"Terraces of Allegheny River", unpublished report. 1932-1935

TERRACES OF ALLEGHENY RIVER, WARREN, PENNSYLVANIA, TO OLEAN, NEW YORK

F. T. Thwaites, 1933

Introduction. During July and August, 1932, the writer was instructor in geology at the Allegany School of Natural History, Allegany State Park, New York. Only three students registered for work in geology and, as all desired to take advanced work, it was decided to study the problem of the terraces of Allegheny River and their relation to the reentrant angle in the drift margin within which the Park is situated. The results of this study are herein set forth not with any idea that they are final, for only about a week was spent on the problem in the field, but to help others who may have the opportunity to make more detailed investigations. The writer is indebted to Miss Carol Y. Mason for aneroid barometer observations.

Previous investigations. Although little detailed investigation of the Allegheny terraces has ever been published, their general nature has been known for a long time. In 1884 Lewis published his mapping of the terminal moraine in southwestern New York. In his introduction to Wright's report on the glacial boundary in 1890 Chamberlin divided the terraces into two groups, (a) high terraces and (b) moraine-headed low terraces. In 1894 the same author in collaboration with Leverett again described the terraces and recognized the possibility that they might be related to three separate glacial advances. Leverett's final report of 1902 summarized the conclusions previously published and gave an extensive bibliography covering much early work in Pennsylvania. He also included a detailed map of the glacial boundary in the Olean quadrangle, New York. In 1927 Lobeck mapped and described the terraces in the vicinity of Allegany State Park but overlooked most of the publications concerning them. He evidently regarded them as entirely the product of the glacial advance which made the moraine northwest of the Park, stating (p. 125): "When the ice occupied the position now marked by the terminal moraine great floods of water poured to the south past Steamburg and through Allegheny valley. It was at this time

that the Allegheny river developed its new course and abandoned the route past Randolph. The old valley became clogged with alluvium and drift as we now see it. As the ice sheet melted back a lake was formed between the moraine and the ice front and covered the present site of Randolph. - - - - - The lowest point of overflow was just south of Johnny Watt hill and it was through this gap just west of Steamburg that its waters poured out until, with the greater retreat of the ice, the lake was drained to the west. The gap just west of Steamburg is flat-floored and with little or no terminal moraine hills. In one or two places - - - there are preserved remnants of the outwash plain at elevations as great as 1460 or more. This is very much higher than the present floor of the valley and presumably means that the waters draining through this gap cut away much of this earlier outwash - - -. At least there is clear evidence that this is an old outlet channel." Leverett appears to have also made recent observations in New York state but the details have not been published.(1930).

Classification of the terraces. The two major groups of terraces recognized long ago by Chamberlin (1890) are (a) the high level discontinuous remnants up to 300 feet above the modern streams and (b) the much less eroded terraces up to 40 feet above the river. Group (a) can be subdivided into at least four subgroups divided according to elevation.

Material. The terraces are underlain by gravel which, for the most part, contains a fairly high proportion of pebbles to sand. The largest stones are several feet in diameter. Some relatively thin layers contain little or no sand and may be classified as "openwork" gravel. Assortment is fair to good and most of the stones are fairly well rounded. They are mainly hard shale and siltstone with a calcitic or dolomitic cement and were derived from the Portage and Chemung rocks to the north. In few places do Canadian crystallines make up more than 10 percent of the pebbles and boulders. The same kinds of far-travelled rocks occur throughout the district examined including the adjacent glacial till. Where fresh the terrace deposits are light gray in color.

To a depth which ranges from a few feet to 20 feet from the surface the deposits are yellowish-brown in color and much or all of the carbonate has been removed by leaching. A considerable part of this carbonate has been redeposited below forming a gravel conglomerate. The early investigators stressed the fact that the high terraces all lie on rock shelves but in New York state this does not appear to be true except where the deposit is close to the side of the valley.

Bedding. The bedding of the terrace sands and gravels is predominantly horizontal. Cross bedding is confined to relatively thin layers, many of them mainly sand, and, with few exceptions, dips in the direction of the present drainage.

DESCRIPTION OF HIGH TERRACES

Clarendon, Pennsylvania. In the Tionesta Valley, southeast of Warren, Pennsylvania, near the village of Clarendon, glacial stones have long been known (Chamberlin and Leverett, p. 273, Leverett, 1902, p. 238, 239, Butts, p. 6-7, Leverett, 1930). The only exposure which the writer could discover in the brief visit to the place on July 19, 1932 is a gravel pit in old Clarendon just northeast of the schoolhouse. Here about 15 feet of much weathered brownish-gray, well-sorted, well-bedded gravel was exposed. The largest boulders observed were slightly over a foot in diameter but few pebbles exceed four inches. According to the Warren quadrangle the highest part of this greatly eroded terrace exceeds 1500 feet elevation or 320 feet above Allegheny River. The well records given by older students of the locality indicate that the gravel lies on a thickness of more than 200 feet of fine sediment. It is clear that the exposed deposit is outwash which was deposited some distance from an ice front long after the present rock bottom of the valleys had been reached by the streams.

Warren, Pennsylvania. Butts mapped several high level terraces near to the junction of the Conewango and Allegheny. Chamberlin (p. 27) gives 1395 as the highest level or about 220 feet above the river. The writer visited only one exposure, the pit of the Carlson-Johnson Gravel Company. Here weathering

extends to a depth of over 20 feet as shown in photo T. 17. This zone had been recently excavated for road surfacing as it contains too much silt and clay for concrete. The lower face of the pit exposed clean sand and light gray gravel much of which is cemented by calcium carbonate. There is some openwork gravel. Some of the cross bedding dips north or away from Allegheny River. The total thickness of the deposit could not be observed.

Russell, Pennsylvania. A gravel pit in Russell, Pennsylvania, just south of the road leading west from the bridge at an elevation slightly over 1380 (60 feet above the Conewango) shows cemented gravel of the same general type as that found in the high terraces. It is probable that this gravel underlies the adjacent moraine of Middle Wisconsin (Cary) age. (For modern classification of the glacial drifts see Kay and Leighton.)

Onoville, New York. High terrace deposits occur east of the river on the New York-Pennsylvania line. At this locality the writer found no good exposures and an aneroid reading made the highest well-defined terrace at 1390 or 120 feet above the river. Rounded pebbles mingled with local residium were observed on top of the rock terrace half a mile west of Onoville on the north road. The map elevation is 1460 or 180 feet above the river. At this locality it is possible that the stones are of glacial rather than fluvio-glacial origin.

Hotchkiss Hollow. The high terraces at the mouth of Hotchkiss Hollow are one of the best known localities in the region. (Photo T. 24). When visited by the writer gravel pits on both the north and south ends of the deposit exposed gravel with boulders up to 3 feet in diameter. Some layers, each less than 6 inches thick, occur of 1/8th to 1 inch openwork gravel in part quite well sorted (Photo T. 6). The cuts did not disclose the depth of weathering on the flat areas, but it is evident that the gravel is disintegrated into a silty clay to a depth of several feet. The map makes the highest level above 1460 but an aneroid reading based on nearby bench marks showed only 1455 or 150 feet above the river. On the south end there is a terrace level at 1390 feet or

85 feet above the river. No bed rock has been discovered beneath the main part of the terrace although the abrupt bend in the river strongly suggests that this remnant is rock defended. (Lobeck, p. 192-195).

Quaker Run. The high terrace which forms a partial dam across the mouth of Quaker Run (Photo T. 62) is known to all who have studied the geology of the Park. There are no good exposures. Aneroid readings show the summit to have an elevation of 1460 or 155 feet above the river. A marked bench on the south end lies at 1390 or 85 feet above ordinary water level. The small remnant north of Holts Run was not visited. (Lobeck, p. 193). An inconspicuous terrace occurs farther south on the same side of the river just north of Wolf Creek. An aneroid reading made the top 1450 or 150 feet above the river. This terrace rests on the bed rock of a steep hillside. (Lobeck, p. 194.)

Pine Creek. The terrace in the valley of Pine Creek is peculiar in that it lies back over a half mile from the river in a tributary valley. The aneroid recorded the top at 1490, 180 feet above the river. There are no good exposures. (Lobeck, p. 197.)

Cricks Run. Just east of the mouth of Cricks Run is a terrace remnant over a half a mile long which, according to the map, exceeds 1460 feet or 140 feet above the river. There is an old gravel pit on the railroad (Lobeck, p. 194, 198) but the writer did not visit it.

Stoneburg. Lobeck (p. 100) mapped old high terraces both half a mile southeast of Stoneburg and along the road east of the village near Bunker Hill School. The elevation may reach 1500 feet in places. There are no good exposures in either locality. In Stoneburg there are two isolated hills with their longer axes parallel and east-west. In the southern one there is a gravel pit which has apparently been open since Lewis' day (p. 159). Lobeck (p. 209-212) describes the pit as gravel overlain by till saying " if the section is fresh, the disturbed upper layers of gravel give evidence of ice movement." The twenty-five foot face was clean on July 28, 1932, when visited by the writer (Photo T. 28). No till could then be distinguished. The top portion of the deposit is very bouldery and is so much weathered that stratification has been destroyed to

a depth of several feet and it is possible that this surficial zone was regarded as till. The matter is, however, unimportant, for such coarse gravel must certainly have been deposited close to the ice front. The fact that the horizontal beds are truncated by the sides of the hill suggested to the writer that the two hills are erosion remnants of a once-continuous outwash plain. In any case they are distinct from the much lower outwash apron of the moraine to the west. This moraine is apparently of Gary age.

Red House. Just north of and across the river from Red House post-office is a much eroded terrace remnant about a mile long. An aneroid reading made the top 1455 or roughly 125 feet above the river. Exposures were poor when visited.

Breeds Run. The terrace just south of Breeds Run is not very much eroded. The map makes the top 1420 but an aneroid reading gave 1450 or 110 feet above the river. Eye estimate favors the map, however.

Elkdale. In the vicinity of Elkdale Station a ridge 30 to 40 feet high nearly blocks the valley of Little Valley Creek forcing it against the western side. Several previous observers seem to have regarded this ridge (Lobeck, p. 123) as the terminal moraine of the Wisconsin drift. East of the highway, in the grounds of the Salamanca Country Club, the topography is broken and at a casual glance resembles that of a moraine. Closer inspection failed to demonstrate the presence of kettles and the writer regards the entire ridge as a greatly eroded terrace remnant. The portion west of the railroad has a flat top at a map elevation of 1480 but the aneroid made it only 1465. However, the control of the aneroid readings at this time of the day was not good and it is far more probable that the map elevation is correct. In this interpretation as outwash the writer is sustained by Lewis (p. 156) who placed the drift margin farther up the valley. Between Elkdale and Salamanca there are several obscure terrace remnants. In West Salamanca there is a rock-defended terrace at an aneroid elevation of 1510 or 150 feet above the river. The low terrace of this tributary

valley is pitted at Little Valley indicating the presence of stagnant ice masses at the time of deposition.

