DRUMLINS AND DILUVIAL CURRENTS

DOUGLAS E. COX*

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An explanation for the origin of drumlins has not been discovered in the context of the glacial theory, yet many people assume they were formed by ice movement. In this article, it is proposed that drumlins can be more readily explained in terms effluvial action. Streamlining of sediments would result from currents of flood waters generated by uplifts of the earth's crust at the end of the flood. The internal composition of the drumlins can be explained by the disintegration of rock upon the release of pressure, which resulted in drumlins of varying composition in drumlin fields.

Introduction

The origin of drumlins has long been a problem in the glacial theory. Since 1865, when the drumlins of Ireland were attributed to glacial movement by H. M. Close, almost all writers on the subject of drumlins have assumed they are of glacial origin.

The writer has suggested that a glacial period is not necessary in a creationist reinterpretation of earth history, and in this article an explanation for the drumlins in terms of currents of the deluge is developed. These streamlined landforms, (see Figure 1, and the front cover) when considered in this context, reveal a great deal of information about the way in which the flood waters retreated from the continents.

Drumlins a Difficulty for the Glacial Theory

It is generally admitted that the true explanation for drumlins has eluded glacialists: "Although many studies have been made of so-called ice-molded landforms, drumlins, drumlinoids, and flutings, their mode of genesis remains unsolved."[1]

Drumlins are sometimes said to provide evidence for glaciation, but the problems in accounting for their structure and distribution may also be said to provide negative evidence, or an argument against the glacial theory.[2] In any theory proposed to explain drumlins, the following characteristics, which are antagonistic to a glacial origin, must be considered.

1. Drift and bedrock would be eroded differently by an ice sheet, yet drumlins of both types may occur in the same drumlin fields, having similar form and orientation.

2. Cross stratified sand and gravel in drumlins is believed to have been deposited during the melting of the ice sheet, but if this were so, the ice sheet would no longer be available to shape the surface of the drift into drumlins.

3. The pattern of stratification in the sand and gravel in many drumlins has not been disturbed by the weight of a vast ice sheet scraping over it.

4. The direction of orientation of drumlins in some regions shows that the direction of flow was uphill. This is explained in the glacial theory as due to the greater thickness of ice at the rear, causing a lateral thrust of the ice sheet. But the drumlins at higher levels are more intricately streamlined and show a faster rate of flow, which could not occur if the ice sheet was being pushed against gravity.

5. Rock basins occur in some drumlinized areas, such as the Finger Lakes of New York. The excavation of deep rock basins probably could not be accomplished by ice erosion,[3] and the concept is inconsistent with the ice simultaneously flowing over the drift without disturbing the patterns of stratification in sand and gravel.

6. The bedrock below the drift is striated but usually has not been streamlined. The striations are attributed to moving ice, but it seems inconsistent to believe the ice slid over both the surface of the drift, and the surface of the bedrock at the same place.

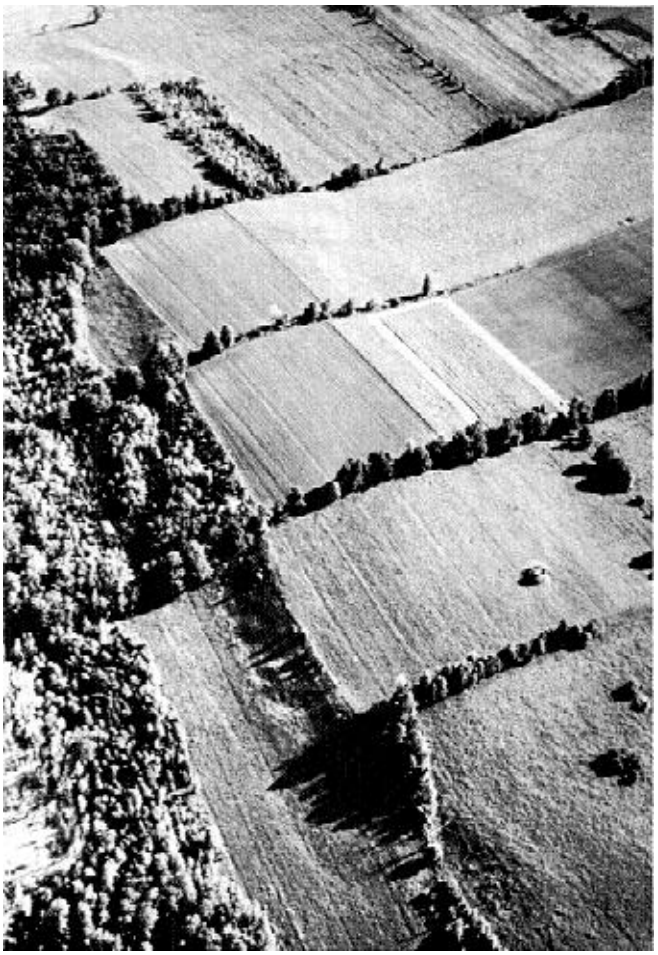


Figure 1. This is an aerial view of a typical drumlin, which is part of a drumlin field between Meaford and Owen Sound, Ontario. These drumlins are oriented approximately north-south, and the direction of flow was toward the south. The view is toward the north-east, in the early morning.

*Mr. Douglas E. Cox receives mail at P.O. Box 18, Petersburg, Ontario, Canada.

7. Drumlins in some regions have been modified by a change in the direction of flow of the agent of streamlining. Crossing patterns of orientation also occur. Even a small change in the direction of motion of a glacier would most likely have obliterated previously formed drumlins.

8. The drumlin form seems inconsistent with ice erosion, which would tend to have a leveling effect rather than molding the country into streamlined hills.

