*Papers*

# Pleistocene, Holocene and Recent Bird Gastroliths from Interior Alaska

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ABSTRACT. Polished and rounded grains of quartz, secondary quartz and chert have been found in loess and peat in interior Alaska. The intermediate diameter of these polished and rounded grains is between 35 and 0.07 mm., with grains of 0.7 mm., 2 to 4 mm. and perhaps 10 to 20 mm. being most abundant. Polish on these grains has been produced by abrasion in bird gizzards. Gizzard-bearing birds are living in interior Alaska today and produce glossy polish on their gastroliths comparable to the polish on gastroliths from the Holocene and Pleistocene deposits. The polish and roundness of Recent bird gastroliths vary, being more pronounced in those of living birds in late winter. Some of the Holocene and Pleistocene polished gastroliths are believed to have been produced by species of birds not now living in interior Alaska, because modal size classes of these ancient gastroliths do not coincide with modal size classes of polished gastroliths from birds living there today.

RÉSUMÉ: *Gastrolithes d'oiseaux pléistocènes, holocènes et récents de l'Alaska intérieur.* On trouve dans le loess et la tourbe de l'Alaska intérieur des grains polis et arrondis de quartz, de quartz secondaire et de chert. Le diamètre intermédiaire de ces grains se situe entre 35 et 0.07 mm, les plus abondants mesurant 0.07 mm, de 2 à 4 mm et peut-être, de 10 à 20 mm. Le poli de ces grains est le produit de l'abrasion dans des gésiers d'oiseaux. Les oiseaux à gésier qui vivent aujourd'hui dans l'Alaska intérieur produisent sur leurs gastrolithes un fini poli comparable à celui des gastrolithes des dépôts holocènes et pléistocènes. Sur les gastrolithes d'oiseaux récents, le poli et l'arrondi varient directement, atteignant un maximum pour les oiseaux vivants à la fin de l'hiver. On peut croire que certaines gastrolithes polies de l'Holocène et du Pléistocène ont été produites par des oiseaux qui ne vivent plus aujourd'hui dans l'Alaska intérieur, car les classes dimensionnelles de ces gastrolithes anciennes ne coïncident plus avec celles des gastrolithes des oiseaux d'aujourd'hui.

РЕЗЮМЕ. *Желудочные камни плейстоценовых, голоценовых и современных птиц из центрального района Аляски.* В лессах и торфяниках центрального района Аляски были найдены округлые полированные частицы кварца, вторичного кварца и кремнистого сланца. Средний диаметр этих частиц лежит в пределах от 0,7 мм до 35 мм. Большинство частиц имеет диаметр 0,7 мм, 2 - 4 мм и, по-видимому, 10 - 20 мм. Полировка частиц осуществлялась в процессе истирания в мускульном желудке птиц. По качеству полировки желудочные камни современных птиц сравнимы с камнями, найденными в плейстоценовых и голоценовых отложениях. Желудочные камни современных птиц отличаются по округлости и качеству полировки, причем наиболее округлые и отполированные камни встречаются у птиц в конце зимы. Предполагается, что некоторые из желудочных камней плейстоценового и голоценового возрастов принадлежали к таким видам птиц, которые более не населяют центральные районы Аляски. Это объясняется разницей в размерах желудочных камней современных и доисторических птиц.

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## INTRODUCTION

The purpose of this paper is to describe some polished grains found in Holocene and Pleistocene loess and peat deposits of interior Alaska, to present the hypothesis that these polished grains were produced by abrasion in the gizzards of birds and to show the nature of gizzard stones of some birds now living in interior Alaska.

Polished grains in unconsolidated sediment or in sedimentary rocks known to have accumulated in aquatic environments are usually considered to evidence abrasion and transport, although some workers believe that certain polished grains belonging to this genetic class may be the result of chemical reaction (Kuenen and Perdok 1962). Beaches and shallow-water bars are the best known environments producing polished grains today (Tricart 1958; Newell *et al.* 1960; Folk *et al.* 1962; Folk and Robles 1964; Folk 1965), though rivers also produce them (Bond 1954).

Another process which produces polished grains having the highest gloss is abrasion of mineral grains with organic food in the gizzards of vertebrates. The most well-known polished stones of this category in North America are gastroliths associated with skeletons of large reptiles, particularly in the Morrison Formation (Jurassic) of Wyoming (see bibliographies in Bryan 1930; Williams 1937). Gizzard-bearing birds also have gastroliths and although these have been known for some time (Forbes 1892; Smith and Rastall 1911; Meinertzhagen 1954; Rajala 1968), there are few data known to us on the size, weight and polish of bird gizzard stones. Only recently have these bird-polished grains been discussed in geological literature (Young 1967; Dixon 1968).

