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Controlling for Landform Age When Determining the Settlement History of the Kuril Islands

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Abstract

Archaeological investigations of settlement patterns in dynamic landscapes can be strongly biased by the evolution of the Earth's surface. The Kuril Island volcanic arc exemplifies such a dynamic landscape, where landscape-modifying geological forces were active during settlement, including sea-level changes, tectonic emergence, volcanic eruptive processes, coastal aggradation, and dune formation. With all these ongoing processes, in this paper we seek to understand how new landscape formation in the Holocene might bias archaeological interpretations of human settlement in the Kurils. Resolving this issue is fundamental to any interpretation of human settlement history derived from the distribution and age of archaeological sites from the region. On the basis of a comparison of landform ages and earliest archaeological occupation ages on those landforms, we conclude that landform creation did not significantly bias our aggregate archaeological evidence for earliest settlement. Some sections of the archipelago have larger proportions of landform creation dates closer to archaeological evidence of settlement and undoubtedly some archaeological sites have been lost to geomorphic processes. However, comparisons between regions reveal comparable archaeological establishment patterns irrespective of geomorphic antiquity.

INTRODUCTION

A major goal of the Kuril Biocomplexity Project (KBP) is to use archaeological ages and site distributions to derive conclusions about human settlement histories, paleodemographic variability, and social interactions in the context of environmental dynamics and change in the Northwest Pacific Kuril Islands. Recognizing that an archaeological record is always filtered and modified by geologic processes, conclusions that incorporate changes and comparisons across time require understanding and controlling for the geological agents (c.f. Schiffer, 1987; Mandel, 2008; Adelsberger et al., 2013; Araujo et al., 2013). The Kuril archipelago is a tectonically and volcanically active region with ongoing landscape-modifying geological forces that include eustatic sea-level change, tectonic emergence and submergence, volcanic eruptive processes (including lava, pyroclastic, and debris flows),

coastal aggradation, and dune formation. With a finite number of habitable locations on such a dynamic landscape, the archaeological record can easily be affected by landscape change.

Three variables contribute to the potential for observing archaeological material of a particular age: (a) the creation of archaeological deposits as a result of human activities on a landscape, (b) the preservation of those deposits on the landscape, and (c) observation and documentation of preserved deposits (Schiffer, 1987). Because the ultimate goal of archaeological analysis is to explain patterned human activities in the past (variable a), the parameters of preservation bias (variable b) and observation bias (variable c) need to be understood. This study aims to examine the extent to which conclusions about occupation history drawn from site analysis in the Kuril Islands may be biased by the history of geomorphological change. Landform creation and modification potentially represents a significant component of archaeological preservation bias and, to a lesser degree, observation bias, which both limit the possibility of identifying older sites. Younger archaeological sites are more likely to be preserved and be found near the modern surface. As a result, they are more easily identified and dated than older sites. Older cultural deposits can be missing or hard to find because of physically, chemically, and biologically induced decay, deep burial, or erosion. Preservation bias thus tends to result in a curvilinear chronological function, where the probability of site preservation declines exponentially with site age (Clevis et al., 2006; Surovell & Brantingham, 2007; Ballenger & Mabry, 2011).

This study focuses specifically on the role of landform creation and modification in removing archaeological deposits from visibility. Landform creation and modification occur when land is created where either none previously existed or where the land surface is modified to the degree that evidence of pre-existing cultural deposits would-be obscured beyond any chance of archaeological detection or dating. For example, a lava or pyroclastic flow could reach the sea, creating new land where none previously existed and/or burying a record of human occupation on a prior land surface under meters of lava or volcanic debris.

In our attention to landform creation and modification, we exclude other preservation factors, such as decay or site erosion. Organic decay of bone, shell, and wood is a significant problem in the acidic Kuril Island sediments; however, much of the archaeological record is relatively nonreactive to the acidic soil (charcoal, pottery, stone artifacts), making it possible to observe and record archaeological deposits even after severe decay of the organic record. On the other hand, erosion cannot be evaluated empirically for the Kurils. While most sites are located in vertically accumulating (depositional) environments, these sites are located near coasts exposed to wave-induced erosion. At present, we lack the means to calculate the rates of coastal erosion to quantify this impact. Erosion has certainly resulted in a loss of archaeological deposits, and our analysis does not seek to evaluate the relative importance of this bias.

By determining the timing of landform creation and modification, we also address a component of observation bias, in that archaeological survey did not consider geomorphic chronologies in survey design. One cannot expect to find 5000-year-old sites by only

looking on 3000-year-old landforms. Biased archaeological patterns will result if surveys focused predominantly on landforms that post-date initial human settlement.

Accepting the limitations of current evidence, this paper specifically evaluates the possibility that formation of new landforms truncate an otherwise continuous chronology of archaeological settlement and, simultaneously, the possibility that survey strategies systematically biased archaeological chronologies by focusing exclusively on young landforms. In either case, dates of land-forming deposits should closely approximate dates of the oldest archaeological sites placed on them as resident populations expanded onto newly available land surfaces. In this study, we compare first archaeological occupation dates of landforms against a record of the landform types and independently estimate landform ages underlying archaeological sites. Results from this work will inform future studies of human settlement history, paleodemography, and human ecodynamics.

BACKGROUND

Brief Geological Overview

The Kuril archipelago island arc is composed of 48 volcanoes active in the Holocene (Global Volcanism Program Database, 2013) and numerous Pleistocene or older (dormant) volcanoes (Figure 1). Unsurprisingly, Quaternary volcanic deposits cover most of the surface (Bulgakov, 1996). The emergence of most of the central islands occurred in the Pleistocene; from Ushishir to Makanrushi islands, the oldest rocks (hyaloclastites and pillow lavas in coastal cliffs) are less than 1.3 million years old based on K-Ar age dating (Ishizuka et al., 2011). The southern and northern islands have been emergent for longer—since the Late Miocene to Early Pliocene (Ishizuka et al., 2011).

