KAMES.

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ABSTRACT. Critcial evaluation of the term *kame* should include recognition of the fact that, originally a colloquial word, it came gradually into scientific use at a time when Pleistocene glacial study was a comparatively new field. Despite assertions to the contrary, by 1895 the term had become adequately defined, and its use in the literature since that time has been far too profitable to merit either abandonment or drastic revision.

Recognition of various modes of origin for kames gives opportunity to use variety names if desired. But as most of the postulated modes of origin include a large element of theory (or hypothesis), scientific interests will be best served by employing a conservative terminology in keeping with the sound field evidence.

CURRENT opinion among those interested in glacial geology is divided over the value of the term *kame*. The case for abandoning the term has been stated recently by Cook (1946), the primary objection being that kame is descriptive of form only, and that "any hillock of glacial material might be called a kame irrespective of its content, structure, or mode of origin." (p. 573.) As glacial hillocks are of diverse materials and structure and are known to have originated in various ways, the term must be either abandoned or redefined. To remedy the situation, Cook proposes the term *kame-complex* for "any area of sag-and-swell topography," and the term *perforation deposit* for isolated hillocks of gravel or sand.

For reasons stated in a later paragraph the present writer believes that any attempt to use kame-complex, as defined, will only bring additional confusion. Moreover, the term perforation deposit may prove to be equally unfortunate because the mode of origin ascribed by Cook to these hillocks is believed to be representative of only a part (possibly only a small part) of the deposits it is supposed to designate. Finally, the term kame has long had a definite and generally accepted place in glacial terminology and is too useful to be discarded.

Though Cook credits James Geikie (1895) with having introduced kame into geologic literature in 1874, Geikie himself (p. 210) gives credit to Jamieson (1874) for having given "the first clear statement of the morainic origin of kames." At a still earlier date, "Dr. Chambers . . . appears to have been the earliest to suspect their morainic character." In Jamieson's

paper the term is spelled *kaim*, which was evidently the original form (Gregory, 1912). Jamieson states (footnote, p. 328): "The word *kaim* is in Scotland generally applied to a narrow steep-sided mound. Some derive the term from the fancied resemblance to a cock's *comb*; others suppose it to come from the Gaelic word *cam*, crooked, often being applied to a curving or crooked hill . . . Mr. Campbell of Islay derives it from *ceum*, a path."

Inasmuch as scientists then were uncertain regarding the derivation of the word, speculation on that subject at this time seems particularly futile. In those days the word *mound* was used to designate a low ridge of indeterminate length, and Jamieson regards the "eskers" in Ireland as being included in the category of kaims. Geikie (1895) implies that in some localities weathered granite knobs were sometimes called kames. As, at a slightly earlier date, no distinction was commonly made between "eskers" and drumlins, the term kaim must have applied equally well to drumlins. From these reports it seems clear that the common people of those regions based their use of the term on form or general appearance only. Jamieson used the term kaim to designate especially the "narrow, steep-sided, curving ridges of sand and gravel, . . . often stratified, although generally in confused irregular beds." (p. 328.) This usage was apparently one of the first steps toward restricting the meaning of the term for scientific purposes. From Jamieson's summary of its status in 1874, Geikie's explanations and usage in the third edition (1895) of his renowned book show that its definition then was essentially that which current users of the term are following. Any ambiguities in Geikie's usage can be ascribed either to uncertainties regarding specific conditions attending deglaciation and the formation of kame deposits, or to the folkway context out of which the term had arisen (or was emerging) and by which he may have been influenced.

As a background for evaluating Geikie's kames, brief comment on some terms of undisputed value may prove helpful. Among the simplest essential words in topographic exposition are a few now in common conversational use such as hill, plain, and slope. These imply form only. Drainage divide is another essential term and is used more frequently in scientific description than in nontechnical literature. It denotes primarily a function, without strong emphasis on form and with no empha-

