggradation of ground ice in exposed lacustrine sediments has lead to a "thaw-lake cycle" and occasional development of ice-cored mounds call "pingos" (Hopkins 1949).

Permafrost also greatly affects ecosystem development by altering soil processes. First, permafrost forms an impermeable layer beneath the active layer that causes the surface soils to become saturated on low-lying areas and gentle slopes (Ford and Bedford 1987). Soil saturation, in turn, reduces soil oxygen and microbial decomposition and, thereby increases organic matter accumulation (Höfle et al. 1998). The saturated soil also contributes to gelifluction movement of soils down slope, in places creating large prominent gelifluction lobes (Holowaychuk and Smeck 1979). Second, the impermeable layer eliminates subsurface leaching so that solute removal is slowed down and occurs laterally. This lateral movement through the active layer creates distinct feathery pattern of "water-tracks" on slopes and enhances plant growth in the drainages (Walker et al. 1989, Kane et al. 1992). Finally, freezing and thawing processes associated with permafrost contribute to cryoturbation (mixing of soil horizons) and development of patterned ground features, such as frost boils and ice-wedge polygons, which provide a range of wet and moist microsites. These processes all alter the composition of vegetation that can grow on the cold, saturated soils.

FIRE

Although fire is not considered to be an important disturbance factor in tundra ecosystems due to the lack of large canopy structures (Patterson and Dennis 1981), periodic summer droughts and thunderstorms have produced several major fires in BELA during the last several decades (Melchior 1979, Wein 1976, Racine 1981, and Racine et al. 1983). Most fires have occurred in the eastern portion of the Seward Peninsula, but incidences also have been fairly frequent near the Kuzitrin River, and to a lesser extent near Imuruk Lake. Fires are notably absent from the coastal plain region. While the effects of fire are variable in this landscape, they can be locally important where they increase the depth of the active layer and initiate permafrost degradation (Racine 1981, Racine et al. 1983).

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CLASSIFICATION AND MAPPING

Classification of landscape-level units within the BELA was done within the ecoregion framework for Alaska, which delineated two ecoregions that encompass the BELA study area: the Kotzebue Sound Lowlands and the Seward Peninsula ecoregions (Nowacki et al., in press). Based on differences in physiography and geology, the landscape classification resulted in the establishment of 5 sections and 12 subsections within the Koztebue Sound Lowlands, and 6 sections and 18 subsections within the Seward Peninsula ecoregion for the preserve area (Table 1). An additional section and 6 subsections were mapped adjacent to the preserve boundaries. The dominant physiography, bedrock geology, geomorphology, permafrost, soils, and vegetation of each subsection are described in Table 2. Representative photos of some of the subsections are provided in Figure 4, while a more complete compilation is provided in Appendix 4.

Mapping of subsections show a progression of narrow coastal subsections in northern BELA to broader regions in the mountains in southern BELA (Figure 5). The largest subsection within BELA was the Bering Straits Lower Coastal Plain (Table 1, Appendix Table 3). The smallest subsection within BELA was the York Upper Floodplains, but this was just a tip of larger subsection that occurs south of BELA. Most of the subsections were comprised of 1–3 polygons, while the coastal plain subsections had up to 10 polygons because of dissection by floodplains (Appendix Table 3). The Goodhope Bay Coast had 46 polygons due to the presence of numerous islands. Aggregation of the subsections into broad sections greatly simplifies the map patterns (Figure 6).

REPRESENTATIVE TOPOSEQUENCES

Toposequences were developed from the literature and airphoto analysis to illustrate the changes in topography, geology, geomorphology, permafrost, soils, and vegetation across the landscape within six representative subsections chosen to cover the entire range of environmental gradients within BELA (Figures 7–12). The toposequences reveal a large variation in the local ecosystems among the various subsections. The subsections include: the Espenberg Coast, which is dominated by marine and estuarine processes (Figure 7); Bering Straits Upper Coastal Plain, which is dominated by thaw lake processes (Figure 8); Bering Straits Lower Floodplain, which is dominated by low-gradient fluvial processes (Figure 9); Imuruk Uplands, which is dominated by colluvial and slope processes (Figure 10); the round non-glaciated Goodhope Mountains, which were formed from alkaline rocks (Figure 11); and the rugged glaciated Bendeleben Eastern Mountains, which were formed from acidic granite rocks (Figure 12).

PARTITIONING OF LAND COVER CLASSES

Comparison of the distribution of land cover classes mapped by Markon and Wesser (1997) among subsections revealed that the subsections were only partially effective at partitioning differences among vegetation and surface characteristics (Table 3). For example, the wet herbaceous class was found almost exclusively on the coastal plain subsections, dwarf shrub- tussock tundra was concentrated on the upper coastal plain, and the dwarf shrub-lichen dominated and sparse vegetation classes were the dominant classes in the Bendeleben Mountains. The comparison also reveals, however, that five of the land cover classes that account for 64% of the area are found in nearly all the subsections, indicating that there is a limit to how effectively the subsections can partition land cover classes.

REPRESENTATIVE PHOTOGRAPHS OF SUBSECTIONS

Note: No representative photographs were obtained for some of the subsections that were outside the park, including Agiapauk Hills (AH), Darby Eastern Mountains (DEM), Kugruk Mountains (KGM), Kougarok Foothills (KOH), Koyuk Hills (KYH), Wales Mountains (WM), and York Mountains (YM).

BEM – Bendeleben Eastern Mountains. The upper slopes of these rugged mountains are covered mostly with sparsely vegetated rock rubble and exposed granitic and metamorphic rock. Lakes occasionally occur in high cirques that were occupied by glaciers in the Pleistocene. The gentler slopes in the foreground have more vegetation, mostly *Dryas*-lichen tundra and low shrubs, with denser shrubs along the drainage in from of the mountain on the left. Photo TJ00M19.

BWM – Bendeleben Western Mountains. The slopes and crests of these mountains are covered mostly with rock rubble or sparse *Dryas*-lichen tundra. The highest parts of these mountains had glaciers in the late Pleistocene, while the region pictured here did not and as a result slopes are relatively gentle and ridgelines are rounded. Valley bottoms are more densely vegetated, with low shrubs on wetter soils. Photo TJ00D14.

BNH – Bendeleben Northern Foothills. These hills and gentle slopes have well-developed gelifluction lobes that resemble a thick batter flowing down the slopes. These lobes form when saturated soil flows downhill very slowly over the permafrost beneath. The light-colored areas are drier and support low shrubs and cottonsedge. The darker lines running downslope on the right are denser and taller shrubs along runoff or seepage zones called water tracks. Tall shrubs are also present in protected areas below the gelifluction lobes; these areas accumulate large, persistent snowdrifts. Photo TJ00X13, 20 Aug 2000.

BSLCP – Bering Straits Lower Coastal Plain. This flat, low-lying region has many lakes formed by thawing of ice-rich permafrost. Recently drained lakes have low ice contents and unvegetated lake bottoms for short periods (right), while older lake basins become completely vegetated with wet sedge tundra (foreground). The area between lake basins in is slightly higher and has tussock tundra (middle). Photo TJ00X64.

BSUCP – Bering Straits Upper Coastal Plain. This gently undulating plain consists of gently convex areas covered by tussock tundra, with slow-moving small streams or wet hollows in between. This upper coastal plain is higher and older than the lower coastal plain. Ice wedge polygons, visible in the photograph center, are probably widespread but usually concealed. Thaw lakes are less common than in the BSLCP unit. Photo TJ00X55, 20 Aug 2000.

BSLF – Bering Straits Lower Floodplains. The lower portions of floodplains that cross the Bering Straits Coastal Plain have low gradient streams that are highly sinuous. Oxbow lakes are common. Point bars and stream banks have well-drained soils that support willow and alder. Fine-grained overbank deposits cover most of the floodplain and have wet soils that support sedge meadows. Photo TJ00X52, 20 Aug 2000.


CDC – the Cape Deceit Coast consists of sandy beaches (visible on the left) and eroding bedrock bluffs with a rocky shore and little beach (on right). The backshore of the beaches and headlands are affected by salt spray and storm surges and support halophytic vegetation. Photo TJ00G33, 20 Aug. 2000.

DU – Devil Uplands. This gently undulating area is composed of volcaniclastic rocks, which were formed from small rock fragments and hot gasses that were expelled explosively from a volcano and spread out over surrounding areas. The sources of these eruptions are now large depressions occupied by lakes (known as maars), including Devil Mountain Lakes (pictured here), White Fish Lakes, and Killeak Lakes. Abundant smaller lakes in this area formed from thermokarst, and their depth attests to the large quantity of ground ice present. Vegetation is mostly tussock tundra, with dense shrubs along drainages. Photo TJ00C18, 21 Aug 2000.

DWM – Darby Western Mountains. These rounded mountains are composed of light-colored carbonate metamorphic rock (marble and schist). Steeper and more convex slopes have mostly sparsely vegetated rock rubble, while lower areas have mostly low shrubs. The calcareous soils result in a distinctly different flora from that on more acidic soils in the Darby Eastern Mountains. Photo TJ00X15, 20 Aug 2000.

EC – Espenberg Coast. A series of roughly parallel low ridges mark former locations of beaches that were at one time exposed to the full force of waves from the Chukchi Sea (background). These beach ridges consist of both beach sediments, and sand dunes now vegetated with grass and crowberry. Swales in between the ridges contain ponds and wet sedge meadow tundra. Tidal mudflats occur in protected, low energy environments, such as the lagoon behind Cape Espenberg (foreground). Photo TJ00C32, 21 Aug 2000.

GBC – Goodhope Bay Coast. This region of tidal mudflats and shallow nearshore water faces Kotzebue Sound and is partly protected from storm waves from the Chukchi Sea. In this low energy environment, extensive tidal flats form are river mouths and support halophytic wet meadows. Muddy barrier bars also are common, but the beach ridges and sand dunes of other coasts are absent. Photo TJ00J05, 21 Aug 2000.

GBLCP – Goodhope Bay Lower Coastal Plain. This nearly level region has numerous thaw lakes; the one in this photo is partially filled with peat and lake sediment, and vegetated with grass marsh. Higher areas surrounding the lake depressions have tussock tundra or willow-sedge tundra. Photo TJ00J06, 21 Aug 2000.


GBUCP - Goodhope Bay Upper Coastal Plain. This very gently undulating plain has numerous thermokarst lakes that are generally smaller and in deeper depressions than in the Goodhope Bay Lower Coastal Plain. The gentle convex slopes between the lakes have mostly tussock tundra, with shrubs along small streams. Photo TJ00H12.

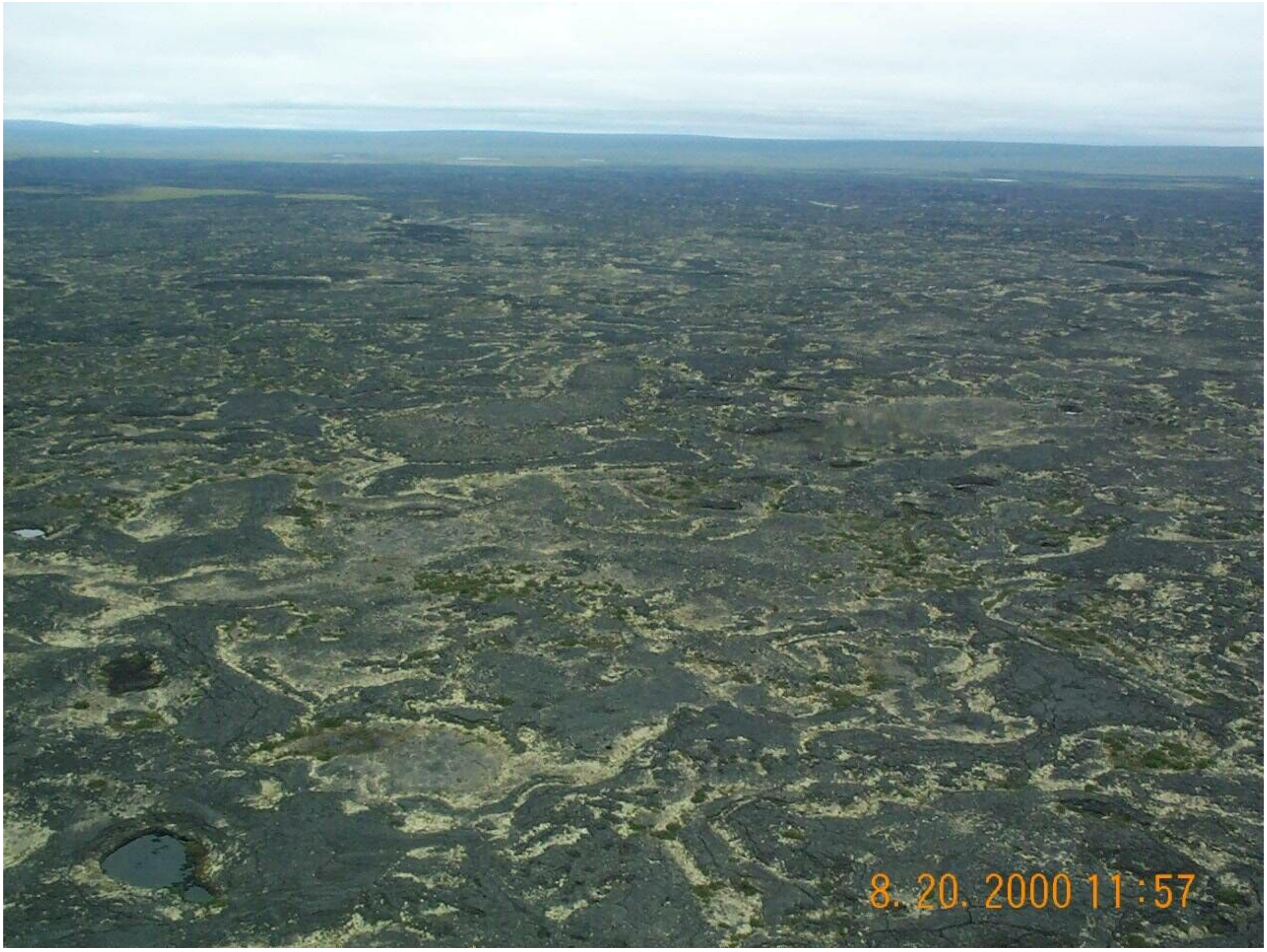
GBLF – Goodhope Bay Lower Floodplains. Similar hydrology, soils, and vegetation to those described for the Bering Straits Lower Floodplains. Photo TJ00C12, 21 Aug 2000.