## POLISHED GRAINS FROM INTERIOR ALASKA

Polished grains have been found in four localities to date: in loess of probable Holocene age at Easter Egg Hill (65° 43′ N., 148° 26′ W.; named in 1962 by the D. Kniffens of Fairbanks because of the highly polished and very well rounded pebbles they discovered while searching for archaeological sites near Livengood townsite); in peat on the Nenana Road, 64° 49′ N., 148° 10′ W.; in redeposited loess of Wisconsin age from the Eva Creek Mine and Ready Bullion Creek Mine, 64° 51′ N., 148° 02′ W.

Polished grains from the Easter Egg Hill locality were collected by the authors in the autumn of 1966 using a grid of 8 stations. A pit was dug at each station and a sample of about 2 lbs. (0.90 kg.) was taken. This site is in the saddle of a low hill; the polished grains are scattered in the loess and can be seen on the surface. A spruce-birch forest is now growing at the site; loess is about 1 foot (0.3 m.) thick in the saddle and thickens to many feet downslope. Bedrock of the hill is Paleozoic black chert and silicified limestone.

Size analyses were made with screens and pipettes at one-half phi intervals. Using a riffle splitter, aliquots of several hundred grains were taken from each one-half phi screen interval (where available) and the abundance of polished grains determined by grid counting with a binocular microscope. These data are given in Fig. 1, in which each sample is represented by two histograms. The lower histogram visually shows the size-frequency distribution of the sample and usually contains two modal-size classes; a coarse mode in the gravel, and a much finer mode in the silt size range which is loess. The upper histogram shows

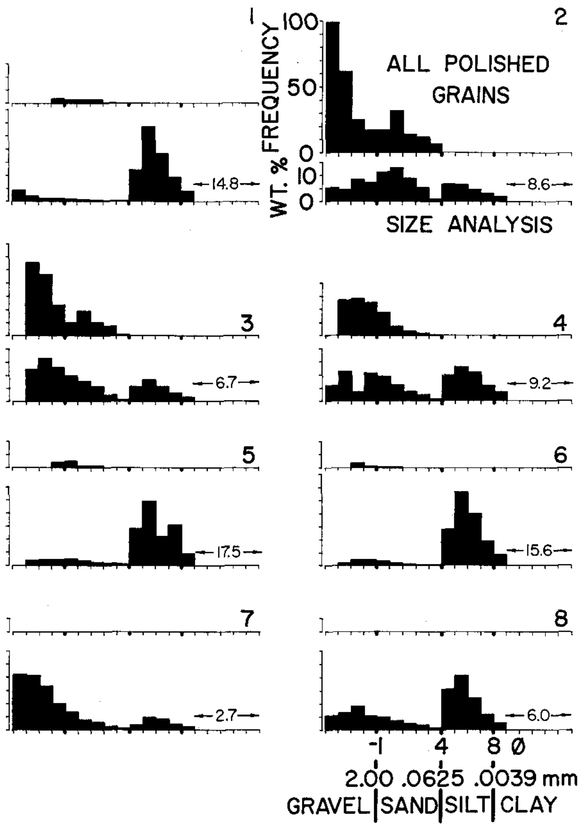


FIG. 1. Histograms showing number frequency abundance of polished grains (upper histogram) and size-frequency distribution by weight (lower histogram) for each of the 8 samples from Easter Egg Hill, Alaska. Bold numbers 1 to 8 represent samples 1 to 8. Lighter numbers with arrows on right of lower histogram show weight per cent of each sample finer than 9.0 phi (.0020 mm.) for which size-frequency data are unobtainable. Upper histogram for samples 7 and 8 show these samples contained no polished grains although grains of the appropriate size are present in the samples, as seen from the size-frequency distribution for each sample.

the size-frequency distribution of polished and rounded grains for that sample; this histogram also tends to be bimodal, but interestingly enough, size modes and polished grain modes do not generally coincide.

Polish has not yet been quantitatively classified, and photographs of the polished grains from sample 2 are presented in Fig. 2. That Fig. demonstrates that the degree of polish is about the same for 16 mm. pebbles, 0.07 mm. sand grains and all sizes in between, and that there is a striking contrast in degree of polish and rounding for the same mineral in each size class. This is contrary to the relationship between size, polish and roundness for beaches, where an optimum size is found for these parameters (Folk and Robles 1964).

