ART. LIX. — *On the relation of the so-called "Kames" of the Connecticut River Valley to the Terrace-formation;* by JAMES D. DANA.

SINCE the publication of my papers of 1875 and 1876 on the stratified drift of Southern New England treating especially of the character and effects of the flood closing the era of ice, large additions have been made to our knowledge of the terraces of the Connecticut Valley, and of some other parts of Northern New England, through the New Hampshire Report of Mr. Warren Upham, published in 1878.* In his Report, Mr. Upham describes in detail the stratified drift or terrace-

* Geology of New Hampshire, Part III, Chapter i, Modified Drift in New Hampshire, by Warren Upham, pp. 3–177. 1878. A synopsis of Mr. Upham's Report, by its author, was published in this Journal, vol. xiv. p. 459, 1877.

formation of the valley; gives the heights of the terraces above the river (and above mean tide) from careful levelings along its course, commencing near the source of the river in Connecticut Lake, 1618 feet above the sea; discusses the origin of the deposits and of their various features; and presents his very valuable topographical details on a map of the valley occupying a series of plates. Besides the ordinary stratified drift, Mr. Upham finds gravel ridges or deposits to which he applies the name "Kames." According to his observations, the "kames" were formed before the deposition of the beds of the terrace-formation and after that of the till or unstratified drift, so that they represent an intermediate stage in the progress of the era and call for special explanations.

The facts from the Merrimac Valley also are presented in a similar way, and with like deductions.

In the study which I had made of the Quaternary of Southern New England, and less perfectly of drift-phenomena elsewhere, I had been led to refer all the stratified drift above the till to the terrace-formation; and no later observations in river valleys had resulted in the discovery of any thing answering to Mr. Upham's "kames." During the past summer, I have been over the region of the Connecticut Valley described by Mr. Upham, in order to obtain a full understanding of his facts, so as to be able to incorporate them with the knowledge I had previously acquired, and I here give an account of what I observed, with my conclusions.

That the subject may be rightly apprehended, I preface my statement with a brief mention, first, of some of the general facts respecting the stratified drift-deposits which I had gathered from personal study, and, next, of the facts and deductions which are brought out by Mr. Upham with relation to the "kames."

I.—(1.) Scratched bowlders and till are almost uniformly absent from the valley terraces of New England and from the stratified beds that make the terrace-deposits. Exceptions occur where the underlying rocks having till over them come so nearly to the surface of any terrace that the till outcrops.

(2.) The layer of till of the hill-slopes is continued beneath the terrace deposits; showing that along the valleys the till with the bowlders was generally deposited first.*

* In the street adjoining my own house, in New Haven, a trench, excavated for a sewer, passed through ten feet of stratified drift, or of the terrace formation, and then opened into a deposit of gravel and scratched stones (including some bowlders of eight to ten cubic feet); and, below two or three feet of this kind of material, entered the Mesozoic sandstone of the region. This sandstone rises in a ridge, above the level of the terrace, 400 yards to the north of the excavation, and must have constituted both the shore and bottom of the valley-waters at the time of the deposition.

(3.) The stratified drift of the valley consists ordinarily of fine material below, and coarser toward or at the top; the bottom portion being commonly of clay or loam, or fine sand with frequently more or less clay; then, following this, layers of sand often fine, but often with more or less gravel; then above, toward the top in the upper fifteen or twenty feet, coarser gravel, and in some regions cobble-stone beds; an order of arrangement, which indicates—in accordance with ordinary hydraulic principles—that the flow of the depositing waters was, as a general thing, less rapid at the time of the early depositions, and most so during the later or that of maximum flood. Exceptions exist along those streams that were torrents, and sometimes at the mouths of tributaries to large streams.

An uppermost sandy layer, of two or three feet thickness, frequently exists, indicating that the ebb commenced in a lessened rate of flow.

(4.) The portion of the terrace formation in a river valley that is nearest to the river or adjoins the channel-way, may, and often does, consist largely of beds of coarse gravel or cobble-stones, while one or two hundred yards away from the river it is composed chiefly or wholly of beds of sand; the river-border deposits being thus coarse because of the sifting or assorting action of the stream in violent flow along its channel or against one or the other side of it. And the coarseness may diminish down stream, because of greater remoteness from the source of coarse material, and also because of a change in the rate of flow, producing less power of transportation and so allowing of a deposition of the sands drifted out above.