GUF – Goodhope Upper Floodplains. This area includes the upper portion of floodplains that occur in the Goodhope Foothills and Mountains. The streams have higher gradients and vary from meandering to braided. The channel deposits are gravelly and barren point bar deposits are extensive. Willows are abundant on the well-drained channel deposits and fine-grained streambanks. Photo TJ00X42, 20 Aug 2000.

GH – Goodhope Foothills. These gently sloping hills are mostly covered with tussock tundra. Dense shrubs grow along drainageways and slopes of occasional lake basins (center). The depth of the thermokarst depression that holds this lake is evidence for high ice content of the underlying sediments. Photo TJ00X41, 20 Aug 2000.

GM – Goodhope Mountains. These low, rounded mountains are composed partly of light-colored carbonate metamorphic rocks. Rock rubble is exposed on convex hilltops, but much of the landscape is vegetated with *Dryas*-lichen tundra on dry rocky soils. The calcareous soils support a wide diversity of flowering plants. Tussock or low shrub tundra on moister sites. Photo TJ00X35, 20 Aug 2000.

IL – The Imuruk Lowlands occupies low areas on the Imukruk Plateau. The circular drained thaw lake basins, are common in the Imuruk Lowlands and usually have wet sedge meadow tundra on peat soils. Aggradation of ground ice in the basins form slightly raised plateaus, or palsas, that support dwarf birch and ericaceous shrubs. Higher areas next to the lakes have tussock tundra. Photo TJ00X29, 20 Aug 2000.



ILF – Imuruk Lava Flows. This plain is covered by basaltic lava that flowed out during eruptions in the late Pleistocene and Holocene. There is much exposed bare rock, due to the lack of weathering on the young deposits. Small patches of soil with shrub-lichen tundra occur in low spots. Photo TJ00X23, 20 Aug 2000.


IU – Imuruk Uplands. These very gently sloping hills have a well integrated drainage network deeply incised stream channels. The broad slopes with shallow soils underlain by permafrost support shrub-rich tussock tundra. Denser and taller shrubs occur along drainageways and small streams. Photo TJ00K19.

KGH – Kugruk Foothills. These rounded hills are mantled with loess and colluvium, with little bedrock exposed. Vegetation is low shrubs and tussock tundra over much of the, with white spruce forest at lower elevations in the southeastern part as shown here. Photo TJ00L19, 21 Aug 2000.

KYL – The Koyuk Lowlands consists of nearly level areas along the Koyuk River. The light-colored areas are tussock or wet sedge meadow tundra, while drainages leading to the river support dense alder scrub. On coarse-grained river deposits next to the Koyuk River there are some balsam poplar and white spruce trees, in addition to tall shrubs. Photo TJ00M24.

KZL – The Kuzutrin Lowlands is nearly level plain with wet thaw lake basins separated by tussock tundra. Thaw lake basins usually support wet sedge meadow vegetation (center). They often are drained by a water tracks leading to better developed drainages. Older basins which have accumulated more ground ice over time often support dwarf birch and ericaceous shrubs on organic-rich acidic soils Photo TJ00X21, 20 Aug 2000.

KZF –Kuzutrin Floodplain. This subsection includes the upper and lower portions of the Kuzutrin Floodplain. Most of the river is low gradient and highly sinuous. Oxbow lakes are common. Willows are abundant close to the riverbank, whereas sedge meadows are abundant on the wet, organic soils on the higher, more distant portions of the floodplains. Photo TJ00X20, 20 Aug 2000.

SC – Shishmaref Coast. A barrier island (the narrow strip of land in the background) separates the Chukchi Sea (on the horizon) from Arctic Lagoon. Small brackish ponds and wet meadows with salt-tolerant grasses and sedges frequently occur on protected mudflats on the seaward side (center left). A bluff separates Shishmaref Coast from the Bering Straits Upper Coastal Plain that was once covered by the ocean when sea level was higher during an earlier period (right). Photo TJ00X75, 20 Aug 2000.

SM – Serpentine Mountains. These rounded mountains composed of granitic rocks have tors (rock pinnacles, visible on the ridge in the background) that are residual rock masses form by weathering away of surrounding material. The horizontal lines on the slope in the background are the lower edges of gelifluction lobes, which form when a wet thawed layer of soil flows downhill over underlying permafrost. These well-drained ridges with rocky soils support *Dryas* and sedge-*Dryas* tundra, with low shrubs in drainageways. Photo TJ00I24.

WC – Wales Coast. Waves from the open ocean of the Bering Strait break on the beach and move sediment along the shore. Sparsely vegetated areas behind the beach occur on low dunes formed from sand blown off the beach. The numerous ponds behind it lie between old beach and dune ridges. This vegetated beach and dune complex has grass and crowberry vegetation on high spots and wet sedge meadow tundra in wetter low areas. In the background is Lopp Lagoon, a large brackish water body. Photo TJ00X69, 20 Aug 2000.

YH – The York Foothills. The area is dominated by rounded hills with long, gentle slopes. Ridge crests and shoulder (center) have dry, rocky soils with Dryas-lichen and sedge-Dryas tundra vegetation. Lower slopes (foreground) have wetter, organic-rich soils that support tussock and low shrub tundra, while drainageways have willow or alder scrub. Photo TJ00X57, 20 Aug 2000.

YUF – York Upper Floodplains. This Detailed Subsection includes several floodplains that occur in the York Foothills and Mountains. The higher gradient streams typically are braided and have higher bedload. Dwarf *Dryas* tundra is common of the gravelly inactive riverbars. Willows are abundant on the lower floodplain steps that receive frequent sedimentation. Oxbow lakes are absent. Photo TJ00X66, 20 Aug 2000.

SUMMARY AND CONCLUSION

Landscape-level mapping of ecological units within the Bering Land Bridge National Preserve was based on a review of ecological characteristics described from numerous field studies, and the differentiation of important large-scale landscape components, particularly physiography and geology. The mapping, done within the framework of the broader ecoregions of Alaska, produced 5 sections and 12 subsections within the Koztebue Sound Lowlands ecoregion, and 6 sections and 18 subsections within the Seward Peninsula ecoregion for the Preserve area. The dominant geologic and geomorphic processes that were used to differentiate the units included: marine and estuarine processes along the coast, thaw-lake processes on the lower and upper coastal plain, fluvial processes on the meandering lower floodplains on the coastal plain and the braided upper floodplains in the mountains, colluvial and slope processes in the rolling hills near Imuruk and Devil Mountain lakes and the mountain foothills, and frost riving and slope processes on alkaline rocks in the Goodhope Mountains and on acidic granite rocks in the Bendeleben Mountains. Occasional large differences among the various subsections in the abundance of land cover classes produced by previous mapping revealed that the landscape-level mapping was only somewhat effective at partitioning land cover classes because many of the dominant plants and land cover types are broadly distributed and, therefore, are found in most subsections. The land cover map, however, used only very broad differences in plant structure that did not incorporate the floristics differences described for the various subsections by many studies. Overall, the evaluation of differences among subsections in land cover classes produced by the land cover map and in floristic differences noted by numerous field studies, indicate the landscape-level partitioning of ecological patterns and processes should be useful for sample stratification for the upcoming biological inventory and monitoring.

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Table 1. Hierarchical grouping of ecoregions, sections, and subsections within the Bering Land Bridge National Preserve (11,274 km²), western Alaska. Areas presented for portions within preserve.

Section	Subsection and Detailed Subsections[1]	Physiography	Geology	Code	Area (km²)
KOTZEBUE SOUND COASTAL PLAIN ECOREGION					
Bering Straits Coast	Wales Coast	Coast	Marine beaches, lagoon, bluffs	WC	4
	Shishmaref Coast	Coast	Marine beaches, lagoons	SC	429
	Espenberg Coast	Coast	Marine beaches, lagoon, bluffs	EC	76
Goodhope Bay Coast	Goodhope Bay Coast	Coast	Marine beaches, lagoon	GBC	52
	Cape Deceit Coast	Coast	Marine beaches, bedrock bluffs	CDC	7
Bering Straits Coastal Plain	Bering Straits Lower Coastal Plain	Plains, flat	Thaw lake, loess, marine, peat	BSLCP	1639
	Bering Straits Upper Coastal Plain	Plains, rolling	Thaw lake, loess, marine,peat	BSUCP	1329
	Bering Straits Lower Floodplains[1]	Floodplain	Alluvium	BSLF	114
Goodhope Bay Coastal Plain	Goodhope Bay Lower Coastal Plain	Plains, flat	Thaw lake, loess, marine, peat	GBLCP	117
	Goodhope Bay Upper Coastal Plain	Plains, rolling	Thaw lake, loess, marine, peat	GBUCP	1322
	Goodhope Bay Lower Floodplains[1]	Floodplain	Alluvium	GBLF	48
Devil Uplands	Devil Uplands	Hills	Volcanic pyroclastics	DU	826
SEWARD PENINSULA ECOREGION					
York Highlands	York Upper Floodplains	Floodplain	Alluvium	YUF	2
	York Foothills	Hills-rounded	Sedimentary and metamorphic, carbonate rocks	YH	86
	York Mountains (outside preserve)	Mountains-rounded	Sedimentary and metamorphic, carbonate and noncarbonate rocks	YM	
	Wales Mountains (outside preserve)	Mountains-rounded	Intrusive, igneous, felsic rocks	WM	
Goodhope Highlands	Goodhope Upper Floodplains[1]	Floodplain	Alluvium	GUF	16
	Goodhope Foothills	Mountains-rounded	Metamorphic, carbonate and noncarbonate rocks	GH	1454
	Goodhope Mountains	Mountains-rounded	Metamorphic, carbonate and noncarbonate rocks	GM	575
	Serpentine Mountains	Mountains-rounded	Intrusive, igneous, felsic rocks	SM	141
	Kougarok Foothills	Hills-rounded	Metamorphic, carbonate and noncarbonate rocks	KOH	35
	Kugruk Foothills	Hills-rounded	Metamorphic, carbonate and noncarbonate rocks	KGH	172

Imuruk Plateau	Imuruk Lowlands	Basins	Colluvium, peat deposits	IL	339
	Imuruk Uplands	Hills-rolling	Colluvium over volcanic basalt	IU	1199
	Imuruk Lava Flows	Uplands-flat	Volcanics: mafic, Quaternary	ILF	423
Bendeleben -Darby Highlands	Bendeleben Northern Foothills	Mountains-rugged	Intrusive igneous and meta-morphic rocks; felsic and mafic	BNH	390
	Bendeleben Eastern Mountains	Mountains-rugged	Intrusive igneous, felsic rocks	BEM	104
	Bendeleben Western Mountains	Mountains-rugged	Intrusive igneous and metamorphic, felsic rocks	BWM	83
	Darby Western Mountains	Mountains-rugged	Metamorphic, carbonate rocks	DWM	12
Kuzutrin Lowlands	Kuzutrin Floodplain[1]	Floodplain	Alluvium	KZF	23
	Kuzutrin Lowlands	Lowlands	Colluvium, peat	KZL	226
Koyuk Lowlands	Koyuk Lowlands	Lowlands	Colluvium, peat	KYL	30

[1] Detailed subsections differentiate floodplains within a subsection, these were grouped with the adjacent subsection at the subsection level.

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Table 2. Description of the bedrock geology, geomorphology, soils, and vegetation of subsections within the Bering Land Bridge National Preserve, western Alaska.

