SOME GEOLOGICAL EFFECTS OF A "CLOUD-BURST" IN THE CHILTERNS

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(With Meteorological Notes by Cameron D. Ovey, B.Sc.. F.G.S.)

In the course of clearing out papers for salvage recently I came across some notes on the remarkable storm which broke over the Chilterns between Fingest and West Wycombe on Sunday, 17th May, 1936, and I was thus reminded of my original intention to put them on record.

The storm was of the very localised convectional type usually known as a cloud-burst, or land waterspout, being an intense fall of rain of brief duration and small areal extension. Although practically no rain fell in Fingest, the valley bottom in which the village lies was quickly flooded by run-off from the high ground to the east which lay in the path of the storm centre, the water being largely canalized by the road which follows the branch valley from Moor End. In places the water in the main road through Fingest rose to a depth of two feet (Pl. I-A). It is doubtful if the intense precipitation lasted for more than a few minutes.

The general weather conditions prevailing at the time of the storm are discussed in the appendix by Flight Lieut. Ovey (p. 277).

Mr. Charles Kimber kindly sent me the following description of the storm as observed by him at Fingest (letter dated January, 1937):

"The afternoon was warm and sunny—almost hot. I don't remember from which direction the wind was blowing [probably from S.E.] but the clouds first appeared from behind the hill between us and Frieth —a black thunder-cloud[1] reaching to a very great height; this moved northwards and more came up

[1] Described by one observer as funnel-shaped.

A. Flooded road—Fingest [C.K.

B. Delta-fan west of Muzwell Farm [K.P.O.

C. Site of delta-fan, Piddington [K.P.O.

to take its place, appearing further and further to the south, so that by the time the later clouds to appear reached us they were further out from the hill and tended to hang over the village. At about 4.15-4.30 quite heavy drops of rain fell for about two minutes. About ten minutes later we became aware that motor cars were backing past the window; so we went to investigate and found the road flooded in front of the churchyard. The water was coming swiftly down the road, and had found a way of escape through the yard of the Chequers and thence flowed through the bottom of the meadow opposite this house [Fingest House], coming to an end in the cultivated ground just beyond and just before reaching Skirmett. It started to rain again . . . but not very hard. The water was flowing very fast and at its deepest was at least knee-deep. That was between 4.30 and 5.15. At about 7.15 I . . . motored up to the Frieth to see where it [the water] had come from and what damage had been done. The water was still flowing but had gone down considerably; however it was still ankle-deep about quarter mile [E.] from the village. At the end of the valley I took the right fork towards Frieth. About 300 yards beyond this fork the tarmac had been torn up and we were able to see the track of the water . . . [from] the Common between Lane End and Frieth. The road from the left fork to the Peacock Inn had also been torn up." Mr. Kimber added this further comment: "At Fingest about half a dozen valleys meet, only one of which forms a getaway—the Hambleden Valley through which runs the stream which rises in Watery Lane at Murray's Farm. In very wet weather I have frequently noticed water coming up through the surface of the road from the Peacock . . . and in fact last winter this road literally burst like a sausage and had to be patched. Since the storm of May 17th I have often wondered whether the road was torn open from above or below."

I am indebted to the Director of the Meteorological Office for the following records of rainfall in the Wycombe region on the day in question (17th May, 1936):

Station.	in.
Hambleden (Hatchmans)	0.1
High Wycombe (Flackwell Heath)	1.04
Radnage (Yewsdene)	1.64

Scattered rain-gauge records in a district affected by a 'cloud-burst' may give little indication of the fall at the centre or centres of greatest intensity of the storm. Thus from the above figures it would appear that Radnage was within the zone of heavy precipitation, although this maximum recorded figure was probably exceeded at Piddington and on the high ground east of Fingest.

Unfortunately the duration of the fall is not known at any point within the storm area. Intense concentration of a relatively small quantity of rain in a short time is often more impressive in its effects than a heavier fall of long duration, especially where the slopes are steep as they are around Fingest and Piddington.