9. There are no deposits of the ice sheet lying above the streamlined surface in drumlin fields, that could have been deposited during the melting of this last ice mass. Yet many drumlins are attributed to erosion by the ice sheet, which would tend to result in accumulation of debris in the glacier.

10. Existing ice sheets do not form drumlins. J. K. Charlesworth stated: "An appeal to modern glaciers is unavailing, since drumlins *in statu nascendi* are unknown though accumulations somewhat resembling them have been described from time to time."[4]

Mysterious Properties Attributed to Ice

To account for drumlins by the action of ice sheets, some physiographers have attributed a mysterious "rhythmic" property to the ice sheets of the past, which caused the molding of drumlins from both bedrock and drift as the ice moved across the countryside. It is proposed that this rhythmic quality caused erosional processes to shape drumlins from hard bedrock, while depositional processes formed drumlins having the same shape and orientation at the same time.

This idea of a wave motion in the ice sheet was popularized by O. D. von Engeln, who developed a concept proposed earlier by Otto Flückiger. The movement of the ice, it was said, was analogous to fluid flow, and "the interior ice flow proceeds in a series of great waves."[5]

This proposal was severely criticised by Max Demorest. He pointed out that the viscosity of ice is so high that the critical velocity of an ice current, at which vortices or other turbulent effects such as waves might be formed, had been calculated to be of the order of the speed of light! Demorest concluded: ". . . one can hardly believe in the correctness of Flückiger's assumption that the ice is or can be undulatory in its motion."[6]

The existence of rhythmic wave properties in the ice sheets was supported by Gravenor and Meneley in a paper on glacial flutings in bedrock in Alberta, and it was suggested that this had caused the regular transverse spacing of parallel ridges, due to the lateral movement of the ice in the troughs. These authors stated:

> The wavelength must . . . be controlled by some physical property of the glacier ice which gives rise to periodic variations in erosive capacity in a direction transverse to the direction of flow. Until more is known about the physics of ice flow it is impossible to suggest a reason for the periodic variation of the erosive capacity of ice.[7]

A recent report on glacial flutings in bedrock in Greenland cited this proposed mechanism, and referred to the possibility of ice flow in tubular vortices.

> To operate the lateral transport of material in the ice, or the rhythmic variation in the intensity of erosion, Shaw invoked ice flow in tubular vortices, which could possibly be generated by the lateral pressure gradient arising from longitudinal crevassing in the glacier.[8]

Smalley and Unwin developed a theory of drumlin formation which depended upon the properties of till, rather than the ice itself. They pointed out that most theories assume "some unspecified process" has operated in the ice sheets of the past:

> Few, if any, of the so-called theories are actually theories, if a theory is required to account for the formation of a streamlined hill of till or rock. Most "theories" are really suggestions for boundary conditions within which some unspecified process operates, and the stipulated conditions may be remarkably imprecise . . . Although much has been written on drumlins, very little hard fact has emerged.[9]

In an attempt to explain the formation of drumlins, S. Aronow suggested "recourse must be had to 'something' in the now vanished ice sheet."[10] A transcendental quality seems to be imputed to the ice of the glacial theory, by such statements. Sir Henry H. Howorth denounced this approach in no uncertain terms:

> It has been my continual complaint for years (Cassandra's voice I know it has been) that the glacialists who appeal to a transcendental ice period have never attempted to show what is the first element in the problem, namely, that ice is capable of the effects which they deduce from it.[11]

The bankruptcy of the glacial theory is evident in the acknowledged failure to explain drumlins after more than a hundred years of investigation.

J. Menzies stated, in a recent review of the problem of drumlin origin: "Drumlins remain a major problem in glacial geomorphology such that no satisfactory explanation to their mode of origin exists."[12]

A new approach to the problem of the origin of drumlins is provided by the mechanism of drift formation, due to a process of *in situ* rock disintegration, which has been proposed by the writer. The currents of the deluge can explain many of the erosional effects which have been attributed to the ice sheets, and the streamlining effects of currents can account for the drumlins in a remarkable way.

A Diluvial Interpretation

Streamline effects of currents are evident in the beds of streams. One of the earliest scientific accounts of drumlins was a study of the parallel ridges of Edinburgh, Scotland, in which these landforms were compared with sand bars and sediment accumulations behind obstacles in the beds of streams.

These streamlined hills of the crag-and-tail type were investigated by Sir James Hall, a friend and admirer of James Hutton, author of the theory of the earth that has come to form the basis of modern geology.

Hall suggested that catastrophic waves from the sea, caused by rapid uplifts of the earth's crust, accompanied by earthquakes, had swept across Scotland and formed the streamlined ridges.[13]

It was claimed that these diluvial waves not only formed streamlined hills, but swept along great

volumes of drift, with erratic boulders derived from sources in the north, and deposited this load of debris behind the rock outcrops in Scotland. Hall believed these revolutions could be reconciled with the Huttonian Theory.

J. K. Charlesworth has described these crag-and-tail structures in Edinburgh as follows:

> The impact side, which is scraped bare, is commonly steep or precipitous and, as at Castle Rock, has a horse-shoe shaped valley half encircling its base and extending leewards as lateral grooves which gradually diminish in cross-section . . . The frontal groove, sometimes undercut or occupied by a rock-basin, may be missing if the obstacle had a lifting effect . . . The tail frequently descends from the very summit of the hill in a smooth, gentle slope whose length depends upon the height of the boss: it may range from several kilometres to only a few metres . . . . The tail may be solid or may consist of drift . . . Tails of drift are very common; crags resemble boulders in a river bed with tails of sediment pointing downstream—the resemblance led Sir J. Hall to invoke strong currents for the Scottish crags and tails.[14]

The diluvial explanation proposed by Hall was well suited for the streamlined hills of Edinburgh, but it could not also account for the presence of parallel grooves and striations on the rock surfaces under the drift, and it was these that some thirty years later were to lead to the adoption of the theory of ice sheets transporting and depositing the drift of the British Isles.