(5.) Terraces of different degrees of coarseness and of different heights were sometimes simultaneously made on opposite sides of a stream, owing to the different rates of flow in the waters along the two sides.*

* Along the middle one of three streams entering the New Haven Bay, called Mill River, coarse gravel and cobble-stone deposits characterize the New Haven terrace-formation all the way to the harbor; they are vastly coarser on the west side of the stream than on the eastern, and in the southern part of its course are most so along a more western line away from the present stream. Moreover, the deposits make a terrace on the *west* side of the stream of only twenty-five feet above mean-tide level, while on the *east* side, where the material is so much less coarse, they rise to a height of forty-three to forty-five feet, or the ordinary level for the New Haven plain at that distance from the Sound. Those coarsest beds were made under the sifting action of the violently flowing waters (the pitch of the stream for some miles back being eight to ten feet a mile), and hence, that is, because of the loss of the finer material in this way, the height attained on the side of most rapid flow was twenty feet below the normal height. Moreover, the violent waters were probably those of the nearing maximum stage of the flood; for the coarse gravel deposits (as various sections show) extend down but fifteen feet from the surface, and rest on beds of sand and fine gravel.

(6.) The terrace-formation of a large and broad valley was made mainly, not from what its river transported, but from the contributions of tributaries. Consequently, (*a*) the height of the maximum flood is best registered in terraces at the mouths of tributaries, and (*b*) where tributaries fail for long distances, there may be only low terraces; further, (*c*) the coarsest gravel beds should exist in the deposits about the mouths of tributaries, and especially in those made along the banks of the *main river* near these mouths, where the contributions were subjected to the sifting action of the swiftly flowing river.

(7.) The extent and height of the terraces made along any part of a valley depended not merely on the amount of contributed material, but also largely on the size and form of the valley. Where very wide and deep, like many lake basins, the deposits were generally sufficient to make only low or narrow terraces; where narrow, the flow of waters was sometimes, because of the diminished width, too rapid for any depositions; but where the valley, though narrow along the main channel had a broad region of ledges on either side that became overflowed when the waters were nearing their maximum depth, a high terrace might then have become of great width; for the shallow region favored deposition by offering resistance to the flow, and however wide needed little material to cover it. Just as this condition favored the making of a broad upper terrace, so it favored the making of a wide terrace at lower levels, especially if the flow of water continued long at those levels.

(8.) Ice-floes, bearing sand, gravel and bowlders, added to the transported material for the terrace-formation; and they should have been abundant during the breaking up, at the time of maximum flood. Being carried by the waters, their distribution of material would have taken place for the most part in accordance with the principles above explained.

II. Mr. Upham adopts in his New Hampshire Report, the view that the valley formations are deposits made by the flood from the melting glacier, and it appears from his explanations that he would accept without objection several of the above explanations. The points of discrepancy, however, are many and important. I cite here only those relating to the "*kames*," and mostly in the author's words. The term *modified* drift is used by him for *stratified* drift.*

Page 12. "The oldest of the deposits of modified drift are long ridges, or intermixed short ridges and mounds, composed of very coarse water-worn gravel or of alternate layers of gravel and sand irregularly bedded." "Their position is generally along the *middle* or *lowest parts* of the valleys." Wherever the

* I have avoided the term *modified*, because it is not known to express in all cases the truth, preferring the non-committal term *stratified*.

ordinary fine alluvium of any terrace occurs adjoining a kame, "it overlies or in part covers the kame deposits," the ordinary terraces being of later formation than the kames.

Page 43. Along the Connecticut, between Vermont and New Hampshire "from Lyme to Windsor, a continuous gravel ridge or kame extends 24 miles, along the middle and lowest portion of this valley, with its top 100 to 250 feet above the river." "Its material is gravel and sand in irregular obliquely-bedded layers, always showing an inclined, and in most cases a distinctly anticlinal or arched stratification. The gravel, which always forms the principal part of the ridge, varies in coarseness from layers with pebbles only 1 or 2 inches in diameter to portions where the largest measure 1½ or 2 feet. The fine kinds prevail." "The sand is usually coarse and sharp, well suited for masons' use; it occurs in layers of varying thickness up to one or two feet, but sometimes it is wholly wanting." "All the materials of this kame, and of its remnants along this valley, are plainly water-worn and stratified."

Page 44. "The most important feature of this kame, if we compare it with others in New Hampshire, is that along its entire extent it constitutes a single continuous ridge which runs by a very direct course nearly in the middle of the valley, having no outlying spurs, branches, parallel ridges, or scattered hillocks of the same material associated with it."

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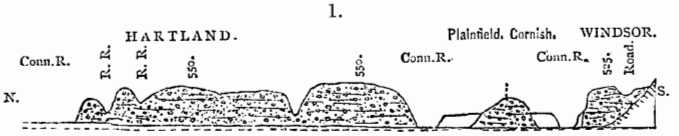

Southern part of the "Kame." in Hartland and Windsor.