Polished and rounded quartz grains found in a peat deposit on the Nenana Road are illustrated in Fig. 3. The intermediate diameter of these grains is about 2.5 mm.

Polished and rounded grains were found in loess of Wisconsin age at the Eva

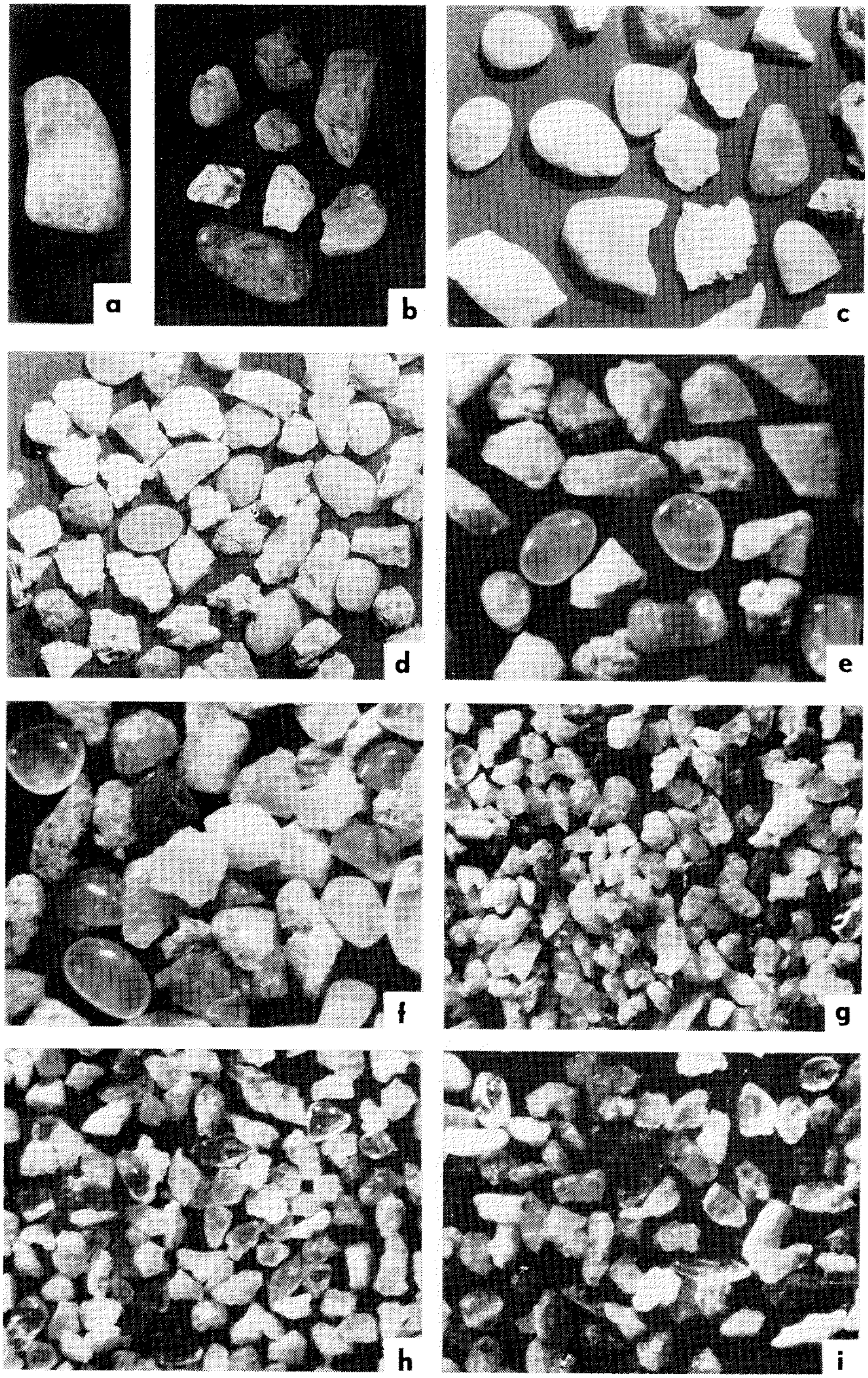


FIG. 2. Photographs of grains separated into one phi size classes, sample 2, Easter Egg Hill. a) grains retained on screen of 16 mm.; b) 8 mm.; c) 4 mm.; d) 2 mm.; e) 1 mm.; f) .50 mm.; g) .25 mm.; h) .125 mm.; i) .0625 mm.