Archaeological Sites

Archaeological research over the past century by Japanese and Russian scholars established a basic culture historical framework that has served also as a loose chronological frame of reference for questions of human colonization. Early archaeological investigations in the Kuril Islands were conducted in the southern and northern islands by Japanese archaeologists in the 1930s (Baba, 1937, 1939; Baba & Oka, 1938). Later, research by Russian archaeologists (Zaitseva et al., 1993; Shubin, 1994; Vasilevsky & Shubina, 2006; Kuzmin et al., 2012) focused mainly in the same areas, although many sites were documented throughout the island chain (summarized in Vasilevsky, 2009). Recent work added to and extended the list of sites and the number of radiocarbon dates, especially in the central region: the International Kuril Island Project (IKIP) brought a team of archaeologists to the island chain in 2000 (Fitzhugh et al., 2002) and KBP conducted archaeological investigations in 2006–2008 on almost every island in the archipelago (Fitzhugh, 2012). While a number of radiocarbon dates had been previously reported from the Southern Kurils (Knorozov et al., 1989; Kuzmin et al., 1998; Zaitseva et al., 1993), IKIP provided the first comprehensive radiocarbon chronology for the greater Kuril chain as a whole (Fitzhugh et al., 2002). Combined, the IKIP and KBP projects, with their focus on the sparsely studied central islands built an archaeological radiocarbon database of over 400 dates from archaeological locales spread from Kunashir in the southwest to Shumshu in the northeast.

More recent research in the South Kuril islands of Kunashir and Iturup has further clarified both the radiocarbon and ceramic chronologies of the earlier occupations on these islands (Vasilevsky & Shubina, 2006; Shubina & Samarin appendix in Fitzhugh et al., 2009a; Yanshina, Kuzmin, & Burr, 2009; Yanshina & Kuzmin, 2010; Kuzmin et al., 2012). Additional radiocarbon dates from KBP will be published in the near future, and are consistent with the overall outlines of prior research (see Fitzhugh, 2012).

The available research indicates that the southernmost islands of Kunashir and Iturup were definitively settled or at least visited by or not long after 7000 ^{14}C yr B.P. (Yankito 1 and 2 sites with radiocarbon dates between 6800 and 7100 ^{14}C yr B.P.; Yanshina, Kuzmin, & Burr, 2009) during the period known in Japan as Early Jomon (Knorozov et al., 1989; Yanshina & Kuzmin, 2010). Ceramic types attributed to the middle and late Jomon (sometimes called “Yuzhno-Kurilsk Culture”) are reported from these islands (Golubev, 1972 in Vasilevsky & Shubina, 2006), indicating human presence through the mid Holocene, though few radiocarbon dates have been reported prior to 4000 ^{14}C yr B.P. (Kuzmin et al., 1998; Fitzhugh et al., 2002). Only around 3500–4000 years ago does human settlement become apparent in the more geographically insular (central) Kuril Islands (Fitzhugh et al., 2002).¹ Radiocarbon dates and archaeological diagnostics of the Late and Final Jomon are found in sites through most of the Kurils at this time. Subsequently, Epi-Jomon materials are found much more common, dating to between 3000 and 1500 years ago or so. Around 1300–1000 ^{14}C yr B.P., the Okhotsk Culture moved in and replaced Epi-Jomon, settling the Kurils from end-to-end. This relatively short-lived occupation was replaced in the second millennium, perhaps after a period of abandonment (Fitzhugh, 2012), by the ethnographically known Ainu who sparsely occupied the chain at the time of the first documented Russian and Japanese contact. The last Kuril Ainu were deported from the Kurils to Hokkaido at the end of the Second World War.

Landform Surfaces

Active processes abound in the Kurils because of the interaction of volcanic, tectonic, marine, fluvial, and eolian processes. Kuril terrestrial landscape surfaces are created or modified through:

1. *Construction of new land by depositional processes that move the shoreline seaward.* Coastal processes can result in accumulation (aggradation) of sediment at the shoreline. New land is accreted to the coastal plain when waves either transport more sediment toward than away from the shore, or are unable to remove sediment as fast as it is added to the intertidal zone. In the Kurils, older islands generally have a greater surface area and thus more rivers and wider drainage networks feed more sediment into the coastal zone than younger, smaller islands. Sediment input enables the construction of coastal landforms associated with river mouths and active littoral zones. Most small islands have narrow beaches with limited sediment in the coastal zone, and therefore fewer sites of coastal aggradation.

¹Insularity or remoteness in this study refers to the distance of islands from adjacent mainland areas that served as potential source locations for populations for Kuril settlement. The central islands are thus considered most insular in this geographic sense. They also happen to be considerably smaller on average than the islands closest to the ends of the chain and are separated from those islands by wide straits with strong tidal currents, further accentuating their remoteness.

Constructive volcanic processes can include lava flows, landslides, or other forms of debris flows. Many examples of these events are known to add land area to islands throughout the Kurils, such as pyroclastic flows from the 2009 Sarychev Peak eruption (Levin et al., 2010), the 1933 Sever-gin Peak debris avalanche (Belousov & Belousova, 1996), or Holocene lava flows that reached the sea from Fuss Peak (Gorshkov, 1970).

