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SHORT NOTES

KETTLE HOLES

By R. P. K. Clark

(Education Centre, New University of Ulster, Coleraine, County Londonderry, Northern Ireland)

Abstract. An alternative origin and significance for kettle holes is considered. Kettles among some kame tracts may be due *not* to melt of buried ice but rather represent the location of ice pillars or roof pendants among stratified subglacial deposits.

Résumé. *Cavités en forme de marmites.* On considère une autre origine et signification pour marmites de glacier. Les marmites parmi quelques traces de "Kame" ne pourraient être dues à la fonte de glace ensevelie mais représentent plutôt la position de colonnes de glace ou de pendants de toits au milieu des dépôts sous-glaciaires stratifiés.

Zusammenfassung. *Sölle.* Für Sölle wird eine andersartige Entstehung und Bedeutung erwogen. Kessel in einigen Kames-Feldern sind eventuell nicht auf das Schmelzen verschütteten Eises zurückzuführen sondern kennzeichnen eher die Lage von Eissäulen oder Dachgehängen innerhalb der geschichteten Grundmoräne.

Appended to White's (1964) account of Whittlesey's early description and explanation of kettle holes is an editorial résumé of Flint's ([1957]) statements on the origin of kettle holes. All the modes of origin summarized there involve ice in a burial-thaw sequence, including certain propositions that:

i. Kettles are hollows in drift which are due to the melting out of glacier ice that had been wholly or partially buried.
ii. Kettles are especially associated with ice termini and zones of thinning.
iii. Kettles are frequently associated with stratified drift.
iv. Hollows of different origin in drift are not kettles.

Clearly, the consequences which flow from these assertions include the attraction of using kettles as diagnostic features despite the lack of very clear criteria for confirming that a hollow originated in a certain way. Inherent in this may be a tendency to assume that most hollows in stratified drift are kettles (*sensu stricto* Flint, [1957]), and that the presence of kettles among kames is indicative of marginal or near-marginal location at the time of supposed burial. The current development of kettles in and among eskers and pro-glacial sediments through the melting of buried glacier ice has been described in some detail from southern Iceland by Price (1969).

An examination of major commonly used geomorphology texts disclosed no important variation in description and explanation of kettles; indeed the phraseology often corresponds quite closely. The main points revealed by comparison are some lack of precision about size and shape, and the commonly used synonyms "pit" and "pitted" for "kettle" and "kettled". The conclusion is that Flint's views represent the consensus upon the nature of kettles.

The purpose of this note is to suggest that, notwithstanding clear evidence that some depressions do form in that way, misleading results may derive from uncritical acceptance of the usual interpretation of kettles among kames and eskers. The stratified deposits of these mounds and ridges frequently show normal faulting. This may occur within the deposits where some settling of whatever origin appears to have taken place; it may also occur adjacent to sloping sides, including some steep enough to be described as ice-contact slopes. In neither location is the faulting in itself diagnostic of the melting of covered glacier ice.

It is also common to find a situation where the surface of the kamiform feature and the upper undisturbed bedding of the deposit are conformable and within the range of dip to be expected in water-lain sediments. In these cases it is probable that the feature would retain its final constructional form virtually intact. In asymmetric cross-sections the steeper side may appear as a constructional feature of steep bedding, sometimes associated with a shift of the crest line during accumulation towards or away from the gentler side, or be characterized by chaotic dumping of sediment during build-up. It may also be a faulted side but it is clear that the steeper side of the feature is not always a collapsed side.

Enclosed hollows are so characteristic of some kame tracts as to lead to them being called kettle moraines. Enclosed depressions also frequently result from the branching and rejoining of eskers, as is especially well seen where thinning ice has very recently revealed these rather fragile features. Flanking hollows often aligned parallel to eskers are recognized as being frequent and integral parts of the landform complex.

It is important to note that undisturbed constructional slopes in kame and esker systems may form, wholly or in part, the sides of enclosed hollows. It is thus seen that not all hollows are due to the melting out of buried ice (glacier or otherwise) for many show no signs of subsidence. Rather they are locations of non-sedimentation.

Studies of deglaciation phenomena have increasingly and convincingly shown that many kames and/or eskers are the result of subglacial sedimentation in single or multitudinous passages beneath ice, the flow of water and the deposition of sediment contributing to undermelt and to the localized raising of the ice base. From an environment of this type, the enclosed depressions (the present kettle holes) indicate the position of former ice pillars or roof pendants. They are thus contemporaneous with the kames or eskers, and together with them form the mould of the undersurface of the ice at the time of last significant sedimentation. This type of melt and sedimentation at the base of the ice is less likely to leave many buried blocks to melt out later than marginal sediment accumulation enveloping thinning ice.

In addition, it is increasingly being realized that as the surface gradients of ice masses may decline and the whole lose mobility while remaining thick, then very broad zones of simultaneously stagnant ice result. Consequently, sorted and stratified subglacial sediments with concomitant hollows may form at a distance from the ice margin. It may be noted that because the ice over these hollows is the thickest and has the lowest base it may gather the thickest skin of ablation moraine, and therefore on both counts it is the longest surviving ice. But this is not burial in the sense of the usual definition of kettles.

It is difficult to know how far from an ice margin, and under what thickness of ice, subglacial drainage can build irregular deposits. It is similarly difficult to determine the distance between specific landforms of subglacial origin and the contemporary ice margin when that margin, obscured by ablation moraine and possibly by outwash, is indistinct, and when, its position determined by continuous downwasting of the stagnant ice, it left little evidence of past locations. Glen (1954) has suggested that water might move under temperate ice masses up to about 200 m thick. British field workers have presented little supporting evidence, most conclusions appearing to reflect the limit of about 90 m suggested by Derbyshire (1961). It is believed that some Norwegian eskers were built beneath ice more than 200 m thick (Gjessing, 1960), and there is evidence from Northumberland of water moving beneath ice 150 to 200 m thick (Clark, 1969). Such depths suggest locations far from ice margins, possibly over 100 km distant in the Norwegian examples. Indications from northern England are that, during the decline of the main Würm ice, kettles were produced at least 30 km from an ice margin.

In summary, it is suggested that certain types of enclosed hollow included in the class "kettle hole" are areas of non-sedimentation, and are not primarily due to the melting out of buried ice. Although they appear, in association with the constructional forms, to indicate stagnating or motionless ice, they cannot safely be used to locate ice margins. It is therefore suggested that the use of the term "kettle hole", whether used descriptively or genetically, be refined and clarified, or that its considerable imprecision be recognized.

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