Allegany. The long distance from Salamanca to Russell seems to contain only very scanty remnants of terraces above the level of the main or low terrace. On the south side, between Riverside Junction and South Vandalia, however, a steam shovel had recently been used to excavate a deep pit in a reentrant of the valley wall where the topography gave little indication of gravel. East of Russell a much-eroded gravel terrace remnant over a mile long is shown in photo T. 34. A pit was being operated in the weathered zone but was not visited by the writer. According to the map the top of the deposit is above 1460 or 80 feet above the river. Across the river, in and east of Allegany, a large terrace remnant may locally exceed elevation 1520 or 120 feet above the river. However, this was not checked with the aneroid and the Salamanca and Olean quadrangles do not show very accurate elevations. Neither remnant shows much of the original surface. Lewis (p. 153) and Leverett (plate IV) both regarded these terraces as sections of the terminal moraine. The former reported "shallow depressions" but the writer could discover neither kettles nor till. A large gravel pit in Allegany (photos T. 32, 33) displayed a deeply oxidized zone 5 to 15 feet thick resting upon strongly cemented, fairly well-sorted horizontally bedded gravel. Cross bedding dips to the west. Some layers consist of poorly sorted open-work gravel. The writer is convinced, as was Lobeck (p. 103), that these deposits are terraces and not terminal moraine. The writer was unable to confirm any of the terraces suggested by Lobeck in the eastern part of Olean finding only rock shelves. When going east of Highway 17, however, he noted a deep cut in what appeared to be a high terrace but did not secure the location.

Summary of high terraces. The high terraces may be divided into the following groups: (a) the Clarendon terrace over 300 feet above the Allegheny River, (b) the Warren terraces at 220 feet doubtfully including the 180 foot

rock terrace at Onoville, (c) the terraces at 150 to 160 feet including Hotchkiss Hollow high level, Quaker Run high level, Wolf Run, Pine Creek, and Salamanca, (d) a group of much eroded terraces which embraces the remnant at the state line, Cricks Run, Red House, Breeds Run, and part of the north Allegany locality, the elevations varing from 110 to 140 feet, and (e) a well-defined group at 80 to 85 feet which includes the low levels at both Hotchkiss Hollow and Quaker Run, and the southern Allegany terrace.

DESCRIPTION OF LOW TERRACES

Pennsylvania. Terraces up to roughly 40 feet above the ordinary level of Allegheny River were noted along much of the valley in Pennsylvania. All are little eroded and, so far as the few good exposures seem indicate, only slightly weathered. No terraces are present in the gap below Kinzua where the river crosses a preglacial divide.

Onoville, New York. About a quarter of a mile west of the Onoville bridge is a gravel pit at elevation 1300. It exposed horizontally bedded stony gravel, in part openwork. A few boulders are present. The weathered zone is only a few feet thick. The terrace between Bone and Pierce Runs is at elevation 1315 or 30 feet above the river. There is a lower level about half as high above the river.

Quaker Bridge. The gravel pit southwest of Tunessasa Indian School near the railroad displayed the following section. The top is at elevation 1340 or 35 feet above the river.

Soil and silty sand with scattered pebbles	2 to 3 feet
Gravel, coarse, very stony, stones to 6 inches, oxidized to a brown color	8 feet
Gravel like above but gray-blue color and in part cemented by calcium carbonate	8

Opposite this point the terrace is at elevation 1350 or 40 feet above the river.

Cold Spring. The terminal moraine at Steamburg is connected to the Allegheny terraces by a great alluvial fan sloping from elevation 1430 at the moraine down to about 1350 close to the river. This fan disturbs the normal arrangement of the terraces in the vicinity of Cold Spring. A gravel pit on Highway 230 on the bank of Cold Spring Creek is shown in photo T. 61. The top four feet is leached of calcium carbonate. Below this zone is about two feet of dark brown oxidized gravel which lies with an abrupt contact on gray gravel largely cemented into conglomerate. On Highway 17, about a mile east of the Indian school, is a pit in a terrace not much over 10 feet above the river. Photo T. 74 shows the face of this pit and demonstrates the relatively shallow weathering. No conglomerate was observed here but the exposure does not extend below the oxidized zone.

Red House. The gravel pit belonging to the State Park lies south of the abandoned chemical plant. It exposed when visited by the writer 8 to 10 feet of much rotted brown sand and gravel lying on cemented gray gravel. The elevation of the top is 1358 or about 28 feet above the river. Red House post office is on a terrace 12 feet lower or 16 feet above the river. One half mile east of the post office on Highway 17 is a gravel pit which is covered by one to one and a half feet of silty gray-yellow soil. Below this is about 8 feet of oxidized brown gravel. No conglomerate was exposed when the writer visited the locality.

Little Valley. As mentioned above, the low terraces extend up Little Valley Creek to the pitted outwash in the village of that name. Above Salamanca the grade of the Allegheny is much lower than it is below if the old and inaccurate Salamanca quadrangle is to be relied upon.

Olean Creek. The low level valley train of the Allegheny receives another tributary train from the north in the valley of Olean Creek. Where examined along the state highway several miles northeast of Olean slightly weathered gravel with stones up to 8 inches in diameter was observed.

Summary of low terraces. So far as the studies of the writer indicate there are two distinct levels of low terraces (a) 30 to 40 feet above the river and (b) about 15 feet above water level. Above the junction with Great Valley Creek at Salamanca the lower level is very extensive and seems to grade into the non-glacial filling of Tunungwant Creek on the south.

INTERPRETATION OF TERRACES

Origin. That all of the heretofore described terraces are of glacio-fluvial origin is very clear. They consist of glacial outwash which was deposited by the drainage from an ice front which stood at or near Steamburg and some distance north of both Salamanca and Olean. Although till may be present at Steamburg, there is no evidence that the deposits at Kinzua and Allegany are moraines. The writer also failed to confirm Lewis' mapping of the terminal moraine in Great Valley north of Salamanca (p. 154-155).

Age of low terraces. That the low terrace group is of the same age as the moraine at Steamburg is clear. This moraine appears from the mapping of Leverett (1902) to be of what was first called Late Wisconsin but which is now classified as Cary age. The highest Cary filling was eroded by waters during the recession of the ice margin to the north. This retreatal drainage had deposited the coarser part of its load farther north and thus was able to erode the older deposits. However, there is no evidence of a drainage outlet at Steamburg which carried water from behind the moraine and the alluvial fan from the moraine is only slightly terraced. Waters from behind the moraine here soon found an outlet down the Conewango.

Age of high terraces. It seems possible that the high terraces are not all of the same age. They may be related to several different glacial stages or substages older than the Cary substage of the Wisconsin invasion. Older students of the terraces in Pennsylvania laid much stress on their conclusion that the highest terraces were deposited before the rock bottoms of the valleys were eroded to their present depth. The studies of the writer

did not support this view. Even the highest and oldest terrace, at Clarendon, Pennsylvania, was deposited in the bottom of a very deep rock valley. Leverett (1930) states: " The glacial deposits of pre-Illinoian age in this valley - - - are of clayey character, as if laid down in ponded water, up to about 1,400 feet in the vicinity of Clarendon, but are gravelly above that level. - - - - - It is probable that the ice sheet in the early glacial stage reached nearly to Clarendon, for the gravel train heads abruptly there." The writer is convinced that these deposits must have been laid down when glacial ice blocked the Allegheny valley to the north. The same author regards the 220 foot terrace at Warren, Pennsylvania, as of Illinoian age and on his map (published by Antevs) places the drift close to there as Jerseyan (probably equivalent to Kansan). He also states: "The terraces of Illinoian gravel are 150 to 180 feet above the Allegheny river ——— -. A valley train seems to have come in from the old upper Allegheny at Steamburg, New York, that filled the valley to an elevation between 1,460 feet and 1,480 A. T. - - - -. It is probable that the upper Allegheny was thrown across the Kinzua col at as early a time as the diversion of drainage past Althom, but pre-Illinoian deposits have not as yet been identified in the part of the present Allegheny above the Kinzua col." The writer admits the possibility that the high terrace at Warren may be as old as Illinoian although it is difficult even after making all possible allowance for the differences in material and subsoil drainage, to conceive of the relatively slight alteration in the weathered zone as representing the same time interval as permitted the formation of several feet of gumbotil farther west.
The other three groups of lower old terraces all show much shallower weathering than is present at Warren, in fact little more than is seen in many places in the low terraces. Conglomerate is not confined to the high terraces but is also well developed in the low terraces. The erosion of such a feature as Hotchkiss Hollow terrace, even allowing for the greater porosity

and the greater resistance of gravel compared with the clay till of southern Illinois, seems to the writer to be far too slight to agree with an Illinoian age. This does not refer to the separation of the several terrace remnants which must have been accomplished rapidly by floods from the melting ice but to gulleying by local precipitation. On the other hand, the maturity of the valley sides at the Kinzua col and in the postglacial stream valleys near Steamburg (photos. T. 19, 29, 30) demonstrates to the writer that the drainage diversions must have been pre-Wisconsin. Such valleys are utterly unlike the post-Wisconsin gorges of Watkins Glen, Genesee River, Cattaraugus Creek, and so forth. Long ago Chamberlin and Leverett (p. 35) stated that: "the earlier invasion of the ice - - - reversed the drainage". It is possible that the terraces now seen are decidely younger than the time of drainage diversion and that the terraces of that remote time have been entirely destroyed by erosion. Data at present available cause the writer to incline to the view that the three lower groups of high terraces at 80-85, 110-140, and 150-160 feet above the river respectively, are all of Wisconsin age belonging to either or both of the earlier substages, Iowan and Tazewell. Judgment is reserved on the age of the 220 foot and 320 foot levels in Pennsylvania. Further studies of the soil profiles in accordance with the system of Leighton and MacClintock is needed before final opinions are possible. In this connection it must be realized that shallow exposures may show only the lighter colored parts of the soil profile and thus give an entirely false impression.

Lake beds of Allegany State Park. The fact that the high outwash terrace deposits accumulated so rapidly that the tributary streams did not have time to aggrade their beds to meet the new baselevel was thoroughly discussed by Lobeck (p. 99-111). He states (p. 107) that : "The clay deposits (in the lakes thus enclosed in the tributary valleys) are rarely more than three or four feet thick and, where cut through by the streams,

are seen to be resting upon beds of gravel presumably left by the stream as it became clogged just prior to the encroachment of the lake upon its valley." The test holes for the Red House dam disclosed from 4 to 20 feet of clay overlying 33 to 45 feet of mixed gravel and clay which is clearly fluvial. Beneath this is at least 13 feet of blue lake clay. Judged in the light of present knowledge of the terraces, this means that the high-level lakes mapped by Lobeck occurred a long time ago. Following that time there was erosion of the outwash to a level below that of the modern stream. During the interval between glacial advances the tributary streams in the Park were able to aggrade their beds with gravel to meet the remnant of the older outwash in the valley of the Allegheny. The last or Cary advance then caused a much smaller and lower lake with whose deposits it is quite possible that some weathered stream deposits have been confused. Whether the time lapse between the two lakes was an interglacial interval or a "subinterval" between substages the evidence is not sufficient to decide.

The reentrant angle in the drift border. The study of the erratics in the terraces and the adjacent drift and of the relations of the terraces to the drift has thus far thrown little light upon the cause of the great reentrant angle in the drift margin north of Allegany State Park. The commonly accepted explanation is that this is the contact of the Erian glacial lobe and the ice which came directly across country from Quebec. Lesley (Lewis, p. xxi, xxxviii) long ago pointed out this fact. In such a situation we should expect to find that there had been shifts from time to time in the position of the angle. It is clear, however, from the fact that the erratics are all the same types of rock that the two lobes came from the same part of Canada. It does not follow that the outer margin of the Wisconsin drift is of the same age at all places. In such rugged country it is difficult, if not impracticable, to compare the age by study of soil profiles, for erosion in many places removes the weathered material as fast as it forms. The writer is distinctly under the impression, although the time allowed for field work

did not suffice to obtain much evidence, that the Cary moraine passes far to the north of Salamanca and connects with the outer of the two moraines in the Finger lake district mapped by Fairchild. In fact such a correlation was long ago postulated by Chamberlin. If such is the case, the outermost Wisconsin drift east of the reentrant is either Iowan or Tazewell or both. The drift margin certinly needs remapping in this region.