2. *Construction of new land by relative sea-level fall (uplift of the land or regression of the ocean).* Pleistocene marine terraces exist throughout the island chain (Melekestsev et al., 1974). These features formed when the paleoshoreline from sea-level highstands associated with previous interglacial periods was uplifted to (or created at) an elevation higher than today's sea level. The uplift that enables Pleistocene marine terrace preservation in the Kurils could be tectonic or volcanic in origin (Korotky et al., 1995). Holocene marine terraces, those formed by coseismic uplift of the coastal zone during earthquakes, are also known to exist (Fitzhugh et al., 2007) but are rare.
3. *Resurfacing of existing landforms by depositional processes.* Depositional processes that cover pre-existing surfaces with new landforms can come from volcanic activities, wind, or rivers. Landslides, pyroclastic flows, debris avalanches, and lava flows from volcanoes and volcanic eruptions can deeply bury pre-existing surfaces and archaeological sites. For example, pyroclastic flows are reported to have covered an Ainu village on Shiashkotan in the late 1800s (Gorshkov, 1970). Eolian sediment transport results in the formation of sand dunes, and rivers can construct fluvial plains (flood plains) in river valleys.
4. *Resurfacing of existing landforms by erosional processes.* The primary surficial erosional agents in the Kurils are waves, rivers, wind, and people. Waves erode into the islands during times of rising or stable sea level, forming wave platforms (submerged) and sea cliffs. Rivers denude the landscape and can carve river terraces as they downcut. Wind erosion includes deflation of sand dunes, which has destroyed stratigraphic context at a number of archaeological sites but often reveals archaeological materials that can be dated (Fitzhugh et al., 2007; Shubina & Samarin appendix in Fitzhugh et al., 2009a). People have resurfaced landscapes throughout the island chain by building roads, airports, trenches, etc. While many archaeological sites have been identified because of road cuts, an unknown number may have been destroyed without documentation; some sites originally identified early in the 20th century have been destroyed since by human activities (O. Shubina, personal communication, 2012).
5. *Destruction or submergence of land.* Explosive caldera-forming volcanic eruptions can remove land area (rather than resurface it) when the new caldera floor is below sea level. Such submarine caldera eruptions were the case for the Pleistocene Uratman eruption, the Lvinaya Past eruption from the early-to-mid Holocene (Gorshkov, 1970), and the approximately 2000-year-old Ushishir eruption (Nakagawa et al., 2008), for example. Relative sea level rise, from eustasy or

tectonic or volcanic subsidence, can also cause terrestrial land to become submerged.

Landform Age

During the IKIP and KBP expeditions, geologists, paleoecologists, and paleogeographers documented landscape history through excavations and analyses of stratigraphic sequences as well as geomorphological structures (e.g., Lozhkin et al. 2010; Ganzey et al., 2011; Razjigaeva et al., 2011b, 2013). Dates of material within or correlated to layers in these stratigraphic sequences provide minimum ages for underlying landform surfaces. In addition to data obtained during the IKIP and KBP expeditions, estimates of the age of landform surfaces in the Kuril Island chain can be supplemented from a few additional sources. Geomorphic maps by Melektsev et al. (1974) from aerial photos provide preliminary age estimates of landforms throughout the archipelago, albeit at a low resolution. Studies of the eruptive histories of the Kuril volcanoes, summarized in Gorshkov (1958) and (1970) and by the Smithsonian's Global Volcanism Program Database, provide the age and products of many eruptions of the Kuril's active volcanoes. Additional work by Russian and Japanese volcanologists has provided additional radiocarbon dates for dating volcanic events throughout the archipelago (Braitseva et al., 1995; Nakagawa et al., 2008, Ponomareva, 2009). Research teams from the Pacific Institute of Geography in Vladivostok have conducted detailed work in the South Kurils (e.g., Korotky et al., 1995, 2000; Razjigaeva et al., 2002, 2004, 2008, 2011a, 2011b, 2013) and determined the magnitude, timing, and duration of Holocene transgressions and regressions based on the stratigraphy of coastal accumulative terraces, dunes, lakes, and lagoons. Research related to KBP has added to records of sea level history, coastal aggradation, and dune formation in other regions of the island chain (cf. Lozhkin et al., 2010; Razjigaeva et al., 2011a; Razjigaeva et al., 2013). Dates of events and landforms obtained by the above studies are almost exclusively from radiocarbon analysis.²

South Kurils—As sea levels rose from the last glacial maximum, Iturup (Figure 1) became a distinct island by approximately 14,000–15,000 years ago and Kunashir (Figure 1) around 7500 ¹⁴C yr B.P. (Bezverkhniy, Pletnev, & Nabiullin, 2002). Water levels rose to a maximum of +2.5–3 m by 6500–6,300 ¹⁴C yr B.P. (Korotky et al., 2000; Razjigaeva et al., 2004) and paleostraits formed in Iturup and Kunashir. Stratigraphic records indicate swamping by 6820 ± 100 ¹⁴C yr B.P. on Iturup (Razjigaeva et al., 2002). During and following this Holocene sea-level highstand, barriers closed off the paleostraits, forming lagoons and lakes (Korotky et al., 1995); many of these lakes persist today. Coastal dune systems developed during slight regressions after maximum sea level as sandy intertidal zones became exposed—onsets of dune formation are dated at 4660 ± 15, 2200 ± 80, 1440 ± 60, and 290 ± 60 ¹⁴C yrs B.P. (Korotky et al., 1995; Razjigaeva et al., 2004). Small transgressions (1 m) occurred from 4010–3400, 2950–2620, and 1170–820 ¹⁴C yrs B.P.;

²The standard procedure of ¹⁴C laboratories is to report conventional ¹⁴C ages with a 1-sigma standard error term (Stuiver & Polach, 1977). Error terms for radiocarbon dates from KBP to IKIP are reported as 1 sigma. Some references for published dates used in this study are not explicit about the type of error term reported. In these cases, we assume that the ¹⁴C dates are conventional 1-sigma error terms.

these transgressions, in addition to the original post-glaciation transgression, all resulted in the formation of coastal aggradational terraces (Razjigaeva et al., 2004).

Volcanoes are active throughout the South Kurils, although the region has proportionally more dormant or quiet volcanoes than the rest of the island chain (Global Volcanism Program Database, 2013; Figure 1). The early-mid Holocene eruption of Lvinaya Past on Iturup may have the most noticeable effects on the landscape in the region. This event was one of the largest known eruptions in the archipelago with eruptive products that included a large submarine caldera on Iturup and an ignimbrite that forms the 50–60 m high Yuzhny isthmus (Global Volcanism Program Database, 2013). Other recent volcanic landforms include the Mendelev volcano debris avalanche, from approximately 4200 years ago, and small lava flows from numerous volcanoes that have reached the sea (Global Volcanism Program Database, 2013).

South Central Kurils—Young and small islands (Figure 1) mean relatively limited development of coastal landforms in the South Central Kurils. Three isolated Pacific-facing coastal plains studied in the region are all young; Dushnaya Bay near the north end of Simushir prograded after 2500 ^{14}C yr B.P., Yuzhnaya Bay on Matua prograded after 1500 ^{14}C yr B.P. and Ainu Bay on Matua prograded after 3300 ^{14}C yr B.P. based on local stratigraphy investigated by KBP researchers. Beyond these three coastal plains, few other sites of significant coastal accretion exist. Shorelines in the South Central Kurils are generally either steep cliffs or a less than 100-m wide zone of primarily boulder or cobble accumulation.