sis at all either on materials or on mode of origin. These illustrations show first the varying degree of technicality of essential terms, and second, that a term may still be useful even though the feature it denotes is not thereby rigidly restricted as to composition, structure, and mode of origin. This lack of rigidity is especially characteristic of words originating among people of nontechnical interests and speech, and these words necessarily retain much of their flexibility of meaning so long as they remain prominent in nontechnical usage. Even though they become obsolete in common speech, such terms cannot be expected to assume scientific precision of meaning suddenly. A transition period is both normal and unavoidable, and during this period writers lacking either in full information or in good judgment may at first use such terms inadvisedly. But if, meanwhile, a term has acquired significant value to an appreciable number of scientific workers through a considerable period of time, that term should not be abandoned merely because of minority misapplication. Perhaps the transition for kame was much less smooth than that for drumlin, and perhaps also some desirable revision and clarification of meaning has been unnecessarily delayed. On the other hand, perhaps a closer scrutiny of Geikie's usage may show that kame was adequately defined well before the close of the last century.

Geikie's Kames.

Regardless of the manner in which kame was introduced into geologic literature, Geikie gave it his wholehearted approval. His use of it in 1895 had the advantage of two decades which had witnessed great strides in the scientific exposition of land forms. The current objections to the term may well be measured by the standards which Geikie summarized for it at that time.

First, the assertion that kame is descriptive of form only is denied by the fact that Geikie classes kames among the deposits of sand and gravel overlying the till. A sand-and-gravel composition was likewise Jamieson's ideal. Geikie's typical kame is a single hillock consisting of cross-bedded sand and gravel near the center and bordered or covered by similar materials which may be slumped on one or more sides. Such is his diagram on page 148 and captioned "Section across kame . . ." Kame gravels are generally poorly washed, and Geikie notes

(p. 183) that "there are occasional exceptions . . . in which . . . the deposits are not only unstratified but earthy, and the stones are angular and subangular, some even showing faint ice-markings." He is careful to note that the ice-markings are faint, suggesting some contrast with unmodified striated stones from known till. A slumped deposit of poorly assorted drift may quite possibly have essentially the same mode of origin as similarly slumped deposits of well-assorted and well-rounded gravel.

Another point in need of clarification is Cook's claim (p. 574) that Geikie avoids using the term kame for the many " 'isolated, solitary mounds' " of gravel and sand. Geikie discusses their occurrence and notes (p. 183) that many of them have been utilized as burial places and as fortified strongholds. "One can easily see how an *abrupt kame or steep cone* might be made a very formidable fortress in the days of spears and arrows." (Italics by the writer.) The context clearly indicates that the words kame and cone are in apposition and do not designate separate categories. This usage also directly contradicts another assertion (Cook, p. 574) that the term "would hardly be applied to a single hillock." The assumption that the term would not be thus applied is evidently a basis for Cook's proposal (p. 574) that the expression kame-complex should convey "the understanding that a complex is a unified whole, and in no sense an association of discrete units." The examples already cited show that Geikie's frequent expression "assemblage of kames" (Cook's kame-complex) means definitely an assemblage of individual hillocks, each of which is a kame. In such an assemblage the limits of any one kame are often an arbitrary matter because of individual irregularity and because of multiple crests, the appearance of which is accentuated by viewing the assemblage from lower ground nearby. Kame-complex may well be adopted to denote an assemblage of gravel-and-sand hillocks (kames), but to apply the term to *any* area of sag-and-swell topography is to include areas of undulating or slightly "drumlinized" till plain whose materials, structure, and mode of origin have little in common with kames. The present writer believes that any attempt now toward such usage could result only in profound confusion, and would discredit rather than promote the study of glacial geology.

The Perforation Hypothesis.

The "isolated, solitary mounds" (kames) are Cook's typical perforation deposits. His hypothesis states that the drift composing these mounds accumulated originally in pools on the surface of a stagnant and waning ice sheet when ablation had exposed sufficient englacial debris. The water in a pool, warmed at the surface, descended because of increased density and melted the ice at the bottom of the pool. In this manner the mass of drift contained in the pool was ultimately lowered onto the ground. A further essential condition postulated is that of ablation chiefly by evaporation, the rate of which was notably reduced as the detrital covering on the ice increased in thickness. Then the downward "perforation" in the pools or water pockets proceeded faster than the general ice surface could be lowered by further evaporation.