Although I did not experience the storm itself I was able next day to investigate some of its geological effects. These were most apparent at two points, both situated on the south-facing slopes of coombes (Fig. 1). It remains uncertain as to whether the rain fell with cloud-burst intensity along the whole of the three mile belt extending S.S.W.-N.N.E. between these two sites, or whether these corresponded with two separate centres of exceptionally intense precipitation. The fact of the topographic similarity of the two localities in question might be cited in support of either hypothesis. Thus the character of the ground surface at both sites was such as to predispose them to the effects of heavy rain more markedly than elsewhere in the rain area (see p. 273); on the other hand

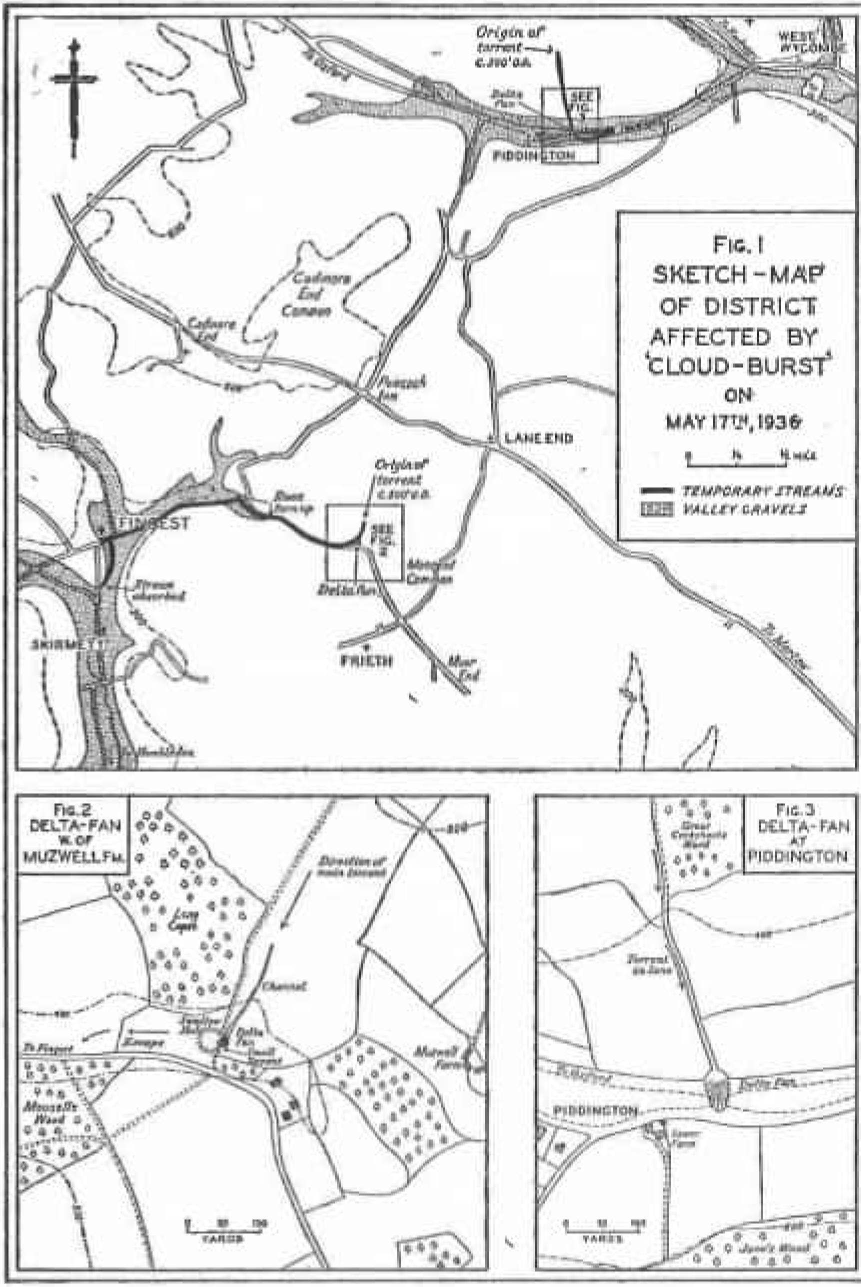

FIG. 1 SKETCH-MAP OF DISTRICT AFFECTED BY 'CLOUD-BURST' ON MAY 17TH, 1936

FIG. 2 DELTA-FAN W. OF MUZWELL FM.