Subsection[1]	Characteristics
Espenberg Coast	Low-lying (elevation range of 0-30 m above mean sea level[amsl]), salt-affected coastal areas near Cape Espenberg exposed to large wind-driven storms. The geology is dominated by Quaternary marine and estuarine deposits that initially formed during the last 5,000 years in response to the slowing of sea-level rise after the retreat of glaciers. The coast is comprised of barrier islands, gravelly beaches, series of sand dunes and swales, tundra-backed coastal bluffs, shallow thaw ponds, lagoons, mudflats, and tidal deltas. Permafrost in discontinuous and palsas occur on the older tundra. Beaches have well-drained gravelly to sandy soils that support a sparse plant cover of early successional halophytic colonizers. Active and stable dunes have well-drained sandy soils that support Elymus meadows and crowberry tundra, while swales have saturated thick peats that support wet sedge meadow tundra. Mudflats and river deltas have poorly developed saturated, loamy soils that support halophytic sedge and grass wet meadows. Lagoons and barrier islands are much less extensive than along the Shishmaref coast and there is a long stretch of eroding tundra bluffs. Photograph
Shishmaref Coast	Low-lying (0–30 m), salt-affected coastal areas along the Bering Straits dominated by lagoons and barrier islands. Soils and vegetation are similar to those described for the Espenberg coast. Photograph
Wales Coast	Low-lying (0–10 m), salt-affected coastal areas along the Bering Straits dominated by lagoons, barrier islands, and eroding tundra bluffs. Soils and vegetation are similar to those in the Espenberg Coast. Photograph
Goodhope Bay Coast	Low-lying (0–30 m), salt-affected coastal areas near Kotzebue Sound that are less exposed to storms. The area is dominated by a large protected embayment with shallow nearshore water and deltaic tidal flats and lacks long barrier islands and beach ridges. Soils and vegetation are similar to those in the Espenberg Coast. Photograph
Cape Deceit Coast	Low-lying (0–50 m), salt-affected coastal areas along the southern margin of Kotzebue Sound dominated by marine beaches, eroding bedrock headlands, and unconsolidated tundra bluffs. Beaches have well-drained gravelly soils that support early successional halophytic colonizers. Eroding bluffs and backshore areas sandy to loamy soils that support Elymus meadows and crowberry tundra. Photograph

Subsection [1]	Characteristics
Bering Straits Lower Coastal Plain	Flat, low-lying (0–60 m) coastal plain along the Bering Straits comprised of alluvial, lacustrine, and marine deposits extensively modified by thaw lake processes and capped with thick loess deposits. Most of the area was formed by a marine transgression ~125 ybp that raised sea levels to 10–15 m amsl. Underlying permafrost is extremely ice-rich, and thermokarst lakes formed from thawing permafrost are abundant. Thaw basins have seasonally flooded, saturated, loamy to peaty soils that support wet sedge meadow tundra. Upland broad ridges and pingos have saturated to moderately well-drained, acidic silty soils that support tussock tundra and sedge-willow tundra. Lake shores and exposed pond bottoms with better-drained soils occasionally support closed low willow scrub and bluejoint meadows. Shallow ponds are often support fresh grass marsh. Photograph
Bering Straits Upper Coastal Plain	An undulating, higher portion (10–100 m) of the coastal plain along the Bering Straits that is similar to the lower coastal plain, except that thaw lakes are less common and the drainage is better integrated so that surface water is less abundant. The upper coastal plain was affected by a large marine transgression ~225 ybp that raised sea levels to ~35 m amsl. Soils and vegetation are similar to those found on the lower coastal plain, except tussock tundra and drainages supporting closed alder and willow scrub are more common. Photograph
Bering Straits Lower Flood-plains[1]	Low-gradient floodplains (0–60 m) formed from meandering freshwater streams that drain into the Chucki Sea. The stratified alluvial deposits include gravelly and sandy channel deposits, sandy levees and point bars, silty and organic-rich overbank deposits, terraces, and oxbows. Permafrost in the channel deposits is ice-poor or may be absent, while substantial ice lenses develop in the later floodplain stages. Margins of the active channel and the active floodplain have well-drained gravels and sands that support partially vegetated areas with pioneering grasses and legumes, or low and tall willow scrub. Inactive and abandoned floodplains have saturated loamy soils with moderately thick organic horizons that support wet sedge meadow tundra. Photograph
Goodhope Bay Lower Coastal Plain	Flat, low-lying coastal plain (0–30 m) along Kotzebue Sound formed during the last major marine transgression. Geomorphology, soils, and vegetation as similar to those described for the Bering Straits Lower Coastal Plain. Photograph
Goodhope Bay Upper Coastal Plain	An undulating, higher portion (10–100 m) of the coastal plain along Kotzebue Sound from Cape Espenberg to Eschscholtz Bay. Geomorphology, soils, and vegetation are similar to those described for the Bering Straits Lower Coastal Plain, but differ in that tussock tundra and shrub birch-ericaceous shrub tundra are prevalent. Due to its proximity to glacial outwash from the Brooks Range, the loess cap presumably is thicker. Photograph
Goodhope Bay Lower Flood-plains[1]	Low-gradient floodplains (0–70 m) formed from meandering freshwater streams. Geomorphology, soils, and vegetation are similar to those described for the Bering Straits Lower Floodplains. The floodplains are less exposed to storm surges and presumably have a slightly warmer climate as indicated by the growth of alders and balsam poplar. Photograph
Devil Uplands	Gently sloping uplands (10–250 m) and cinder cones formed by volcanic activity during the Pleistocene. Volcanic deposits include basaltic ash, massive pyroclastic flows, and explosion breccia. The explosive eruptions formed some of the largest maars (shallow broad craters) on earth. The Devil Mountain Lake maar was formed circa 17,500 ybp, the South and North Killeak Lake Maars at >40,000 ybp, and the Whitefish maar around 100,000-200,000 ybp. Sandy ash from the last eruption buried thick carbonate loess deposits and was subsequently covered by thin loess deposits. Gentle slopes have saturated, acidic, loamy soils with thick surface organic horizons that support tussock tundra and mesic shrub birch-ericaceous shrub. Exposed ridges have sandy soils developed from the ash and support Dryas-lichen tundra. Thaw basins and swales have saturated, acidic, loamy soils with thick surface organic horizons that support wet sedge meadow tundra. Drainages are dominated by closed tall and low willow scrub. Lake margins and beaches support early successional forbs, crowberry tundra, and alder-willow scrub. Photograph
Goodhope Upper Flood-plains[1]	High-gradient floodplains (25–125 m) formed from braided or headwater streams. Deposits include gravelly active channel deposits, point and lateral bars, and overbank fines; oxbows are lacking. Streams originate in areas with carbonate bedrock. Soils are poorly described, but reportedly included saturated loamy soils with thick organic horizons. Vegetation is dominated by low willow scrub and partially vegetated gravel bars. Photograph

Subsection [1]	Characteristics
Goodhope Foothills	Gently rounded foothills and slopes (10–600 m) of the Goodhope Mountains that are underlain by metamorphic carbonate and noncarbonate rocks, including marble, pelite, calc schist, mafic schist. Most of the area, however, is mantled with loess and colluvium. Rocky ridges and outcrops have well-drained, poorly developed alkaline soils that support Dryas-lichen and sedge-Dryas tundra. Colluvial slopes have saturated, loamy soils with thick organic horizons that frequently are highly turbated from frost action and gelifluction. Vegetation is dominated by sedge-Dryas tundra. Drainages have saturated loamy soils with thick organic horizons and support closed low willow scrub. Alder occasionally is present. Photograph
Goodhope Mountains	Rounded mountains (60–630 m) near Goodhope Bay comprised of metamorphic carbonate and noncarbonated rocks, including marble, pelite, calcareous schist, and mafic schist. Lower slopes and saddles are mantled with stratified, rocky colluvium. Rocky ridges and outcrops have excessively drained, poorly developed alkaline soils that support Dryas-lichen and sedge-Dryas tundra, or occasionally are barren. Alkaline-adapted plants predominate, including *Dryas integrifolia, Rhododendron lapponicum, Artemisia senjavinensis, Papaver walpolei, Parrya nudicaulis, Phlox sibirica*, and *Saxifraga oppositifolia*. Colluvial slopes have saturated loamy soils with thick organic horizons that frequently are highly turbated from frost action and gelifluction. Vegetation is dominated by tussock tundra and sedge-Dryas tundra. Drainages have saturated loamy soils with thick organic horizons and support closed low willow scrub. Photograph
Serpentine Mountains	Rounded to prominent fellfield mountains (110–780 m) near the headwater of the Serpentine River comprised of felsic igneous and metaplutonic rocks including monzogranite, syenogranite, and granitic orthogneiss. Region includes a small disjunct mountain near the upper Inmachuk River comprised of monzogranite, quartz monzonite, and syenite. Rocky ridges have excessively drained, strongly acidic soils that support Dryas-lichen and sedge-Dryas tundra, or occasionally are barren. Acid-adapted plants predominate, including *Dryas octopetala, Rhododendron camtschaticum, Carex rariflora, C. microchaeta, Luzula tundricola, Geum glaciale, Oxytropis mertensiana, Primula stricta*, and *Saxatilis serpyllifolia*. Lower slopes and saddles have saturated, loamy to rocky soils with moderately thick organic horizons support tussock tundra, mesic shrub birch-ericaceous scrub, and low shrub birch-willow scrub. Drainages support willow and alder scrub. Photograph
York Upper Floodplains	High-gradient floodplains (15–60 m) formed from braided or headwater streams in the York Highlands. Geomorphology, soils, and vegetation are similar to those described for the Goodhope Upper Floodplains. Photograph
York Foothills	Gently rounded foothills and slopes (20–350 m) on the northern side of the York Mountains that are underlain by metamorphic carbonate and noncarbonate rocks, including marble, calc schist, mafic schist. Colluvium and loess mantle most of the area. Soils and vegetation are similar to those described for the Goodhope Foothills. Photograph
York Mountains	Rounded mountains western Seward Peninsula comprised of sedimentary and metamorphic-carbonate and noncarbonate rocks, including limestone, dolomitic limestone, marble, pelite, calc schist, mafic schist, chlorite schist, graywacke, slate, and calcareous siltite. Geomorphology, soils, and vegetation are similar to those described for the Goodhope Mountains. (No photograph available.)
Wales Mountains	Rounded to steep mountains in two small regions near the Wales coast, comprised of felsic igneous rocks, including granite and granitic gneiss. Soils, and vegetation are like those in the Serpentine Mountains. (No photograph available)
Agiapuk Hills	Gently rounded foothills and slopes on the southern side of the York Mountains that are underlain by sedimentary carbonate rocks, mostly limestone. Soils and vegetation are like those in the Goodhope Foothills. (No photograph available.)
Kougarok Foothills	Gently rounded foothills and slopes (60–290 m) on the south side of the York Mountains that are underlain by carbonate and noncarbonate metamorphic rocks, including marble, quartz-graphite schist, chlorite-albite schist, calcareous schist, pelite, and mafic schist. Most hills are mantled with colluvium. Soils and vegetation are similar to those described for the Goodhope Foothills. (No photograph available.)
Kugruk Foothills	Rounded hills (120–490 m) near the Kugruk River that are underlain by carbonate and noncarbonate metamorphic rocks, including marble, pelite, quartz schist, calcareous schist, mafic schist, and dolostone. Most of the area is mantled with loess and colluvium. Geomorphology, soils, and vegetation are similar to those described for the Goodhope Foothills, except that white spruce forests are common in the southeast corner. Photograph

Subsection[1]	Characteristics
Kugruk Mountains	Rounded mountains near the Kugruk River that are underlain by carbonate and noncarbonated metamorphic rocks including marble, schiest, and dolostone. Geomorphology, soils, and vegetation are similar to those described for the Goodhope Mountains, except that white spruce forests are common in the southeast corner. (No photograph available.)
Imuruk Lowlands	Low-lying (100–350 m) areas on the Imuruk Plateau that are dominated by organic, colluvium, and loess, and alluvial deposits. Thaw lakes and ice-wedge polygons are prevalent. Most of the area has saturated peat soil that support wet sedge meadow tundra. Drainages support closed tall alder-willow scrub. Photograph
Imuruk Uplands	Gently rolling hills (70–550 m) on the Imuruk Plateau that are underlain by Tertiary volcanic basalt. Most of the region is mantled by colluvium and loess. Slopes have saturated, acidic, loamy soils with moderately thick organic horizons that support mixed shrub-sedge tussock tundra and mesic shrub birch-ericaceous scrub. Flat summits and toeslopes have very poorly drained peat soils that support wet sedge meadow tundra and sedge-birch tundra. Drainages support alder and willow scrub. Thaw lakes are uncommon, except for Imuruk Lake. Photograph
Imuruk Lava Flows	Flat to gently sloping (50–530 m) areas on the Imuruk Plateau formed by the Lost Jim and Gosling lava flows composed of alkali olivine basalt and vent deposits. The young Holocene and late Pleistocene flows have little soil development and are largely barren with scattered forbs and lichens. Occasional small patches of loess support ericaceous shrub-lichen tundra. Small drainages and sunken depressions support open alder scrub. Photograph
Kuzitrin Floodplain[1]	Low-gradient floodplains (40–120 m) formed from meandering freshwater streams. The stratified alluvial deposits include gravelly and sandy channel deposits, sandy levees and point bars, silty and organic-rich overbank deposits, terraces, and oxbows. Permafrost in the channel deposits is ice-poor or absent, while substantial ice lenses aggrade in the later floodplain stages. Margins of the active channel and the active floodplain have well-drained gravelly or sandy soils that support partially vegetated areas with early successional grasses and legumes, or closed to open, low and tall willow scrub. Inactive and abandoned floodplains have saturated loamy soils with moderately thick organic horizons that support wet sedge meadow tundra. The region lacks balsam poplar or spruce forests. Photograph
Kuzitrin Lowlands	Low-lying areas (40–210 m) in the Kuzitrin River valley formed from alluvial, colluvial, and loess deposits. Thaw lakes and ice-wedge polygons are prevalent. Most of the region has saturated peaty soils that support wet sedge meadow tundra. Better-drained permafrost plateaus and interfluves have saturated, loamy soils with thick organic horizons that support tussock tundra. Photograph
Koyuk Lowlands	Low-lying areas (200–350 m) in the Koyuk River valley formed from alluvial, colluvial, and loess deposits. Tertiary volcanic basalt outcrops occasionally occur. Soils and vegetation are similar to those described for Kuzitrin Lowlands, except that balsam poplar or spruce forests occasionally occur on well-drained soils. Photograph
Koyuk Hills	Gently round hills on the eastern slopes of the Darby Mountains, comprised of metamorphic carbonate and noncarbonated rocks. White spruce forests are common on gentle slopes with well-drained soils. Alder and willow thickets are common in drainages. (No photograph available.)
Bendeleben Northern Foothills	Hills and gentle slopes (50–710 m) along the northern margin of the Bendeleben Mountains comprised of colluvial deposits and occasional outcrops of felsic igneous and noncarbonate metamorphic rocks, including monzogranite, migmatite, gneiss, and schist. Frost-riven fellfields, large gelifluction lobes, and watertracks are prevalent. Exposed, dry ridges and backslopes have excessively drained acidic soils that support Dryas-lichen tundra. Slopes have somewhat well-drained to saturated, acidic soils that support mesic shrub birch-ericaceous scrub and ericaceous scrub. Swales and drainages have saturated organic soils that support alder and willow scrub and sedge-birch tundra. Photograph
Bendeleben Eastern Mountains	Rugged mountains (250–990 m) in the eastern portion of the Bendeleben Mountains formed from felsic igneous and noncarbonate metamorphic rocks, dominated by monzogranite, gneiss, and schist, with minor amounts of migmatite, granodiorite, and quartz monzodiorite. The area was glaciated during the Pleistocene and cirque lakes are abundant. Many exposed headwalls are barren, while more protected dry ridges and backslopes have excessively drained, strongly acidic soils that support Dryas-lichen tundra. Lower slopes have somewhat well-drained to saturated, acidic soils that support mesic shrub birch-ericaceous scrub and ericaceous scrub. Swales and drainages have saturated organic soils that support wet sedge meadow tundra. Photograph

