Alternative Explanations

What can we say of the authenticity of the story itself? Besides the two suggestions that (1) Lady Hope made up the whole account, or that (2) Darwin really became a Christian but his relatives sought to hide this, two other possibilities should be considered. (3) Perhaps Darwin did meet with Lady Hope but she later elaborated what were his much more non-committal statements. (4) Or perhaps Darwin did say all the things reported in the story, but he did so as a cover to avoid being evangelized by Lady Hope—a technique frequently encountered in personal work with unbelievers of the sort of strongly non-confrontational temperament Darwin is known to have had. The Darwin correspondence mentioned above makes alternative (2) unlikely, but there is still more work to be done before we can give a final verdict on this story.

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VARVES — THE FIRST "ABSOLUTE" CHRONOLOGY
PART I—Historical Development and the Question of Annual Deposition

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Abstract

Varves have been used to set up the first "absolute" chronology, which significantly exceeds the Scriptural time scale from Genesis. Observations of modern glaciers and recent climate simulations show that the ice sheets during the Ice Age melted rapidly, much faster than indicated by varves. A further investigation of varves demonstrates that other mechanisms deposit varve-like couplets in a short time. Therefore, "varves" are not necessarily annual. A method to distinguish between annual depositional sequences and other mechanisms is difficult to apply.

Introduction

A varve is generally defined as a sedimentary lamina or sequence of laminae deposited in a body of still water within one year's time (Bates and Jackson, 1984, p. 551). More specifically, a varve is considered two sublayers, each seasonally deposited in a glacially-fed lake. The lower "summer" sublayer usually consists of light-colored silt or sand, and the upper "winter" sublayer consists of dark-colored fine silt or clay, which often contains organic residues.

Varves form in deep lakes or in brackish estuaries in which the salt content is less than in ocean water. The water must be deep enough to protect the sediment from erosion caused by wind-generated waves and currents and from biogenic mixing of the sediments at shallow depths. Varves normally do not form in ocean water. The reason for this is the reactions of salt ions with the silt and clay particles, causing them to coagulate and sink to the bottom, forming a featureless or massive deposit. Figure 1 shows a picture of a typical varved sequence from an ancient pro-glacial lake in Ontario, Canada. A pro-glacial lake is a lake that forms at the edge of a glacier or ice sheet.

Varves are a type of rhythmite. A rhythmite is a repeating unit of sedimentation that does not imply limits of thickness, complexity of bedding, time, or depositional environment (Bates and Jackson, 1984, p. 432). Rhythmites display alternations of two or more rock units, such as siltstone alternating with sandstone. A laminite is similar to a rhythmite, except the lithologies are random. An annual period is the feature distinguishing a varve from a rhythmite.

Establishment geologists have employed "varves" to date the deglaciation of the last ice age of the Pleistocene Period. As the ice sheets receded, pro-glacial lakes or brackish estuaries temporarily formed in many areas, and in these water bodies rhythmites often developed. Supposed varves have also been used to determine the amount of time since the ice sheet melted. Varves have been especially employed in Sweden to develop the Swedish Time Scale, the first "absolute" and "exact" chronology according to Antevs (1922, p. ix). Important varve chronologies have also been generated in Finland, the north central and northeast United States, and southeast Canada.

The varve chronology is considered to be so accurate that it compares favorably with the carbon-14 dating method (Olsson, 1970). A revised Swedish Time Scale suggests that C-14 ages may be less than real time between 10,000 and 12,000 years ago (Stromberg, 1985, p. 104). Varve chronology is used to date geological and archeological events and to calibrate other dating methods. Cato (1987, p. 52) informs us of the importance of a revised varve chronology:

> The consequences of the present connection of varve series to the present are far-reaching not only for the Swedish Geochronological Time Scale but also for all the geological and archeological