FIG. 3 DELTA-FAN AT PIDDINGTON

there are meteorological grounds for thinking that the topography may have caused heavier precipitation in the neighbourhood of these two points, as the adjacent coombes provided leeward slopes.

The first site to be described lies about one mile E.N.E. of Fingest in the upper part of the coombe which is followed by the Moor End-Fingest road (Fig. 2). Here in the field adjoining the bend in the road west of Muzwell Farm, I observed a delta-fan (Pl. I-B) consisting of a flat-topped lobe of clean washed sand, 36ft. long, 12ft. wide and 3ft. high, fringed by an extensive lower-lying spread of mud. The whole delta covered an area of about 100 sq. yards. At its narrower end, or origin, there was a gully some 6-9 feet wide and 1 ft. deep eroded in the ploughland and extending N.N.E. to S.S.W.[2] Strangely enough the delta-fan terminated at the eastern margin of a natural drainage hollow, or swallow-hole. The floor of the swallow-hole was covered by sandy mud which appeared to have entered by a minor channel from the east, skirting the edge of the main delta-fan.

An examination of these deposits and of the adjoining ground enabled one to deduce what had probably occurred. Evidently the fields to the north-west of Muzwell Farm had received the brunt of the cloud-burst, probably becoming flooded within a few minutes. These fields are crossed from north to south by a shallow depression marking an incipient tributary coombe, with head at about 500 ft. above O.D., and the water had evidently been canalised by this, and formed a torrent of considerable transporting power. At first the swallow-hole, which lies close to the axis of the main coombe at just under 400 ft. above O.D., absorbed the greater part of the water

[2] Precisely similar effects of heavy rain on ploughed land in Lincolnshire are illustrated by S. G. Brade-Birks in *Good Soil*. (Eng. Univ. Press, 1944, fig. 47, p. 186).

reaching it; but before long it became choked and a delta-fan was built up on the flattish grassed area at the margin of the hollow. There were clear signs that the choked swallow-hole had eventually been circumvented, the water escaping down the main line of the coombe. It is possible that before the swallow-hole became choked the water entering it had passed through a dry fissure system in the chalk to re-emerge at a lower level, giving rise on the floor of the coombe at about 350 ft. O.D. to a perched bourne which might have burst through weak points in the road surface as suggested by Mr. Kimber. On the whole I would say this is unlikely, although it is tempting to invoke the hypothesis, if only to account for the broken surface of the road from the Peacock, which is otherwise difficult to explain, for I obtained no evidence that that road had received any considerable run-off from the area of intense precipitation. However, it must be remembered that 'pot-holes' in a road surface which has not been repaired for some time are readily aggravated even by moderate rain, and maybe this is all that had happened.

It is noteworthy that the torrent which produced the delta-fan east of Fingest had nowhere crossed an outcrop of sand; the whole of the sand forming its core had been washed out of the soil of the fields over which the flood water had passed. The sand was fine and mainly quartzose (although there was slight admixture of microscopic flint chips) and originally derived in the soil from down-wash of Reading Beds as represented in the Lane End outlier. On the analogy of this delta-fan I have suggested elsewhere[3] that the sand-filled swallow-hole excavated by Dr. Grahame Clark at Farnham Park, Surrey, may have been filled by centripetal drainage

[3] *Proc. Prehist. Soc.*, N.S., v (1939), p. 108.

of flood-water charged with sand washed out of a gravel soil. The flooding in that case might well have been due to intense rains in the later Mesolithic period.