The principle of convection melting in the manner described by Cook is well known, though the extent to which it has contributed to the origin of isolated kames in our middle latitudes seems problematical. In particular, two questions regarding the hypothesis may be raised at this point. First, the dominance of evaporation implies little if any removal of clay and silt from the drift set free on the ice surface. These materials are abundant in the New York drift of which Cook writes, and could reasonably be expected to form an impervious cover on the floor of a lakelet. Though, as Cook suggests, melting could still continue along the sides of the pool, further progress in deepening would be checked by concomitant extension of the impervious cover. Though this process of deepening or perforation is believed to be now in progress on the piedmont Malaspina Glacier in Alaska, Cook offers no data to show that the englacial drift in the Malaspina contains as much clay and silt as the last Pleistocene ice sheet held in the New York area.

The second question concerns the postulated predominance of evaporation of the Pleistocene glacier. On the glaciers of Spitzbergen at present, evaporation accounts for only about 3 per cent of the total ablation as measured by Ahlmann (1936). Any likelihood that the relative rate of evaporation during deglaciation in the middle latitudes was notably higher seems remote. The writer's studies of the drift in central New York have led to the interpretation that melting by sunshine was a dominant factor in deglaciation, and the numerous iso-

lated kames in that region are believed to be related to copious meltwater drainage upon and probably within and beneath the stagnant marginal zone of the glacier. Further discussion of these features is given in a later paragraph.

In this connection one may raise a question regarding the photograph, Plate I, accompanying Cook's paper. It shows an unusually symmetrical knoll which he designates as a "perforation cone composed almost wholly of cobblestones." To the present writer, such a deposit suggests strong action by meltwater, both in rounding the stones and particularly in effecting the observed size-sorting. This in turn suggests that melting probably exceeded evaporation as an ablation factor by a considerable margin. Vigorous meltwater drainage would modify greatly the process of deposition by convection melting. It might favor the convection process by providing a clay-free deposit in an ice-surface depression, but the incidental flow of water would subordinate if not obliterate the circulation due to differences in water density.

Meltwater-stream Hypothesis.

Many of the isolated kames and small groups of kames in central New York occur on hill slopes well above the valley floors, especially at or near the upstream ends of short channels cut in sags (cols) across drainage divides. The presence of these channels is evidence of voluminous meltwater flow upon the stagnant ice at a time when the hilltops were being uncovered in the course of downwastage. Copious meltwater flow at that stage is believed to be due to strong insolation which, at a slightly later stage, was apparently responsible for the pronounced concentration of drift along the east sides of north-south valleys in comparison with the west sides, and also in the general diagonal or asymmetrical positions of the end moraines in valleys through the Finger Lakes district. (Holmes 1946.)

Under these conditions, accelerated melting should have developed around each ice-free hilltop, resulting in a moat or pond surrounding the emerged land. Meltwater streams flowing generally southward to the ice margin could be expected to flow from pond to pond, some of the ponds possibly receiving inflowing streams from more than one direction. At this stage also, quantities of englacial drift were probably being freed at

the surface and were available for transportation. An inflowing stream would therefore build a deltaic cone where it entered a pond, though the deposit might not attain any strong resemblance to a delta because of the unstable conditions of melting and channel shifting. This mode of origin is believed to account for many kames in these locations.

As the ponds removed the coarser sediments from the drainage waters, the stream load carried through any appreciable distance consisted of materials easily held in suspension, and channel deposits between ponds were probably scarce. However, eddies or curves along the stream courses would offer ideal situations for the melting out of pockets or potholes, abrasion by sediment being an important factor. Such a hole would continue to deepen until the current could no longer carry all the sediment past the hole. Should a settling basin upstream become filled with sediment, the hole next downstream might receive a sudden influx of coarse material. Drainage changes under these circumstances were conceivably rapid, and should such a hole be abandoned by stream diversion it might then continue to deepen by convection melting. But as downwastage by insolation and abundant surface drainage was probably much more rapid than pocket deepening by the perforation process, the pocket deposit might later be eroded and redeposited at a lower level. The fillings in some of the hypothetical pockets were evidently built directly on solid ground, for the mounds of gravel have preserved their random cross-bedding with but little or no disturbance except at the margins. These are the isolated kames believed to be of ice-pothole origin. They need not have any trace of channel filling leading away from the site, though some kame series suggest the probable locations of contemporaneous meltwater streams. Comparable deposits lowered through any appreciable distance by the perforation process would be expected to lose all stratification.