Subsection [1]	Characteristics
Bendelebe nWestern Mountains	Rugged mountains (230–1010 m) in the western portion of the Bendeleben Mountains formed from felsic igneous and noncarbonate metamorphic rocks, dominated by gneiss, schist, and monzogranite, with small amounts of syenogranite and quartz diorite. The area was glaciated during the Pleistocene. Geomorphology, soils, and vegetation are similar to those described for the Bendeleben Eastern Mountains. Photograph
Darby Western Mountains	Rounded mountains (230–740 m) in the western portion of the Darby Mountains and in a narrow, central portion of the Bendeleben Mountains formed from carbonate metamorphic rocks, including marble, calcareous schist and mafic schist. The area was glaciated during the Pleistocene. The climate on the southern Seward Peninsula is somewhat wetter than the northern portion. The alkaline soils and vegetation are similar to those described for the Goodhope Mountains. Photograph
Darby Eastern Mountains	Rugged mountains of the Darby pluton comprised of monzogranite, granodiorite, and some mafic igneous rocks. The area was glaciated during the Pleistocene. Geomorphology, soils, and vegetation are similar to those described for the Bendeleben Eastern Mountains. (No photograph available.)

[1] Floodplains were differentiated as "Detailed Subsections", portions of a subsection not large enough to map at the subsection level.

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Table 3. Distribution (% of area) of landcover types among subsections, Bering Land Bridge National Preserve, western Alaska. Bolded values indicate land cover types that have large differences among subsections. Blanks indicate not present.

Subsection[1]	Silty Water	Clear Water	Wet Herba-ceous	Mesic/ Dry Herbaceous	Closed Low Shrub - Alder/ Willow	Open Low Shrub - Alder/ Willow	Dwarf Shrub - Tussock Tundra	Closed Low Shrub - Dwarf Birch/ Erica-ceous	Open Low Shrub - Dwarf Birch/ Erica-ceous	Dwarf Shrub - Lichen Domin-ated	Sparse Vegeta-tion	Barren	Total[2]
Shishmaref Coast	**1.5**	**1.4**	0.6	0.1	0.1	<0.1	<0.1	<0.1	0.1		<0.1	<0.1	3.8
Espenberg Coast	<0.1	0.2	0.3	<0.1	0.1	<0.1	<0.1	<0.1	<0.1		<0.1		0.7
Goodhope Bay Coast	<0.1	0.3	0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1		<0.1		0.5
Cape Deceit Coast	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1		<0.1		0.1
Wales Coast	<0.1	<0.1	<0.1	<0.1	<0.1		<0.1		<0.1		<0.1	<0.1	<0.1
Bering Straits Lower Coastal Plain	0.4	1.2	**6.0**	**3.0**	0.5	0.1	**0.6**	0.3	**2.3**		0.1	0.1	14.5
Goodhope Bay Lower Coastal Plain	<0.1	0.1	0.3	0.3	0.1	<0.1	0.1	0.1	0.1		<0.1		1.0
Goodhope Bay Upper Coastal Plain	<0.1	0.3	**1.4**	**3.7**	0.5	0.2	**2.0**	**1.1**	**2.6**		<0.1	<0.1	11.7
Bering Straits Upper Coastal Plain	0.1	0.6	**2.6**	**3.2**	0.6	0.2	**1.1**	0.4	**2.9**		<0.1	<0.1	11.8
Bering Straits Lower Floodplains[1]	<0.1	0.1	0.2	0.1	0.3	<0.1	<0.1	0.1	0.2		<0.1	<0.1	1.0
Goodhope Bay Lower Floodplains	<0.1	<0.1	0.1	<0.1	0.1	<0.1	<0.1	0.1	0.1		<0.1	<0.1	0.4
Goodhope Upper Floodplains[1]		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1		<0.1	<0.1	0.1
Kuzutrin Floodplain		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1		<0.1	<0.1	0.2
York Upper Floodplains[1]		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1		<0.1	<0.1	<0.1
Imuruk Lowlands	0.6	0.1	0.2	0.5	0.1	<0.1		0.2	0.9	0.4	<0.1	<0.1	3.0
Kuzutrin Lowlands	<0.1	0.1	0.1	0.6	0.1	<0.1	0.2	0.2	0.6	<0.1	<0.1	<0.1	2.0
Koyuk Lowlands	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.1	0.1	<0.1	<0.1	0.3
Imuruk Lava Flows	<0.1	<0.1	0.2	0.1	0.2	<0.1	<0.1	0.2	0.3	0.3	2.4	<0.1	3.7
Imuruk Uplands	<0.1	0.1	0.1	**2.7**	0.4	**0.4**		**1.7**	**4.1**	1.1	0.1	<0.1	10.6
Devil Uplands	<0.1	0.7	0.5	**1.5**	0.4	0.2	**0.5**	**1.2**	**2.3**	<0.1	<0.1	<0.1	7.3
York Foothills	<0.1	<0.1	0.1	0.1	<0.1	0.1	<0.1	<0.1	0.3	0.1	<0.1		0.8
Kougarok Foothills			<0.1	0.1	<0.1	<0.1	<0.1	0.1	0.1	<0.1	<0.1		0.3
Goodhope Foothills	<0.1	<0.1	0.1	**4.0**	**0.7**	**0.5**	0.2	**2.2**	**4.3**	**0.8**	<0.1	<0.1	12.9

Kugruk Foothills	<0.1	<0.1	<0.1	0.1	0.3	0.2		0.3	0.4	0.1	<0.1	<0.1	1.5
Bendeleben Northern Foothills	<0.1	<0.1	<0.1	0.5	0.3	0.2	<0.1	0.6	**1.1**	**0.7**	0.1	<0.1	3.5
Goodhope Mountains	<0.1	<0.1	0.1	**1.2**	0.3	0.2	<0.1	0.4	0.8	**2.0**	0.2	<0.1	5.1
Darby Western Mountains			<0.1	<0.1	<0.1	<0.1		<0.1	<0.1	<0.1	<0.1	<0.1	0.1
Serpentine Mountains	<0.1	<0.1	<0.1	0.1	0.1	0.1		0.2	0.3	0.3	0.2	<0.1	1.2
Bendeleben Western Mountains			<0.1	<0.1	<0.1	<0.1		<0.1	0.1	0.2	**0.3**	<0.1	0.7
Bendeleben Eastern Mountains	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1		<0.1	0.1	0.2	**0.6**	<0.1	0.9
Total	2.8	5.1	13.1	22.0	5.5	2.6	4.8	9.4	24.1	6.2	4.1	0.3	100

[1] Detailed subsections differentiate floodplains within a subsection, these were grouped with the adjacent subsection at the subsection level.
[2] Shadows cover <0.1% of area.