The fact that under intense rains silts may be deposited high on the upper slopes of a coombe is worth noting in connection with the interpretation of Pleistocene terrace deposits. Thus patches of water-laid silts of late date (judged by fossil content) occurring at high levels in a river valley should be interpreted as evidence of fluviatile aggradation only with due reserve.[4]

The second site of marked geological effect within the storm area was at Piddington (Fig. 3), about a mile west of West Wycombe. Here the main London-Oxford road (by-passing the hamlet) was blocked to traffic for many hours by a delta-fan of coarse flint gravel and sand, approximately 6 ft. high in the middle, 120 ft. long and 60 ft. wide (Pl. II).[5] When I saw it much of the material had been removed, but it was still an impressive sight. The debris which had composed the fan contained flints measuring up to 9ins. by 6 ins. The sand matrix consisted mainly of microscopic flint chips.

The fan had clearly been formed by a torrent originating about 500 ft. above O.D. on the south side of the watershed which separates the Piddington valley from the Radnage valley to the north. The torrent had been canalised by the sunken lane which runs southwards down the shallow lateral coombe on the west side of Great Cockshoots Wood (Pl. I-C) ,discharging on to the floor of the Piddington valley at the point where the lane joins the Oxford road. The torrent had developed considerable erosive and transporting power; it had

[4] cf. J. P. T. Burchell, *Geol. Mag.*, 1936, p. 551.

[5] This photograph appeared in the *Evening Standard* of 18th May, 1936.

stripped off the gravelly surface of the lane to a depth of six inches or so, exposing raw Clay-with-flints. When I saw the lane it looked like the dry bed of a mountain torrent.[6] Gullies a foot deep had been excavated at the sides of the lane; in places the hedge-row banks had been under-mined. At the back of the delta-fan the torrent had gouged a hollow 3-4 ft. deep.

The excavation of the floor and sides of the lane had apparently provided the bulk of the material of the delta-fan, amounting to something like 500 cubic yards of sandy gravel. Presumably the water carrying the suspended clay had escaped down the valley road in the direction of West Wycombe and the River Wye, much of it being absorbed *en route* by drains and by the sub-soil of the adjoining fields on the south side of the road. Had it become ponded it would have laid down a deposit of red brickearth similar to that exposed a few years ago in trenches opened in the floor of the Misbourn Valley between Wendover and Missenden.

It is worth recording that the cloud-burst water had flattended the grass on the unfurrowed north-facing slope of the Piddington valley which consisted of pasture, but it had produced no erosive effects there; nor had any appreciable deposit accumulated at the foot of this slope, for example, by Lower Farm. Storm water only begins to have marked erosive effect, even on steep declivities, at points where there is an absence of vegetation or artificial protective cover; moreover its erosive power rises steeply as its effective volume becomes increased through canalisation in coombe or gully. The location of the geological effects of the storm

[6] Gilbert White describes the effects of a cloud-burst at Selborne on 5 June, 1784: "The hollow lane towards Alton was so torn and disordered as not to be passable till mended, rocks being removed that weighed 200 weight." (Letter lxvi to Barrington).

PLATE II

Piddington: delta-fan of gravel in course of removal from Oxford after cloud-burst on 17 May, 1936 of May 17th appears admirably to illustrate these principles of "gully-erosion."

The bottoms of the mainly dry valleys of the Chilterns are lined almost throughout their length by deposits of poorly-sorted sandy gravel of precisely the same character as the Piddington delta-fan, but mainly of Late Pleistocene age (thus the deposits on the floor of the Wendover gap exposed in the gravel pit one mile south-east of Wendover Station have yielded mammoth remains).[7] The road-cutting which flanks the Piddington delta-fan itself reveals just such a deposit (see Pl. II). These Dry Valley Gravels, as they have been called by the Geological Survey, were probably formed at a time when there was a general absence of vegetation, so that flooding of the valley sides periodically caused extensive transport of the deep flinty soils, left by the weathering of the local Chalk and Clay-with-flints under periglacial conditions. Most of the coarser material was dumped in the Chiltern valley bottoms, but the bulk of the finer material (clay and silt) was transported into the main river valleys beyond, where some of it accumulated as brickearth. The flooding responsible for the formation of the Dry Valley Gravels was probably due to melting of snows on the Chilterns at the end of the Ice Age, rather than to exceptionally intense rain, although that may have been a contributory factor.