Page 45. "In calling this kame continuous from Lyme to Windsor, it is not meant to imply that it is now entire, since it has been frequently cut through and considerable portions swept away by the main river and its tributary streams; but that so much of it remains as to make it certain that it originally formed an unbroken ridge." The former southward continuation of the kame below Windsor is stated to be "probable though now shown by only a few fragments." Mr. Upham then mentions, on p. 47, facts from the vicinity of Windsor, showing at one place in the valley "gravel which is unmistakably that of a kame"; just south, what "seems to be a kame deposit;" and 1½ miles south, "distinct remains of the kame," forming the east border of the terrace, both kame and terrace being 150 to 170 feet above the river. For the next 11 miles no indication of the kame are seen; and beyond are only remains at long intervals more or less distinct.

The preceding figure is part of a section, given on p. 45 of the Report, intended to show the general features of the southern part of this kame ridge (exaggerated relatively in height) in Hartland and Windsor; and the following (from p. 40) is a transverse section of the Connecticut valley through the Hart-

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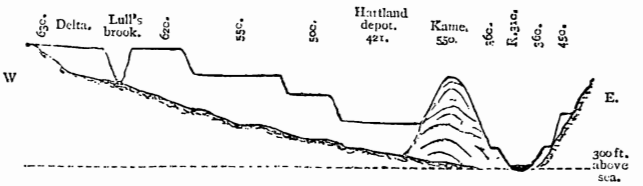

Transverse Section in Hartland and Plainfield.

land deposits, exhibiting the position of the kame just west of the river channel, and its relation to the terrace-formation and the several terraces of the valley.

The adjoining figure, from page 37 of Upham's Report, will help further to explain the author's views. It represents the Hanover "kame," with the outline of the terrace-plains on the opposite sides of the Connecticut. The kame, *k*, is represented as constituting a ridge, coarsely stratified, buried beneath the terrace formation, up to its very top, on the landward side, but uncovered on the side toward the river. A section taken a little farther north would have exhibited the "kame" projecting above the terrace-plain.

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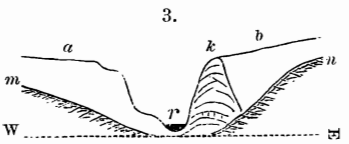


Section of the Hanover Kame, *k*, on the east side of the Connecticut River, *r*; *m n*, the till-covered underlying rocks; *a*, terrace in Norwich 505 feet high above mean-tide level and 132 feet above low water in the river; *b*, terrace in Hanover 515 to 545 feet high.

"Kames" are also described as occurring in the valley to the north, but at long intervals.

As to origin:

P. 176. The kames "were deposited, as explained on pages 13 and 14, by glacial rivers, at the final melting of the ice sheet, in *channels formed upon the surface of the ice.* When the bordering ice-walls and its separating ridges and masses disappeared, the gravel and sand remained in long steep ridges, or in irregular short ridges and mounds."

P. 44. The infrequency of angular fragments and bowlders shows "that the kame of the valley was formed in an open ice-channel." P. 14. On the ice in these "channels were deposited materials gathered by the streams from the melting glacier. By the low water of winter, layers of sand would be formed, and by the strong currents of summer, layers of gravel, often

very coarse, which would be very irregularly bedded." "The glacial rivers which we have described appear to have flowed in channels upon the surface of the ice, and the formation of the kames took place at or near their mouths, extending along the valley as fast as the ice-front retreated." P. 44. "When the river entered upon the work of excavating its present channel in the alluvium, the kame was a barrier which confined erosion to the area on one of its sides and protected its opposite side; so that this ridge of gravel often forms the escarpment of a high plain with the river flowing at its base."

The chief points urged by Mr. Upham with regard to the so-called "kames," exclusive of those pertaining to mode of origin, are:—origination: after the till and before the stratified drift of the terraces; material: chiefly beds of gravel; structure: usually arched or anticlinal; situation: generally between the river and the upper terrace, and often making the riverward limit of the latter, also, in many cases, partially isolated and ridge-like, owing to a depression between it and the terrace, and sometimes a large depression; height: frequently the same with that of the upper terrace or a little above it. Further, his descriptions show that he refers coarse cobble-stone deposits in the riverward part of the terraces always to "kames."

In my study of the facts relating to the Connecticut Valley "kames," I commenced at Windsor, the southern limit of the great line of "kames," and examined the valley formations at various places from that place to Lyme, and thence northward to Barnet and Lancaster: and the report I have to make is unfavorable to the "kames." I made levelings at various places in order more surely to identify the terraces mapped by Mr. Upham, and to apprehend their true relation to the Connecticut Valley, and also, to add, if possible to the facts. My trials soon satisfied me as to the essential correctness of his measurements.