CONCLUSIONS

The work of the writer in and near Allegany State Park has thus far shown that:

(a) the terraces of the Allegheny valley can be divided into two groups, first the low and slightly eroded levels up to 40 feet above the river, and second, the high, eroded terrace remnants up to 320 feet.

(b) the terraces are all of glacial outwash origin.

(c) the low terraces date from the formation of the terminal moraine of the Cary substage of the Wisconsin glaciation.

(d) the high terraces may be in part of pre-Wisconsin age ~~age~~, that is the 320 and 220 foot levels in Pennsylvania, but the remnants in New York do not appear to be older than the Iowan or Tazewell substages of the Wisconsin glaciation.

(e) all of the high terraces were deposited after the valleys had been eroded to their present rock bottoms.

(f) the diversion of the Allegheny river took place in pre-Wisconsin time, possibly at the time of the formation of the oldest and highest terraces.

(g) the high-level lakes shut in the tributary valleys by the high outwash fill in the Allegheny valley occurred long before the deposition of the moraine at Steamburg so that the absence of shore features is to be expected; their deposits are buried under a considerable thickness of fluvial gravel which was deposited during a time of ice recession.

(h) no data was secured on the cause of the reentrant angle in the drift margin or the time relations of ice advances on its two sides.

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that the Allegheny river developed its new course and abandoned the route past Randolph. The old valley became clogged with alluvium and drift as we now see it. As the ice sheet melted back a lake was formed between the moraine and the ice front and covered the present site of Randolph. - - - - - The lowest point of overflow was just south of Johnny Watt hill and it was through this gap just west of Steamburg that its waters poured out until, with the greater retreat of the ice, the lake was drained to the west. The gap just west of Steamburg is flat-floored and with little or no terminal moraine hills. In one or two places - - - there are preserved remnants of the outwash plain at elevations as great as 1460 or more. This is very much higher than the present floor of the valley and presumably means that the waters draining through this gap cut away much of this earlier outwash - - -. At least there is clear evidence that this is an old outlet channel." Leverett appears to have also made recent observations in New York state but the details have not been published.(1930).

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DESCRIPTION OF HIGH TERRACES

Clarendon, Pennsylvania. In the Tionesta Valley, southeast of Warren, Pennsylvania, near the village of Clarendon, glacial stones have long been known (Chamberlin and Leverett, p. 273, Leverett, 1902, p. 228, 239, Butts, p. 6-7, Leverett, 1930). The only exposure which the writer could discover in the brief visit to the place on July 19, 1932 is a gravel pit in old Clarendon just northeast of the schoolhouse. Here about 15 feet of much weathered brownish-gray, well-sorted, well-bedded gravel was exposed. The largest boulders observed were slightly over a foot in diameter but few pebbles exceed four inches. According to the Warren quadrangle the highest part of this greatly eroded terrace exceeds 1500 feet elevation or 320 feet above Allegheny River. The well records given by older students of the locality indicate that the gravel lies on a thickness of more than 200 feet of fine sediment. It is clear that the exposed deposit is outwash which was deposited some distance from an ice front long after the present rock bottom of the valleys had been reached by the streams.

Warren, Pennsylvania. Butts mapped several high level terraces near to the junction of the Conewango and Allegheny. Chamberlin (p. 27) gives 1395 as the highest level or about 220 feet above the river. The writer visited only one exposure, the pit of the Carlson-Johnson Gravel Company. Here weathering

extends to a depth of over 20 feet as shown in photo T. 17. This zone had been recently excavated for road surfacing as it contains too much silt and clay for concrete. The lower face of the pit exposed clean sand and light gray gravel much of which is cemented by calcium carbonate. There is some openwork gravel. Some of the cross bedding dips north or away from Allegheny River. The total thickness of the deposit could not be observed.

Russell, Pennsylvania. A gravel pit in Russell, Pennsylvania, just south of the road leading west from the bridge at an elevation slightly over 1280 (60 feet above the Conewango) shows cemented gravel of the same general type as that found in the high terraces. It is probable that this gravel underlies the adjacent moraine of Middle Wisconsin (Cary) age. (For modern classification of the glacial drifts see Kay and Leighton.)

Onoville, New York. High terrace deposits occur east of the river on the New York-Pennsylvania line. At this locality the writer found no good exposures and an aneroid reading made the highest well-defined terrace at 1390 or 120 feet above the river. Rounded pebbles mingled with local residium were observed on top of the rock terrace half a mile west of Onoville on the north road. The map elevation is 1460 or 180 feet above the river. At this locality it is possible that the stones are of glacial rather than fluvio-glacial origin.

Hotchkiss Hollow. The high terraces at the mouth of Hotchkiss Hollow are one of the best known localities in the region. (Photo T. 24). When visited by the writer gravel pits on both the north and south ends of the deposit exposed gravel with boulders up to 3 feet in diameter. Some layers, each less than 6 inches thick, occur of 1/8th to 1 inch openwork gravel in part quite well sorted (Photo T. 6). The cuts did not disclose the depth of weathering on the flat areas, but it is evident that the gravel is disintegrated into a silty clay to a depth of several feet. The map makes the highest level above 1460 but an aneroid reading based on nearby bench marks showed only 1455 or 150 feet above the river. On the south end there is a terrace level at 1390 feet or

85 feet above the river. No bed rock has been discovered beneath the main part of the terrace although the abrupt bend in the river strongly suggests that this remnant is rock defended. (Lobeck, p. 192-195).

Quaker Run. The high terrace which forms a partial dam across the mouth of Quaker Run (Photo T. 62) is known to all who have studied the geology of the Park. There are no good exposures. Aneroid readings show the summit to have an elevation of 1460 or 155 feet above the river. A marked bench on the south end lies at 1390 or 85 feet above ordinary water level. The small remnant north of Holts Run was not visited. (Lobeck, p. 193). An inconspicuous terrace occurs farther south on the same side of the river just north of Wolf Creek. An aneroid reading made the top 1450 or 150 feet above the river. This terrace rests on the bed rock of a steep hillside. (Lobeck, p. 194.)

Pine Creek. The terrace in the valley of Pine Creek is peculiar in that it lies back over a half mile from the river in a tributary valley. The aneroid recorded the top at 1490, 180 feet above the river. There are no good exposures. (Lobeck, p. 197.)

Cricks Run. Just east of the mouth of Cricks Run is a terrace remnant over a half a mile long which, according to the map, exceeds 1460 feet or 140 feet above the river. There is an old gravel pit on the railroad (Lobeck, p. 194, 198) but the writer did not visit it.

Steamburg. Lobeck (p. 100) mapped old high terraces both half a mile southeast of Steamburg and along the road east of the village near Bunker Hill School. The elevation may reach 1500 feet in places. There are no good exposures in either locality. In Steamburg there are two isolated hills with their longer axes parallel and east-west. In the southern one there is a gravel pit which has apparently been open since Lewis' day (p. 159). Lobeck (p. 209-212) describes the pit as gravel overlain by till saying " if the section is fresh, the disturbed upper layers of gravel give evidence of ice movement." The twenty-five foot face was clean on July 28, 1932, when visited by the writer (Photo T. 28). No till could then be distinguished. The top portion of the deposit is very bouldery and is so much weathered that stratification has been destroyed to

a depth of several feet and it is possible that this surficial zone was regarded as till. The matter is, however, unimportant, for such coarse gravel must certainly have been deposited close to the ice front. The fact that the horizontal beds are truncated by the sides of the hill suggested to the writer that the two hills are erosion remnants of a once-continuous outwash plain. In any case they are distinct from the much lower outwash apron of the moraine to the west. This moraine is apparently of Cary age.

Red House. Just north of and across the river from Red House post-office is a much eroded terrace remnant about a mile long. An aneroid reading made the top 1455 or roughly 125 feet above the river. Exposures were poor when visited.

Breeds Run. The terrace just south of Breeds Run is not very much eroded. The map makes the top 1420 but an aneroid reading gave 1450 or 110 feet above the river. Eye estimate favors the map, however.

Elkdale. In the vicinity of Elkdale Station a ridge 20 to 40 feet high nearly blocks the valley of Little Valley Creek forcing it against the western side. Several previous observers seem to have regarded this ridge (Lobeck, p. 123) as the terminal moraine of the Wisconsin drift. East of the highway, in the grounds of the Salamanca Country Club, the topography is broken and at a casual glance resembles that of a moraine. Closer inspection failed to demonstrate the presence of kettles and the writer regards the entire ridge as a greatly eroded terrace remnant. The portion west of the railroad has a flat top at a map elevation of 1480 but the aneroid made it only 1465. However, the control of the aneroid readings at this time of the day was not good and it is far more probable that the map elevation is correct. In this interpretation as outwash the writer is sustained by Lewis (p. 156) who placed the drift margin farther up the valley. Between Elkdale and Salamanca there are several obscure terrace remnants. In West Salamanca there is a rock-defended terrace at an aneroid elevation of 1510 or 150 feet above the river. The low terrace of this tributary

valley is pitted at Little Valley indicating the presence of stagnant ice masses at the time of deposition.

Allegany. The long distance from Salamanca to Russell seems to contain only very scanty remnants of terraces above the level of the main or low terrace. On the south side, between Riverside Junction and South Vandalia, however, a steam shovel had recently been used to excavate a deep pit in a reentrant of the valley wall where the topography gave little indication of gravel. East of Russell a much-eroded gravel terrace remnant over a mile long is shown in photo T. 34. A pit was being operated in the weathered zone but was not visited by the writer. According to the map the top of the deposit is above 1480 or 80 feet above the river. Across the river, in and east of Allegany, a large terrace remnant may locally exceed elevation 1520 or 120 feet above the river. However, this was not checked with the aneroid and the Salamanca and Olean quadrangles do not show very accurate elevations. Neither remnant shows much of the original surface. Lewis (p. 153) and Leverett (plate IV) both regarded these terraces as sections of the terminal moraine. The former reported "shallow depressions" but the writer could discover neither kettles nor till. A large gravel pit in Allegany (photos T. 32, 33) displayed a deeply oxidized zone 5 to 15 feet thick resting upon strongly cemented, fairly well-sorted horizontally bedded gravel. Cross bedding dips to the west. Some layers consist of poorly sorted open-work gravel. The writer is convinced, as was Lobeck (p. 103), that these deposits are terraces and not terminal moraine. The writer was unable to confirm any of the terraces suggested by Lobeck in the eastern part of Olean finding only rock shelves. When going east on Highway 17, however, he noted a deep cut in what appeared to be a high terrace but did not secure the location

Summary of high terraces. The high terraces may be divided into the following groups: (a) the Clarendon terrace over 300 feet above the Allegheny River, (b) the Warren terraces at 220 feet doubtfully including the 180 foot

rock terrace at Onoville, (c) the terraces at 150 to 160 feet including Hotchkiss Hollow high level, Quaker Run high level, Wolf Run, Pine Creek, and Salamanca, (d) a group of much eroded terraces which embraces the remnant at the state line, Cricks Run, Red House, Breeds Run, and part of the north Allegany locality, the elevations varing from 110 to 140 feet, and (e) a well-defined group at 80 to 85 feet which includes the low levels at both Hotchkiss Hollow and Quaker Run, and the southern Allegany terrace.