Some instances of aligned kames probably represent gradation to an esker form. Possibly, after establishment of a channel at or near the bottom of the ice, a series of pockets was melted out before arrival of excess gravelly sediment, but conditions changed before a continuous deposit of channel gravel accumulated.

The simplest mode of origin postulated for kames is probably that of deposition in a motch or re-entrant along an ice margin, as diagrammed in the well-known text by Emmons, Thiel, Stauffer, and Allison, to which Cook alludes (p. 573). It suffices for the elementary student who can spend only a few moments on the subject, but it is not to be taken as the way in which all kames have developed.

Problems of Application.

The foregoing statements are based on the partial definition that an ideal kame is a mound of assorted glacial drift. As to form, the mound may be either symmetrical or irregular, though the degree of irregularity and development of multiple crests permissible in a single kame must remain a matter of judgment by the field observer. Gradation to "an assemblage of kames" is an ever-present problem except where the deposit consists of only a definite single mound. Any structure normal to glaciofluvial gravel, sand, and silt may be expected and should be permissible. Acute problems may arise because the size-sorting may be so poor as to simulate unassorted drift. Many stones in kame gravels have a partial coating of clay, though striated stones in kames are relatively few.

An uncommon type of gradation from assorted to unassorted drift is known from a few places in central New York. These deposits seem to have resulted from removal of the finer grade-sizes from till by meltwater escaping beneath the glacier margin while deposition was in progress. In places this has left a gravelly residue which is best regarded as a form of lag concentrate rather than as a glaciofluvial deposit because apparently much of the material was never moved by water. The occurrence of such deposits in an area of sag-and-swell topography requires careful use of any technical and pertinent terms.

A mass of drift in a stagnant pool, lowered onto the ground surface without any through-flow of water adequate to remove the finer constituents, would probably arrive at its final position devoid of stratification and size-sorting. Because of this probability, conclusive evidence of composition and structure should be available before stating definite conclusions as to precise mode of origin. As mentioned in an earlier paragraph,

the present writer doubts that deposits made in this manner are of general occurrence in middle latitudes.

Those (if any) who insist that each mode of origin for deposits otherwise similar justifies its own special name for its particular deposits are ever in danger of using terminology unwarranted by the field evidence. As Cook has appropriately stated (p. 577), "We have . . . in each case, the very last episode only from which to reconstruct a history that may not have been as brief as casual observation in the field would suggest." The present writer would add that even at best, our postulated modes of origin are of the nature of theories rather than certainties. Confronted by a gravelly hillock, much embarrassment may well attend any feeling of compulsion to apply this term in case the hill originated according to hypothesis A, or that term in case it originated according to hypothesis B. Many such hills lack suitable exposures from which the structure can be determined adequately. In such a case a much safer course is to call it a kame, giving it a variety name if its actual mode of origin can be discerned with fair accuracy or completeness. Thus possibly a perforation kame may be identified,—or a delta-cone kame, or a subaerial kame of the textbook. In many cases all that can be stated with certainty is that the gravel was brought across an ice surface at a level at least as high as the top of the kame, that arrival of the materials was attended by a flow of water (at some stage) adequate to account for the observed size-sorting, and that the configuration of the ice and of any associated surface was such as to cause accumulation of the gravel, with or without subsequent modification by slumping.

The following summary or definition is believed to represent Geikie's usage as well as that of present-day writers who employ the term: A kame is a mound composed chiefly of gravel or sand, whose form has resulted from original deposition modified by any slumping incident to later melting of glacial ice against or upon which the deposit accumulated.

The isolated symmetrical kame, such as Geikie represents by his cross-section diagram (p. 183), may well stand as the ideal type. From this, all gradations to compound kame and kame-complex can be found. Flat-topped kames, as part of a kame-complex, may grade into an outwash plain. In such situations, one must realize the possibility that among the gravelly

knobs may be one or more which could have originated as isolated kames, and not necessarily as a consequence of collapse attending melting of buried ice that may have underlain outwash in that vicinity. Similarly, kame terraces may be bordered by kames partially or wholly detached from the terrace deposits, which may or may not have a mode of origin the same as that of the terraces.

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