Streamlining Action of Currents

Sir James Hall noted the similarity of the parallel ridges he described to snowdrifts formed by strong winds in winter storms, a similarity which has been also noted by other investigators:

> Drumlins, as experimental evidence confirms, are streamlined; they present their steeper face to the moving medium, in order to offer the minimum resistance to the flow by hindering the formation of vortices in the rear (which act as a drag on the moving body). Similar adjustment is seen in snow forms, in certain dunes and sandbanks in rivers, in the shape of torpedoes or fishes . . .[15]

The shape of drumlins indicates that fluid flow and sediment transport has been involved in their formation. The process of streamlining in the formation of sandbars and snowdrifts involves both deposition and erosion. The erosion occurs at the stoss end while deposition occurs at the lee end of the bed form.

V. R. Baker showed that hundreds of streamlined loess hills in eastern Washington were formed subfluvially by catastrophic floods. These resemble drumlins in shape, average 40 meters in height and were formed by currents with a velocity of 12-15 meters per second in a depth of 60 meters of water.[16]

These streamlined hills occur in a region where giant current ripples, with heights of 50 feet and spacing of 500 feet, and other evidence of fluvial action show rapid currents that are attributed to floods resulting from the failure of an ice dam which ponded about 500 cubic miles of water in glacial Lake Missoula. Baker wrote:

> Because the Missoula floods involved the largest discharges of fresh water that have been documented in the geologic record, the study of these events will establish some upper limits to our knowledge of the short term erosive and transport capabilities of running water.[17]

Large scale landforms in eastern and central Washington and other regions have been identified with the effects of diluvial currents by J. L. Cunningham.[18] He noted these so-called glacial deposits were similar to the effects of currents, and questioned their supposed glacial origin.

Streamlining of hills into the drumlin form is demonstrated from observation of the effects of the catastrophic floods on the Columbia Plateau in eastern Washington. The drumlins in other areas may have an origin similar to that of the drumlin-like loess hills reported by Baker. They would thus have been formed from unconsolidated material.

It is proposed that bedrock drumlins were formed when the rock was unconsolidated. This would be reasonable if these sediments were deposited during the flood, and eroded when the continents were elevated at the end of the flood.

Evidence for the unconsolidated condition of the sedimentary formations in the Great Lakes area, at the time of erosion of the basins of the Great Lakes, was presented in a previous article.[19]

R. L. Folk showed that stream flow can cause either transverse or longitudinal vortices, that minimize friction at the bed surface. Where longitudinal vortices occur, considerable sediment transport is possible. In this type of flow, the shape of the stream bed is congruent with the water surface.[20]

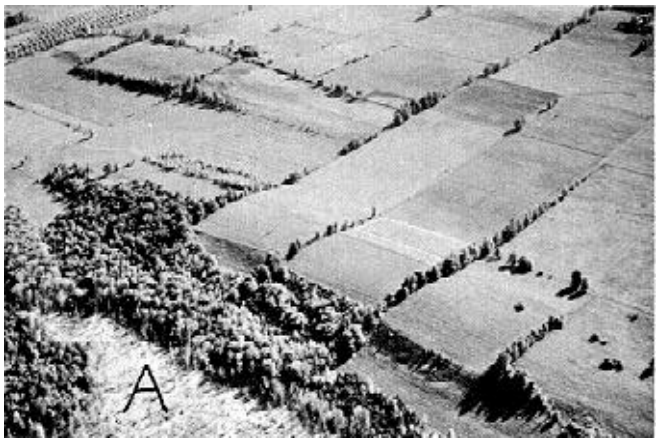
The troughs between drumlins may have been the sites of longitudinal vortices in the currents. (see Figure 2) Folk described the vortices as not remaining fixed in position, but "they wander back and forth like a swarm of slithering snakes."[21]

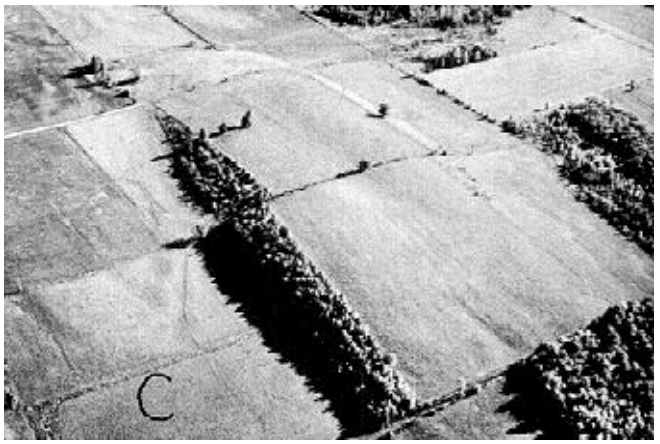
The mobility of the vortices would have the effect of rounding the crests of the drumlins.

As the depth of water decreased, the vortices would tend to be concentrated in the troughs, where erosion would be intensified. Material from the troughs would be deposited on drumlins located downstream. The role of longitudinal vortices was crucial in the formation of drumlins, in this fluvial interpretation.

It seems obvious that where flood waters flowed rapidly over flat plains of unconsolidated sediments, a streamlined bed would develop. Rapid currents have momentum, and patterns of drumlins are due to the momentum of the currents. The form of drumlins is one which minimizes turbulence.