DESCRIPTION OF LOW TERRACES

Pennsylvania. Terraces up to roughly 40 feet above the ordinary level of Allegheny River were noted along much of the valley in Pennsylvania. All are little eroded and, so far as the few good exposures seen indicate, only slightly weathered. No terraces are present in the gap below Kinzua where the river crosses a preglacial divide.

Onoville, New York. About a quarter of a mile west of the Onoville bridge is a gravel pit at elevation 1300. It exposed horizontally bedded stony gravel, in part openwork. A few boulders are present. The weathered zone is only a few feet thick. The terraces between Bone and Pierce Runs is at elevation 1315 or 30 feet above the river. There is a lower level about half as high above the river.

Quaker Bridge. The gravel pit southwest of Tunessasa Indian School near the railroad displayed the following section. The top is at elevation 1340 or 35 feet above the river.

Soil and silty sand with scattered pebbles	2 to 3 feet
Gravel, coarse, very stony, stones to 6 inches, oxidized to a brown color	8 feet
Gravel like above but gray-blue color and in part cemented by calcium carbonate	8

Opposite this point the terrace is at elevation 1350 or 40 feet above the river.

Cold Spring. The terminal moraine at Steamburg is connected to the Allegheny terraces by a great alluvial fan sloping from elevation 1420 at the moraine down to about 1350 close to the river. This fan disturbs the normal arrangement of the terraces in the vicinity of Cold Spring. A gravel pit on Highway 280 on the bank of Cold Spring Creek is shown in photo T. 61. The top four feet is leached of calcium carbonate. Below this zone is about two feet of dark brown oxidized gravel which lies with an abrupt contact on gray gravel largely cemented into conglomerate. On Highway 17, about a mile east of the Indian school, is a pit in a terrace not much over 10 feet above the river. Photo T. 74 shows the face of this pit and demonstrates the relatively shallow weathering. No conglomerate was observed here but the exposure does not extend below the oxidized zone.

Red House. The gravel pit belonging to the State Park lies south of the abandoned chemical plant. It exposed when visited by the writer 8 to 10 feet of much rotted brown sand and gravel lying on cemented gray gravel. The elevation of the top is 1358 or about 28 feet above the river. Red House post office is on a terrace 12 feet lower or 16 feet above the river. One half mile east of the post office on Highway 17 is a gravel pit which is covered by one to one and a half feet of silty gray-yellow soil. Below this is about 8 feet of oxidized brown gravel. No conglomerate was exposed when the writer visited the locality.

Little Valley. As mentioned above, the low terraces extend up Little Valley Creek to the pitted outwash in the village of that name. Above Salamanca the grade of the Allegheny is much lower than it is below if the old and inaccurate Salamanca quadrangle is to be relied upon.

Olean Creek. The low level valley train of the Allegheny receives another tributary train from the north in the valley of Olean Creek. Where examined along the state highway several miles northeast of Olean slightly weathered gravel with stones up to 8 inches in diameter was observed.

Summary of low terraces. So far as the studies of the writer indicate there are two distinct levels of low terraces (a) 30 to 40 feet above the river and (b) about 15 feet above water level. Above the junction with Great Valley Creek at Salamanca the lower level is very extensive and seems to grade into the non-glacial filling of Tunungwant Creek on the south.

INTERPRETATION OF TERRACES

Origin. That all of the heretofore described terraces are of glacio-fluvial origin is very clear. They consist of glacial outwash which was deposited by the drainage from an ice front which stood at or near Steamburg and some distance north of both Salamanca and Olean. Although till may be present at Steamburg, there is no evidence that the deposits at Elkdale and Allegany are moraines. The writer also failed to confirm Lewis' mapping of the terminal moraine in Great Valley north of Salamanca (p. 154-155).

Age of low terraces. That the low terrace group is of the same age as the moraine at Steamburg is clear. This moraine appears from the mapping of Leverett (1902) to be of what was first called Late Wisconsin but which is now classified as Cary age. The highest Cary filling was eroded by waters during the recession of the ice margin to the north. This retreatal drainage had deposited the coarser part of its load farther north and thus was able to erode the older deposits. However, there is no evidence of a drainage outlet at Steamburg which carried water from behind the moraine and the alluvial fan from the moraine is only slightly terraced. Waters from behind the moraine here soon found an outlet down the Conewango.

Age of high terraces. It seems possible that the high terraces are not all of the same age. They may be related to several different glacial stages or substages older than the Cary substage of the Wisconsin invasion. Older students of the terraces in Pennsylvania laid much stress on their conclusion that the highest terraces were deposited before the rock bottoms of the valleys were eroded to their present depth. The studies of the writer

did not support this view. Even the highest and oldest terrace, at Clarendon, Pennsylvania, was deposited in the bottom of a very deep rock valley. Leverett (1930) states: " The glacial deposits of pre-Illinoian age in this valley - - - are of clayey character, as if laid down in ponded water, up to about 1,400 feet in the vicinity of Clarendon, but are gravelly above that level. - - - - - It is probable that the ice sheet in the early glacial stage reached nearly to Clarendon, for the gravel train heads abruptly there." The writer is convinced that these deposits must have been laid down when glacial ice blocked the Allegheny valley to the north. The same author regards the 220 foot terrace at Warren, Pennsylvania, as of Illinoian age and on his map (published by Antevs) places the drift close to there as Jerseyan (probably equivalent to Kansan). He also states: "The terraces of Illinoian gravel are 150 to 180 feet above the Allegheny river ---- -. A valley train seems to have come in from the old upper Allegheny at Steamburg, New York, that filled the valley to an elevation between 1,460 feet and 1,480 A. T. - - - -. It is probable that the upper Allegheny was thrown across the Kinzua col at as early a time as the diversion of drainage past Althom, but pre-Illinoian deposits have not as yet been identified in the part of the present Allegheny above the Kinzua col." The writer admits the possibility that the high terrace at Warren may be as old as Illinoian although it is difficult, even after making all possible allowance for the differences in material and subsoil drainage, to conceive of the relatively slight alteration in the weathered zone as representing the same time interval as permitted the formation of several feet of gumbotil farther west.

The other three groups of lower old terraces all show much shallower weathering than is present at Warren, in fact little more than is seen in many places in the low terraces. Conglomerate is not confined to the high terraces but is also well developed in the low terraces. The erosion of such a feature as Hotchkiss Hollow terrace, even allowing for the greater porosity

and the greater resistance of gravel compared with the clay till of southern Illinois, seems to the writer to be far too slight to agree with an Illinoian age. This does not refer to the separation of the several terrace remnants which must have been accomplished rapidly by floods from the melting ice but to gulleying by local precipitation. On the other hand, the maturity of the valley sides at the Kinzua col and in the postglacial stream valleys near Steamburg (photos. T. 19, 29, 30) demonstrates to the writer that the drainage diversions must have been pre-Wisconsin. Such valleys are utterly unlike the post-Wisconsin gorges of Watkins Glen, Genesee River, Cattaraugus Creek, and so forth. Long ago Chamberlin and Leverett (p. 35) stated that: "the earlier invasion of the ice - - - reversed the drainage". It is possible that the terraces now seen are decidely younger than the time of drainage diversion and that the terraces of that remote time have been entirely destroyed by erosion. Data at present available cause the writer to incline to the view that the three lower groups of high terraces at 80-85, 110-140, and 150-160 feet above the river respectively, are all of Wisconsin age belonging to either or both of the earlier substages, Iowan and Tazewell. Judgment is reserved on the age of the 220 foot and 320 foot levels in Pennsylvania. Further studies of the soil profiles in accordance with the system of Leighton and MacClintock is needed before final opinions are possible. In this connection it must be realized that shallow exposures may show only the lighter colored parts of the soil profile and thus give an entirely false impression.

Lake beds of Allegany State Park. The fact that the high outwash terrace deposits accumulated so rapidly that the tributary streams did not have time to aggrade their beds to meet the new baselevel was thoroughly discussed by Lobeck (p. 99-111). He states (p. 107) that : "The clay deposits (in the lakes thus enclosed in the tributary valleys) are rarely more than three or four feet thick and, where cut through by the streams,

are seen to be resting upon beds of gravel presumably left by the stream as it became clogged just prior to the encroachment of the lake upon its valley." The test holes for the Red House dam disclosed from 4 to 20 feet of clay overlying 33 to 45 feet of mixed gravel and clay which is clearly fluvial. Beneath this is at least 13 feet of blue lake clay. Judged in the light of present knowledge of the terraces, this means that the high-level lakes mapped by Lobeck occurred a long time ago. Following that time there was erosion of the outwash to a level below that of the modern stream. During the interval between glacial advances the tributary streams in the Park were able to aggrade their beds with gravel to meet the remnant of the older outwash in the valley of the Allegheny. The last or Cary advance then caused a much smaller and lower lake with whose deposits it is quite possible that some weathered stream deposits have been confused. Whether the time lapse between the two lakes was an interglacial interval or a "subinterval" between substages the evidence is not sufficient to decide.

The reentrant angle in the drift border. The study of the erratics in the terraces and the adjacent drift and of the relations of the terraces to the drift has thus far thrown little light upon the cause of the great reentrant angle in the drift margin north of Allegany State Park. The commonly accepted explanation is that this is the contact of the Erian glacial lobe and the ice which came directly across country from Quebec. Lesley (Lewis, p. xxi, xxxviii) long ago pointed out this fact. In such a situation we should expect to find that there had been shifts from time to time in the position of the angle. It is clear, however, from the fact that the erratics are all the same types of rock that the two lobes came from the same part of Canada. It does not follow that the outer margin of the Wisconsin drift is of the same age at all places. In such rugged country it is difficult, if not impracticable, to compare the age by study of soil profiles, for erosion in many places removes the weathered material as fast as it forms. The writer is distinctly under the impression, although the time allowed for field work

did not suffice to obtain much evidence, that the Cary moraine passes far to the north of Salamanca and connects with the outer of the two moraines in the Finger lake district mapped by Fairchild. In fact such a correlation was long ago postulated by Chamberlin. If such is the case, the outermost Wisconsin drift east of the reentrant is either Iowan or Tazewell or both. The drift margin certainly needs remapping in this region.

CONCLUSIONS

The work of the writer in and near Allegany State Park has thus far shown that:

(a) the terraces of the Allegheny valley can be divided into two groups, first the low and slightly eroded levels up to 40 feet above the river, and second, the high, eroded terrace remnants up to 320 feet.

(b) the terraces are all of glacial outwash origin.

(c) the low terraces date from the formation of the terminal moraine of the Cary substage of the Wisconsin glaciation.

(d) the high terraces may be in part of pre-Wisconsin ~~ice~~ age, that is the 320 and 220 foot levels in Pennsylvania, but the remnants in New York do not appear to be older than the Iowan or Tazewell substages of the Wisconsin glaciation.

(e) all of the high terraces were deposited after the valleys had been eroded to their present rock bottoms.