A number of volcanoes in the South Central Kurils have added new land area or resurfaced pre-existing landforms from volcanic eruptions in the Holocene. The Ushishir eruption of approximately 2000 ^{14}C yr B.P. formed the caldera in the Ushishir Group (Figure 1) and covered the island group in a thick layer of erupted material (Nakagawa et al., 2008; Razjigaeva et al., 2011a). Twenty-five kilometers away on Rasshua Island this eruption deposited up to 10 cm of ash between two cultural deposits of the Epi-Jomon phase (Fitzhugh, 2012). The Sarychev Peak eruption in 2009 on Matua covered the north half of the island in new pyroclastic material (Levin et al., 2010), mantling landforms underneath. Volcanoes on Simushir also created new landforms in the Holocene, including pyroclastic flows that reached the sea from Prevo Peak and Zavaritsky and lava flows from Prevo Peak and Goraschaia Sopka (Global Volcanism Program Database, 2013).

North Central Kurils—Fewer coastal aggradational landforms exist in the North Central Kurils (Figure 1) than elsewhere in the archipelago and none have been studied in detail. However, the volcanoes in this region are highly active and new landforms from volcanically induced landslide, debris avalanche, and pyroclastic flow deposits can be found on every island. One significant volcanic eruption, that of Tao Rusyr in southern Onkotan approximately 7500 ^{14}C yr B.P. (Braitseva et al., 1995), resulted in an ignimbrite that covered at least one sixth of the island (Ponomareva, 2009). Multiple Holocene debris avalanches and pyroclastic flows can be found on Shiashkotan, and Kharimkotan, and at least one recent event is found on each of Ekarma, Chirinkotan, and Makanrushi islands (Fitzhugh et al., 2009a and 2009b; Nakagawa et al., 2008; Razjigaeva et al., 2011a).

North Kurils—The North Kurils (Figure 1), like the South Kurils, have existed for longer (Ishizuka et al., 2011), are larger, and therefore have greater drainage areas to input sediment into the coastal zone to form coastal plains than the central islands. Holocene sea-level highstand in the North Kurils is estimated to have occurred approximately 6000 ^{14}C yr B.P., based on sea-level curves for Primor'ye (“southeast Maritime Region”) and radiocarbon dates of maximum transgression on Kamchatka between 6390 ± 50 and 6000 ± 130 ^{14}C yr B.P. (Lozhkin et al., 2010; sea level cited as Korotky et al., 2004). Stratigraphy from Pernatoe Lake on southern Paramushir additionally indicates a sea-level regression from 5200 to 5100 cal yr B.P. and dune formation between 5000 and 4000 cal yr B.P. based on sedimentation rates in Pernatoe Lake (Lozhkin et al., 2010). Volcanoes on Paramushir are active; most have young lava flows (Global Volcanism Program Database, 2013). In contrast, Shumshu is the only large island in the archipelago without an active volcano.

METHODS

Archaeological Sites and Occupational History

In order to compare archaeological and landform age data, the archaeological sites with known latitude and longitude were first compiled based on data available from IKIP, KBP, or published in Zaitseva et al. (1993). O. Shubina (personal communication, 2012) provided locations of sites published in Zaitseva et al. (1993). Some sites from older studies, such as from the 1930s, could not be located again. The earliest identified occupations based on pottery typology and the oldest dated radiocarbon samples with stratigraphic context were recorded for each site. Sites named in reports by KBP or IKIP as archaeological based on sedimentary appearance but without associated archaeological material or housepits found were removed from the list. Sites listed in Zaitseva et al. (1993) with uncertain locations were combined with sites from IKIP or KBP with similar or identical names and descriptions when applicable. Additionally, sites that were less than 0.5 km apart and on the same landform (see next section) were also combined.

The earliest occupation of each site is represented by a compilation of radiocarbon dates from all excavations and soil probes at the locality and a typological analysis of pottery sherds found *in situ* or in surface collections. Typological pottery analysis was performed by E. Gjesfjeld using previously established Hokkaido pottery typologies and culture age ranges in combination with recent radiocarbon dates and pottery associations specific to the Kuril Islands developed by KBP (cf. Ohyi, 1975; Tezuka & Fitzhugh, 2004; Deryugin, 2008). Archaeological radiocarbon dates were limited to only those from wood charcoal recovered in cultural strata. Analysis of the species and size of the wood charcoal indicate the material included both local species and driftwood from relatively short-lived trees; offset dates between plant growth and use by humans is expected to be less than 200 years. The most dominant species were *Larix/Picea*, *Pinus*, *Salix*, and *Salicaceae* with a lesser frequency of *Populus*, *Betula*, and *Alnus* (Shaw, 2010).

Landform Type

The landform under each archaeological site was identified using descriptions in archaeological reports, site photographs, site maps, local stratigraphic sections, field notes,

and satellite imagery in Google Earth. The combination of report descriptions, field photographs, and satellite imagery verified latitude and longitude of site locations. Landforms identified in this study can be classified into the following broad categories:

1. *Coastal plain*: Low elevation landforms adjacent to the shoreline, formed from or related to marine processes (Figure 2A). This landform category is also known as an “accumulative terrace” or “coastal aggradational terrace.” The definition includes beach ridges but specifically excludes dunes for the purposes of this study.
2. *Coastal dunes*: Sand dunes formed near the shoreline from eolian processes, generally on a coastal plain (Figure 2B).
3. *Terrace*: Relative flat, continuous surface formed by either paleo lava flows (lava flow terrace) or by marine processes during Pleistocene sea-level high-stands followed by tectonic uplift (marine terraces; Figure 2C). Subdivision between Pleistocene-aged lava flow terraces and Pleistocene marine terraces were made when identifiable, but this was not always possible because the morphology of the two can be hard to differentiate. There were no sites in our database identified to be on recent Holocene-aged lava flow terraces, thus this type of landform does not have its own category in this analysis. Additionally, river terraces are excluded from the “terrace” definition for this study.
4. *River terrace*: Flat surface carved along the edge of a river valley as the river erodes into a landscape (Figure 2F).
5. *Fluvial plain*: Sediments deposited by a river. Marshes and wetlands associated with a river valley are also included in this category.
6. *Landslide*: For the purpose of this study, “landslide” includes deposits ranging from rock falls, to lahars, to debris avalanches, to lateral blasts of volcanoes (Figure 2D). These types of deposits can be but are not necessarily associated with a volcanic eruption. Deposits that were clearly from a pyroclastic flow were excluded.
7. *Ignimbrite*: Deposits from a pyroclastic flow (Figure 2E). These deposits are the direct result of a large volcanic eruption.
8. *Volcanic edifice*: The primary components of a volcano derived from a volcanic eruption. The category includes lava domes, cinder cones, calderas, crater rims, and proximal lava flows.
9. *Transition between landforms*: This classification was used when the site was located at the boundary between identifiable landforms. Transitions between terrace and coastal plain or between fluvial plain and coastal plain are useful distinctions because landscape age can still be estimated.

Landform Age

The age of a landform is defined as the time when soil began forming on the modern surface—in other words, when a deposit left by humans might be reasonably expected to be preserved in the soil and accessible by archaeologists. Landscape age was determined based on both regional and local information. Local information included stratigraphy and

associated radiocarbon dates from numerous excavations by IKIP- or KBP-affiliated researchers, published stratigraphic sections on the same landform surface as archaeological sites, and dated volcanic histories from previous studies. Local information could be applied to all landform types. Regional information of climate and sea-level changes within the South Kurils and within the North Kurils indicated when marine terraces could have formed, when coastal plains began aggrading, and when coastal dunes were active (see Background section for the timing of these events); local site analyses provided these data for the South Central Kurils and were not necessary in the North Central Kurils for this study. Climate and sea-level information generally only provided maximum age of the landform; minimum age was estimated from the oldest radiocarbon dates of the archaeological site or nonarchaeological local stratigraphy, whichever was older. Correlation of regional sea-level data in particular assumes that local, site-specific, tectonic or volcanic land-level change has not been a significant factor at individual sites. This assumption is likely not valid for every location; a few cases of local tectonic offsets were noted by geologists in regions without archaeological sites (Fitzhugh et al., 2007), thus some of the sites in our database could be similarly affected and therefore have erroneously young or old land-form ages. However, because few sites rely on regional correlations for formation ages, we expect the impact of local tectonism to be of a relatively minor concern in this analysis.

Predictions

A comparison between geological and archaeological dates allows us to identify the proportional relationship between landform creation and the establishment of the archaeological record. In aggregate, if the oldest sites were created at the same rate as habitable landforms over any given interval, then it is reasonable to conclude that the rate of site formation in that interval could be geologically controlled and not directly representative of changes in human occupation intensity. If the two data sets are relatively independent, especially if the archaeological data set post-dates geological landform creation by a large margin, then we can exclude landform creation as a significant factor in the temporal distributions of dated archaeological components.

Analytical Criteria

The following analyses are based on the landform age results and the oldest occupation date at each site.

Count of sites at a given time period—Each data set was divided into 500-yr bins from 12,500 ^{14}C yr B.P. to the present and the number of new land-forms and the number of oldest occupations were tallied, respectively, using only uncalibrated radiocarbon ages. Oldest occupations were based mainly on radiocarbon dates. Those dates with error ranges that did not cross a 500-yr division boundary were easily assigned to a single time period. Those dates with error ranges (typically ± 25 to 30 ^{14}C yrs) crossing a 500-yr bin boundary were assigned to the bin with $>50\%$ of the uncalibrated age range. The range between minimum and maximum age estimates for pottery typologies and the timing of landform creation typically exceeds 500 years; see Supplementary Tables SI and SII for exact estimates of age ranges. We therefore distributed these age ranges uniformly among all bins covering the uncertainty—that is, into a constant probability of $1/y$ in each bin, where y

equals the number of 500-yr bins across which the estimated occupation (pottery) or formation (landform) age range spanned. For example, if the possible age of landform formation spanned 3000–1000 ^{14}C yrs B.P., the probability of the landform existing from 3000 to 2500 ^{14}C yrs B.P. is one-fourth (and thus counts as one-fourth of a landform at this time period), 2500–2000 ^{14}C yrs B.P. is one-fourth, and so on. Because of this methodology, the count of new landforms is not always an integer.

Cumulative count of sites—In addition to the change in the number of new land-forms and first occupations of landforms in each time period, we also calculated the cumulative number over time. The cumulative count of landforms that existed at any time period reflects the total number of land surfaces in existence and available to be settled in that period. Cumulative sums of first occupations represent the total number of landforms that have seen at least one occupation. Because of the nature of our data set (in which we consider only landforms that have archaeological sites), ultimately every landform we consider has been settled by the present time period. For these calculations, we use standard life table methods from Gehan (1969).

Cumulative proportion of occupied sites—We compute the cumulative proportion of first archaeological sites on a landform as the ratio of the cumulative occupations divided by the total first sites available. Standard errors of the cumulative proportion were computed using Greenwood's actuarial method for cumulative distributions (Gehan, 1969, eq. 3.3). Confidence intervals (95%) were computed from the standard errors to help clarify whether the proportions truly change over time, or whether values fall within the sampling error.

Proportion of occupation—The proportion of occupation is simply the ratio of the number of occupied sites divided by the available land-forms (those that exist at time x) per 500-yr increments. Standard errors were computed using ordinary estimates for proportions (Gehan, 1969, appendix) and used to compute 95% confidence intervals.

RESULTS

Archaeological Sites

The compiled archaeological site list was ultimately reduced to 57 from the original 126 so that all sites fit the inclusion criteria for this study. Radiocarbon dates and pottery typology had been analyzed for 71 sites, but land-form types could not be identified for 14 of those sites (Supplementary Tables SI and SII). A majority of the sites eliminated from our analysis were sites excavated in the 20th century for which reliable dates and location information was scarce. Even so, around 40% of the sites on the compiled list were located in the more studied and more accessible South Kuril region.