It also seems evident that momentum and minimizing turbulence would not be significant factors in anything as slow moving as an ice sheet, as noted by physicist A. T. Waterman in a comment on von Engeln's hypothesis of a wave motion in the glaciers: "I cannot conceive of anything as slow as a glacier producing effects . . . which depend primarily upon momentum."[22]





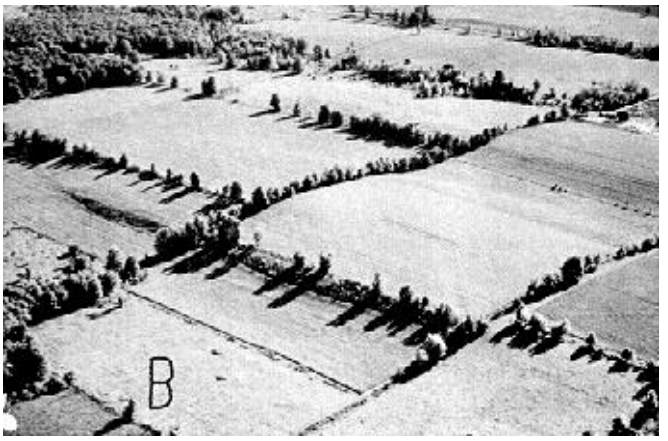


Figure 2. A: This is another view of the drumlin shown in Figure 1. Another drumlin can be seen in the upper left of the picture. It is suggested that the troughs between the drumlins were the sites of logitudinal vortices during the formation of the drumlins by rapid currents.

B: Another view of drumlins in the same region, showing the troughs between drumlins. It is necessary, in any explanation of drumlins, to account for the formation of the parallel troughs, just as much as for the form of the drumlins themselves.

C: This picture shows a modified drumlin. in which two separate crests can be distinguished. It is suggested that this feature of drumlins can be explained by decreasing depths of water, and decreasing size of the vortices in the currents, which tended to produce multiple drumlins on an already streamlined sediment surface.

In their efforts to explain drumlins in terms of the glacial theory, investigators may have confused effects which are actually indicative of rapid fluid flow with effects that moving ice may produce due to its rigidity. It is suggested that the drumlins are the product of rapid flow-of water, not of ice.

Drumlin Structure

The required context for drumlin formation is that unconsolidated sediments were swept by currents. These could have been generated by uplifts of the earth's crust at the end of the flood. The flow would be radially away from the centers of uplift, and the direction of these currents would be indicated by the patterns of drumlin orientation.

An explanation for the variety of composition of drumlins is provided by the proposed mechanism of drift formation by in situ rock disintegration. This mechanism was outlined in a previous article.[23]

The lithification of the streamlined sediments would form bedrock drumlins. Most of these were subjected to disintegration, resulting in drift drumlins. Intermediate types, containing part drift and part bedrock, occur where the process of shattering penetrated only part of the drumlin.

Erosion may have followed disintegration in some areas, resulting in the redeposition of drift along the flanks of the drumlins.

The concept of *in situ* disintegration thus provides an explanation for the varying structure of drumlins in a single drumlin field. All the drumlins in the field were initially molded in the same way. Flint has written:

> There seems to be a complete gradation, independent of outward form and within a single field, from rock to drift. This suggests that any one group was molded contemporaneously under a single set of controls[24]

Studies of the bedrock profile in drumlin fields show a marked contrast between the streamlined surface topography and the irregular shape of the bedrock. (See Figures 3 and 4.) Geologic sections showing the erratic shape of the bedrock below a drumlinized area were illustrated by S. Aronow, in a study of drumlins in North Dakota.[25] The depth to bedrock in the region varied from 0 to 200 feet.

The structure of drumlins in southeastern Wisconsin has been studied by W. C. Alden.[26] Records of wells drilled on or around drumlins showed a great variation in the structure of the drumlins. Some consisted mostly of drift, others were mostly bedrock, covered with a thin veneer of drift. The depth of the drift in the area was variable, in places reaching as much as 300 feet.

From the point of view of the glacial theory, the surface of the bedrock below the drift ought to have been streamlined and worn smooth by the movements of the ice sheet, rather than the surface of the drift. But in drumlin regions the opposite conditions exist.

The erratic shape of the bedrock below drumlins is explained by the varying degree of penetration of the surface of shattering. The contrast between the bedrock surface and the drift surface is due to each surface being formed by different processes. One surface was formed by a rock shattering process, the other by the streamlining action of currents.

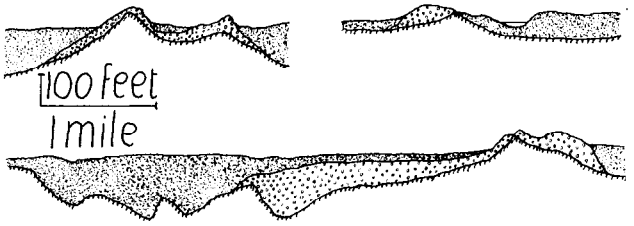


Figure 3. These are geologic sections in a drumlin field, in the Warwick-Tokio area, North Dakota. The erratic shape of the bedrock is in sharp contrast with the nearly level surface of the streamlined drift. This is drawn after Aronow's work, Reference 10. Note that the vertical scale is exaggerated. Shading with dots indicates outwash; with little circles, till.