(f) the diversion of the Allegheny river took place in pre-Wisconsin time, possibly at the time of the formation of the oldest and highest terraces.

(g) the high-level lakes shut in the tributary valleys by the high outwash fill in the Allegheny valley occurred long before the deposition of the moraine at Steamburg so that the absence of shore features is to be expected; their deposits are buried under a considerable thickness of fluvial gravel, which was deposited during a time of ice recession.

(h) no data was secured on the cause of the reentrant angle in the drift margin or the time relations of ice advances on its two sides.

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Chamberlin Terminal moraine

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Pre-Wisconsin terraces in the Ohio Basin

General features and relations.—~~The~~ In the valleys of the upper Ohio and its tributaries ~~there are~~ both glacial and non-glacial terraces on rock shelves and in abandoned courses, all of them much more weathered and eroded than the lower terraces of Wisconsin age. ~~In early days~~ Long ago G. F. Wright regarded these deposits as evidence of a glacial lake, caused by ~~the~~ an ice ~~crossing~~ dam in the Ohio at Cincinnati, but other geologists afterward assigned a ~~later the~~ fluvial origin to the gravels. ~~was recognized by other geologists. However,~~ Opinion has been sharply divided on the position of the rock floor at the time of aggradation. There seems to have been no attempt to discriminate more than one stage of pre-Wisconsin valley filling. The likeness of these deposits to the pre-Wisconsin terraces of the Driftless Area is very striking, and ~~it seems probable that~~ their history may have been ~~was~~ essentially the same (18).

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Previous investigations. Although little detailed investigation has ever been made of the terraces of Allegheny River in New York their general nature has been known for a long time. In his introduction to Wright's report on the glacial boundary Chamberlin in 1890 divided the terraces into two great groups, (a) the high terraces and (b) the moraine-headed terraces. The great difference in age of the two groups was stressed. In 1894 the same author in collaboration with Frank Leverett again described the terraces and recognized the possibility that they may be of three different ages. Their conclusions on the relation of the terraces at Stemaburg, New York, to the terminal moraine are exactly the same as those reached by the writer so long after. Leverett's final report of 1902 summarized the conclusions previously published and gave an extensive bibliography covering much early work in Pennsylvania. In 1910 Butts mapped the terraces near Warren, Pennsylvania but added nothing to the previous knowledge of their age relations. Lobeck in 1927 mapped and described the terraces in the vicinity of Allegany State Park, New York but seems to have overlooked much of the earlier literature concerning their ages. He regarded them as entirely the product of the last glaciation stating: (P. 125)

"When the ice occupied the position now marked by the terminal moraine great floods of water poured to the south past Steamburg and through Allegheny valley. It was at his time that the Allegheny river developed its new course and abandoned the route past Randolph. The old valley became clogged with alluvium and drift as we now see it. As the ice sheet melted back a lake was formed between the moraine and the ice front and covered the present site of Randolph. --------
The lowest point of overflow was just south of Johnny Watt hill and it was through this gap just west of Steamburg that its waters poured out until, with the greater retreat of the ice, the lake was drained to the west. The gap just west of Steamburg is flat-floored and with little or no terminal moraine hills. In one or two places----there are preserved remnants of the outwash plain at elevations as great as 1460 or more. This is very much higher than the present floor of the valley and presumably means that the waters draining through

this gap cut away much of this earlier outwash-----. At least there is clear evidence that this is an old outlet channel."

Leverett appear to have also made recent observations in New York State

Subdivision of terraces. The terraces of Allegheny River and its tributaries have long been divided into two great grouns: first the low, broad, slightly dissected, rather sandy levels from a few feet to roughly 40 feet above normal river level, and second, the high, discontinuous, for the most part very stony terraces up to 300 feet above the present day streams. It is probable that the high terraces can be sudivided further into at least four groups, ~~although data now available do not permit this to be done with certainty~~.

Material. The terraces are underlain by gravel which for the larger part contains a fairly high proportion of pebbles. The material ranged from large boulders down to sand, with the latter for the greater part subordinate in amount to the pebble Assortment is fair to good but no screen tests were made by which a quanitative classification can be formulated. Some of the thinner layers are of the "openwork" type, that is without any sand in the holes between the pebbles. The stones are chiefly siltstone derived from the Portage and Chemung beds. Canadian crystallines in few places make up as much as 10 percent of the total of sizes which are easily determinable in the field. The same kinds of far-traveled stones were found in the distant examined Where unweathered the gravel is light bluish-gray in color but near the surface this is replaced by a brownish yellow color and within this zone, which is from a few feet to fully 20 feet thick, the carbonates have been largely leached away. The carbonate, chiefly calcite, has been redeposited below the weathered zone forming much of the gravel into a conglomerate. Early investigators stressed the fact that the high terraces all lie on rock benches but this the writer was unable to confirm in the area he examined. He found only two on rock shelves which may have extended across the valleys

Bedding. The bedding of the gravels is predominantly horizontal. Cross bedding is confined to relatively thin layers many of them rather sandy and with few exceptions dips in the direction of the present drainage.

98-112, 119-126, 161-169, 192-218) has described and mapped the region close to the Park in considerable detail. Much has been written on the outwash terraces of the Allegheny River lower down its course in Pennsylvania but little attempt was made to follow up the literature on this region which is separated by many miles from the district seen in the field. The earlier work is summarized by Chamberlin and Leverett.

THE TERRACES; DESCRIPTION

General statement. The terraces of Allegheny River and its tributaries may be divided into two great classes: first, the lower, broad slightly dissected levels from a few feet to roughly 20 feet above water level, and second, the higher discontinuous fragments of terraces from 30 up to 160 feet above river level. All terraces are made of glacial outwash which consists of gravel and sand. Pebble counts show for the most part less than 10 percent of Canadian pebbles. Locally the gravel has been cemented by calcium carbonate into a fairly firm conglomerate. The group of high terraces will be considered first.

DESCRIPTION OF HIGH TERRACES

Clarendon

South of Warren, Pa. In the Tionesta Valley, southeast of Warren, Pennsylvania, near the village of Clarendon, glacial stones have long been known. Both Leverett and Butts ascribe the deposits to ice but the only exposure which the party of the writer was able to find in a brief visit is a gravel pit in Old Clarendon, just northeast of the schoolhouse. About 15 feet of fairly (much weathered, well-sorted and well-bedded gravel was exposed on July 19, 1932. Few stones of more than 4 inches in greatest dimension could be seen although some of these exceed a few reach a diameter of over a foot in diameter. The erratics appeared to be the same as those noted farther north in the younger drift. The deposit which reaches an elevation of 1500 feet according to the Warren quadrangle, is certainly not till and could not have been deposited close to the ice front.

Warren, Pennsylvania. Butts mapped several high level terraces of glacial outwash near to and in Warren, Pennsylvania. All are close to the junction of the Conewango and the Allegheny and reach an maximum elevation of roughly 1380 1395 feet. The only exposure visited in was the pit of the Carlson-Johnson Gravel Co., 203 Dartmouth St. Here the top 20 feet of the deposit is greatly weathered and

oxidized as shown in photo T. 17. This part had been recently excavated with a steam shovel ~~to use on~~ for purposes roads. The lower face of the pit shows clean sand and gravel of light grey color much of which is cemented by calcium carbonate. Some of the gravel is of the "openwork" type with little sand but is not as well sorted as are openwork gravels on a beach. Some of the cross bedding dips north ~~into~~ away from the Allegheny River. Bed rock below was not observed.

Russell, Pennsylvania. A gravel pit in Russell, Pennsylvania, just south of the road leading west from the bridge at elevation slightly over 1280 (60 ft above stream) shows cemented gravel of the same general type as that of the high terraces. The surrounding moraine is for the most part composed of till. The exposure, although not conclusive, suggests the possibility that the terminal moraine of the Middle Wisconsin ~~or~~ (Cary) ~~drift~~ rests upon a remnant of a high terrace.

~~Onkax~~ Onoville, New York. High terrace deposits are known on the New York-Pennsylvania line east of the river near the extreme southwest corner of Allegany State Park, ~~xshortxdistancexwestxofxthexwestxbridgehead~~, and apparently on the north road about a half mile west of Onoville. The first named has no good exposures so far as could be seen and apparently reaches an elevation of about ~~1400~~ 1390 feet (corrected). ~~Thexgravelxpitxatxanxelevationxofx1300xonlyxslightlyxhigherxthanxthexmainxterracexatxthexbridgehead~~ The shelf on the north side of the Sawmill Run valley west of Onoville reaches an elevation of 1460, 180 ft above river and has some water-worn stones on top. ~~It is composed mainly of shale.~~ It is possible that the stones, some of which were found in situ mixed with local residium, are of glacial rather than glacio-fluvial origin.

Hotchkiss Hollow. The high terrace at the mouth of Hotchkiss Hollow is the best known in the district. (photo T 24) Pits on the north and south flanks were studied ~~on July 12, 1938.~~ at the time of visit These displayed fairly well sorted to very well sorted gravel ~~which contains~~ with scattered boulders up to 3 feet in diameter. Some layers, each less than 6 inches thick, of 1/8 to 1 inch diameter openwork gravel were observed. (photo T 6) Weathering is well marked and the highest part of the terrace is distintegrated into a silty clay soil to a depth estimated at ~~x~~ not less than 10 feet. The highest part of

the terraces is at elevation above 1460. The south side shows ~~several levels~~ These are weathered to a depth of 4 to 6 feet. ~~particularly at elevations 1400 and 1380.~~ The presence of a bed rock basement has not been demonstrated although the abrupt bend in the Allegheny River north of this terrace strongly suggests that such is present. (Lobeck 192-195)

Quaker Run. The high or ~~1480 foot~~ terrace at the mouth of Quaker Run is known to almost all visitors ~~of~~ to the Park. Indeed, it was once suggested that a ~~lake~~ lake be made by damming ~~to dam~~ the Run at the south end of this gravel terrace where the present stream is cutting ~~a gorge~~ in the shale. There are ~~s~~ no good exposures but float seems to indicate rather coarse stony gravel. A smaller remnant ~~occurs~~ north of Holts Run. ~~was not visited.~~ (Lobeck p 193) Gravel also occurs on the face of the bluff just north of Wolf Creek forming an inconspicuous terrace. (Lobeck p 194)

Pine Creek. The terrace remnant in Pine Creek valley is much dissected but reaches over half a mile back from the main valley. The highest elevation is 1480. Exposures are poor and little new could be observed. (Lobeck p 197)

Cricks Run. Just east of the mouth of Cricks Run is a terrace remnant over half a mile long which ~~reaches~~ exceeds 1460 feet. Lobeck (P.) ~~reports~~ described an exposure on the railroad but the writer did not visit it.

Steamburg. Lobeck (p. 100) mapped old high terraces both half a mile southeast of Steamburg and along the road near Bunker Hill School. The elevation may locally reach 1500 feet. There do not seem to be any good exposures in these. The writer is convinced that the gravel pit in Steamburg (~~Lobeck p. 212~~ 209-~~212~~) is not covered by till despite his ~~predecessors~~ Lobeck's statement (p. 209) that "if the section is fresh, the disturbed upper layers of gravel give evidence of ice movement." The twentyfive foot face was clean on July 28, 1932 when visited with the class. The few feet at the top is very bouldery and has been so greatly weathered that the originally poor stratification has been destroyed It is possible that till was present but has been dug away for in any case the very coarse stony gravels must have been deposited close to glacial ice. The great amount of cementation and the truncation of the horizontal beds by the sides of the hill indicate to the writer that the whole mass is an erosion

remnant of a much higher outwash plain that that which merges into the moraine of Cary age half a mile farther west. The hill less than half a mile north of the gravel pit seems to be made of weathered gravel and is apprently of the same origin. Neither one is a part of the Cary moraine. It was described by Lewis p. 159

Red House. Just north and across the river from Red House is a terrace remant about a mile long which reaches elevation ~~1480~~ 1460. It is much eroded but exposures were poor at the time of the writer's visits.