The South Kurils have two of the oldest radiocarbon dates in the archipelago— 7055 ± 45 (AA-78928) ^{14}C yr B.P. from the Yankito 2 site (Yanshina, Kuzmin, & Burr, 2009) and 5010 ± 65 (lab identification number unknown) ^{14}C yr B.P. from the Belozyrka 1 site (O. Shubina, personal communication, 2011) as well as three sites with pottery typologies indicating occupation between 5500 and 4500 ^{14}C yrs B.P. (Olya, Kapsul point 1, and Golovnina Beach; Supplementary Table SI). The North Kurils similarly have older sites of

earliest occupation— 5290 ± 35 (OS-97898) ^{14}C yr B.P. at Baikovo 1 and two more sites between 3500 and 4000 ^{14}C yrs B.P. (Supplementary Figure S1). In contrast, the South Central Kurils have only one dated site with occupation close to 3500 (3540 ± 30 [OS-79602] ^{14}C yr B.P.) at Rasshua 1 and the oldest site in the North Central Kurils is 3070 ± 25 (OS-80121) ^{14}C yr B.P. at Cape Gorely'y (Supplementary Table SI). All other sites in the central regions of the Kurils are less than 2500 ^{14}C yr B.P. (Supplementary Figure S1).

Landform Surfaces and Ages

Of the original 126 Kuril Island archaeological sites, the underlying landform type could be identified and the age of formation could be approximated for 87—more sites than had radiocarbon dates or pottery typologies (Figures 3 and 4, Supplementary Tables SI and SII).

South Kurils—More than half of archaeological sites in the South Kurils were located on surfaces that formed in the Holocene (Figure 3). All but one of these young sites are on land-forms that were built by river, wind, or marine (coastal) processes since the Holocene sea-level highstand, thus relatively few are as old as 7000 ^{14}C yr B.P. (Supplementary Figure S1). Even so, pottery found in Kunashir and Iturup indicate some human presence across the intervals since that date.

South Central Kurils—A majority of the landforms underlying archaeological sites in the South Central Kurils are Pleistocene terraces (Figure 3). Of the remaining sites, four are closely linked to landforms created by or built after the 2000-year-old UsKr caldera-forming eruption on Ushishir (Nakagawa et al., 2008), one is located on the young coastal plain of Ainu Bay on Matua, and the other is on a lava dome inside Broutona Bay, Simushir that may be up to 10,000 years old (Y. Ishizuka, personal communication, 2012) (Supplementary Figure S1). The large number of Pleistocene sites (Figure 3) suggests that the overall pattern of archaeological temporal distribution in this region is independent of land formation.

North Central Kurils—The North Central Kurils contain many young landforms that are generated by volcanic activity (Figure 3). Four or five separate landslide/debris avalanche surfaces that formed in the Holocene underlie almost half of the archaeological sites (Figure 4; Supplementary Figure S1) and are not the only landslide/debris avalanches present in the region. A number of sites on Onkotan are built on top of the wide-spread pyroclastic flow deposit, or river terraces cut into this ignimbrite, from the 7500 ^{14}C yr B.P. eruption of Tao-Rusyr, thus limiting archaeological visibility to the time since this date. Coastal plain accumulation and development of dune systems are minimal and few aggradational terraces wider than 50 m exist anywhere in the region. Only the landform at one site, Nemo Bay 1, which is located at the transition from a fluvial to coastal plain, can be linked to Holocene coastal processes (Figure 4). Because of the many sites on young landslides (Figure 3), the North Central Kurils have a relatively low percentage of sites on surfaces that existed prior to 3000 ^{14}C yr B.P. (Table I), thus implying that geological factors could bias the early- or mid-Holocene record here.

North Kurils—The North Kurils have the fewest number of reported sites, and most are Pleistocene in age (Figures 3 and 4, Table I). Currently only one archaeological site sits on

an accumulative coastal plain and one on a sand dune that likely deposited on a Pleistocene surface (Figure 3). Although Paramushir has many locations of coastal accumulation, sites found to date are generally not on these surfaces. T. Pinegina (personal communication, 2012) suggests that even embayments with good sediment supply on Paramushir have coastal plains younger than 2000 years old, and many are younger than 300–400 years. From working the east coasts of the North Kurils, T. Pinegina notes that the region has a very slow uplift rate—Pleistocene marine terraces are low elevation in this region compared to the rest of the island chain, and in some places the coastal area has experienced net subsidence. The low uplift rate is supported by the archaeological site landforms analysis, where Pleistocene terraces underlying North Kuril sites are typically less than 10 m elevation compared to 20–80 m terraces in other regions of the Kurils. The large number of sites on Pleistocene landforms (Figure 3; Table I) suggests that the overall pattern of archaeological temporal distribution in this region is independent of land formation.

DISCUSSION

Comparing Frequencies of Landform and Archaeological Establishment

To address the influence of landform creation on the archaeological record, Figure 5 plots the frequencies of landform creation compared to the earliest dated archaeological deposit. Figure 5A and C shows these data in terms of count of new landforms or first occupations per 500-yr interval, while Figure 5B and D presents the cumulative number of landforms available for occupation compared to the number of sites that have been occupied prior to or during a given 500-yr interval. From these plots, it is clear that frequencies of both landform and archaeological distributions increase faster in the late Holocene compared to earlier times. We should note here that the uncertainty of the exact timing of landform creation is quite large in many cases (represented by the length of the gray bars in Figure 4).

After approximately 7000 ^{14}C yr B.P., the rate of new landform creation increased (Figure 5A and B), with three distinct time periods of increasingly faster rates of landform creation, seen in Figure 5A at 7500–6500, 5500–4000, and 2500–3000 ^{14}C yrs B.P. The timing of these periods of new landforms can be correlated to the initiation of sea-level stabilization, the timing of pervasive eolian dunes in the South Kuril Islands, and increased numbers of landslides and volcanic activity in the North Central Kuril Islands. First settlement of landforms increased episodically from approximately 7000 ^{14}C yr B.P. to 2000–2500 ^{14}C yrs B.P. and has generally decreased since that time.