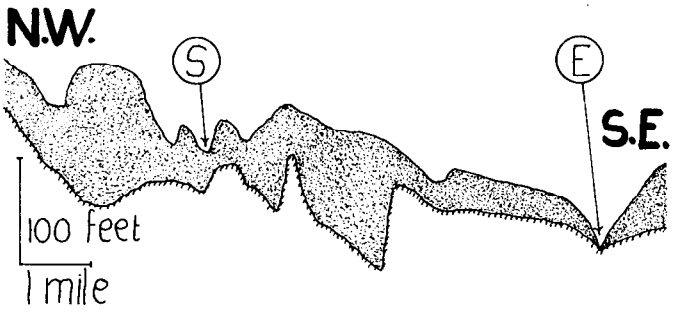


Figure 4. This is a profile showing the drift thickness (much exaggerated) and the shape of the bedrock along a line between Guelph and Rockwood, Ontario. The section is almost parallel to the direction of drumlin orientation. The data are from the depths of wells, reported on the drift thickness sheet, Guelph area, by M. A. Voss, 1969. Ontario Dept. of Mines. S indicates the Speed River, E the Eramosa River.

Drumlins may show some signs of faulting and movement of the drift within, which can be explained by the effects of expansion of the drift during the disintegration. Eskers may occur in drumlin fields, and these have been interpreted in terms of the effects of expansion.[27]

In some drumlins that have been exposed in cross section by erosion or in road cuts, a concentric layering is present. Fairchild found this concentric structure in drumlins along the south shore of Lake Ontario, that had been severed by wave action. He interpreted this as evidence for a "plastering on" of material from the ice sheet.[28]

This concentric structure within some drumlins can be explained in terms of the disintegration process. The surface of disintegration may have penetrated down into the drumlin in planes conforming with the shape of the drumlin.

The idea of rock disintegration *in situ* forming the drift solves the enigma of the varying composition of the drumlins. Erosion by ice sheets would not form hills of bedrock with the same form and dimensions as hills of drift being deposited at the same time.

Stratified drumlins are explained by erosion in the glacial theory, and require a resurgence of the ice sheet over the drift deposited by the melting ice. The mixed-up sequence of events, which requires the existence of moving ice after it had melted, is an obvious flaw in the glacial explanation of drumlins.

The complicated events required to explain drumlins in terms of glacial action suggest their formation by these causes would be highly improbable, and that drumlins would be rarely found. But multiple thousands of drumlins have been mapped in Europe and North America. H. L. Fairchild wrote:

> It is apparent that the drumlin-building process involved many factors, and most of them indeterminate. The problem is exceedingly complicated, including not only the difficult subject of the behavior of plastic solids but the action of the plastic ice under a complexity of geologic conditions.[29]

The vast numbers of drumlins in drumlin fields, and their similar features in different continents, argue against a complex mechanism of formation. The explanation of drumlin formation is relatively uncomplicated when they are considered in the context of the conditions existing at the last stage of the flood.

Patterns of Drumlins

The patterns of drumlins reveal the immense scale of the events which caused them. For the drumlins to have been formed with parallel alignment, they must have been contemporaneous. Vast areas of the world have been swept by streamlining currents of the flood.

Drumlins show a trend of the current flow from the north, that can be explained by rapid elevation of the polar regions at the end of the flood. Flow of the waters across the continents, and locally down valleys towards the oceans, caused streamlining of the landscape.

One of the largest and most remarkable drumlin fields in the world is in central New York, where the drumlins number about 10,000. About 7,000 drumlins occur in southern Ontario.

East-central Wisconsin has about 5,000 drumlins; in south-central New England there are about 3,000, many of which consist of rock. In Nova Scotia, there are 2,300 drumlins.

Flutings across the plains of western Canada and northern United States may outnumber these regular drumlins. Flint stated: "Large groups of remarkable long narrow forms occur in various parts of the Great Plains in Canada and northern United States. Some are chiefly bedrock; others are chiefly drift. Possibly such forms outnumber "conventional" drumlins."[30]

One of the most curious facts about patterns of drumlins is the uphill orientation in many areas, that shows flow of currents over hills, escarpments, and from out of the sea.

In north central New York the direction of flow was from out of the region of Lake Ontario, uphill towards the Allegheny highlands to the south.

A group of drumlins east of Owen Sound, Ontario, shows that flow was from out of Georgian Bay, uphill towards the Niagara Escarpment. A fan shaped pattern of drumlins south of Green Bay, Wisconsin, shows a similar uphill flow.

In Ireland, patterns of flow attest to diluvial action, rather than glacial movement. Flow direction was from out of the sea at Belfast Lough, over rising ground to the south.

Complex, arcing patterns of flow characterize the vast drumlin fields in Ireland. The patterns show a concentration of currents in low regions. Charlesworth wrote:

> The drumlins of North-East Ireland belong to what appears to be the most remarkable drumlin assemblage in the world, far exceeding in extent of ground and numbers those of any other British area or even those of Western Central New York . . . It comprises tens of thousands of drumlins, and covers an area which can scarcely be less than 4,000 square miles.[31]

The direction of flow of the currents which shaped the drumlin field in Northern Germany was from out of the Baltic, fanning out across the lowlands.

These patterns of flow all show spilling of the waters to the south as the crust of the earth was rapidly elevated towards the north. The warping of ancient shorelines in all these regions corresponds with the inferred crustal depression towards the north, and subsequent uplift.

Variations in Drumlin Form

The drumlins vary in form from oval hills to very long, low profile flutings. There may be a transition from one kind to another in a drumlin field.

The variations in the form of drumlins in north central New York were studied by J. W. Miller Jr. He found that the drumlins on the low plains near Lake Ontario were large, flat topped, and poorly streamlined.[32]

Further south they became better streamlined, and tended to be grouped in clusters. Still further south, on the rising slopes of the Allegheny Upland, the drumlins were smaller, more intricately streamlined, with steep sides and narrow crests. In the region of the Cayuga trough the drumlins became elongated flutings.