Breeds Run. The little ~~1480~~ 1420 terrace just south of Breeds Run is not greatly eroded and clearly is not the highest level.

Elkdale. In the vicinity of Elkdale Station a ridge 20 to 40 feet high nearly crosses the valley of Little Valley Creek. All previous observers seem to have unhesitatingly regarded this as the terminal moraine of the Wisconsin drift.. (Lobeck, p. 123) In the grounds of the Salamanca Country Club, east of the State Highway, gulleying locally resembles morainal topography but so far as the writer could see there are no kettles. West of the highway, and especially west of the railroad, the top of the ridge is flat at elevation 1480. Cuts show that the material is coarse ill-assorted stony gravel which is greatly weathered to a depth of at least 10 feet. The ~~feature~~ ridge appears to be a remnant of a terrace preserved because the stream here swings over against the west wall of the valley. Lewis did not map this as part of the terminal moraine (p. 156) Both higher and lower in this valley other less ~~clearcut~~ evident terraces rise high above the uneroded Wisconsin outwash which is pitted at the village of Little Valley. There is a suggestion of a high terrace at elevation 1480 in West Salamanca.

Allegany. The long ~~interval~~ distance from Salamanca to ~~South Vandalia~~ Russell shows only scanty remnants of high terraces. Between Riverside Junction and ~~South Vandalia~~ Russell, however, a steam shovel had recently been used to excavate a deep pit in a reentrant of the valley wall where topography gave little indication of gravel. East of Russell a much eroded gravel terrace over a mile long is shown in photo T. 34. A pit which was being worked in the weathered zone was not visited by the writer. The top exceeds elevation 1480. Across the river in and east of

Summary of high terraces. The high terraces may be divided into the following groups: (a) the much eroded deposits near Clarendon, Pennsylvania, which rise to roughly 300 feet above Allegheny River, (b) the high terrace at Warren, Pennsylvania, 220 feet above the river, which it is possible that the high rock shelf at 180 feet west of Onoville may be correlated, (c) a considerable group of terraces with flat tops which rise to 150 to 160 feet above the river, including Hotchkiss Hollow high level, Quaker Run high level, Pine Creek, and Wolf Run, and Salamanca, (d) a number of much eroded terraces at ~~levels varrying~~ from ~~120~~ 110 to 140 feet, ~~above the Allegheny~~ including ~~Onoville~~ the terrace at the state line, Cricks Run, Red House, Brush Run, ~~Salamanca~~, and the ~~south~~ north side at Allegany, and (e) a well-defined group at 80 to 85 feet ~~high~~ including Hotchkiss Hollow low level, Quaker Run low level, ~~Brush Run~~, and the south side at Allegany.

~~As far as I have had the chance to see the higher the terrace the the~~ In general, the higher the terrace the deeper the weathering.

Allegany a large area of terrace may reach 1520 feet (120 ft) although this is far from certain. It is deeply eroded with little of the original surface remaining. Leverett (Lewis, p. 153) and plate IV) regarded this as part of the terminal moraine of the Wisconsin drift and the former reported "shallow depressions" but the writer was unable to find either till or kettles. A large gravel pit (photos T. 32, 33) shows a weathered zone with veins of iron oxide from 5 to 15 feet deep resting upon strongly cemented, fairly well-sorted gravels in horizontal beds. Cross bedding where present dips to the west. Some layers consist of poorly sorted openwork gravel. The writer is convinced, as was Lobeck, (p. 103) that this is a terrace and not a moraine. A reconnaisance along roads northeast of Olean failed to find any of the questionable terraces ~~marked on the~~ map by Lobeck (p. 103), ~~with a question.~~ Shelves ~~of~~ bed rock were ~~alone discovered.~~ seen only However, when going east on New York Highway 17 a deep cut in what appeared to be old terrace gravel was noted some miles beyond ~~east~~ of Olean.

Insert next page

DESCRIPTION OF Low Terraces

Pennsylvania. Terraces to ~~roughly~~ about 40 ~~30~~ feet above ordinary water level of the Allegheny River were noted along much of the valley in Pennsylvania. All are little eroded and, so far as the few good exposures seen indicate, only slightly westhered. No terraces are present in the narrows where the stream crosses a preglacial divide.

Onoville, New York. About a quarter of a mile west of the Onoville bridge is a gravel pit at elevation 1300. It exposes horizontally bedded stony gravel, in part openwork. A few boulders are present. The weathered zone is only a few feet thick. The terrace between Bone and Pierce Runs is at 1315 or 30 ft above the river - another 15' below

Quaker Bridge. The gravel pit southwest of Tunessasa Indian School near the railroad shows the following section: Top elevation is 1340 or 35 ft above river

Soil and silty sand with scattered pebbles	2 to 3 feet
Gravel, coarse, very stony, ~~size~~ sizes to 6 inches, oxidized to brown color	8

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Terrace Warren 220
Onondle 120-180
Hotchkiss 150 - 85
Quaker 155 85
Pine 160
Cuba 170 160 140
Red House 130?
Brecks — 80
Salamanca 120
Allegany 120 80

Groups
I Warren 220
Onondle W 180

II Hotch high 150
Quaker 155
Pine 160
Wolfram 150
Hotchkiss low 85
IV Quaker " 85
Brecks 80
Allegany 80

III Onondle low 120
Cuba 140?
Red House 130
Brecks 110
Sal. 120
Allegany 120

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TERRACES OF ALLEGHENY RIVER, WARREN, PENNSYLVANIA, TO OLEAN, NEW YORK

F.T. Thwaites

Introduction — Previous investigations
Description
  High terraces
    South of Warren, Pa.
    ~~Near~~ Warren and Russell, Pa.
    Onoville rock terrace, N. Y.
    Steamburg
    Elkdale
    ~~Terraces of~~ Allegany Valley below Salamanca
  Low terraces " " above "
Interpretation
  Origin of terraces
  Age
  Relation to glacial lakes of A. S. P.

Conclusions

Introduction. During July and August, 1932, the writer was instructor in geology at the Allegany School of Natural History, ~~in~~ Allegany State Park, New York. Only three students registered for work in geology and as all desired to take advanced work it was decided to study the problem of the terraces of the Allegheny River and their relation to the ~~drift~~ reentrant angle in the drift margin within which the Park is situated. It was hoped that ~~important~~ light might be shed on the time relations of the ice sheets on the two sides of this angle. The following report sets forth the results secured in only ~~seven days~~ about a week of field work. The conclusions herein reached are not final but are put on paper for the benifit of others who may have the opportunity of carrying forward the study of the problem. The writer is indebted to Miss Carol F Mason for aneroid observations

Previous investigations. Little detailed investigation of the ~~mid~~ terraces and glacial deposits within the area under discussion is now published. Leverett ~~has~~ dicussed the drainage changes due to glaciation (Leverett, 1891, 1894, 1896, and ~~1902~~ 1902) and briefly described the ~~adjacent~~ glacial and glaciofluvial deposits of the area (1902, p. 129-132, 226-227, ~~226~~ 228-239, 436, 432, 463-464, plate ~~facin~~ IV in pocket). Butts (1910, p. 6-7, 9) described briefly the terraces and drift of the Warren quadrangle, Pennsylvania. Lobeck (1927, p.

Gravel like above but gray-blue color and in part cemented by calcium carbonate 8

It is a question whether this gravel is actually of the age of the low terrace or has been eroded down to that level from a high terrace. opposite Quaker Bridge station the terrace is 1350 or 40 ft above the river.

Cold Spring. The Cary moraine at Steamburg is connected to the Allegheny terraces through a great alluvial fan which slopes from about 1420 elevation at the edge of the ~~drift~~ moraine to about 1350 close to the river. The presence of this fan ~~somewhat~~ interrupts the normal sucession of low terraces.

A gravel pit on New York Highway 280 on the bank of Cold Spring Creek is shown in photo T. 61. The top 4 feet is leached of calcium carbonate. Below this the suceeding two feet are dark brown in color and there is a sharp contact below this layer with gray gravel in part cemented into conglomerate.

On New York Highway 17 about a mile east of the Indian School is a pit in a terrace not much over 10 feet above the river. Photo T. 74 shows the face and demonstrates the relatively slight amount of weathering although oxidation extends to the bottom. No conglomerate was found. The terrace

Red House. The Allegany State Park gravel pit lies south of the abandoned chemical plant. It shows 8 to 10 feet of much rotted brown sand and gravel below which there is much conglomerate. ~~The topography suggests that~~ This may be slightly higher than the main low terrace in which case it is part of the series of high terraces. The elevation is 1358, about 28 ft above river. R# 90 a 1346 or 16 above river. One half mile northeast of the postoffice on Highway 17 is a pit belonging to some Indians. The top one to one and a half feet is a silty gray-yellow soil. Below this to a depth of about 8 feet from the surface is loose sandy gravel ~~x~~ oxidized to brown color. There is no conglomerate. ~~The elevation~~ Elevation is below.

North of Olean. A cut on the state highway north of Olean showed well sorted gravel with well rounded stones up to 8 inches diameter. The ~~evidence of~~ weathering is moderate in amount.

Summary of low terraces. There seem to be two distinct levels of low terraces one 30 to 40 feet above the river and another roughly 15 feet lower. The upper level locally shows considerable weathering.

INTERPRETATION OF TERRACES

Origin of the terraces. All of the heretofore described gravel deposits are explicable as glacial outwash. Apparently the ice front must have been near Steamburg on the northwest and somewhat north of Olean to the east. It is possible that some till is present at Steamburg but there is none at Allegany. The deposits at Allegany and Elkdale are certainly not moraines. There is no evidence of anything but stream deposition at any point which was observed by the writer.

Age of the terraces. The relations at Steamburg definitely prove that only the low terraces are of Cary age. The alluvial fan from that moraine was not terraced to any material extent by glacial waters during the dissapation of the Cary ice but has been somewhat eroded by Cold Spring Creek. Glacial waters from northwest of the terminal moraine found escape via Conewango Creek to Warren, Pensylvania. The high terraces were eroded to essentially their present form before the deposition of the low terraces. There age is, therefore, pre-Cary. Judging from the deep weathering and for the most part considerable erosion it seems more plausible to correlate them as pre-Wisconsin rather than as either Tazewell or Iowan, although it must be realized that the eivdence is not decisiive. If pre-Wisconsin it seems logical to correlate them with the Illinoian which has been identified by Leverett in the vicinity of Warren, Pennsylvania. The deposits at Clarendon, Pennsylvania, however, could not have been deposited at the same time as the highest terraces known farther north. They must have been laid down when the glacier crossed the Allegheny near Warren but this does not in itself mean that they are very much older than the other deposits farther north which might have been formed during the recession of the same ice sheet. It is obvious that the high terraces were formed at the time of, or later than, the diversion of the preglacial Alleghey from a northward course to the Lake Erie basin to its present route. The maturity of the gorges across cols also demonstrtes this the fact that the diversion occured in pre-Wisconsin time.