Windsor.—At Windsor (on the west side of the Connecticut) the upper terrace of the village rises to a height of about 216 feet above the river or 520 feet above the sea-level. I saw no good opportunity for a satisfactory examination of the material of its lower part beneath the village; but in the upper part found it to be fine sand and loam, though somewhat pebbly through the upper 25 feet.

South of the village lies Ascutney Pond, a north and south body of water made by damming the waters of Ascutney brook; on the *east*, the pond is separated from the Connecticut River by a ridge of stratified material, nearly flat-topped, having about the same height as the upper terrace. Mr. Upham says, somewhat doubtingly, that this ridge "seems to be a kame de-

posit." It ends southward in rocky ledges. A mile and a half farther south, the high river terrace consists along its eastern margin of very coarse gravel, and is pronounced therefore to be in this part the "remains of the kame."

I found this ridge east of Ascutney Pond to consist mainly of loamy material, or sandy loam, like the terrace west of Windsor, with little gravel and that chiefly over its upper surface or in an upper layer. But directly *west* of the Pond there is a terrace (not referred to particularly by Mr. Upham) whose material is made up largely of coarse gravel, in part cobble stones, and coarsest in its upper layers, which in this portion is as much entitled to be called "kame" as that "a mile and a half farther south." This terrace rises westward to a level plain at 448 feet above the sea-level, and then another at 480, and this last rises to 525 feet, which is the height given by Upham for the possible "kame" east of the pond. Its gravelly character continues, but diminishes northward.

I found no evidence whatever that the eastern portion of the terrace was a "kame," that is, a part separate in time of origin from the rest; the evidence was all against such a conclusion. Moreover there was an abundant source at hand for the amount of coarse gravel and cobble stones; for Ascutney or Mill Brook, rising in northwest Reading, flows with rapid descent by the north side of the lofty Ascutney Mountain (3320 feet), and would have been a great transporter from the drift-covered country it drained. The position of the stream, and its relation to the southward-flowing Connecticut, account for the distribution of the "kame" material or coarse gravel of the Windsor region, including that of Windsor village, mentioned by Mr. Upham, and also for the isolation of the ridge on the east side of the pond.

Two miles north of Windsor a kame is entered on Mr. Upham's map. Much coarse gravel here makes the outer or westward portion of the upper terrace, which is by the map 500 feet above the sea-level. Besides coarseness of gravel, I saw no evidence of a kame, that is of any deposits that were distinct from the terrace in original deposition. A brook comes from the west just north of the "kame."

Hartland station, 4½m. north of Windsor.—At this place stands the "kame" ridge represented in Upham's section reproduced, on page 456, of which he says: "At one place, east of Hartland depot, this plain (that of the upper terrace) has been swept away from both sides, and the kame forms a conspicuous steep ridge 125 feet in height [above the depot plain, 240 feet above the river]. Wherever it is exposed, it is readily recognized by the pebbles which strew its surface, and which are very rarely found in the ordinary modified drift of the valley."

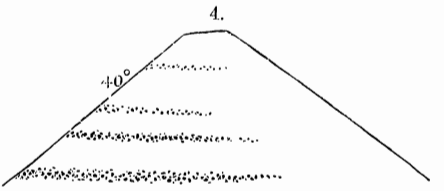
I ascended this prominent "kame" with my interest greatly augmented by the description in the Report. The narrow plain between it and the station (see the section) was covered with pebbles from an underlying gravelly layer. The same gravelly layer made apparently the base of the "kame," for some loose cobble-stones were found at the base of the slopes and for 10 to 15 feet above. But on ascending the ridge, no gravel was anywhere observed at a higher level; on the contrary, all was fine loam or fine sandy loam to the very top. And on descending, the same proved to be true; the only gravel was at its base, 50 feet above the river and nearly 200 feet from the top, according to my leveling. There were no good sections, but if made of gravelly layers, loose stones or pebbles would have worked out to the surface and shown themselves somewhere over the earthy sides.

A few rods west and northwest of the Hartland depot there was gravel in the terrace, and much of it; and according to the description of "kames," there was, as far as material goes, a "kame." On the first terrace-plain, about 65 feet (by my leveling) above the railroad track (or 486 to 490 above the sea level) large stones (1 to 10 inches across) lay over the surface, and very many in the sloping section of it facing the railroad track. From this terrace-plain, some rods to the west, there is an abrupt rise to the next higher terrace, and here the material is fine sandy loam with no pebbles. The natural conclusion is that the gravelly stratum is a lower part and the sandy loam an upper part of the same terrace formation, precisely as in the so-called "kame;" and, secondly and accordingly, that the "kame" is nothing but a piece of the terrace-formation. Lull's Brook here comes in from the west and is no doubt accountable for the coarse gravel.