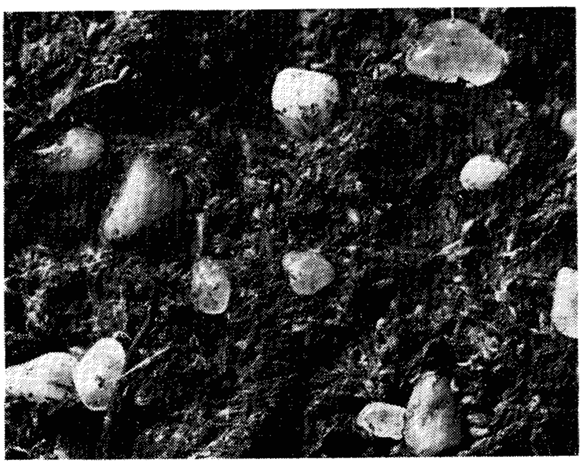

FIG. 3. Polished grains found in peat on the Nenana Road.

Creek and Ready Bullion Creek mines by Guthrie, and John Matthews, a former graduate student in Geology at the University of Alaska. Guthrie and Matthews were wet-sieving loess to concentrate small mammal and insect fossils from samples of about one ton each. Polished and rounded quartz grains mixed with dull and angular quartz and mica grains were recovered on a screen with 0.42 mm. openings (total weight recovered 12.4 gm.). Thus grains smaller than 0.4 mm. were not seen; the size of the polished and rounded grains recovered from the loess is about 3 mm. Of course the original distribution of these grains in the loess is not known.

## ORIGIN OF THE POLISH

### In situ *abrasion*

An understanding of the polished grains from Easter Egg Hill requires answers to three questions: 1) what process has produced the glossy polish? 2) how can it be that some grains are polished and rounded and other grains are dull and angular, although both are composed of the same mineral and are in physical contact with each other? and 3) why do the polished grains tend to be most abundant in certain sizes and yet occur over such a wide size range? Satisfactory answers for polished grains from Easter Egg Hill should make the polished grains in peat and redeposited loess self-explanatory.

Grains with a glossy polish are unusual (Pettijohn 1957); processes known to produce high polish are abrasion by wind-blown sand or ice crystals, abrasion in water or abrasion in gizzards. It was suggested to the authors that polish might be produced by abrasion due to downslope transport in solifluction lobes.

Polish due to wind-caused abrasion can be quickly eliminated because this process produces facets and no polished grains of this report have any facets. Abrasion on beaches or rivers seems unlikely, as judged from the physical occurrence of the grains, but it is admitted that the Easter Egg Hill polished grains could be inherited from Tertiary sediment of probable fluvial origin (Florence Weber, personal communication).

Polish due to solifluction abrasion or other soil processes was considered, and some tumbling barrel experiments were designed to evaluate those processes. Examination of pebbles and grains tumbled with wet loess from Easter Egg Hill shows that polish can be produced in the tumbling barrel and that *all grains* are affected. Tumbling barrels may not reliably duplicate nature, and more importantly, grains from Easter Egg Hill are mixtures of polished and rounded with dull and angular grains; therefore, *in situ* soil or solifluction abrasion has not produced the polish. In fact, the outstanding contrast between polished and dull grains of the same size, mineral type and site of occurrence seems to be a compelling argument against all processes of *in situ* abrasion.

*Gastroliths*

The possibility of abrasion in bird gizzards as an explanation for the polished grains of this report occurred independently to Guthrie working on polished grains from loess and to Hoskin working on polished grains from Easter Egg Hill. Robert Weeden and Larry Ellison of the Alaska Department of Fish and Game confirmed the correctness of this idea. Weeden has a long-term project in progress with ptarmigan and Ellison has a similar project with grouse; both of these birds have gizzards and gizzard stones, or gastroliths.

FIG. 4. Grains from spruce grouse gizzard. Ellison's sample number SG-84-63. Grains retained on screen of 2 mm.