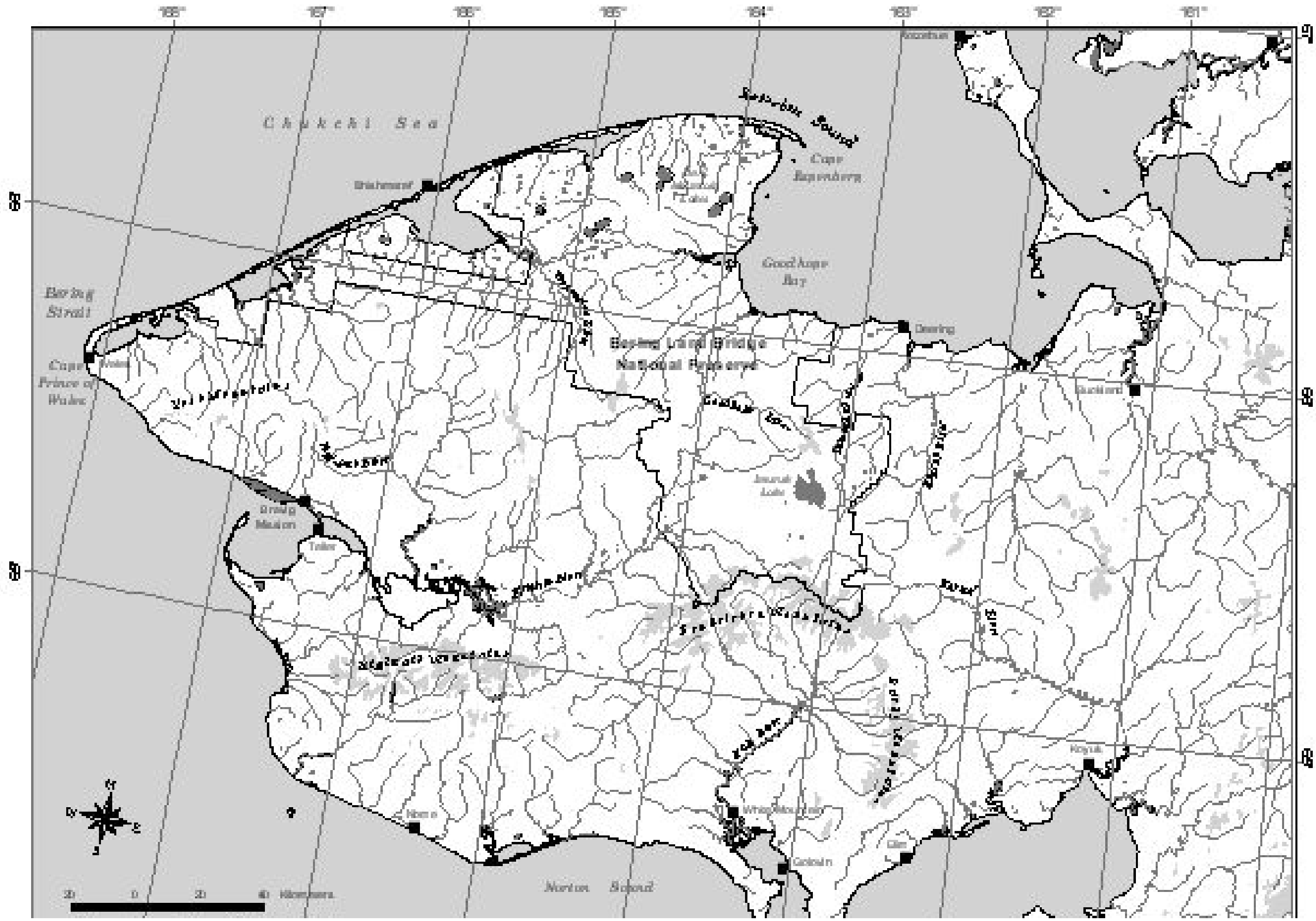

Figure 1. Location of the Bering Land Bridge National Preserve, western Alaska

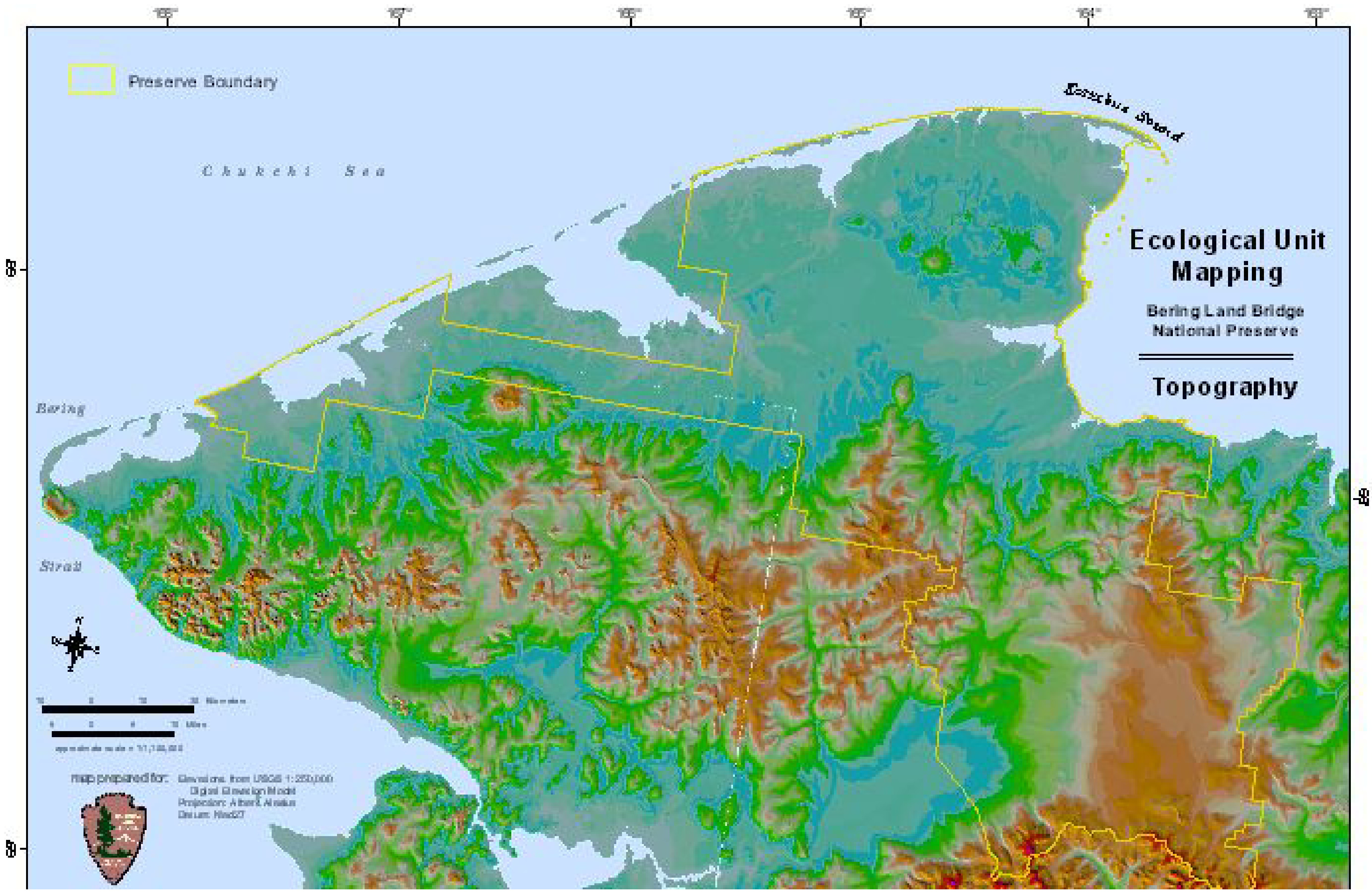

Figure 2. Map of topography surrounding the Bering Land Bridge National Preserve, western Alaska.

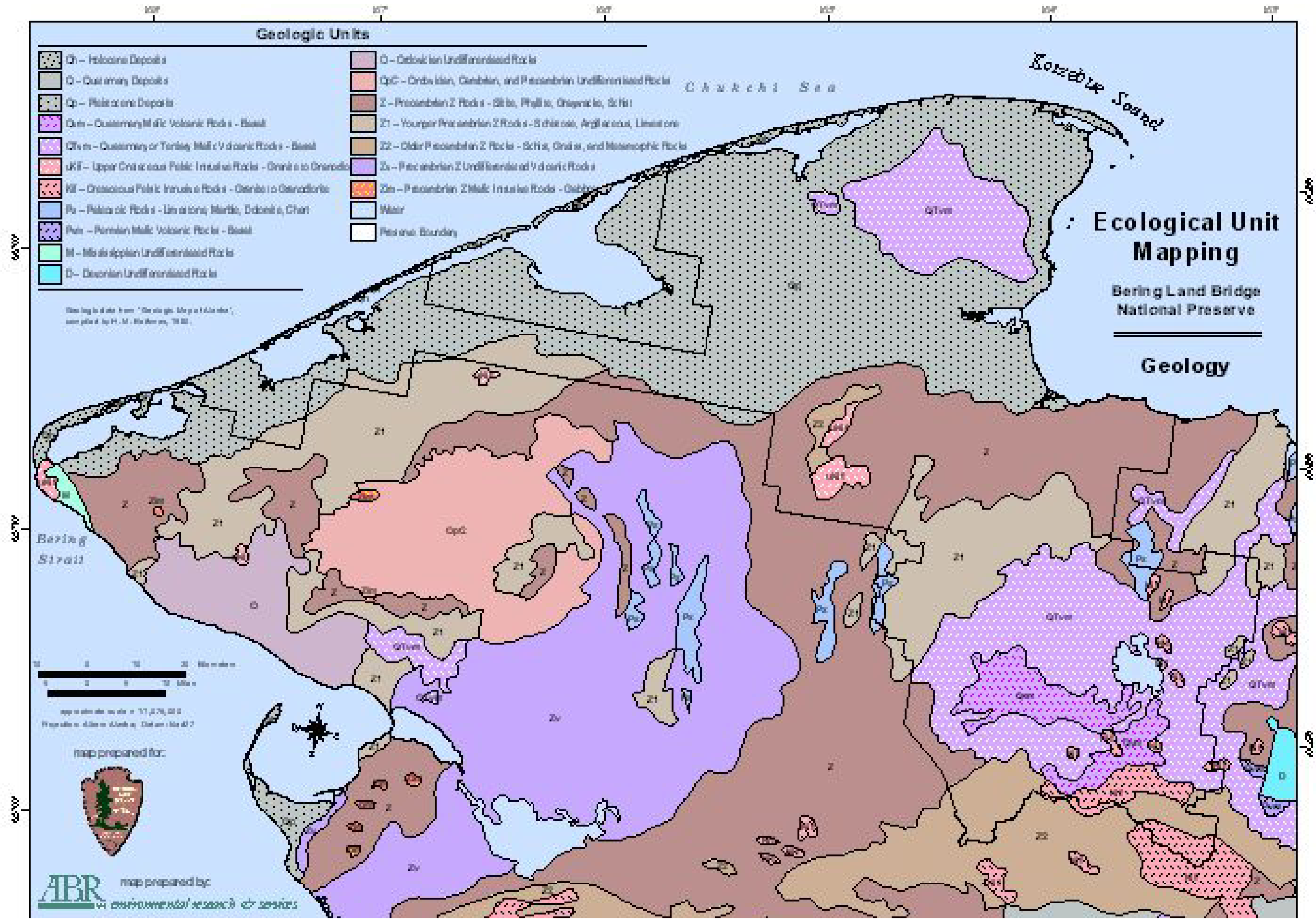

Figure 3. Map of bedrock geology surrounding the Bering Land Bridge National Preserve, Western Alaska

Figure 4. Oblique aerial photographs of representative subsections within the Bering Land Bridge National Preserve, western Alaska. Photographs represent the Espenberg Coast (upper left), Bering Straits Lower Coastal Plain (upper right), Bering Straits Lower Floodplains (middle left), Imuruk Uplands (middle right), Goodhope Mountains (lower left), and Bendeleben Eastern Mountains (lower right).

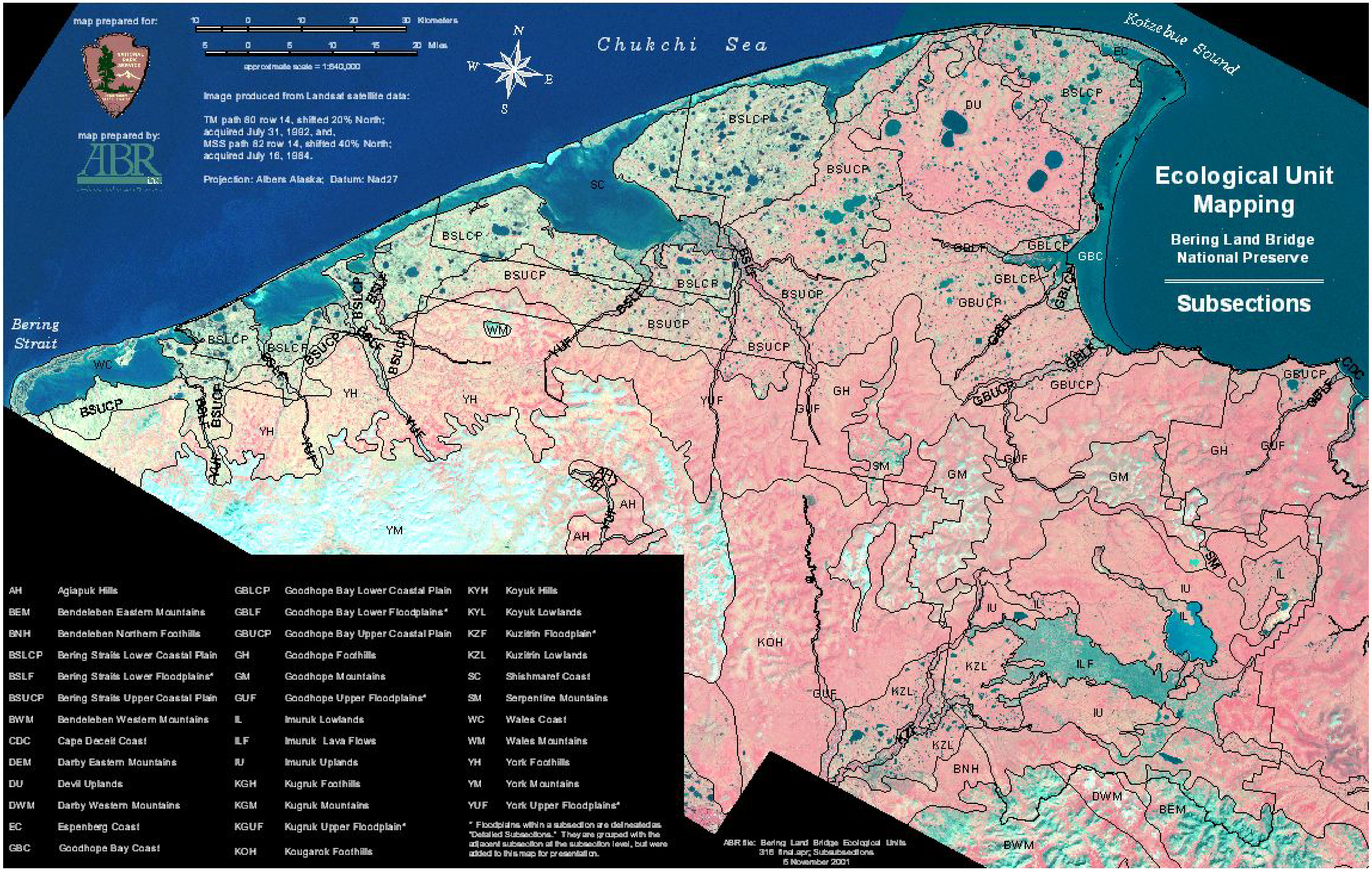

Figure 5. Map of subsections within the Bering Land Bridge National Preserve, western Alaska.

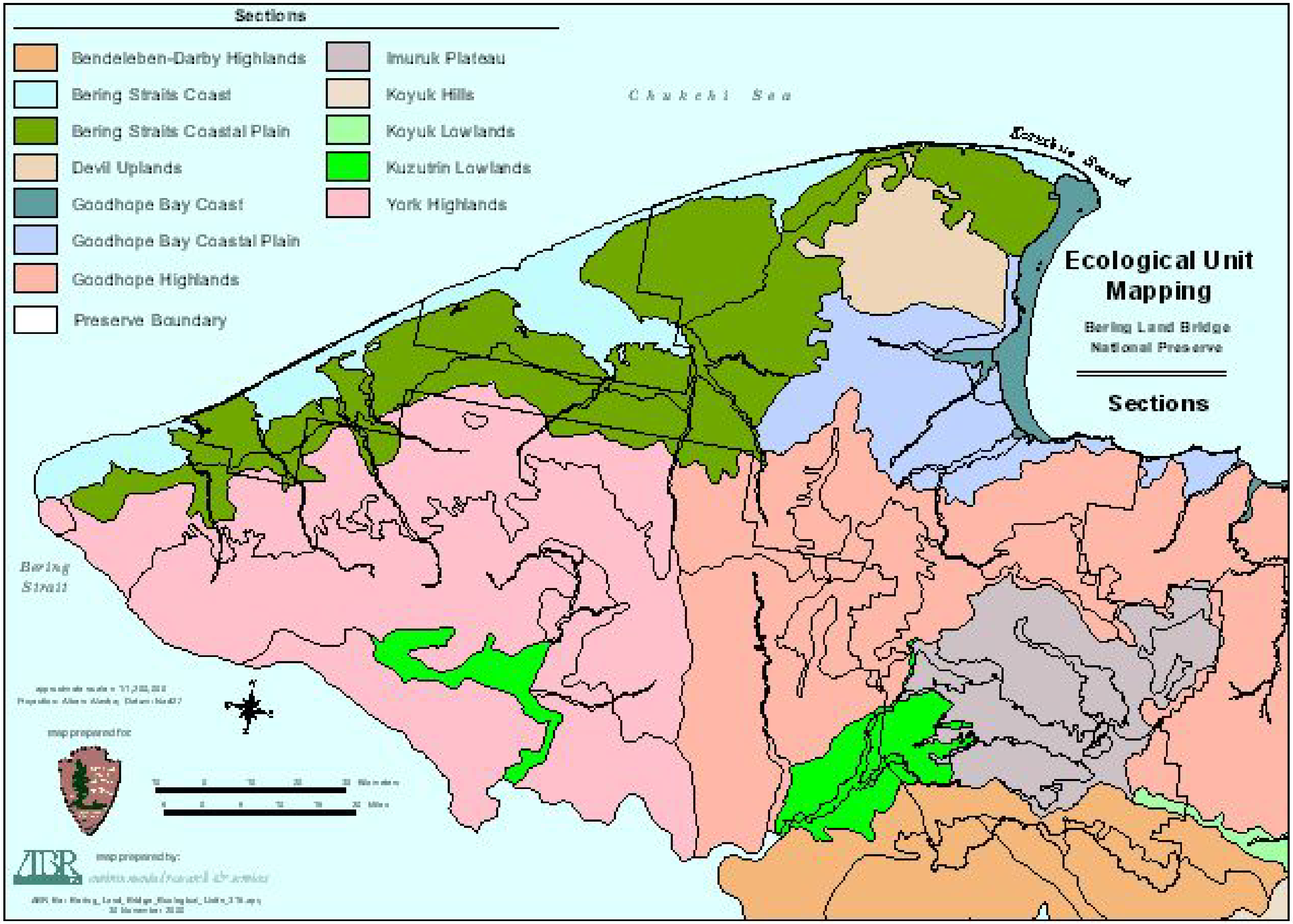

Figure 6. Map of sections with subsection subdivisions within the Bering Land Bridge National Preserve, western Alaska.