North Hartland, nearly 4 miles north of Hartland.—At North Hartland station, there commences, according to Upham's map, another "kame" a mile long; it is near the river, close by the west side of the railroad. Its height by the map is that of the upper terrace-plain, or 550 to 560 feet above mean-tide level. Very coarse gravel shows itself in an oblique section of the terrace formation or "kame" facing the railroad, becoming cobble-stone layers 70 to 80 feet above the track. The coarseness diminishes to the northward. The large torrential stream, Quechee river, rising in the Green Mountains, enters the Connecticut here, and seemed to be a sufficient source for all the depositions; while the fact that the contributions were contributions to the Connecticut, which was in rapid flow off its mouth, accounted for the distribution of the especially coarse accumulations along the riverward border of the terrace.

In Hartford, Vt., at White River Junction, 4½ miles north of North Hartland.—On the west border of the Connecticut about White River junction, or at the mouth of White River, there is a short "kame" according to Upham's map south of this river, and one, a mile and a half long, north of it. The White River valley is here very broad, like a piece of the Connecticut, and as it rises westward but slowly, it opens to view a portion of the Green Mountain range, which is the chief source of its waters. The Connecticut valley terraces of the region are high—not far from 180 to 235 feet above the river, or 510 to 570 above mean tide level; but that to the north, owing to the retreat in the hills is much the most extensive, and hence the greater length of the northern of the two "kames."

The *southern "kame"* commences within a few yards of the railroad station and hotel, where an excellent section of it is exposed to view. The pitch of the slope toward the Connecticut is about 40°. The structure is well-bedded throughout. The layers consist of cobble-stones, finer gravel and coarse sand. The coarsest cobble-stone layers are below, and some of the rounded stones from them are one to over one and a half feet in diameter. Other cobble-stone layers, less coarse, occur at different levels above, alternating with an increasing thickness of gravel; and toward the top, which is near the top of a ter-



Upper part of the section of the "kame."

race-plain, the material is finer gravel and sand. Fig. 4 shows the position of the cobble-stone beds in the upper half of the section. The beds are not continued through the figure because in the western portion of the section the layers were mostly concealed by slides; but it was manifest from the few and smaller stones on the surface that there was a marked diminution in coarseness to the westward even in the first 100 yards.

The cobble-stone beds exposed to view in the section stop short off below at a level about 20 feet above the level of the railroad track, or 56 feet above the river (low water), and underneath occurs a bed of coarse sand, having the flow-and-plunge structure well marked. A section of the same sand-bed was observed 70 yards to the south, evincing that it is not a local deposit. But the depth to which it was exposed was hardly 8 feet; and it may be that there are other stony layers

underneath. Above the top of this section there is a nearly even terrace-plain, 160–170 feet above the river, or 493 to 503 above mean-tide level. This plain rises to the southwest to a maximum height (not observed by Upham) of 570 feet. The material is fine sand and sandy loam. But along the riverward border of this terrace plain, where it is lowest (493 feet), stands a steep narrow ridge, 50 to 65 feet high, which, judging from the stones of its surface, is made chiefly of beds of cobble-stone gravel. The top is 546 feet (Upham), above the sea.

The cobble-stone character of this ridge and its position make it eminently "kame"-like. But the evidence from the section described, as well as from the plain around, is directly opposed to the idea that it is the top of a buried gravel ridge, existing there before the terrace material was deposited.

In the section, the obvious facts are: that these upper cobble-stone beds—those of the top ridge—are underlaid, first by layers of sand and fine gravel, and then below by alternations of coarser beds; that all the beds are horizontal instead of arched; that they diminish rapidly in coarseness westward, or up White River, showing this even in the first 100 yards, and less rapidly southward or down the Connecticut, the coarsest deposits being at the angle in the terrace formation between the two streams. All the beds are evidently those of the terrace-formation, and the cobble-stone ridge at top is the youngest instead of the oldest.

The *northern* "*kame*," or that north of White River, commences about half a mile from the railroad station. A section is exposed to view at its southwest angle, facing White River, exhibiting very similar features to those presented by the northern kame near the railroad. It is horizontally bedded throughout, and the coarsest beds are below; and some of the rounded stones from the beds are two feet in diameter.

But the cobble-stone beds are of less extent, for they reach only to a height of 45 feet above the railroad track, or 81 above the river, and are coarsest at 16 to 26 feet. Above the 45 feet the beds are of coarse and fine gravel, and increasingly finer to the top of the terrace, 510 feet (Upham) above mean tide. Below 15 feet above the railroad the beds are concealed.