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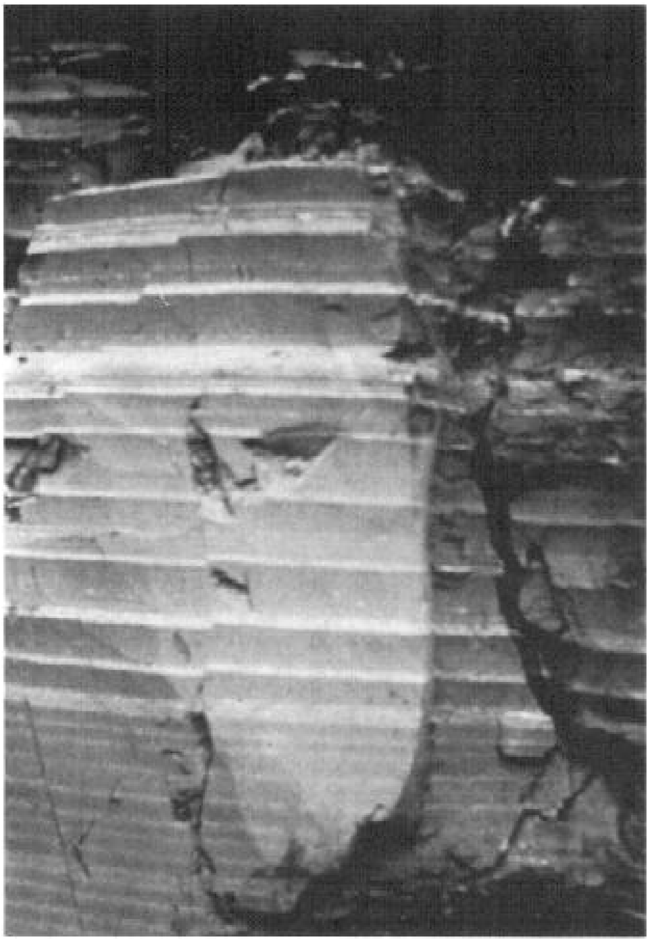

Figure 1. A "varve" section taken from Twin Falls Dam, Ontario, Canada. Notice the abrupt change in couplet thickness near the bottom of the photograph. Courtesy of the Geological Survey of Canada.

> events, intercalibrations etc. which are temporally or otherwise based on it.

Varve chronology poses a problem to biblical creationists. The derived dates are greater than allowed by the Scriptural time scale from Genesis. The "varves" seem to indicate that an ice sheet melts very slowly over thousands of years. For example, in Sweden the varve chronology indicates that the ice began to retreat from southern Sweden about 13,000 years ago and finally left central Sweden about 9,000 years ago.

In Parts I and II of this paper I will examine varves to see whether they are accurate time recorders. I will focus on the "varves" in Sweden and in the Connecticut River Valley in New England. Part I will show how the varve chronology was constructed and how it has changed with time. New evidence that ice sheets melt much faster than indicated by this chronology will be presented. The presumed annual period of "varves" will be questioned. Several other mechanisms can rapidly deposit varve-like layers. Methods to distinguish true varves from the other varve-like rhythmites are equivocal.

Historical Development

In 1884 Gerard De Geer, a Swedish geologist, fashioned the first varve correlations around Stockholm, Sweden. He developed his idea by noting the similarity of the varve couplets to tree rings. Stromberg (1983, p. 97) points out: "The regular and continuous distribution of the varves convinced him [De Geer] that they, too, were annual." After measuring the thickness of varve sequences at a number of points, he at first correlated sections only about 100 meters apart. He hesitated to expand the spacing of varve correlations. But 20 years later he took this bold step and correlated his earlier measurements to sections a kilometer away. Within a few more years De Geer and colleagues developed a varve time scale of ice recession along the east coast of southern and central Sweden. The right hand diagram in Figure 2 shows areas in Sweden where the classical (De Geer) and revised chronology was developed. The left hand diagram shows the time frame for the chronologies.