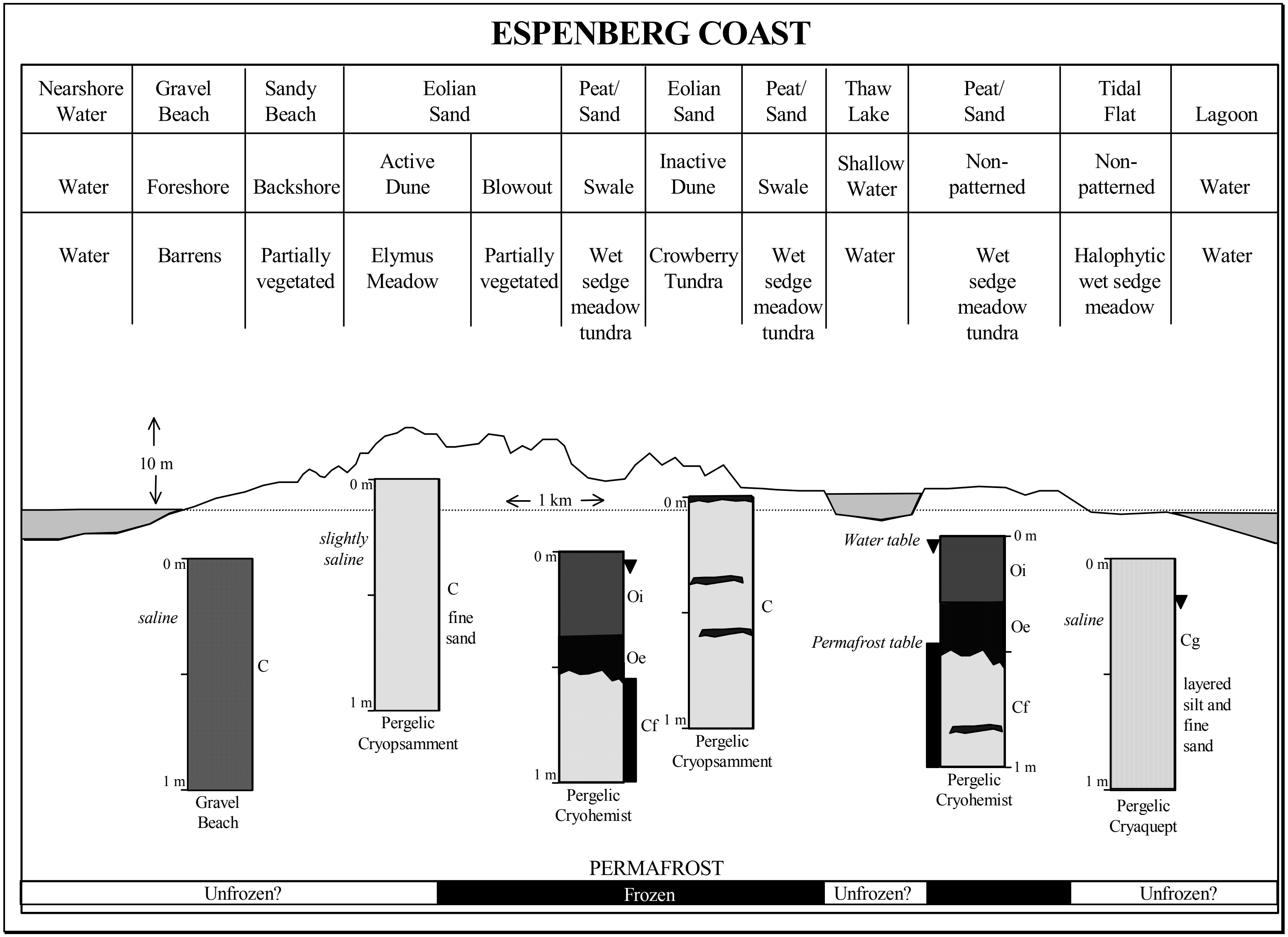

Figure 7. A generalized toposequence illustrating relationships among topography, geomorphology, permafrost, soils, and vegetation within the Espenberg Coast subsection.

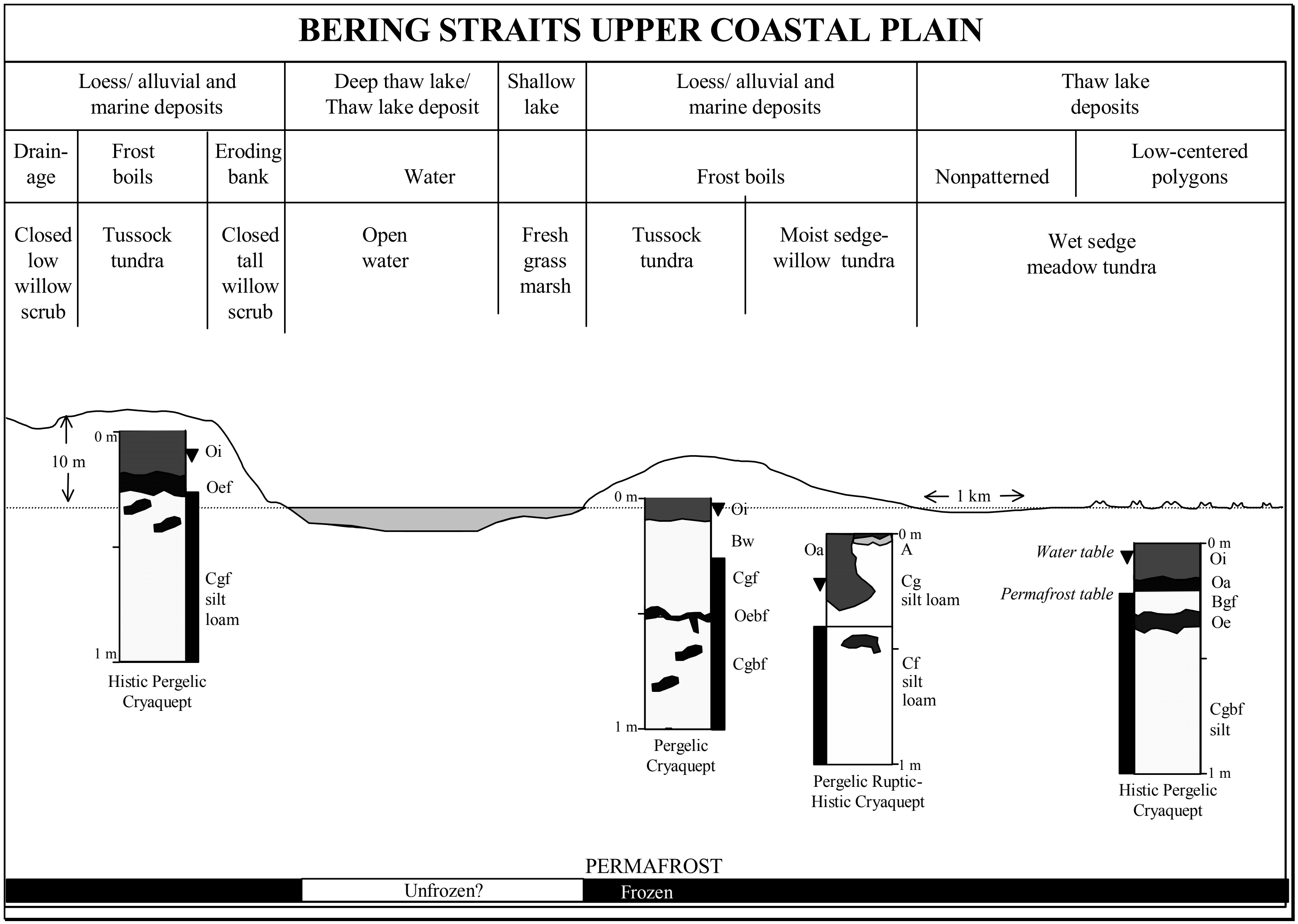

Figure 8. A generalized toposequence illustrating relationships among topography, geomorphology, permafrost, soils, and vegetation within the Bering Straits Upper Coastal Plain subsection.

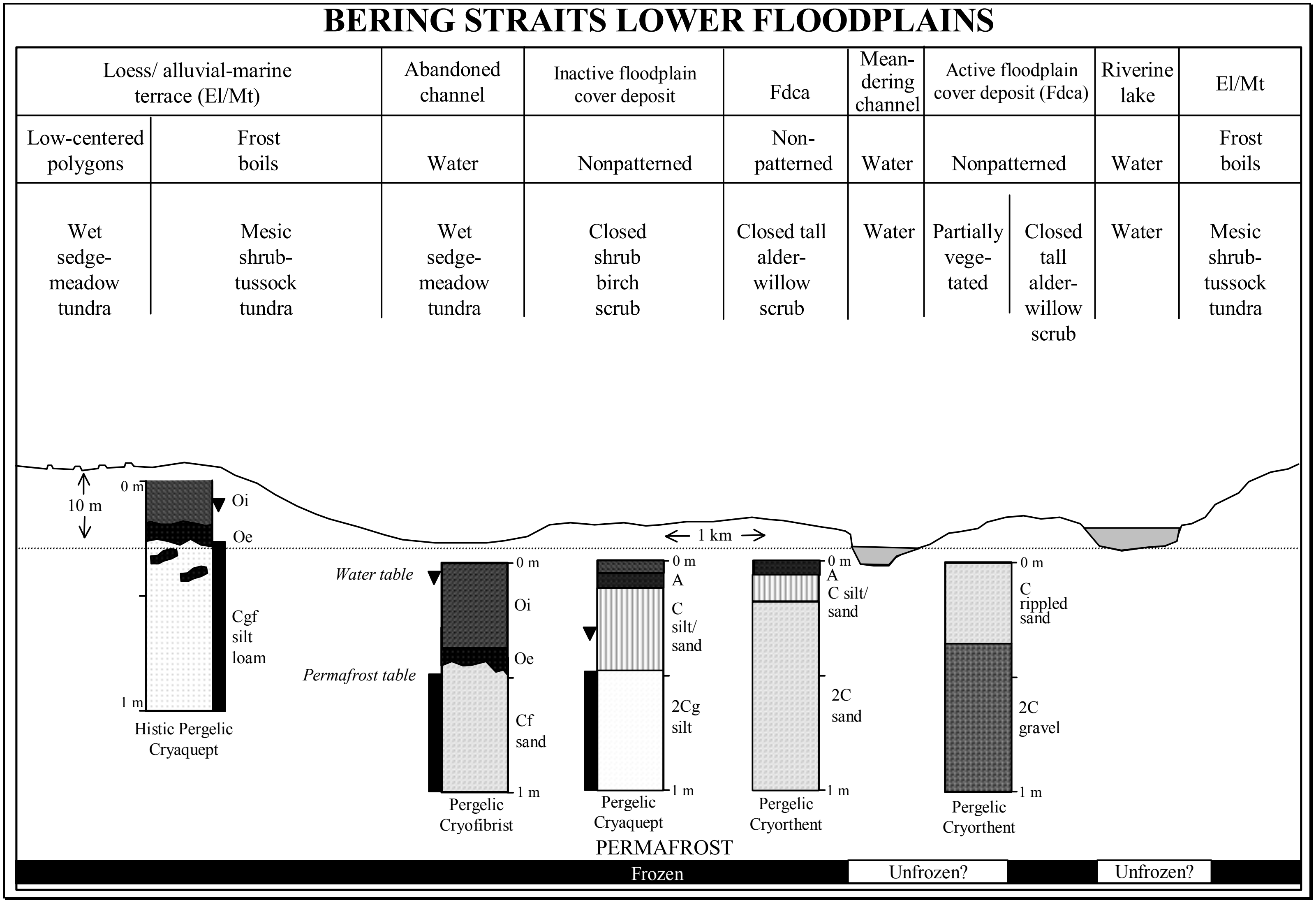

Figure 9. A generalized toposequence illustrating relationships among topography, geomorphology, permafrost, soils, and vegetation within the Bering Straits Lower Floodplains subsection