The importance of the geological work of intense rains in temperate regions is only just beginning to be realised. Soil-or-gully-erosion in the deforested areas of North America has brought the subject into prominence. Recently, Dr. R. H.

[7] Geology of Aylesbury and Hemel Hempstead, *Mem. Geol. Surv.* (1922), Pl. I, gravel pit which yielded mammoth teeth (one tusk in Aylesbury Museum, another in the possession of Sir Alan Barlow).

Rastall[8] has concluded that the total annual rainfall of any area is less important as a factor in denudation than the distribution of the rainfall, and that concentrated falls of the cloud-burst type are "probably the most powerful of all agents of erosion and transport . . . . . and often play an important part in aggradation as well."

Dr. J. Glasspole in his comprehensive account of intense rains[9] classifies them according to extension in space and time, and also according to origin (orographic, cyclonic and instability precipitation are the three main types). Characteristics of the West Wycombe storm of May 17th were its intensity, short duration and small areal extension. Its association with thunderstorm conditions indicates that it was a case of instability precipitation in association, as Flight Lieut. Ovey shows (p. 278), with a degenerate cyclonic frontal system (occluded front), and this was sufficient to produce the necessary convectional uplift in the warm unstable mass flowing from the southeast. Falls of this type—usually known as cloud-bursts—appear to be significantly frequent in certain upland regions, suggesting that topographic relief is commonly a factor in their genesis.[10] Thus cloud-bursts have frequently been recorded in the Yorkshire Wolds.[11] These chalk uplands, with a seaward facing dip-slope rising northwestwards to over 500 ft. above O.D., are deeply incised by narrow branching valleys. They are in many respects therefore similar to the Chilterns. One locality in the Wolds, Langtoft, has been the site of a catastrophic flood due to a cloud-burst on two occasions within recorded history; on 10th April, 1657, and

[8] *Geol. Mag.*, 1944, pp. 39—42.

[9] *Minutes Proc. Inst. Civ. Eng.*, 29 (1930), pp. 137—194.

[10] cf. ibid., p. 164.

[11] J. D. Hood, "Waterspouts on the Yorkshire Wolds . . .", Driffield (1892); G. W. Lamplugh, *The Naturalist*, 1904, pp. 194-5; E. M. Cole, *The Naturalist*, 1910, pp. 255-6.

on 3rd July, 1892. Records show the impressive erosional effects of these storms. The 1892 storm was of such intensity that it is believed to have represented a fall of the order of an inch and a half of rain per minute.[12] In these instability rains considerable coalescence of drops no doubt takes place (see p. 280), but not to the extent of producing a continuous column of water as is popularly imagined when the term 'land waterspout' is used.

Data on the frequency of cloud-bursts in the Chilterns are unfortunately lacking, but many will recall the "double" thunderstorm[13] which broke over the Missbourn-Chess watershed (at c. 500 ft. above O.D.) on Friday, 17th May, 1918—antedating the West Wycombe storm by eighteen years (curiously enough to the very day!). Chesham was so severely flooded that considerable damage was caused and a relief fund had to be raised to help those whose property had suffered (see account in *The Bucks Examiner*, 24th May, 1918). The lower part of the town was affected most (in places the water rose to a depth of four feet), so presumably the water poured mainly through Herbert's Hole and Pednor Bottom which conjointly debouch on to the floor of the Chess Valley below Chesham Park. My father (T.P.O.) was cycling down the Misbourn Valley between Wendover Dean and Great Missenden at the time the storm broke there, and took shelter in the Lodge of Woodlands Park, which stands near the foot of the slope of the northern side of the valley. He tells me that within a few minutes water was pouring in through the doors of the lodge, flooding the rooms to a depth of a foot or so. He and the lodge-keeper between them carried out 160 buckets of water! A long section of the high stone wall forming the south-western boundary of the park was broken and overturned by a torrential sheet of

[12] Glasspoole, op. cit., p. 173.