While De Geer and his colleagues completed the deglaciation portion of the "Swedish Time Scale," Ernst Antevs (1922, 1925, 1928) developed a varve chronology in New England and southeast Canada. The North American varve chronology was matched to those in Sweden by a transcontinental correlation (De Geer, 1928). Up until the 1950's, the Swedish Time Scale was the standard chronology for all parts of the world (Schove and Fairbridge, 1983). De Geer (1928) considered his varve chronology continuous and exact, and even applicable internationally. He and his colleagues used the Swedish Time Scale to date other

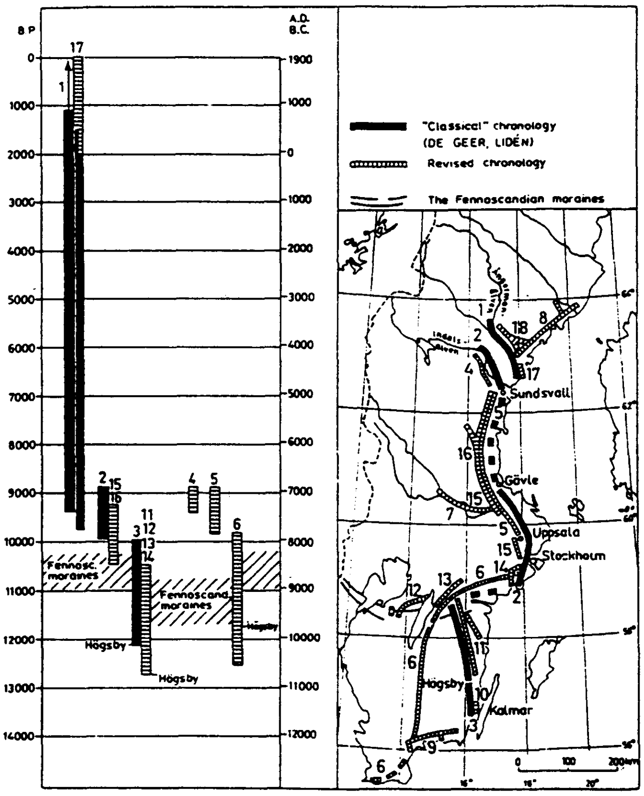

Figure 2. The geography and chronology of the "classical" and revised Swedish Time Scale. The Fennoscandian moraines are marked on the map as long dashed lines. The numbers refer to the work of different investigators (not listed). Reprinted from "Revision of the lateglacial Swedish varve chronology" by Bo Strömberg from *Boreas* 1985, vol. 14, with permission of Universitetsforlaget AS.

cyclic sedimentary layers for areas as far away as Iceland, the northwest Himalayas, Chile, India, and Argentina. De Geer progressed from timidly correlating Swedish rhythmites 100 meters apart to brazenly dating events world-wide by correlation to the Swedish Time Scale.

At the same time the deglaciation varve chronology was developed, geologists sought methods to connect the final melting of the ice sheet to the present. De Geer failed to accomplish this task, but Ragnor Lidén succeeded in the early part of the twentieth century. Sweden has been rising isostatically ever since the ice sheet melted, as shown by raised beaches and a currently shrinking Baltic Sea. There has been a corresponding progradation of river deltas and estuaries of major river valleys in central and northern Sweden. Most of the rivers have not deposited rhythmites. However, the Ångermanälven River in central Sweden occupies a former fjord and is apparently the only river that has continuously deposited rhythmites since deglaciation (Cato, 1985, p. 117). Lidén correlated "varve" sections, from where the ice last melted, downstream to the mouth of the Ångermanälven River. He derived a post-Ice Age time scale of about 9,000 years (Cato, 1987).