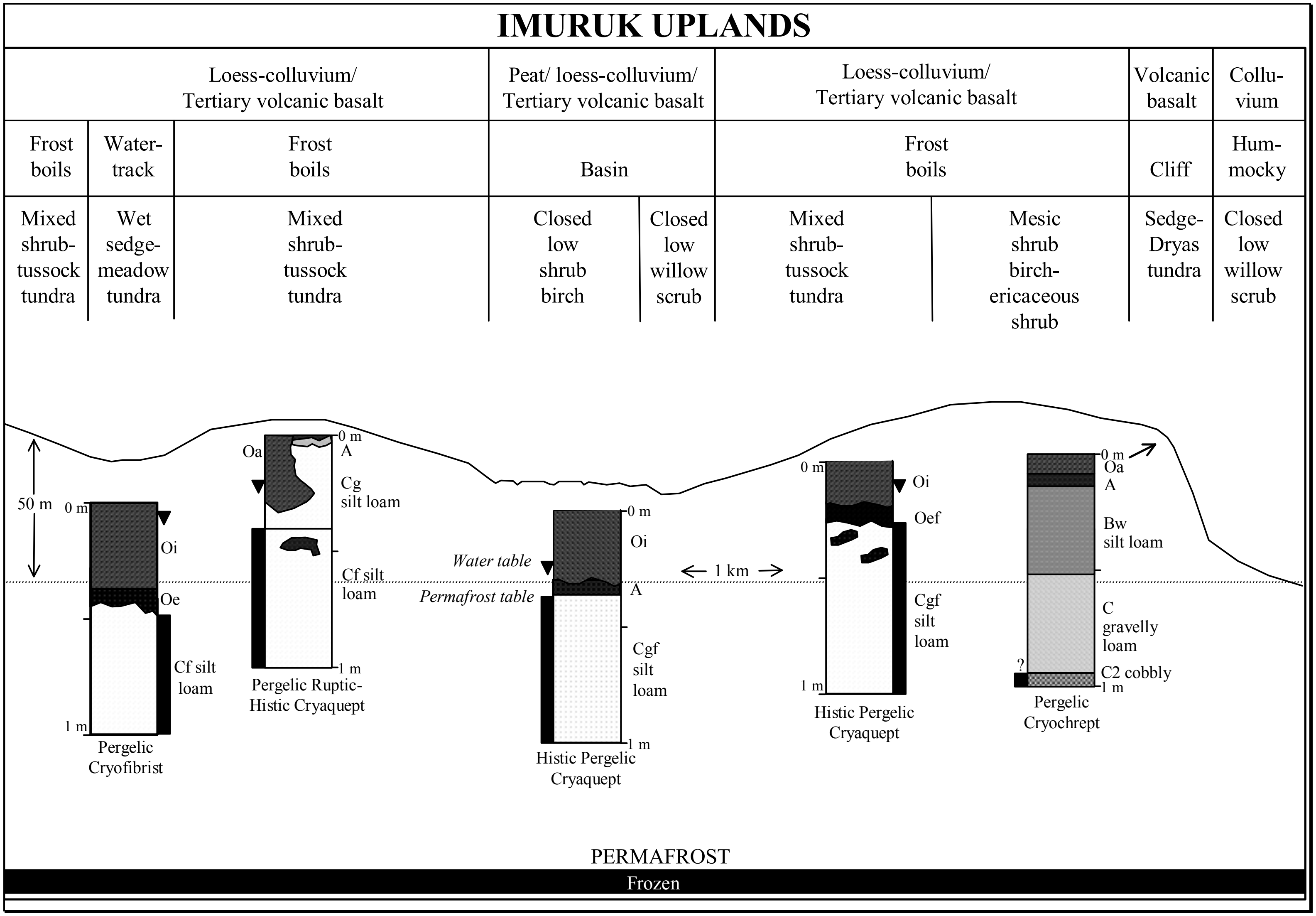

Figure 10. A generalized toposequence illustrating relationships among topography, geology, geomorphology, permafrost, soils, and vegetation within the Imuruk Upland subsection.

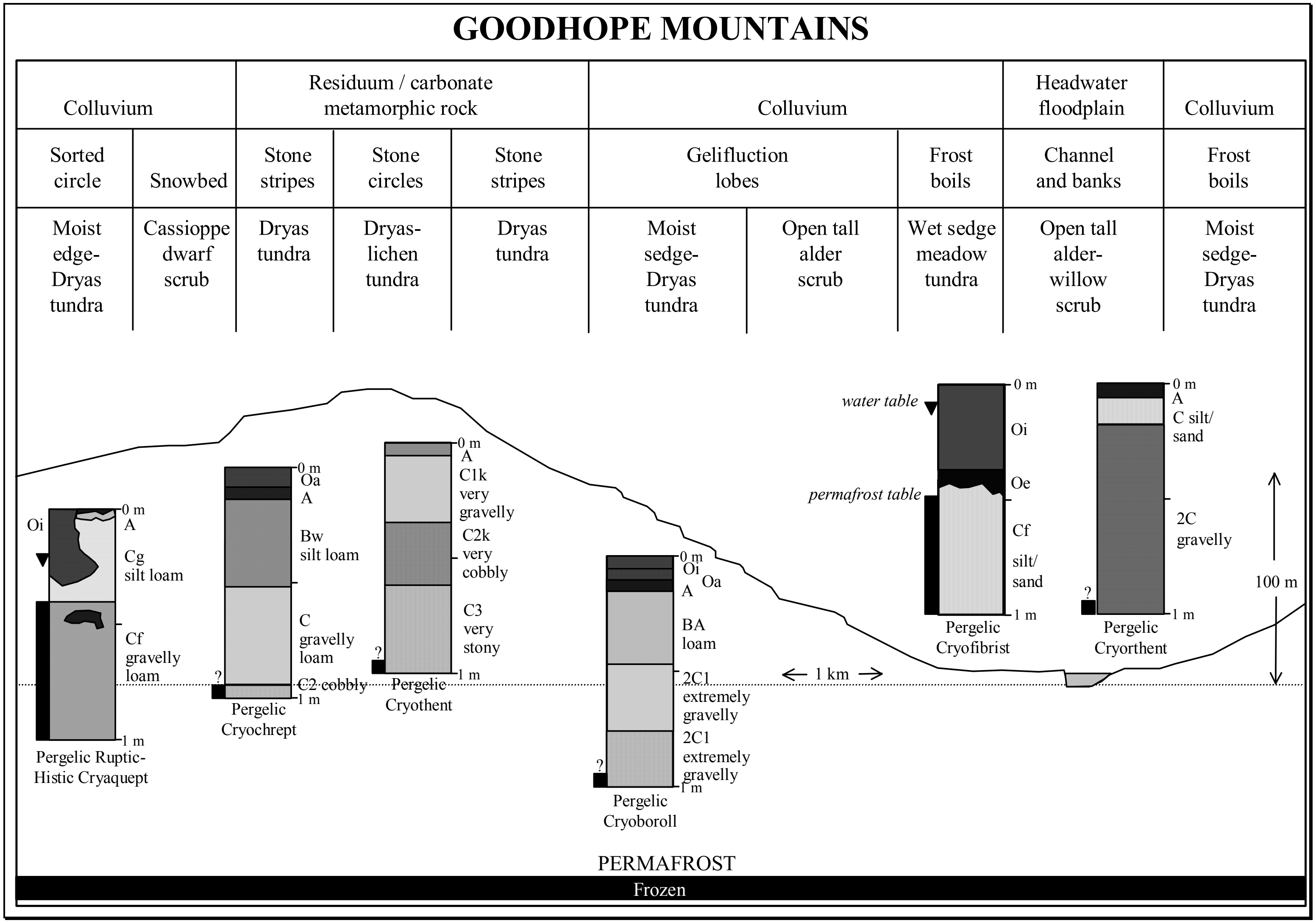

Figure 11. A generalized toposequence illustrating relationships among topography, geology, geomorphology, permafrost, soils, and vegetation within the Goodhope Mountains subsection.

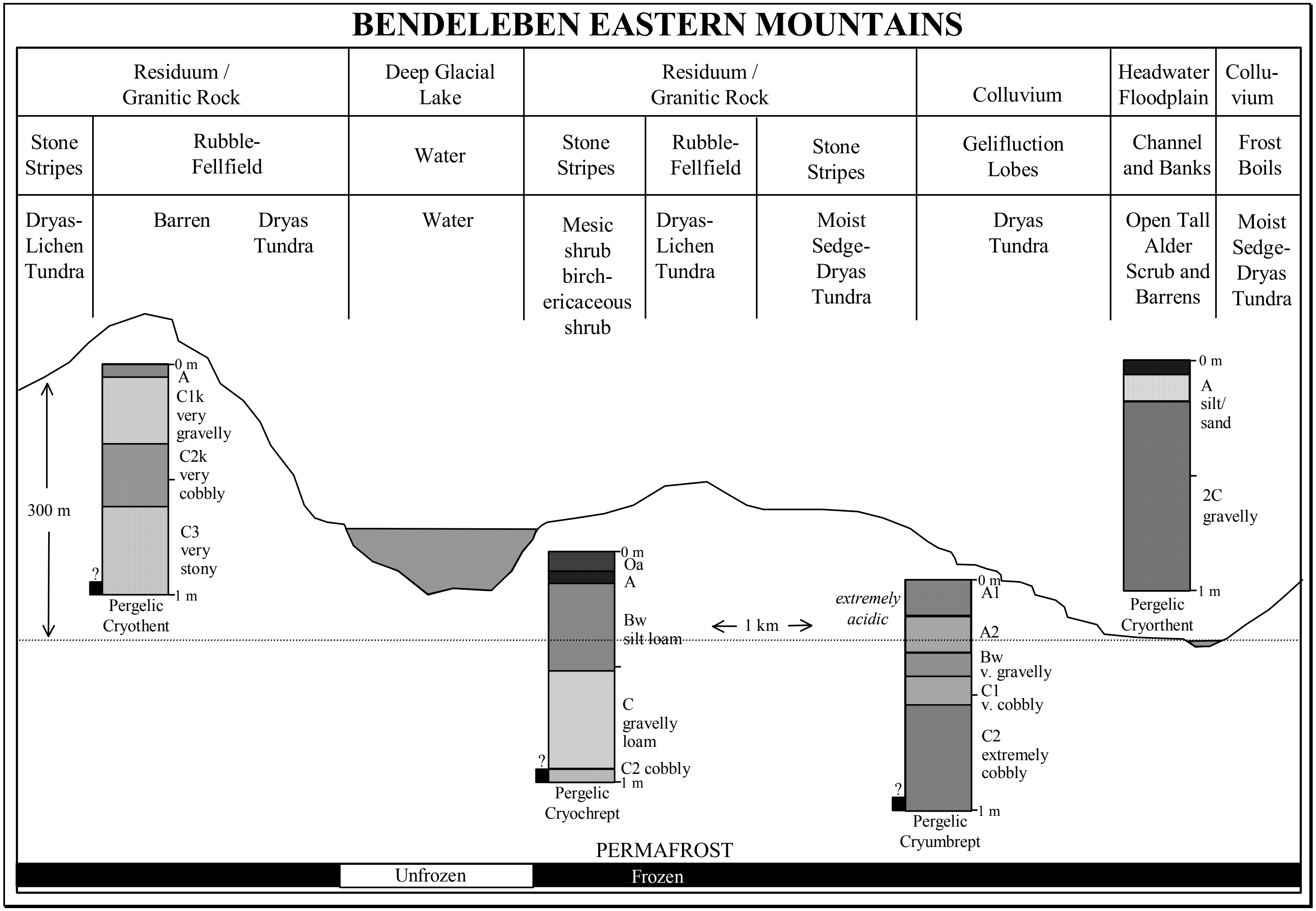

Figure 12. A generalized toposequence illustrating relationships among topography, geology, geomorphology, permafrost, soils, and vegetation within the Bendeleben Eastern Mountains subsection.

APPENDIX 1. NUMBER OF OBSERVATIONS IN LITERATURE DATABASE (BELA LANDSCAPE COMPONENT DATABASE.XLS) FOR EACH AUTHOR BY SUBSECTION AND LANDSCAPE COMPONENT.

Sub-section	Component	References
BEM	Geology	(3) Till et al. 1986;
	Geomorphology	(1) Hollowaychuk and Smeck 1979;(1) Kaufman et al. 1991;(1) Matthews 1974;
	Soils	(5) Van Patten 1990;
	Vegetation	(5) Racine and Anderson 1979;(5) Swanson et al. 1985;
BNH	Geology	(1) Kaufman et al. 1990;(4) Till et al. 1986;
	Geomorphology	(1) Kaufman et al. 1991;(1) Matthews 1974;
	Soils	(3) Van Patten 1990;
	Vegetation	(3) Harris 1988;(1) Racine and Anderson 1979;(6) Swanson et al. 1985;(6) Welp and Sowl 1990;
BSLCP	Geomorphology	(1) Hollowaychuk and Smeck 1979;(1) Hopkins 1973;(2) Hopkins 1982;(1) Kidd 1990;
	Soils	(3) Hofle et al. 1998;(2) Van Patten 1990;
	Vegetation	(3) Hofle et al. 1998;(4) Racine 1977;(5) Swanson et al. 1985;
BSLF	Geology	(1) Till et al. 1986;
	Soils	(2) Van Patten 1990;
	Vegetation	(8) Swanson et al. 1985;
BSUCP	Geomorphology	(1) Hopkins 1973;(1) Hopkins 1982;(1) Hopkins 1988;
	Soils	(3) Van Patten 1990;
	Vegetation	(5) Racine and Anderson 1979;(8) Swanson et al. 1985;
BWM	Geology	(4) Till et al. 1986;
	Geomorphology	(1) Kaufman et al. 1991;(1) Matthews 1974;
	Soils	(14) Van Patten 1990;
	Vegetation	(3) Swanson et al. 1985;
CDC	Geology	(1) Till et al. 1986;
	Geomorphology	(1) Matthews 1974;
	Paleoecology	(1) Matthews 1974;
	Vegetation	(6) Matthews 1974;
DEM	Geology	(1) Till et al. 1986;
DU	Geology	(4) Beget et al 1996;(1) Hofle and Ping 1996;(3) Hopkins 1988;
	Geomorphology	(1) Hofle and Ping 1996;(1) Hollowaychuk and Smeck 1979;