The timing and pattern of greater numbers of young landforms was initially unexpected based on our starting assumption that rates of landform creation should be effectively constant through time. We can suggest two possible explanations to account for this observation. The first is that the late Holocene was geomorphologically more active than earlier periods. A second and mutually inclusive explanation is that the newly created landforms exist in the most geomorphologically active areas, those most prone to resurfacing or remodeling, such as coastal zones (strongly affected by relative sea-level change) and the flanks of volcanoes (affected by volcanic eruptions). If so, older landforms would-be disproportionately under-represented in the database due to burial or removal by more recent processes. In either case, a greater number of newly added landforms closer to

the present would disproportionately bias the archaeological distribution to more recent times. In general, the archaeological record shown in Figure 5 is consistent with an age bias, leading to the uncontroversial conclusion that the archaeological pattern is subject to some amount of preservation-biased attrition (cf. Surovell & Brantingham, 2007).

However, closer inspection reveals that the archaeological pattern appears largely independent of landform creation. The plot in Figure 5A reveals significant variability in the timing of archaeological foundation ages, with periods of both rapid increases and rapid declines in the numbers of new sites created. This variation is not a simple reflection of a small sample size because the landform data set (which does not show such variability) is of the same size. Declining rates of site initiation at 5000, 3500, 2000, and 500 ^{14}C yrs B.P. (Figure 5A) cannot be explained by any known geomorphic process, though small samples could render the older two of these declines unreliable.

Moreover, while the trends of archaeological and geological data are similar, the rate and timing of changes are not, as would be expected if there was a readily available population to colonize new landforms resulting in the creation of sites whenever new land became available. As reflected in the cumulate plots of Figure 5B and D, land-form creation accelerated earlier and at a slower rate than archaeological settlement. By 5000 ^{14}C years ago, 50% of existing landforms in our study were in place, while it took another 3000 years to achieve this proportion of archaeological sites. If sites were created in proportion to available landforms (assuming a constant availability of population, perhaps looking to settle new landforms that covered older ones), then the rate of site establishment per landform (Figure 5C) should decrease over time as younger time periods accumulate more unchanging land-forms. This is true after 2000 ^{14}C yr B.P., but not 7000–2000 ^{14}C yrs B.P. Similarly, the trend in rates of new site formation in Figure 5D should be close to a horizontal line near 100%. That the rate of new site establishment increases relative to landform age in this plot strongly suggests an independent factor or factors govern(s) site creation. These factors could include increasing intensities of human occupation and/or changes in the nature of cultural settlement distribution, for example, a shift to more or less permanent (and archaeologically observable) settlement patterns.

Regional Variations in Settlement

Holocene-aged landforms underlie the majority of sites excavated in the South Kurils and North Central Kurils, Pleistocene landforms dominate the record in the North Kurils (Figure 3; Table I). The South Central Kurils are divided between Pleistocene and very young landforms within the data set with both landform age and occupation age (Table I). The South Central Kurils data set of all landform ages (including those without dated archaeological sites) are dominated by Pleistocene landforms (Figure 3). From these data, we can assume that settlement patterns in the North Kurils are as robust as possible, in relation to the preservation and observation bias on which this study focuses and considering the low total number of sites in the region (Table I). The oldest sites in the Kurils were found in the South Kurils within a relatively small subset of the total South Kuril sites—seven to nine landforms older than 7000 ^{14}C yr B.P. versus 24 total landforms (Table I). Table I shows that a subset of seven to nine landforms is only slightly more than the number

of landforms older than 7000 ^{14}C yr B.P. in the other regions of the Kurils. Additionally, many excavations on Pleistocene-aged landforms contained young (mid and late-Holocene aged) archaeological evidence (Figure 4), implying that older human occupations would have been observed had they existed in significant density and even distribution across the landscape. From these observations, we can cautiously conclude that the post-3500 ^{14}C yr B.P. earliest evidence of settlement in the more insular Kurils (South Central and North Central regions) reflects a delay in colonization/establishment of human occupations in these regions compared to the South and North Kurils. The existence of many Pleistocene or early Holocene landforms in each subregion of the Kurils (Figure 4; Table I), even within our data set, implies that if occupations predated the earliest sites found to date, they are unlikely to have been substantial in terms of density or permanence of settlement. Of course, dating additional sites in our database or the addition of new archaeological survey and dating evidence for newly discovered archaeological sites and geomorphic landscapes would help test this hypothesis further.

Applying Landform Age Bias to the Archaeological Record

Within the data set of analyzed locations, there are twice as many available landforms at the present as there were approximately 7000 ^{14}C yr B.P. As mentioned above, this is clear indication that preservation bias must be accounted for in future studies of the archaeological record of the Kurils. However, more sites became occupied between 2000 and 4000 ^{14}C yr B.P. than in the last 2000 years; up to 25% of sites were settled at the peak occupation period compared to only 7% in the most recent 500 years (Figure 5C). Arguably the change in occupation rate is due to some aspect of demographic and/or cultural change and therefore, at least, some archaeological conclusions about human behavior in the Kurils can be made with confidence. If humans occupied the same percentage of the landscape over time, as expected if the islands were sufficiently populated that new, habitable landforms would-be attractive for settlement, then new landforms should be settled in proportion to their creation. Therefore, any time period for which the radiocarbon dates indicate fewer occupied sites than an older time period (Figure 5A) can be considered a significant deviation from geomorphic expectations. Because we are only looking at existing landforms with archaeological sites found on them, land-forming processes cannot drive a decrease in occupied sites within our data set. The overall increase in occupation rate until 2000 ^{14}C yr B.P., followed by a decrease, implies expanding and contracting settlement frequencies and not just geomorphological biases in site preservation.

Creation-Occupation Time Difference

An interesting observation that resulted from this analysis is that landslide sites in the North Central Kurils (Baskmak, Kharimkotan, Cape Ankuchi, Bukta Zakat, Bukta Vostok) were all settled relatively quickly (within a maximum of ~1000 ^{14}C years) after formation (Figure 4). Some coastal sites in the South Kurils may similarly have been occupied quickly (as exemplified by Kasatka Bay and Kubushevskaya sites), although exact dating of these landforms was particularly challenging with available data. Why were the landslides in the North Central Kurils occupied so quickly, compared to other landform types? Potentially this is because the landslides formed relatively low-lying and accessible areas in a region generally characterized by steep cliffs and inaccessibility. They may have also covered pre-

existing sites that were then “reoccupied” on the new surface following the working assumption of geomorphic controlled archaeological settlement that does not appear to hold for the larger, archipelago-wide data set.