From 1950 to 1980, the Swedish Time Scale came under criticism and was supplanted by the Carbon-14 dating method, which contradicted some aspects of the varve chronology. During the 1970's, the Carbon-14 method came under scrutiny due to small differences between it and the bristlecone pine chronology from the White Mountains of eastern California. Due to the importance of finding an accurate year-to-year absolute chronology (Fairbridge, 1981; Schove and Fairbridge, 1983), geologists in Sweden have been revising the Swedish Time Scale.

Method of Varve Correlation

Before embarking further on an analysis of varve chronology, the method of constructing the chronology based on varve correlations will be briefly discussed. A more detailed evaluation will be given in Part II of this paper. Before I studied varves I thought each varve sequence was a long succession of thousands of couplets. By simply counting the couplets in one varve core or section, the time since deglaciation was established. This is not correct. In Sweden, each varve section is very short, most often represented by less than 200 couplets (Olsson, 1970, p. 219). Few layers of varved clay were deposited because the pro-glacial lakes were short lived.

To construct a long chronology the thickness of each couplet in each varve section is measured and plotted on graph paper. A jagged curve results by connecting the points. By curve matching of small varve sections or unusual "varves," the varve sequences are correlated temporally. Figure 3 is a matching of 12 varve sections from southeast Sweden. The longest section is reported at 170 years while the shortest is only 50 years. In each of the 12 sections, the height of the jagged line represents the thickness of the "varves." The time axis is horizontal in increments of 10 years with the youngest to the left, which is the opposite of most plots. The 12 sections are matched and correlated through about 220 years. Figure 3 is one of two suggested correlations, which differ by 85 years.

Ice Sheets Melt Rapidly

The slow melting rates for ice sheets inferred from varve chronology does not agree with observed data from modern glaciers and the results of newer general circulation models of the atmosphere and ocean. The observed melting rate in the ablation area of many