For that matter, the maturity of the valley sides in many of the postglacial divesion channels near Steamburg (photo T. 29, 30) strongly suggests that they are pre-Cary in age.

Relation to glacial lakes.

These conclusions are exactly in accordance with thos long ago reached by Chamberlin and Leverett who state (Chamberlin and Leverett, p. 35) "the earlier invasion of ice ---reversed the drainage and partially filled the valleys."

The glacial streams from the Cary ice which deposited the low terraces found the drainage in essentially the same location that it is today. Long enough time had elapsed to weather down the sides of the post-early drift valleys as may well be seen south of Kinzua, Pennsylvania. During the dissapation of this ice sheet glacial floods which had deposited the heavier part of their load farther upstream slightly eroded the Cary outwash forming the two low terraces.

The possibility still remains that not all the high terraces are of the same age. Certainly, the amount of weathering observed in them varies widely as does their elevation. The highest levels, as at Warren, Hotchkiss Hollow, and Allegheny seem to show the deepest soil profiles. In this connection it must be recognized that in many shallow exposures Horizons 1 and 2 of Leighton and MacClintock's classification, are light colored thus giving a false impression of freshness. Horizon 2 is a silt with relatively few stones, all of a very resistant nature. Horizons 3 and 4, where oxidation predominates, are much more striking though of very irregular thickness. On account of the coarseness of the finer materials in gravel these horizons were not clearly distinguished in the field. If there are really two different ages of high terraces it seems probable that the younger one lies not far above the level of the low terraces.

Lake beds of Allegany Park. The fact that the high outwash terrace deposits accumulated so rapidly that the tributary streams did not aggrade their beds to meet the new baselevel was thoroughly discussed by Lobeck (p. 99-11). ~~Mxxxthatxthexxmuchxgreaterxagexxfxthxx factx~~ He states (p. 107) that: "The clay deposits(in the lakes) are rarely more than three or four feet thick, and, where cut through by the streams, are seen to be resting upon beds of gravel presumably left by the stream as it became clogged just prior to the encroachment of the lake upon its valley." The test holes at the dam in Red House valley show from 4 to 20 feet of clay overlying 33 to 45 feet of mixed gravel and clay. Beneath this is at least 13 feet of blue clay. Judged in the light of present knowledge of the age relations of the terraces this lowest clay represents the deposit in ~~the~~ lakes which ~~were~~ contemporaneous with ~~the earlier filling~~. In the suceeding interglacial interval the stream resumed its course and aggraded its bed because all the early outwash had not been removed during terracing. The upper clay is in part due to weathering of the gravel and in part to slack water deposition of the stream when its outlet was raised during the later or Cary glaciation. Such a history does not agree with the conclusion of Chamberlin and Leverett that the earliest fill took place before the rock bottom of the valley had been eroded to its present level. It would, however, fit with their hypothsis of three periods of valley filling in which case the lower clay in Red House valley would correspsoond with the aggradation of the terrace ~~withxthexParkx~~ at the Park gravel pit ~~lower down the valley~~. In any case, however, it is easy to understand why lake deposits are ~~in fact~~ so scanty in and why beach lines have never been discovered, at the level of the highest terraces.

Relation of terraces to the reentrant in drift margin. The study of the erratics in the terraces and adjacent drift and of the relations of the terraces to the drift has thus far thrown little light upon the cause of the great reentrant angle in thedrift margin within which Allegany Park is situated. Lewis (p. xxxx) explantion: The commonly accepted explanation is that it is the point of contact of the Erian Lobe and the ice which came directly across countryfrom Quebec. Lesley (Lewis, p. xxi, xxxviii) long ago pointed out this fact. In such a situation we should expect to find that there was more or less sifting of the point of junction from time to time. It is clear, however, from the fact that the erratics are all of the same types that the two lobes came across the same part of Canada. The writer is distinctly under the impression, although the time allowed for field work did not suffice to obtain much evidence, that the moraine of the Cary drift passes far to the north and correlates with the outer of two of the Finger Lake morainic systems (Fairchild) In fact this correlation was long ago postulated by Chamberlin. If such is the case the outermost Wisconsin drift east of the reentrant angle is either Tazewell or Iowa or both.

Future work. It cannot be stated too emphatically that the Pleistocene geology of western New York needs restudy in the light of present knowledge of the glacial succession farther west. In order to reach definite conclusions studies of not only the topographic forms of the drift and associated terraces but their material and degree of alteration as shown by soil profiles are needed over a considerable terriotry. The writer feels that he has merely scratched the surface of a vast problem.

~~1565 B. d 58~~

Leverett, Frank. A J S (3) 42, 1891 - 200 - 212 not to point

Leverett ~~Chamberlin~~ A J S 3 47, 1894, 247-283 - pre Wis age of Terraces p 272 - Clarendon Ter. same as my statement 273 Lewiston = moraine at Steuben NY 274 interpretation 278-283

Am Geol. 18, 1896, 368-379 N.G.

Leverett, Frank, glacial formation of Erie and Ohio basins: 1902

US GS Mon 41, pp 88 (reference)

129-132 shows reversal of a Riv

226-227 divides border of Wis Dept - not settled

old drift 228-239

mapping of drift pl 15, p 436 - Test 437-

outwash 463-464 complete

Plate IV maps drift at ~~Salt~~ Olean - present

Butts, Charles, Warren Folio No 172 1910

pre-Kansan or Kansan p 6-7

well at Clarendon gravel 2 s @ 150 & 208 each ±12' thick

Total drift 215, Clarendon gravel to 1500'

Terraces p 7

Lacustrine p 9

Lobeck 1927 98-112, 119-126, 161-169, 192-218

Fig 103 p 212 suggests Tuscarora at Steuben pit

Wright GF (and Chamberlin TC) The glacial boundary in western Pa O. Ky, Ind, & Ill.

USGS Bull 58, 1890

light terraces 24-32 descriptions

from "moraine-headed terraces" p. 32

distance difference p 33-37

"the earlier moraine of ice that covered the drainage ~~of~~ and partially filled the valleys." p 35

1395 @ Warren - Pelton 1915 - p 27.

C & L. AJS 47 p274

"at Steamboat, (N) (W), the high terraces slope rather rapidly down the stream, the rate being ten feet per mile. They also slope downward in the opposite direction, i.e., up the stream. At Chico we also in the portion of the valley where both flow descends northward, the drift reaches the great depth of 400 ft."

Mr. Frederick Thwaites
Science Hall
U. of Wisconsin
Madison, Wis.

Geology Report -

Hilda Dwyer
732 E. 234 St.
New York, N. Y.

"Gravel Terraces of the Upper Allegheny River Valley"

Geology 2 Report

Durfee, Wilda--August 1932.

Introduction

The advanced geology for the summer of I932,given under the directorship of Mr.Thwaites(Wisconsin),consisted of an original problem-a study and correlation where possible of the outwash terraces of the upper Allegheny River valley.

The area studied in greatest detail was the valley northward from Warren,Pennsylvania to Olean,New York,* including the valleys of the tributaries-Tionesta Creek,Cold Spring Creek,Conewango Creek, and Quaker Run.

The region studied is part of the outwash plain from the Pleistocene glacial sheets.It is our belief that the terracing is due to river erosion of the glacial-fluviatile deposits;the higher terraces being the eroded remnants of an outwash plain considerably older than that which merges into the terminal moraine at Steamburg, N.Y.and from which the lower terraces have been cut.The terraces are composed mainly of gravel in which many cuts have been made which often reach a considerable level above the river.

In studying our area,we tried to correlate the terraces on the basis of: topographic interpretation with barometric corrections;the presence of foreign rocks(in this case crystalines as the country is all sedimentary),the kind,the state of preservation,and the relative percentage of the foreign rock,and the depth of weathering in the exposures studied-the deeper the weathering,the longer the time of exposure and hence the older the age of the deposit. In distinguishing the glacial deposits from the fluviatile,we use the usual criteria of stratification and bedding,color of the deposit,and the additional criterion that in a river deposit the pebbles point upstream at an angle to differentiate the river deposited glacio fluviatile from the lake laid deposits.

* See Fig - #1, #2.

Fig #1 – City of Salamanca as seen from a high terrace to the east

Fig #2 – Allegheny River near Onoville seen from Elko high terrace

Previous Investigations on the subject

I. Second Geological Survey Pennsylvania Report--Carll I880

2. Preliminary Report on the Geology of the Cattaraugus and the Chautauqua Counties (N.Y. State Museum I890-Randall)

3. Lewis -American Phil. Society Report Twenty

Report Z second Geological survey, Pennsylvania

4. Wright-Bulletin # 58 U.S.G.S. I890

5. Chamberlain and Leverett-American Journal sciences series three XLVII I894

6. Seventeenth annual report of State Geologist I897

7. Tarr "Physical Geography of N.Y. State" I902

8. State Museum Report Part I I903

9. Warren Folio U.S.G.S. Pennsylvania-New York I9IO Charles Butts

IO. N.Y. State Museum bulletin#255 I924-W.J. Miller

II. Lobeck. A.K. "A Popular Guide to the geology and the Physiography of Allegany State Park."

Observations and Data

When first considering the terraces of the upper Allegheny River, one is impressed by the difference in the altitude of the terraces. There seems to be too distinct levels-one about I420 and a lower level at about I2-I300 feet elevation, For example, there are wll defined high terraces at Hotchkiss Hollow(I460), Pine Creek, (I5I2), Breeds Hollow(I440); good examples of low terraces are found at Bone Run (I320), Peters School(I322), Shongo (I360), and Holt's Run(I322).* Upon projecting these terraces on a profile of the river (see profile), the distinctness of the levels is very striking.

The highest point of the terminal moraine in the Steamburg region is about I400 feet. Therefore it is not probable that outwash terraces which today stand at a level considerably above I400 feet could have been derived from a moraine at that level. This gave us our first hint that the higher terraces might have been the eroded outwash remnants of an earlier ice advance than the Steamburg moraine one. Lobeck in his book postulates that these terraces are deltas built by tributaries in a glacial lake which may have filled the valley north of Warren due to ice damming in the Warren region. Our problem then, was to ascertain the kind of deposits these terraces are, and the relative ages of their formation.

Detailed studies of gravel pits revealed that although some sand was present, the majority of the material is fairly well stratified pebbles and sand interbedded with some openwork gravel. Unlike quiet water lacustrine deposits, the pebbles are at an angle pointing upstream(a characteristic of stream deposits) The sand fillings can be justified on the basis of the filling of holes on a bar during low water. The gravels showed none of the chacteristics of delta deposits such as a marked foreset bed.

To substantaite our belief that the terraces are due to stream erosion, we took a trip to Big Bend, Pa. The valley at Big Bend is by far too wide and mature to have been worn away since the mos

*see fig #3

fig #3 — Holt's Run high terrace as seen from the low terrace on the south side of the Run (low terrace in foreground)

fig #4 - Holt's Run high terrace from the high terrace on the south side of the Run

most recent glaciation. Also, outside (south) of Big Bend where the glacial damming was to have occurred, we saw terraces which corresponded in elevation and general appearance to those north of Big Bend.