These variations in drumlin form show the agent of streamlining was faster at the higher altitudes to the south. Such an increase in the rate of flow would not be possible if the drumlins were shaped by an ice sheet being pushed uphill by a thicker ice mass to the north, which could not move faster than the ice mass causing the push. But the increase in speed is what would be expected if the drumlins were shaped by diluvial currents.

The continuity of stream flow requires the velocity of the currents increases where the bed is rising. The form of the New York drumlins shows this increased rate of flow where the depth of water was less.

The principle of continuity is illustrated in the flow of a stream. Where the bed is deep, the flow is slow. Near the shores of Lake Ontario the drumlins are large due to slow and deep current flow. Where the bed of the stream is shallow, there is rapid flow, so the flow of the currents would be faster at the higher elevations of the Allegheny Uplands, creating the intricately streamlined drumlins.

Modified Drumlins

In the diluvial environment, there was a continual decrease in the depth of the waters as the continents emerged. Successively lower shorelines in many regions attest to the lower water levels. Drumlins also record the effects of the decreasing depth of the flood waters as they were formed.

In some regions the drumlins have been modified by currents subsequent to their original formation. Examples of multiple drumlins, consisting of several small drumlins clustered on the same base, were reported by Alden[33] in Wisconsin, and by Fairchild in New York.[34] The form of the initial drumlin can be detected in these clusters.

These have been referred to by F. T. Thwaites as "overridden drumlins" and were described by him as follows:

> In some regions the direction of ice movement changed markedly after the formation of drumlins . . . Many such drumlins have been overridden without any marked change in shape; some have had their new tails aligned to the new direction . . . in some instances a long drumlin has been changed into several whose long axes cross the old axis at a high angle.[35]

Modification of drumlins in this manner has also been reported from central Scotland. Large drumlins have been reshaped into clusters of smaller ones at an oblique angle to the original drumlin. As many as nine drumlins have been detected on a single base.[36]

In the diluvial environment, changes in the depth of the water as the continents emerged would cause the vortices to become smaller, resulting in the reshaping of large drumlins into smaller ones. The changes in the direction of flow of the currents could have resulted from shifting of the centers of uplift, spilling the waters in a different direction.

Changes in the direction of flow of the currents could also have been caused by the elevation of highlands above water level, forcing the currents into new channels. This may have occurred in central New York as the Allegheny highlands were elevated above the water level.

The emergence of the highlands would prevent further flow towards the south, causing the waters to flow around the highlands. Drumlins at the western end of Lake Ontario show a different direction of flow from those north and south of the lake, indicating a flow towards the west. Those at the eastern end of the lake have been modified by a flow towards the Hudson valley in the southeast.[37]

If the drumlins had been overridden by ice sheets after their original formation, it seems likely that they would have been removed entirely rather than modified by deflection of their tails.

Evidence for Crustal Uplift

There are several indications that vertical movements of the earth's crust may have been a major aspect of the flood. Present ideas about the earth's composition do not provide an easy mechanism for the amount of vertical movement which is indicated by the earth's surface features.

In the central Great Lakes region the sediments thicken away from the Canadian Shield. The formations are tilted toward the sedimentary basins in the region. Erosion of these sediments has formed cuestas with steep escarpments around the Michigan Basin.

The orientation of the drumlins in New York and southern Ontario shows the direction of current flow which caused the drumlins was in the direction of dip of the sedimentary strata, which could indicate the uplift which tilted the strata also initiated the currents that shaped the drumlins.

Many of the drumlins in the vicinity of the Niagara Escarpment are oriented normal to the trend of the escarpment. This would be expected if the currents which formed the drumlins also eroded the escarpment.

Relationships between drumlin orientation and the dip of sedimentary strata would not be expected from the point of view of the glacial theory. Since it is believed that the escarpments were eroded long before the glacial period, there would be no correspondence between the supposed direction of ice motion and the structure of the sedimentary rocks beneath. Actually the escarpments would form a barrier to the ice movement.[38]

In the diluvial theory, the escarpments and drumlins were formed by the same events, so there is a natural relationship. Major patterns of drumlins were determined by differential uplifts of the earth's crust which are evident in the tilt of sediments originally deposited horizontally.

Warping of abandoned shorelines is another clear indication of crustal uplift. The regions of maximum uplift can be determined by following the ascending shorelines. In the Great Lakes region it seems to be a general rule that these areas were sources of the flow indicated by the patterns of drumlins.

The shorelines record the last and lowest stages of the flood, and were probably formed after the shaping of the drumlins in deeper waters. Many of the abandoned shorelines are found on the sides of drumlins.

Conclusion

Creationists believe there was a world wide flood in which significant geologic effects would have been inevitable. These effects included sediment deposition and erosion, and it is likely that streamlining would occur in the right conditions.

The glacial explanation of drumlins suffers from major contradictions and flaws, and an alternative interpretation in terms of rapid water flow provides more consistent and reasonable answers. Currents of flood waters shaped previously deposited sediments while these were unconsolidated.

The process of rock disintegration *in situ* forming the drift, frequently exhibiting the pattern of cross stratification, is crucial in understanding the structure of drumlins. Since not all drumlinized areas were affected by the disintegration, drumlins of bedrock occur together with other types consisting of drift or part drift and part bedrock. The conditions in which the shattering process is believed to have occurred are compatible with the events proposed for the formation of drumlins.