On the top of the high terrace, along its riverward border, some spots of cobble-stone gravel occur, but no distinct gravel ridge like that of the southern kame.

The interior of this "kame" is fortunately more or less perfectly exposed to view in both *longitudinal* and *transverse sections*; and it is remarkable that these sections have nothing "kame"-like in them.

The longitudinal or *north and south* section extends along a

cut or gorge commencing close by the west side of the cobble-stone exposure just described. The gorge (with its carriage road at bottom), seemingly divides off a veritable "kame" from the terrace west of it; but the beds on the opposite sides of this cut so correspond, that there can be no doubt of stratigraphic unity.

The section of the "kame" along this gorge is more or less obscured by slides, but not in all parts. It shows, first, that the stony beds diminish rapidly in coarseness away from White river or to the north. One hundred feet up the gorge, the cobble-stones are half smaller and extend up to a height of only 30 feet above the level of the railroad, or 66 feet above the river, and beyond this they continue to diminish. At 400 feet up the gorge, the ascending road along its bottom reaches a height of 28 feet above the railroad level, and here, in the exposed section on the *east side*, there is a bottom layer of sand, and above the sand 30 feet in thickness of clay; and this clay outcrops on the west side of the gorge as well as the "kame"-side, proving that the deposits of the supposed "kame" are one in bedding and material with those of the terrace formation, just as the high terrace plain above the whole (510–520 feet) is one from the Connecticut westward.

To the eastward of this section, toward the railroad, the deposits diminish in coarseness; and the same change continues northward along the railroad, where the surface material of the lower part of the terrace-slope shows stones only to a height of 20 or 30 feet, or less, above the track.

One of the *east-and-west* sections of the "kame" exists about half a mile north of the south end. A gorge intersects the deposit which is cut down to the level of the railroad track and extends inward (westward) to the center of the "kame" line. But there is nothing kame-like within it, and least of all at its inner extremity. On its *north* side, it has no cobble-stone beds, not even gravel beds; the material is fine sand delicately straticulate. On its south side, in the part nearest to the river, there occurs, in a large mass that has slipped down from above, a thin bed of small stones (three inches in diameter) with some gravelly and sandy layers below; elsewhere the material is sand. In the inner part of the cut, besides the fine sand, there is a bed of light-colored clay and sandy clay between 60 and 90 feet above the railroad, and above this within a few feet of the top, sand and fine gravel.

There is however one "kame"-like feature. Upon the top of the terrace (here about 510 feet above mean tide), near the inner end of the gorge there is an isolated knoll about 30 feet high, and of rounded form, which has many cobble stones over its surface, some of them 10 inches in diameter—indicative of

cobble-stone beds within. It has no continuation north or south. The material of the plain around is sand or fine gravel, like that of the upper part of the section. The following figure shows the position of the gravel-made knoll, the form of the

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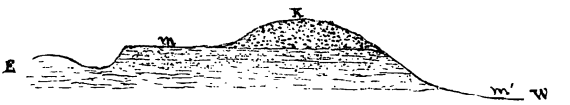

surface north and south, and a section of the beds which according to the facts in the gorge, underlie it. The material of the knoll at top is manifestly the *latest* of the terrace-deposits.

The beds below the level of the railroad were not exposed to view at this place.

The second *east-and-west section* occurs about a fourth of a mile farther north. A long and deep gorge here cuts through the deposits of the 520-foot terrace, nearly to the level of the river, intersecting the "kame" line and extending nearly half a mile to the westward. There is less of kame-like features here than in the preceding gorge. Along the bottom of the deep cut, where a stream flows in some seasons, lay pebbles and some cobble-stones, derived from layers below the level of the railroad track, and these continued for about 300 yards west of the railroad. At a higher level the material is sand or very fine gravel, and the latter in some parts at the top. The sides of the cut were mostly covered by the fallen sands, so that the existence or absence of beds of clay could not be ascertained. A unity of structure from east to west was manifest. Nothing answered to the description of a kame; all was apparently of the terrace formation.

Hanover, New Hampshire, four miles north of White River Junction.—In the town of Hanover, a "kame," according to Upham's map, borders the Connecticut for three miles, to a point north where the river makes an abrupt bend, and thence it follows in the same direct line, the *western* or Vermont side of the river in the towns of Norwich and Thetford, nearly to Thetford village, making in all a length of about seven miles.