From the above studies, we concluded that we were working with terraces formed by the erosion of an outwash plain, by the Allegheny River, and that there were two stages of glaciation followed by erosion as evidenced by the terrace levels.

Studies of the general aspect of the high and low terraces:*

A. Low terraces in detail

1. Gravel pit in the low terrace north of Hotchkiss Hollow
2. Gravel pit in terrace north of Onoville, N.Y.
3. Low terrace, railroad cut between Elco and Wolf Runs
4. Red House east of the river**

In each of the pits, the general conditions were very similar. The cuts are quite old consequently a great deal of slumping has taken place. At Wolf Run the cut was deeper and fresher, and the evidences of deep weathering more striking. Thick deposits of gray clay and gravel conglomerate (products of deep weathering) are not present to any great extent.

B. High terraces in detail

1. Gravel pit in Hotchkiss Hollow terrace
2. Steamburg gravel pit
3. Carlson and Johnson gravel pits at Warren, Pa.
4. Cuts at Elkdale
5. Olean Creek terrace
6. Pine Hill water way ditch
7. Cold Spring high terrace
8. Elco high terrace
9. Gravel pit in terrace at Russell
10. Pit two miles wst of Quaker Run-Wolf Run road intersection.

The cuts in the high terraces are, in general fresher, and the color considerably darker than in the lower terraces. The strik-

* See fig. #3, #4 ** See fig. #5

fig #5 – Low terrace near Red House
gravel pit showing stratification

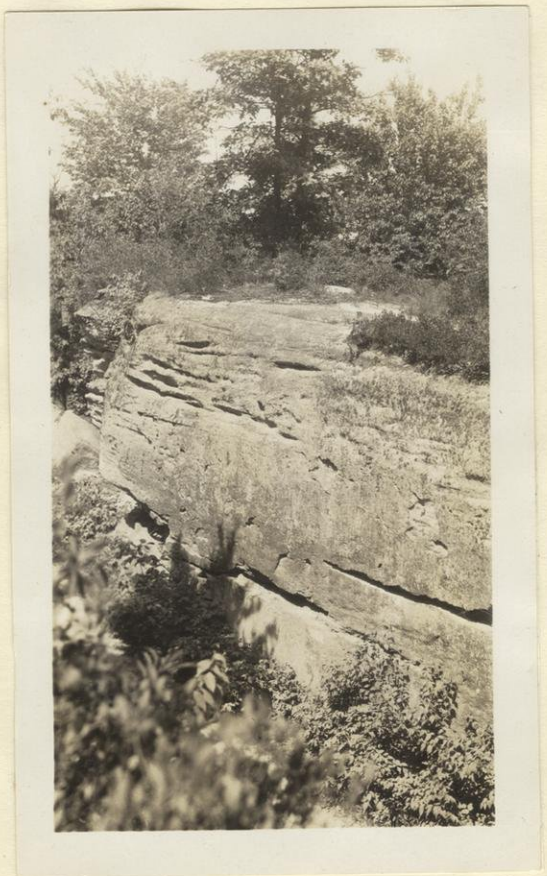

fig #6 -
"The Pass" near Warren, Pa.
formed by a joint plane in
Olean conglomerate

ing difference, however, is the presence of a gray clay, a product indicative of great weathering and great age. At Warren*, the cut is some fifteen or more feet deep, about eight feet near the top being markedly clayey. This clay is present in great quantities at Pine Hill, Steamburg, and Cold Spring. In general, the amount of cemented conglomerate is in far greater proportion in the higher terrace cuts. A satisfactory explanation for the formation of this gravel has not been offered other than that it is found in the zone of redeposition (Zone A near the surface, coarse material; B. coarser than A-zone of leaching; C. zone of cementation or redeposition)

Studies of foreign rock in high and low terraces

A. Numerical studies

I. Low terraces:

a) Low terrace north of Hotchkiss Hollow; boulders an inch or more in size

58 siltstones
8 cherts
4 vein quarts
2 quartzites
2 granites
I gneiss
2 red porphery

Total 7I (II crystalines, 60 sedimentaries)

2. High terraces

a) Warren pit

8 chert
5 red Medina sandstone
I8 siltstones
9 shales
3 vein quartz
2 gneisses

See fig #6 - "The Pass" north of Warren

2 granites

total 49 (7 crystalines, 40 sedimentaries)

b) Steamburg

68 miscellaneous sediments

I1 red sandstones

I2 cherts

IO miscellaneous igneous

Total IOI (IO igneous,9I sediments)

c) Pit east of Red House

I4 cherts

IO fossilifer us sediments

II red sandstones

5 crystalines

total 40 (5 ignous,35 sediments)

From the numerical studies little can be gathered,as the proportion of crystalines varies with the locality.At Steamburg the percentage and the size of the crystalines seems greater probably due to its proximity to the ice front.In general the chert content seems much higher in the high terraces.This was the only striking fact revealed and it is probably due to weathering that the chert is so abundant.

Detailed studies of the Correlation of the igneous rocks

Detailed studies of the rocks were a great disappointment as far as correlation goes.We had hoped to show by the rock studies that certainrocks were peculiar to high terraces,certain to low,and thus try to show the direction of the ice movement;distinguishing if possible two separate flows.Laboratory sturies of the crystalines showed that all could be cerrelated-high and low terraces alike as for example

I. a fine grained basic structure with a pencil structure-
low terrace at Red House and high terrace at Allegany

2. diorite Steamburg high and Allegany high

3. pink banded gneiss Steamburg and Olean Creek high terraces

Distribution of the terrace gravels

Following the Great Valley Creek northwardfrom Salamanca,and Wrights Creek eastward to the Humphrey section,one does not find definite evidence of gravel on the hilltops.Had there been terrace gravels here.we could have attributed the terraces of the Salamanca and Olean areas to a different ice advance as these are too high and too far from the Steamburg moraine to be outwash.

Physiographic studies and their evidence:

About one mile from Steamburg(west) a smaller valley opens into the main valley which immediately attracts attention because of its V shaped gorge.The surrounding valleys are broad and flat. We followed this ravine to near the Corbett SchoolHill region.The gorge is undeniably younger than the nearby valleys,but it lacked cliffs and rock outcrops which usually distinguish a very youthful valley.It is not mature enough to be attributed to a stage of interglacial erosion.This bit of evidence once more substantiates our theory that two stages of glaciation,not one,are responsible for the major topographic forms of this region including theterraces. The high terraces are due proabaly to anearlier advance of the ice than the last Wisconsin represented at Steamburg.

At Big Bend,there is a gorge cut by the now south flowing Allegheny River.South of Big Bend,the valleyis narrow and deep.* North of Big Bend the valley widens considerably to become flat bottomed and broad.** Drillings in the rock floor are claimed by Leverett to have been evidence that the rock floor slopes to the north whereas the present level of the river flowing over glacial filling slopes to the south.These and other evidences of of preglacial drainage such as the northward outlet to Lake Erie of the Allegheny River through the Cassadaga-Chautauqua Lake region bespeak reversal of drainage from north flowing to south flowing. The valley at Big Bend is too mature to have been formed since

* See fig #7

** See fig. #8, #9

Fig #7-
Allegheny River south of Big Bend showing narrow V shaped valley

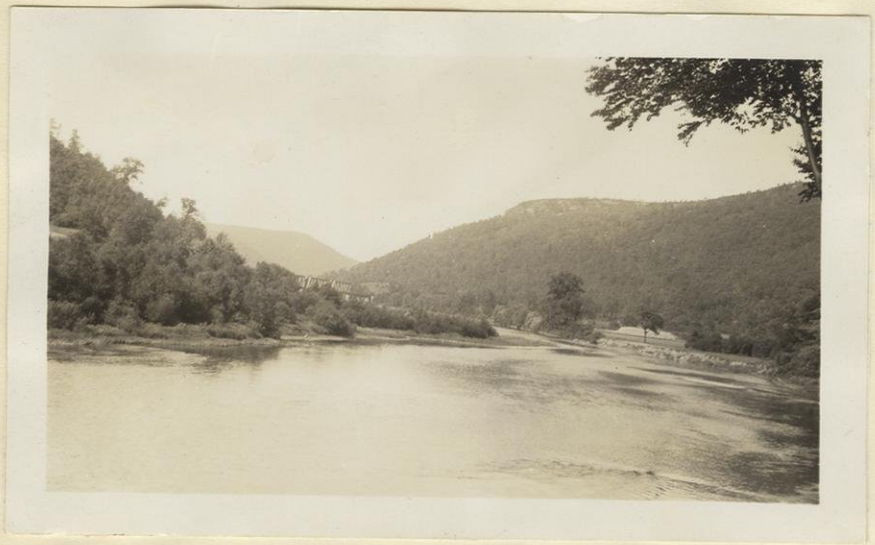

Fig #8
Allegheny River north of Big Bend, Pa showing widening valley

Fig #9
another view of the Allegheny River north of Big Bend.

the latest Wisconsin advance.This reversal of drainage must have occurred before this time and thus have been due to at least A previous advance of the ice,to which we may correlate the high terraces. In substantiation of this, there are terraces of the latest Wisconsin drift south of Big Bend where the reversal took place.

In the Tionesta Valley south of Warren, thereare remnants of outwash terraces at a level comparable to the high terraces of the upper valley. Waters from an ice front must have washed down this valley despite the fact that the channel of this discharge stands 225 feet above the present level of the water.This again postulates a previous ice advance,a lobe of which may have stood in the valley at Warren,and may have retreated from there,though we find nothing which is definitely glacial deposit south of Russell.

At Steamburg the terminal moraine of the last Wisconsin advance is distinctly present;this moraine is badly weathered and postulates a previous ice advance.

Interpretation

In light of the foregoing evidence,we concluded that,as the high terraces are too high to be outwash from the Steamburg moraine, these are deeply eroded terraces remnants of a previous ice advance. The weathering in the terraces proper substantiates this.

The age of the former sheet or sheets we could not determine other than southof Big Bend it is Prelast Wisconsin judging from its distribution and weathered condition.Butts attributes this last moraine to post Kansan,but in a locality where so little is exposed, these things are but conjecture.

In reconstructing the glacial history of this region,it is our belief that the following took place.

An early pre-Wisconsin ice,advance,drift of which is represented near Warren by terraces in the Tionesta Valley.It is possible that the outwash from this advance caused the stream to chnge its direction.

A pre-Wisconsin or early Wisconsin ice advance represent d by the moraine at Russell which can be traced north as far as Steamburg. It is most probable that the high terraces belong to this advance and that the interglacial gorge west of Steamburg was formed between this and the Steamburg terminal moraine advance.
Last Wisconsin advance represented by the moraine at Steamburg, the outwash of which formed the basis for the present lower terraces.
Post glacial erosion and the formation of the terraces due to the increased corroding and eroding power of the Allegheny during high water times such as melting ice periods.

The extent of the glacial advances could not be accurately determined because so much of the topography is covered with heavy vegetation. There is apparently no difference in the nature of the foreign rock in the outwash terraces. The direction of the ice advance could not be determined either as all the rocks seemto be those of the Erian advance-the crystalines being derived mainly from Canada.

Conclusions

We believe that the terraces of the upper Allegheny river represent the river eroded remnants of glacial outwash plains of two distinct ages, the low terraces derived from the latest Wisconsin advance represented by the terminal at Steamburg, and the high from an early or pre-Wisconsin advance represented by the drift of the hilltops near Warren.