[13] There appear to have been two centres of intensity in this storm.

water which transported great quantities of soil and stones down the valley side, depositing them as an enormous delta-fan which blocked the Wendover-London road. Deep gullies were found to have been eroded in the higher slopes. Mr. R. W. Sloley informs me that the surface of the road leading down Frith Hill into Great Missenden was torn up and gullies nearly two feet deep were eroded at the sides of the road. He says that hail fell on Frith Hill, apparently at a late stage in the storm,[14] and that the hailstones were of exceptional size. Eight days later hailstones half an inch in diameter were still lying in large heaps by the roadside.

A great deluge is said to have affected the region of Chesham Bois and Latimer in 1879, and has been compared with that of 17th May, 1918,[15] but no details are known. Perhaps Holloway Lane owes something of its sunken character to this and earlier storms of unusual magnitude. Searchers of old Buckinghamshire records (letters, diaries—and even account books) would do well to keep a look out for references to such exceptional storms and their ravages. We have much to learn from their distribution and frequency.

In conclusion, I should like to express my gratitude to Mr. Kimber for allowing me to make use of his observations, and for putting at my disposal his photographs of the floods at Fingest; also to Flight Lieut. Cameron Ovey, at present serving as a Meteorological Officer in the R.A.F., for his helpful collaboration in the investigation of the 1936 storm and its effects.

14 "Hailstones start as snow-flakes formed in the upper part of a thundercloud. They develop through the condensation of water drops while they are being suspended and whirled about by the vertical updraught, and they fall when this convection is cut off, or the stones attain a weight at which they are overcome by the force of gravity. Hail can occur under thunderstorm conditions at any time of the year, but is particularly common in spring when the freezing level is often low." C.D.O.

15 *The Bucks Examiner*, 24th May, 1918.

APPENDIX

METEOROLOGICAL NOTES ON THE CHILTERN 'CLOUD-BURST' OF 17TH MAY, 1936

By CAMERON D. OVEY, B.Sc., F.G.S.

The official weather charts covering the day in question[16] show a shallow trough of low pressure extending across the British Isles between weak depressions northwest of Ireland and the eastern English Channel, with anticyclones over the Baltic and central Atlantic.

The shallow trough, so called, marked the boundary between two totally different types of air mass: (1) maritime polar air flowing slowly over the country from north and northwest, and (2) warm unstable air from the E.S.E. flowing in a strong stream from South-eastern Europe. From the charts showing data at 13 G.M.T. and 18 G.M.T. on May 17th (No. 27206) it is evident that the front, or occlusion marking the boundary between these two air masses, passed across the Chilterns at the point under consideration, and was oriented N.N.W.-S.S.E. Between 13.00 and 18.00 G.M.T. it had moved very slightly west, and by 01.00 G.M.T. on May 18th it had accelerated its westward path through increased anticlockwise circulation round the deepening depression over Spain and the building up of a ridge of high pressure across Scotland between the two anticyclones. From the data available it appears that the air mass from Europe was unstable (i.e. temperature fell very rapidly with height) and by 4.15 p.m. (16.15 G.M.T.) or so would have reached or just passed the maximum diurnal surface temperature and, therefore, the convective energy would have been approximately at its zenith. On contact with the air mass of polar origin it would have been forced upward over the

16 Daily Weather Reports of the Meteorological Office, London: International Section, Nos. 27205-6, May 16-18th, 1936.

surface of this cooler air, which was flowing from the northwest. This mechanical uplift, together with the additional convective energy due to the effect of the sun's heat on the earth's surface, causing 'hot air to rise', would produce the maximum activity along such a boundary, or front. A further contributor to the excessive uplift of the European air was the fact of its flowing approximately from London in a W.N.W. direction, and therefore up the dip-slope of the Chilterns; moreover it came into contact with the cold, polar air at about the summit level of these hills giving, therefore, in addition, an orographic maximum uplift. The total convective energy thus produced must have been strong enough to drive the 'thunder-head' through the original warm air, which still existed above the occlusion. This warmer air was sufficiently high and cooled to allow the thundercloud to rise through it, just as relatively warm bonfire smoke rises through the less warm surrounding air.