Patterns of drumlins show the courses of flow of the currents which caused the streamlining of sediments. These patterns conform with the locations of upwarped shorelines and with the direction of dip of the sedimentary formations in many areas, indicating that differential uplift of the earth's crust probably initiated the rapid currents which shaped the drumlins. The new explanation of the drumlins provides a means by which the conditions which existed in the final stages of the flood can be more fully understood. These conditions existed over considerable areas in Europe and North America. The currents of flood waters may have caused different kinds of effects in other regions, and the possible effects of these currents should be considered in accounting for the surface features of the earth.

Appendix: Drumlins Associated with Giant Ripple Marks

On the Bruce Peninsula in Ontario, a pattern of linear ridges is evident, which is a striking feature on topographic maps and aerial photographs. The ridges resemble giant ripple marks trending transverse to the axes of drumlins on the Bruce Peninsula. See Figures 5-7.

A series of these ridges and troughs occurs northeast of the group of drumlins near Sky Lake, and exposures can be seen along highway 6 about 2 miles north of the village of Mar. The ridges are sinusoidal in section, crests are 12 to 20 feet in height, and the spacing between crests is about 250 feet. They are thus about half

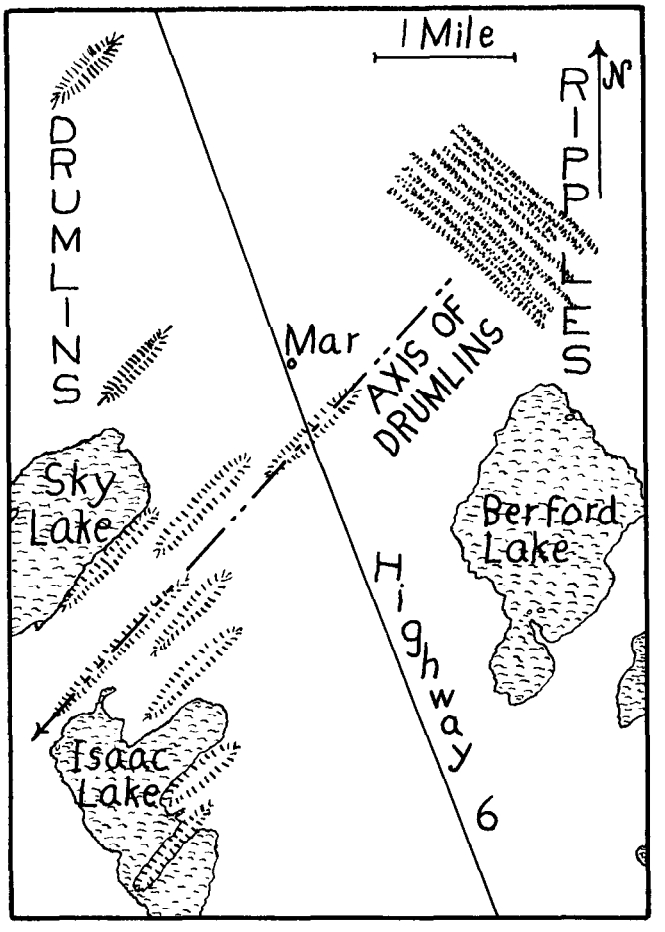


Figure 5. This map shows the location of the ripples, close to drumlins, on the Bruce Peninsula, Ontario. The location is about 44°45′ north latitude, 81°10′ west longitude.

the size of the giant ripples described by Baker. (Reference 16.)

These features, unlike those reported by Baker, are composed of dolomite bedrock. The pattern of the ridges transects the boundaries of the Paleozoic Guelph and Lockport formations. This suggests they are not reefs, but more likely are erosional features.

Their association with drumlins, and orientation normal to the axes of the drumlins and the axis of the Colpoys Bay "reentrant" in the Niagara Escarpment, indicates they may have been formed at the time of the formation of the drumlins on the Bruce Peninsula.

The uplift of the Shield area east of Georgian Bay at the end of the flood may have generated the currents which spilled across the Bruce Peninsula and formed these linear ridges. It is believed that tectonic uplift at this time was also responsible for the present dip evident in the sedimentary rocks in southern Ontario, and the warping of the ancient shorelines around the basins of the Great Lakes.

Erosion of the unconsolidated limestone sediments would result, and the giant ripples developed in the unconsolidated dolomite formations where the depth of the water and current velocity favored the formation of transverse vortices. A transition to longitudinal vortices could have occurred in deeper waters to the southwest where the drumlins were formed.

The Sky Lake area drumlins were subsequently subjected to disintegration, as many of these drumlins contain cross stratified sand and gravel.

Another example of transverse ripple-like features occurs near the eastern shore of Owen Sound, south of the large bedrock drumlin known as Coffin Hill.