Polish of bird gastroliths is nearly equal to that of polished grains from Easter Egg Hill; this can be seen by comparing polished gizzard stones from a spruce grouse (Fig. 4) with polished grains of a comparable size from Easter Egg Hill (Fig. 2, d). It can be argued that birds selectively pick up and swallow polished grains from the ground and soil, so that it is necessary to attempt to prove that the observed polish and roundness of bird gastroliths is produced within the bird gizzard. Probably controlled experiments with caged birds would be best, but an alternative avenue was chosen for convenience and availability of data which support the bird gizzard polish hypothesis.

Birds with gizzards purposely pick up and swallow small pebbles and sand grains as apparently without them to grind their food the birds cannot assimilate their diet of seeds, and willow and spruce buds. Using the collections of Weeden and Ellison, standard sieve analyses and weight measurements were made for 6 closely-related species of gizzard-bearing birds; 5 species from interior Alaska and 1 species, the blue grouse, from southeastern Alaska. Results of these analyses are presented in Fig. 5 (size) and Fig. 6 (weight), and show that enough

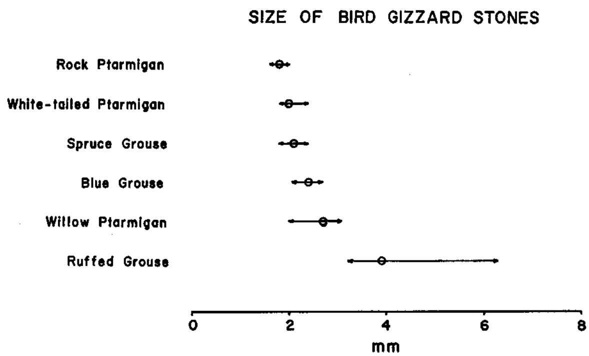


FIG. 5. Range and graphic mean size of gizzard stones from birds living today in interior Alaska. Ten analyses for each species except spruce grouse which has 9.

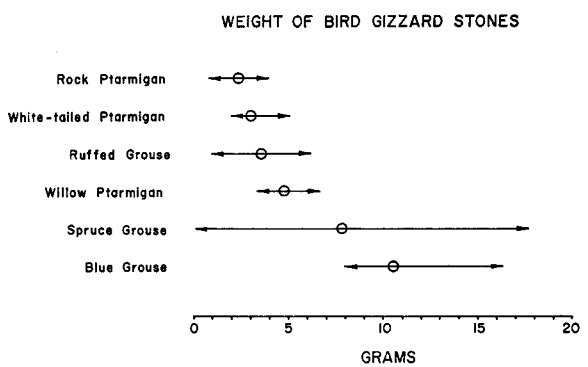


FIG. 6. Large and average weight of gizzard stones from birds living today in interior Alaska. Ten analyses for each species except spruce grouse which has 9.

grains of the appropriate size are present in bird gizzards easily to account for the abundance of grains accumulated in sediment. To show that polish and rounding were the result of abrasion within the gizzard, scatter diagrams were made plotting Powers (1953) roundness against time of year (Fig. 7) and degree of polish against Powers roundness (Fig. 8). Enough gizzards were available only for the rock ptarmigan, but spot checks of gizzard contents for the other 5 species listed in Figs. 5 and 6 showed similar trends. The data in Fig. 7 show that Powers roundness for rock ptarmigan gastroliths tends to be lowest in the summer when stones are everywhere available to the birds. With the coming of snow cover in late September, Powers roundness increases and is highest in late winter when snow covers the ground and grains are no longer available. When the snow melts in late March or early April, grains are again available, and there is a consequent drop in Powers roundness as the rock ptarmigan picks up grains from the ground. The scatter diagram of degree of polish against Powers roundness (Fig. 8) shows a linear relationship; gastroliths taken from bird gizzards in late winter are always polished and rounded whereas gastroliths from birds killed in summer tend to be dull and angular.

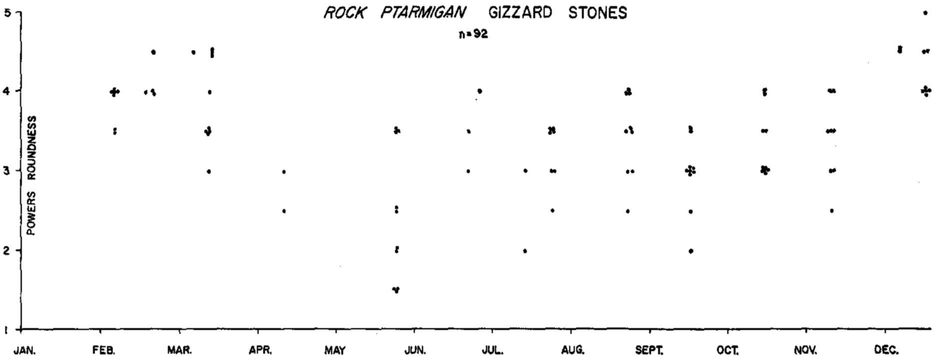


FIG. 7. Scatter diagram of Powers roundness against time of year for 92 gizzards of the rock ptarmigan. Each point represents Powers roundness judged to be representative of the gizzard contents. Only mineral grains judged.