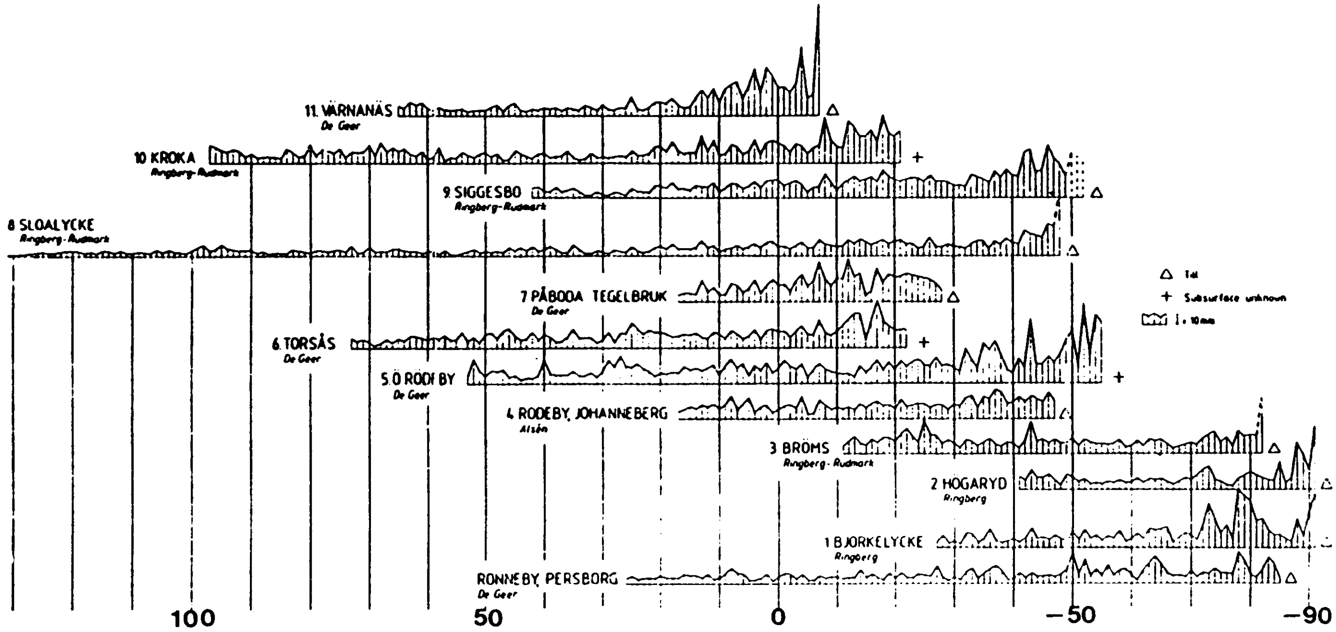

Figure 3. The correlation of 12 "varve" diagrams from southeast Sweden. Note that time is positive left. This is one of two preferred alternatives, which differ by 85 years. Reprinted from "Varve chronology based upon glacial sediments in the area between Karlskrona and Kalmar, southeastern Sweden" by Bertil Ringberg and Lars Rudmark from *Boreas* 1985, vol. 14, with permission of Universitetsforlaget AS.

Norwegian, Icelandic, and Alaskan glaciers is about 12 meters of thickness a year (Sugden and John, 1976, p. 39). These glaciers are located in high latitude mountains close to the ocean. Smaller, but still high melting rates occur in the ablation zones of glaciers dominated by a cold continental climate. For instance, Beget (1987, p. 85) has observed that glaciers at 70°N latitude in northeast Canada melt at 5 to 7 m/yr at low elevations and 1.5 to 3 m/yr at elevations greater than 1,000 meters. Such high ablation rates are principally due to strong solar radiation in summer.

Several positive reinforcement mechanisms bring the observed melting rate in the ablation zone of the Jakobshavns Glacier in West Greenland up to an impressive 55 m/yr (Hughes, 1986). These positive feedback mechanisms are stronger absorption of sunlight and heat by crevasses, greater addition of meltwater to the base of the glacier, and calving into water. These effects accelerate melting and would also operate locally during the melting of the Laurentide, Scandinavian, and Cordilleran ice sheets during the post-Flood Ice Age (Oard, 1990a).

At an ablation rate of 10 m/yr, and assuming the huge ice thickness postulated by uniformitarian scientists, the Laurentide, Scandinavian, and Cordilleran ice sheets would melt in several hundred years. These ice sheets were in more favorable areas for melting than present-day glaciers, so the above estimate is conservative.

General circulation models of the atmosphere and ocean are now pointing to the conclusion that if the ice sheets could form at all, they would disappear rapidly (Rind, 1987; Rind, Peteet, and Kukla, 1989). Most previous models have been inadequate for determining the ice sheet melting rate (Rind, Peteet, and Kukla, 1989, p. 12,853). Some of the problems with these models include poor parameterization of complex variables, too high an albedo of melting snow and ice, and much too high annual precipitation (Oard, 1984a, p. 70). The albedo is the amount of solar radiation in tenths reflected from a surface.

Unfortunately, the current models continue to use too high an albedo for melting snow and, therefore, underestimate melting rates. For instance, Rind, Peteet, and Kukla (1989, p. 12,854) use an albedo of 0.5 for melting snow and pure ice. However, the albedo of melting snow drops to 0.4 after two weeks of melting (U.S. Army Corps of Engineers, 1956, Plate 5-2, Figure 4). Ice has an albedo between 0.2 and 0.4 (Paterson, 1981, p. 305). Rind, Peteet, and Kukla (1989) also did not consider the positive reinforcement mechanisms of crevassing, calving into pro-glacial lakes or marine bays, and blowing dust deposited on the ice. Nevertheless, Rind (1987) reports that in his model ice sheets averaging 2,500 meters thick completely melt in 1,000 to 4,000 years. Such a rapid melting rate, according to uniformitarian standards, also raises the question of how can an ice sheet grow this thick if the melting tendency is so powerful?