The only section of the Hanover "kame" which I have personally examined, is that on the road side between the bridge and the village—the one figured by Upham on page 39 of his Report. At this place, the riverward portion of the stratified drift, or that spoken of by Upham as the "kame," is separated from the following portion by a depression produced by undermining and a dropping of great masses to a lower level, and consequently there are at this place two bluffs, the western which is that of the so-called "kame," and an eastern, which is referred by Upham to the ordinary terrace-formation. In his

figure of the section of the kame here exposed to view, it is made to consist of somewhat arched beds, with alternations of coarse stony layers and finer material alike from top to bottom. I found the bedding horizontal, like that of the eastern of the bluffs; its beds, composed largely of sand and fine gravel, with but few of cobble-stones: and the top portion made of very fine sand, identical in its light color, fine straticulation and other features, with the top portion of the eastern bluff. The latter bluff differs in consisting throughout of stratified sand, and this difference between the deposits near the river and those more remote is not uncommon.

Prof. O. P. Hubbard, of the Medical School of Dartmouth College at Hanover, and formerly Professor of Chemistry and Geology in the Academic Department, has obtained for me the following additional facts respecting the region of the supposed "kame."

He states that no coarse gravel or cobble-stone beds exist along the top of the "kame" *south* of the above mentioned section for the half mile to Mink Brook, and none *north* of the same for nearly a mile, so that this kind of evidence as to the existence of a "kame," fails in these portions. Farther north, above the village of Hanover, there is on the "kame" ridge an area of cobble-stones, and two to three hundred yards beyond this, across a deep cut leading to the river, a grass-covered knoll made up of coarse gravel and cobble-stones, some of the stones a foot or more in diameter. The knoll was found by measurement to be fifteen feet high above the terrace-plain; it marks the spot which is made by Upham, the highest part of the kame, 556 feet above mean tide level. Prof. Hubbard ascertained with a spade that the knoll was composed of coarse gravel, and *rested on* fine sand or sandy loam like that which makes the top portion of the terrace-formation between there and the village and also at the bluffs described above and elsewhere. He concluded, therefore, that the coarse cobble-stone deposit was but 15 feet thick; and, from the level of the other cobble-stone area, that the latter corresponded in position to the lower portion of this deposit. In the deep cut between the two cobble-stone areas the beds are not exposed, but no stones show themselves, and the material was evidently of the same fine sandy nature. Just south of the more southern area three large excavations have been made on the east side of the "kame" ridge to its top, for filling a bog, and these show only sand; but the northern is so near the cobble-stone layer that some of the stones have fallen into it. The evidence obtained by Prof. Hubbard thus appears to prove that the coarse gravel of the two areas is only the top deposit of the terrace-formation, such as characterizes in many other places its riverward portion.

Norwich, Vermont.—The continuation of the Hanover "kame" northward along the west border of the Connecticut in Norwich, passes, near the end of its second mile, the valley of Pompanoosuc River. About a mile south of this turbulent stream, a road ascends from the borders of the Connecticut River to the summit of the high terrace, crossing the "kame" where its height is 565 feet (Upham), half a mile south of the highest point, 600 feet. Along the road are sections of the deposits, showing the inner nature of the Norwich "kame." Where the road commences the ascent some cobble-stones lie scattered over the surface, such as had been found common along the road at the base of the "kame" for the half mile or more to the south. Above this, for the next hundred feet, there is sand, finely straticulate, with occasional fine gravel. Nearing the top, the beds become coarse gravelly, and then there are large cobble stones; and this upper coarse-gravel portion rises above the general level of the plain, making a low ridge which is the crest of the so-called "kame." In the higher part, to the north, some stones, as stated by Upham, are 4 to 5 feet in diameter and angular.

Nothing was observed on the ascent from the river, or on the west side, to suggest a suspicion that this cobble-stone deposit was the top of a narrow range of coarse gravel beds buried beneath the terrace-formation; on the contrary, the evidence from the sections along the ascent, and especially the succession of beds toward the top from sand beds to gravel beds, and then to the coarse cobble-stone gravel, strongly confirmed the natural inference that all was one consecutive series, with the cobble-stone deposit the uppermost and therefore the latest. West of the cobble-stone ridge, or the "kame," the terrace has great extent. The surface falls off immediately 40 feet, exposing the materials that lie beneath, and these are sand and fine gravel as on the east side.

The Pompanoosuc river was probably the chief source of this coarse material of the summit. To the southwest, about the village of Norwich, the terrace is quite stony over much of its surface from the contributions to the terrace of Blood Brook.

In Thetford the "kame" becomes very low before the village is reached.

The other reputed "kames" of the Connecticut River valley I have not particularly examined, But as the line from Windsor to Thetford is "the kame of the Connecticut valley," essentially "a continuous gravel ridge or kame, extending 24 miles," and is made, in Mr. Upham's work, the text for the description of "kames" in general, details from the other minor "kames" in the valley are not necessary for a right conclusion.