The statement in Mr. Kimber's letter that the cloud moved northwards may indicate that the air from the E.S.E. was deflected rather more towards the north on coming into contact with the barrier of cold air, which must have been a few miles to the west of Fingest, just as water flowing obliquely towards a sloping wall would be deflected. More and more cloud would by the same token appear to the south as more and more air arrived to be forced upwards, thus supplying further energy for the maintenance of the storm.

The above interpretation of the West Wycombe storm is based on theoretical considerations supported by the evidence of topography and the synoptic charts. Upper air information in regard to winds, temperature and humidity would have been necessary for a complete investigation.

A few general observations on 'cloud-bursts' may not be out of place here.

The following definition of a 'cloud-burst' is of interest in connection with the geological effects of this type of storm recorded in the Chilterns and Yorkshire Wolds.

"Cloud-burst.[17]—A term commonly used for very heavy rain, usually associated with thunderstorms. Extremely heavy downpours are sometimes recorded, which in the course of a very short time tear up the ground and fill gullies and watercourses; this may happen at any place, but it occurs frequently in hilly and mountainous districts, where it may sometimes be due to the sudden cessation of convectional movement, caused by the supply of warm air from the lower part of the atmosphere being cut off as the storm moves over a mountain range. With the cessation of the upward current, the raindrops and hailstones which it had been supporting must fall in a much shorter time than they would have done had their ascensional movement continued."

The storm of 17th May, 1936, may well have been of the type described in the latter half of this definition. The supplying warm air would have descended any leeward hillslope (e.g. possibly provided by the coombes) and this may have caused sufficient check to the speed of the strong vertical air currents supporting water drops within the thundercloud against the force of gravity to cause a 'cloud-burst'. If this had been the case one would expect to find that there was a slight westward movement of the frontal surface; as in fact there was, for the weather charts for May 17th and 18th clearly reveal the development of an easterly wind system on both sides of the front.

[17] The Meteorological Glossary. *Stationery Office Publn.* 3rd Edit., 1939, pp. 45-6.

[18] c.f. "The Surrey Hailstorm of July, 1918," J. E. Clark, *Q. J. Roy. Met. Soc.*, xlvi (1920), p. 273.

Although the erosional effects of the 'cloud-burst' were specially marked at two points only, it is just possible that geomorphological factors accounted for this, and that the downpour actually formed a continuous or semi-continuous belt.[18] On the other hand a sudden checking of the vertical air-flow probably caused the 'cloud-burst', and in view of the topography it is not altogether unlikely that this took place at two points. In frontal storms there is often more than one centre of intensity along the line of the front.

Coalescence of raindrops in 'cloud-bursts' only takes place up to a certain limit, i.e. 5.5 mm.[19] The reason for this is that beyond a certain point the terminal velocity of falling drops does not increase with the size of the drops, but tends to decrease, because the drops become depressed in form, spreading out horizontally. Thus air resistance is increased, and for drops greater than 5.5 mm. the deformation is sufficient to cause them to break up. In a 'cloud-burst' there may be a fall of about 2,000 drops (most of which will be about 1 mm. in diameter—and even that is a large drop!) per square meter per second.[20] Lenard found that no rain can fall through an ascending current of air whose vertical velocity is greater than 8 metres per second; hence the truth of the layman's observation that the worst thunderstorms often occur with no rain at all, the downpour being arrested until the supporting vertical currents are checked or cut off.

[19] ibid., pp. 155-6.

[20] P. Lenard, *Met. Z., Braunschweig*, XXI (1904), pp. 249-62.