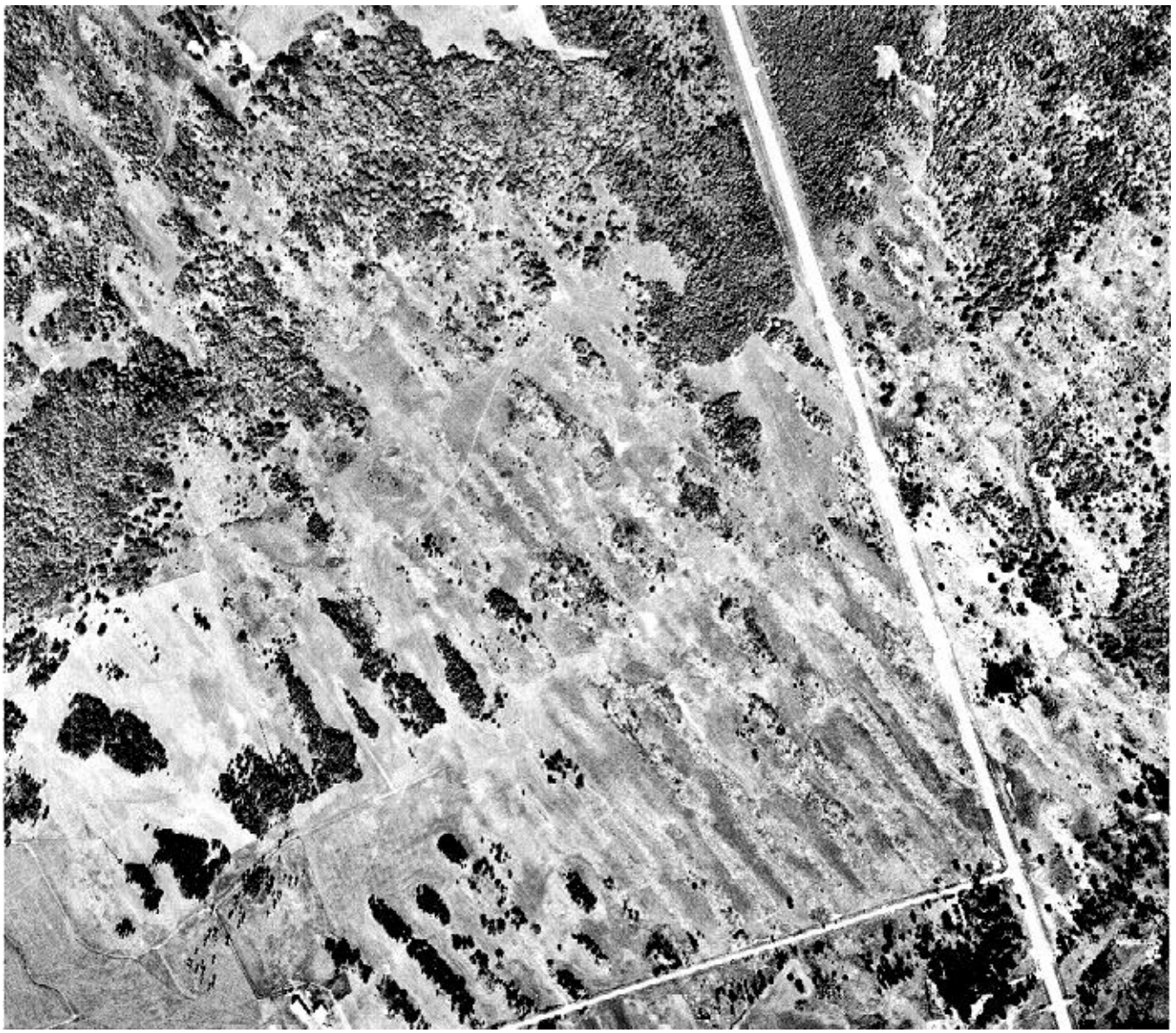


Figure 6. This is an aerial view of ripples, not far from the region shown in Figure 5. The right and left edges of the picture are oriented in the direction indicating north-south; and the total extent north-south of the part shown is about one mile. The heavy white line, running approximately NNW-SSE is Ontario Highway 6.

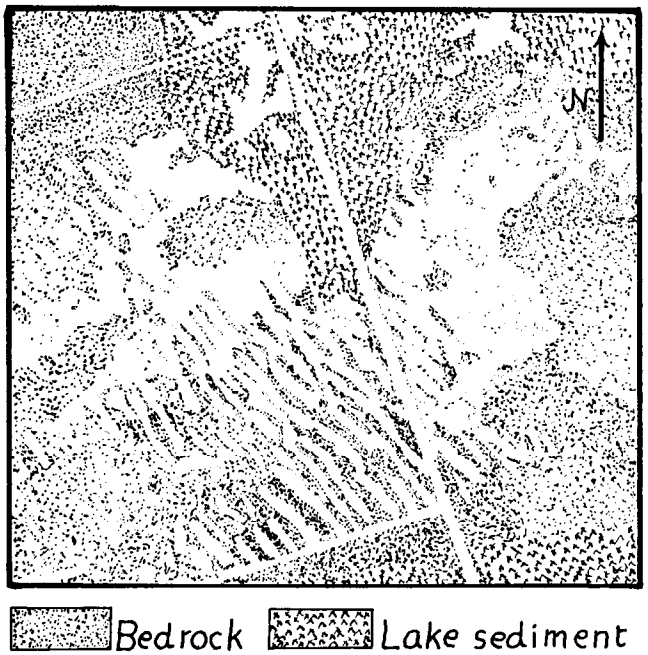


Figure 7. This is a drawing, made from an aerial photograph, of ripples near those shown in Figure 6. Again, Ontario Highway 6 is seen running NNW-SSE.

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Appearance Does Not Prove Descent

(Continued from Inside Back Cover)

Do you follow my argument?

If an evolutionist cannot prove the existence of a common ancestor even for hares and rabbits, *how much less* has he any right to claim that man and monkey have a common ancestor even if some creature were *known* to exist that walked on two legs and possessed a brain capacity of (say) 900 cc?

In other words, I believe we can afford to treat Leakey's discoveries with complete disdain because they prove absolutely nothing about genetic descent *even if all he claims for them were true.* As Bible-believers, all we are required to teach is that the human race was created *de novo*, genetically distinct from all other animals. I do not see that we are required to teach that no creatures have ever existed which might have *looked* more like humans than do any modern anthropoids.

Comments invited.

Yours sincerely,
David C. C. Watson
c/o ICR MidWest, P.O. Box 75,
Wheaton, Illinois, 60187

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