	Paleoecology	(1) Hamilton and Brigham-Grette 1991;
	Soils	(1) Hofle and Ping 1996;(1) Hofle et al. 1998;(1) Van Patten 1990;
	Vegetation	(1) Hofle et al. 1998;(7) Racine and Anderson 1979;(13) Welp and Sowl 1990;
DWM	Geology	(5) Till et al. 1986;
EC	Geomorphology	(4) Jordan 1988;(1) Mason et al. 1995;(6) Mason et al. 1997;(1) Swanson et al. 1985;
	Soils	(3) Hofle et al. 1998;(3) Van Patten 1990;
	Vegetation	(3) Hofle et al. 1998;(3) Mason et al. 1997;(5) Racine 1977;(7) Racine and Anderson 1979;(4) Swanson et al. 1985;
GBC	Geomorphology	(1) Swanson et al. 1985;
	Vegetation	(4) Swanson et al. 1985;(1) Wright 1980;
GBLCP	Geomorphology	(1) Hollowaychuk and Smeck 1979;(1) Hopkins 1973;(2) Hopkins 1982;
	Soils	(1) Hofle et al. 1998;(1) Van Patten 1990;
GBLF	Geology	(1) Till et al. 1986;
GBUCP	Geology	(1) Till et al. 1986;
	Geomorphology	(2) Heiser and Hopkins 1995;
	Soils	(2) Van Patten 1990;
	Vegetation	(5) Swanson et al. 1985;(3) Wright 1980;
General	Climate	(1) Hofle et al. 1998;(1) Hopkins 1982;(1) Van Patten 1990;
	Geology	(1) Sainsbury 1972;
	Geomorphology	(4) Hollowaychuk and Smeck 1979;
	Paleoecology	(1) Elias et al. 1991;
	Soils	(7) Hollowaychuk and Smeck 1979;
	Vegetation	(22) Hanson 1953;(12) Markon and Wesser 1997;(8) Racine and Anderson 1979;
GH	Geology	(4) Till et al. 1986;
	Soils	(5) Van Patten 1990;
	Vegetation	(1) Racine and Anderson 1979;(5) Swanson et al. 1985;(4) Welp and Sowl 1990;(1) Wright 1981;
GM	Geology	(3) Till et al. 1986;
	Soils	(6) Van Patten 1990;
	Vegetation	(2) Racine and Anderson 1979;(5) Swanson et al. 1985;
GUF	Geology	(1) Till et al. 1986;
	Geomorphology	(1) Hollowaychuk and Smeck 1979;
	Soils	(2) Van Patten 1990;
	Vegetation	(1) Racine and Anderson 1979;(4) Swanson et al. 1985;
IL	Geology	(1) Till et al. 1986;

	Geomorphology	(2) Hopkins 1949;(1) Roeder and Graham 1979;
	Soils	(1) Van Patten 1990;
	Vegetation	(2) Swanson et al. 1985;
ILF	Geology	(3) Till et al. 1986;
	Geomorphology	(1) Hollowaychuk and Smeck 1979;
	Micro-topography	(1) Hopkins 1949;
	Soils	(1) Van Patten 1990;
	Vegetation	(1) Harris 1988;(3) Racine and Anderson 1979;(1) Swanson et al. 1985;
IU	Geology	(2) Till et al. 1986;
	Micro-topography	(2) Hopkins 1949;
	Paleoecology	(1) Colinvaux 1964;(1) Hamilton and Brigham-Grette 1991;
	Perma-frost	(4) Hopkins and Sigafoos 1950;
	Soils	(3) Racine 1977;(1) Van Patten 1990;
	Vegetation	(4) Colinvaux 1964;(3) Hopkins 1949;(4) Hopkins and Sigafoos 1950;(3) Racine 1977;(3) Racine 1980;(2) Racine and Anderson 1979;(3) Racine et al. 1983;(6) Swanson et al. 1985;
KGH	Geology	(6) Till et al. 1986;
	Soils	(2) Van Patten 1990;
	Vegetation	(1) Hanson 1953;(1) Markon and Wesser 1997;(1) Racine and Anderson 1979;
KGUF	Geology	(1) Till et al. 1986;
	Vegetation	(1) Racine and Anderson 1979;
KOH	Geology	(3) Till et al. 1986;
	Soils	(3) Van Patten 1990;
KYL	Geology	(3) Till et al. 1986;
	Vegetation	(1) Matthews 1974;(5) Swanson et al. 1985;
KZL	Geology	(1) Till et al. 1986;
	Soils	(2) Van Patten 1990;
	Vegetation	(1) Racine and Anderson 1979;
KZLF	Geology	(1) Till et al. 1986;
	Soils	(2) Van Patten 1990;
	Vegetation	(6) Swanson et al. 1985;
SC	Geomorphology	(4) Jordan 1988;(4) Mason et al. 1995;(1) Swanson et al. 1985;
	Soils	(2) Van Patten 1990;
	Vegetation	(4) Swanson et al. 1985;

SM	Geology	(5) Till et al. 1986;
	Soils	(3) Van Patten 1990;
	Vegetation	(1) Racine and Anderson 1979;(5) Swanson et al. 1985;(4) Welp and Sowl 1990;
WC	Geomorphology	(4) Jordan 1988;(2) Mason et al. 1995;
	Soils	(2) Van Patten 1990;
WM	Geology	(1) Sainsbury 1972;
YH	Geology	(1) Hudson 1977;(3) Sainsbury 1972;(2) Till et al. 1986;
	Soils	(2) Van Patten 1990;
	Vegetation	(5) Swanson et al. 1985;
YM	Geology	(3) Hudson 1977;(8) Sainsbury 1972;
	Soils	(5) Van Patten 1990;
YUF	Geology	(1) Till et al. 1986;
	Soils	(2) Van Patten 1990;
	Vegetation	(4) Swanson et al. 1985;

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APPENDIX 2. CLASSIFICATION AND BROAD GROUPINGS OF BEDROCK GEOLOGY THAT EMPHASIZES DIFFERENCES WEATHERING, RUGGEDNESS, AND SOIL CHEMISTRY.

Class	Description
Sedimentary-carbonate (Sc)	Sedimentary rocks dominated by carbonate materials, primarily calcite ($CaCO_3$) and magnesite ($Mg\ CO_3$). Rocks include limestone, dolostone, and calcareous sandstone. Soils formed from these rocks generally are alkaline and rich in humus. Phosphorus availability is reduced by fixation in various calcium phosphate compounds (hydroxyapatite, flouroapatite). In addition, at pH values above 7, excess calcium may hinder absorption and utilization of phosphorus by plants.
Sedimentary-noncarbonate (Sn)	Sedimentary rocks other than limestone, including conglomerate (pebble and cobble rich), sandstone (sand-rich), graywacke, shale (clay-rich), argillite (clay minerals) and chert (SiO_2). Generally low Ca and Na and high Al concentrations lead to acid soils. High soluble aluminum concentrations can lead to plant growth problems (root growth stopped at Al as low as 1 mg/L). Phosphorus is fixed in large amounts as aluminum and iron phosphates in acid soils.
Quaternary-carbonate (Qc)	Quaternary sediments that are derived from glacial, fluvial, eolian, or colluvial processes and are rich in carbonates derived from original bedrock sources. Tend to occur in areas where precipitation is less than evaporation.
Quaternary-noncarbonate (Qn)	Quaternary sediments derived from glacial, fluvial, eolian, or colluvial processes that are low in carbonates. Tends to occur in areas where precipitation exceeds evaporation.
Quaternary-saline (Qs)	Quaternary sediments of marine or eolian origin that are high in halites (NaCl).
Volcanic-felsic-younger (Vfy)	Felsic extrusive igneous rocks that have light-colored mineral assemblages rich in silica content, such a quartz (SiO_2, highly resistant to weathering), orthoclase feldspar ($KAlSi_3O_8$), and muscovite mica (sheet silicates, $KalSi_3O_{10}$). Rocks include rhyolite, felsite, rhyocacite, trachyte, and quartz trachyte. Soils are absent to very thin and acidic.
Volcanic-felsic-old (Vfo)	Similar to above, except rocks were formed during Tertiary or older periods and, therefore, are more highly weathered. Weathering forms acidic soils.
Volcanic-mafic-young (Vmy)	Mafic and intermediate extrusive igneous rocks have dark-colored mineral assemblages with low silica content and high metallic bases, such as amphiboles (Ca, Na, Mg, Fe rich), plagiocase feldspar ($NaAlSi_3O_8$, $CaAl_2Si_2O_8$), pyroxenes and olivine (high in Fe, Mg, Ca) and biotite mica (sheet silicate rich in Fe, Mg, and Al). The iron- and magnesium-rich minerals are more easily weathered than granites. Mafic rock types include basalts and diabase and intermediate rocks include andesite and dacite. Soils on the Quaternary age rocks, are absent or thin.
Volcanic-mafic-older (Vmo)	Similar to above except rocks were formed during the Tertiary or older periods and, therefore, are more highly weathered.
Volcanic-pyroclastics (Vp)	Detrital volcanic materials that have been explosively or aerially expelled from a volcanic vent. Deposits include volcanic conglomerates, tuffs, ash, ash-flow, and all other tephras.
Intrusive-felsic (If)	Felsic and meta-plutonic rocks that have mineral assemblages dominated by light-colored minerals such as quartz, orthoclase feldspars, and muscovite. Rocks include granite, granodiorite and syenite. Metaplutonic rocks include granitic gneiss, serpentinite, ultramafic gneiss, and soapstone. Soils generally are acidic and podzolization is more fully developed.
Intrusive-mafic (Im)	Intermediate, mafic and ultramafic plutonic rocks that have dark-colored mineral assemblages with significant amounts of iron and magnesium. Intermediate rocks dominated by plagioclase feldspars include quartz-diorite, monzodiorite, and quartz-monzodioriite. Mafic rocks dominated by pyrioxene and plagioclase feldspars include gabbro and olivine-gabbro. Ultramafic rocks are rich in olivine and pyroxene and include hornblendite, pyroxenite, and peridotite. Soils usually are neutral to alkaline.
Metamorphic-carbonate (Mc)	Metacarbonate sedimentary rocks consisting essentially of calcite and/or dolomite. Rock is primarily marble.
Metamorphic-noncarbonate (Mn)	A diverse group of meta-sedimentary, meta-pelitic, and meta-volcanic rocks that lack carbonates. Metasedimentary rocks include metaconglomerate, metagraywacke, phyllite, slate, quartzite, and schist (K, Mg, Fe, Al rich), while marble may be a minor component. Metavolcanic rocks include greenschist, greenstones, schists, amphibolite, olivine, and phyllite.

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APPENDIX 3. HIERARCHICAL GROUPING OF ECOREGIONS, SECTIONS, AND SUBSECTIONS WITHIN THE BERING LAND BRIDGE NATIONAL PRESERVE (11,274 KM^2), WESTERN ALASKA.

Section	Subsection and Detailed Subsection[1]	Code	Number of Polygons	Area (km^2)	Area (ha)	Area (ac)	Area (%)
Bering Straits Coast	Wales Coast	WC	4	4	423	1046	0.0
	Shishmaref Coast	SC	3	429	42884	105967	3.8
	Espenberg Coast	EC	1	76	7647	18896	0.7
Goodhope Bay Coast	Goodhope Bay Coast	GBC	46	52	5159	12748	0.5
	Cape Deceit Coast	CDC	1	7	701	1733	0.1
Bering Straits Coastal Plain	Bering Straits Lower Coastal Plain	BSLCP	8	1639	163949	405124	14.5
	Bering Straits Upper Coastal Plain	BSUCP	10	1329	132917	328445	11.8
	Bering Straits Lower Floodplains[1]	BSLF	6	114	11355	28058	1.0
Goodhope Bay Coastal Plain	Goodhope Bay Lower Coastal Plain	GBLCP	3	117	11695	28899	1.0
	Goodhope Bay Upper Coastal Plain	GBUCP	3	1322	132174	326608	11.7
	Goodhope Bay Lower Floodplains	GBLF	2	48	4799	11859	0.4
Devil Uplands	Devil Uplands	DU	1	826	82597	204101	7.3
York Highlands	York Upper Floodplains[1]	YUF	1	2	227	561	0.0
	York Foothills	YH	4	86	8579	21199	0.8
Goodhope Highlands	Goodhope Upper Floodplains[1]	GUF	2	16	1648	4072	0.1
	Goodhope Foothills	GH	5	1454	145428	359359	12.9
	Goodhope Mountains	GM	2	575	57481	142038	5.1
	Serpentine Mountains	SM	2	141	14058	34738	1.2
	Kougarok Foothills	KOH	1	35	3544	8757	0.3
	Kugruk Foothills	KGH	2	172	17183	42461	1.5
Imuruk Plateau	Imuruk Lowlands	IL	3	339	33882	83723	3.0
	Imuruk Uplands	IU	3	1199	119888	296248	10.6
	Imuruk Lava Flows	ILF	1	423	42281	104477	3.8
Bendeleben-Darby Highlands	Bendeleben Northern Foothills	BNH	1	390	38994	96355	3.5
	Bendeleben Eastern Mountains	BEM	1	104	10421	25751	0.9
	Bendeleben Western Mountains	BWM	1	83	8347	20626	0.7

	Darby Western Mountains	DWM	3	12	1177	2909	0.1
Kuzutrin Lowlands	Kuzutrin Floodplain	KZF	2	23	2343	5791	0.2
	Kuzutrin Lowlands	KZL	2	226	22582	55802	2.0
Koyuk Lowlands	Koyuk Lowlands	KYL	1	30	3047	7529	0.3
		Total	125	11274	1127411	2785882	100.0

[1] Detailed subsections differentiate floodplains within a subsection, these were grouped with the adjacent subsection at the subsection level.

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