Conclusion.—The conclusion from the investigation is, as already indicated, the following: that the supposed "kames" are portions of the terrace-formation, with which they usually correspond approximately in height; and that their materials were the same in source with the rest of the stratified drift, and the beds the same in time of origin.

The gravelly character of the terrace-formation off the mouths of the tributaries of the Connecticut is often mentioned by Mr. Upham; and, if the above conclusion is right, the coarse material of the "kames" is to be explained on the same principle. The position of these coarsest deposits, near the borders of the flooded Connecticut, whether they make the lower or the upper beds, is a consequence of the rapid flow of the waters in this great stream, which drifted away much of the finer material within reach and left stones. The coarsest stone beds at the mouth of White River are located where the two streams—both great streams then—join, that is, where the great contributor of gravel and stones encountered the great distributor.

The deposit of gravel and stones in the upper portion of a terrace I have attributed to the violence of the flood when at its maximum stage. But in the region of the so-called "kames," from Windsor to Thetford and beyond, floating ice was probably needed for much of the transportation; and ice-floes would have been abundant at the time, when the glacier-ice was in rapid process of dissolution about the slopes of the Green Mountains—the range at the head of the principal tributaries in this part of the Connecticut valley. At the same time, the Connecticut, by its rapid flow along its eastern side at one time and its western at another, would have determined an accumulation of stony material along its borders, as a great river now produces accumulations on its banks different from those more distant. Here the floating ice with its burden of earth and stones would have been stranded as well as other transported materials. Moreover such deposits might have been raised ten feet or more above the plain adjoining, as now happens on large streams from modern floods. But there is no occasion to account for a cobble-stone deposit along the whole top of any of the so-called "kames;" for, only a small fraction of each has a crest of this kind; or any difference in structure from the ordinary terrace-formation, except that in some cases, near tributaries, they have more of coarse gravel below.

In Haverhill the angular stones and gravel, brought down the Ammonoosuc on ice-floes, made in one place a thick till-like deposit lying unconformably over the stratified drift and continued some distance down the riverward slope of the terrace. This is an exceptional case, due probably to the fact that the White Mountains, the source of the stream, are near by.

But the ridge-like feature of many of these coarse upper deposits, on the riverward part of the terrace-formation, that is, their standing up 15 to 60 feet above the level of the terrace around, and sometimes higher, is in part, if not chiefly, due to erosion. The Norwich stony deposit, on the top, south of the Pompanoosuc, has a large and broad depression west of it; and so has that south of White River Junction, that of Hanover, and others. Even the little knoll described on page 463 has its adjoining depressions, as shown in the figure there given, and the gulch descending from the southern one of these depressions may be a further consequence. The waters of rains, making rills or streamlets, easily remove the sand and fine gravel of the terrace-formation; but they make comparatively little impression on the beds of coarse gravel and cobble-stones, because of the size of the stones and often also their partial consolidation by iron oxide (limonite). Hence the waters which fall over the stony surface find a place of descent and wear away on either side; and with every new inch of descent gained there is a gain in fall and force, and a quickening of the work of erosion. The channel begun is deepened and widened, waters from the plain flowing in and helping in the removal: and thus broad channels like river-channels may form over wide plains, and deep gorges be cut through to their depths if a place of discharge is at hand. Besides, the river at the time of greatest height swept over the terrace plains with often 40 to 60 feet or more of depth, and large denudation in some parts would have been the consequence.

The above explanations have reference to those so-called "kames" examined by me in the Connecticut River valley. I make no sweeping application of them to those which have been described from other regions that I have not seen. It was my purpose to have studied, the past season, also the terraces of the Merrimack valley, but time failed me.

The gravel ridges of the vicinity of Andover, Massachusetts, first described by Prof. E. Hitchcock, and lately studied with care and designated "kames" by Prof. G. F. Wright, appear to represent a phenomenon of a different class. I had the guidance of Prof. Wright in a day's excursion over them, and was led to think, as he does, that these isolated ridges of unstratified coarse gravel and stones are of morainic sub-glacier origin; and, perhaps, lateral, though sub-glacier, moraines, left between bodies of ice that moved southeastward along the depressions—now marsh-filled—which exist either side of them. But without more study of them, and especially of their relation to the deposits of the Merrimac valley, I would not express a decided opinion on the question.

Nothing has here been said with regard to the "kettle-holes," that is, isolated kettle-shaped and often pond-containing depressions, which, in Mr. Upham's view, were connected in origin with the "kames;" and for the reason that they occur also over ordinary terrace-plains. Further, Mr. Upham's hypothesis as to the origin of "kames" there is obviously no occasion here to discuss.

Some points in the explanations above advanced need, in view of the difference of opinions among writers, further consideration, and will be made the subject of another communication.