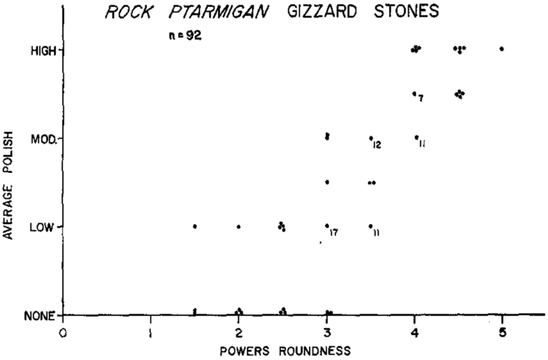


FIG. 8. Scatter diagram of degree of polish against Powers roundness for 92 gizzards of the rock ptarmigan. Each point represents Powers roundness and degree of polish judged to be representative of the gizzard contents. Only mineral grains judged

It is believed that the above data supply answers to the questions posed about the polished grains from Easter Egg Hill: 1) polish is produced by abrasion in bird gizzards, 2) polished and rounded grains are mixed with dull and angular grains because the polished grains stayed for a time in a bird's gizzard and the dull grains did not, and 3) polished grains tend to be abundant in certain sizes because these are the sizes preferred by a given species of bird. The bimodal size-frequency distribution of polished grains from Easter Egg Hill suggests that gastroliths from at least 2 species of birds have accumulated there. As suggested previously, polished grains from the Nanana Road peat and from Eva Creek and Ready Bullion Creek loess represent gastroliths from birds that died in winter.

Accepting this hypothesis, which species of bird is responsible for the polished grains at each locality? Matching modal size classes for polished grains in sediment against modal size classes of gastroliths for each species should give the answer. Visual inspection of peat and redeposited loess polished grains suggests that they were produced by a species of grouse or ptarmigan. When modal size class matching is attempted for the polished grains from Easter Egg Hill however, corresponding modal size classes for grains from loess and grains from living

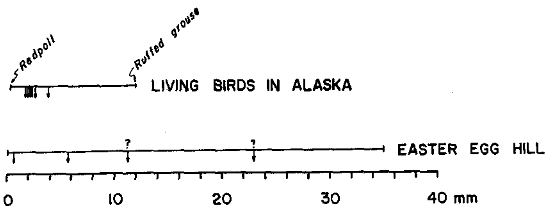


FIG. 9. Summary of maximum, minimum and modal size classes for polished grains from loess and from gizzards of living birds of interior Alaska. Bars indicate range, arrows indicate modal size classes.

birds cannot be found. This is illustrated in Fig. 9. Assuming that the size class approach is a valid one, it is necessary to conclude that polished grains from the loess of Easter Egg Hill, particularly the larger grains, were produced in the gizzards of birds which do not live in interior Alaska today. It is admitted, however, that examination has not been made of gastroliths from all birds now living in interior Alaska. We believe there is no insurmountable problem with the absolute size of these larger polished grains (maximum intermediate diameter is 35 mm.) because polished grains of 20 mm. from Moa gizzards have been found in loess deposits of South Island, New Zealand (Young 1967, Fig. 2). However, it is probably a mistake to expect a linear relationship between body size and gizzard stone size as the capercaille (a turkey-size grouse) living in Siberia and Scotland today has only 3.6 to 5.0 mm. gizzard stones (Rajala 1958, Fig. 2, p. 91). From the literature reviewed in the preparation of this report, it would seem that gizzard stone size is best correlated with diet. Perhaps a careful study of gizzard stones from all birds living today in interior Alaska would result in finding the producer of the polished grains from Easter Egg Hill.

## CONCLUSIONS

1) Polished grains from peat and loess of Holocene and Pleistocene age from interior Alaska seem to have been produced by abrasion in the gizzards of birds.
2) Each species of gizzard-bearing bird tends to choose grains of a certain size for its gastroliths.
3) Bird gastroliths may be more common than previously thought.

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