CONCLUSIONS

The results of this study lend support to behavioral interpretations of the oldest archaeological radiocarbon ages throughout the Kuril Archipelago. Fitzhugh et al. (2002) presented the first comprehensive radiocarbon chronology for the Greater Kuril Islands and used the oldest dates from each island for their potential significance as an indication of initial colonization of the islands. The active geological history of the islands, nevertheless, posed an obvious challenge. Could we take the archaeological dates to represent anything more than the residual record remaining after geological events had buried or destroyed evidence of older settlements? Based on the analyses presented here, we can draw several conclusions about the likelihood of land creation biasing the representativeness of the archaeological settlement database.

1. Increasing rates of landform creation toward the present indicate a degree of preservation bias in the archaeological data since the mid Holocene.
2. However, the delay of a few thousand years between acceleration of landform creation and acceleration of archaeological site creation in the mid-to-late Holocene suggests that changing frequencies of archaeological settlement in this time range are relatively independent of landscape creation and most likely reflect changes in the intensity of human settlement in the archipelago.
3. Mid-to-late Holocene-aged landforms underlie the majority of sites excavated in the South and North Central Kurils; Pleistocene landforms dominate the record in the North Kurils and much of the South Central Kurils. The number of excavations made in Pleistocene-aged landforms with later (mid and late-Holocene aged) archaeological evidence adds confidence that we could have found older human occupations had they existed in significant density across the landscape. We thus conclude cautiously that the later establishment of the South Central and North Central Kuril archaeological record reliably reflects a delay in colonization/establishment of human occupations in these regions compared to the South and North Kurils. If Pleistocene or early Holocene occupations existed in the South or North regions, they must not have been substantial in terms of density or permanence of settlement. Alternatively, these early occupants lacked the ability or interest in settling the more insular islands.
4. Many young, relatively low-elevation landforms appear to have been occupied comparatively quickly (within a maximum of 1000 ^{14}C yrs) after formation in areas with limited low-lying topography, implying a preference for low-elevation sites.

The results of this study do not remove all taphonomic complications. Changes in relative sea level, for example, would have submerged sites originally settled near sea level in the early Holocene and Pleistocene. Limits in sampling effort and possible biases in research design remain potential confounding factors in archaeological interpretations. Nevertheless,

controlling for these other factors to the extent possible, the results reported here allow us to approach the larger sample of archaeological radiocarbon dates from the KBP with greater clarity as we seek to explore settlement history and occupational intensity through the prehistory of the Kuril Islands.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Figure 1.

Location of archaeological sites in the Kuril Islands. For the purposes of this study, the archipelago is divided into four regions (dark gray boxes): South Kurils, South Central Kurils, North Central Kurils, and North Kurils. Inset: regional setting of the Kuril Islands.

Figure 2.

Examples of landscape categories. (A) Coastal plain, beach ridge sequence (indicated by white bar)—Dushnaya Bay, Simushir. Photo: T. Pinegina. (B) Coastal dunes (indicated by white bar)—Kubushevskaya, Iturup. Photo: B. Fitzhugh. (C) Terrace (surface indicated by black arrows)—Onekotan. Photo: M. Etnier. (D) Landslide (indicated by white bar)—Bashmak landslide, Shiashkotan. Photo: M. Etnier. (E) Ignimbrite (upper surface indicated by black bar)—Tao-Rusyr ignimbrite of 7500 ^{14}C yr B.P., Onekotan. Photo: A. Ritchie. (F) River terrace—carved into the Tao-Rusyr ignimbrite (terrace surfaces indicated by black arrows), Onekotan. Photo: A. Ritchie.

Figure 3.

Pie charts indicating the type of landforms on which archaeological sites sit (large circles) and the age, Holocene or Pleistocene, of the landforms (small circles), divided by region. The total number of sites presented here includes 30 landforms with no radiocarbon dates or pottery typologies not included in Figures 4 or 5.

Figure 4. Estimates of landform age, organized by oldest occupation (oldest upper left, youngest lower right). Each archaeological site is represented by a horizontal bar. Landforms did not exist where the bar is black and did exist where the bar is white. Gray indicates the minimum and maximum age of formation. Oldest archaeological radiocarbon dates from each site are represented by black vertical bars. Pottery typology dates are indicated by gray dashes and are only noted if there was no associated radiocarbon date. Landform types are indicated on the left edge.

Figure 5.

(A) Number of landform locations that were newly formed compared to the first occupations of landforms in a given time period based on the age of the landform and radiocarbon or pottery dates. All data are binned into 500-yr intervals. See text for discussion of age error. (B) Cumulative number of archaeological sites that contain strata of x age, compared to sites that have an occupation at least as old as time x , derived from the curves in (A). (C) Proportion of newly occupied sites compared to the number of existing landforms (the landform curve in B). See text for calculation of confidence interval. Error cannot be calculated for time periods with no occupation. (D) Proportion of landform locations that had been occupied at least once by time x .

Summary of landform age analyses for archaeological sites with dated archaeological material in the Kuril Islands. The range of number of landforms older than a specific age is calculated using the maximum and minimum estimate of landform age.

Table 1

	Number of Locations with Dates for Landform and First Occupation	Total Landforms with Ages Older Than							
		7000 ¹⁴ C yr B.P.		5000 ¹⁴ C yr B.P.		3000 ¹⁴ C yr B.P.			
		Number	Percent	Number	Percent	Number	Percent	Number	Percent
South Kurils	24	7-9	29-38	9-17	38-71	14-22	58-92		
South Central Kurils	10	5	50	5	50	5	50		
North Central Kurils	16	6-7	38-44	6-7	38-44	6-9	38-56		
North Kurils	7	5-7	71-100	5-7	71-100	5-7	71-100		