In an elaboration of Rind's computer simulation, Rind, Peteet, and Kukla (1989) tackle the question of how an ice sheet develops in the first place. They used solar radiation slightly less intense than at present, as postulated by the astronomical theory of the Ice Age (the Milankovitch mechanism). But they discovered, nevertheless. that all the winter snow over areas formerly covered by ice sheets melts during summer. Trying to aid ice sheet growth, the next computer simulation began with an initial 10 meter thick ice sheet over all the land once covered by the ice sheets. They also reduced the sea surface temperature to presumed Ice Age values. Running the simulation with these changes, the 10 meter thick ice sheet, instead of growing melted in 5 years! They conclude that ". . . we do not really understand the cause of the ice ages and the Milankovitch connection" (Rind, Peteet, and Kukla, 1989, p. 12,851).

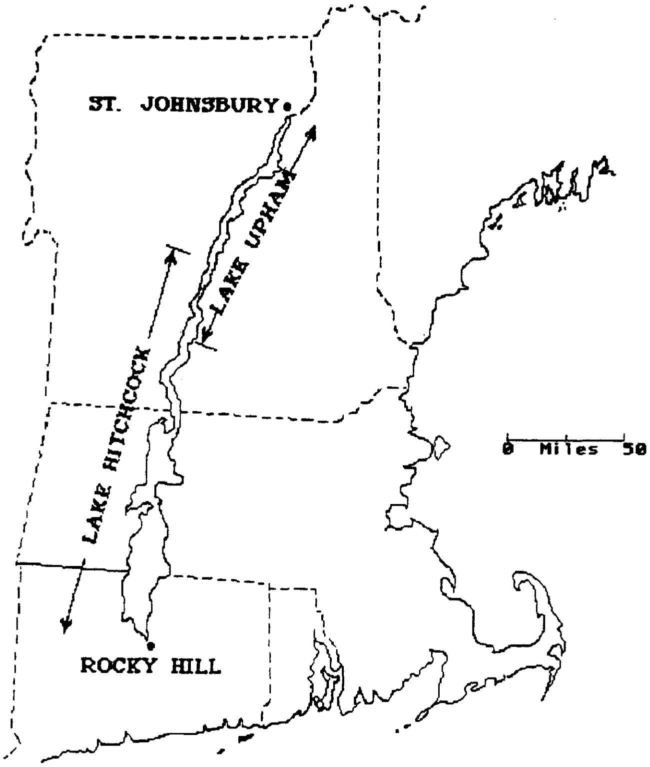

Figure 4. Map of ancient Lake Hitchcock and Lake Upham in New England. Redrawn from Ashley, 1972 by Dale Niemeyer.

The above results are consistent with previous evidence that the astronomical theory of the Ice Age is too weak to cause an ice age (Oard, 1984a, b, 1985). An ice age cannot be initiated without a special catastrophic mechanism. The aftermath of the Genesis Flood provides such a mechanism (Oard, 1979, 1987, 1990a, b, c). With a 5-month warm season average for solar and infrared radiation under postulated ice age conditions. the energy balance over a snow cover indicates a post-Flood ice sheet would have melted rapidly. The estimated melting rate is at least 10 m/yr at the periphery and probably more than 5 m/yr in the interior. This rate is consistent with observed data and the new general circulation model results.

The implication of the above research indicates that the ice sheets melted catastrophically. Some glacial geologists are now postulating the rapid formation of drumlins and meltwater scouring features due to catastrophic sheet flooding during deglaciation (Shaw and Kvill, 1984: Shaw and Sharpe, 1987; Shaw, 1988, 1989; Shaw, Kvill, and Rains, 1989; Shaw and Gilbert; 1990: Sharpe and Shaw, 1989).

Tunnel valleys, trough-like depressions in bedrock, are abundant along the periphery of the former Laurentide and Scandinavian ice sheets. In Minnesota west of Lake Superior, tunnel valleys average 10 m deep and about 0.5 km wide, but can be as deep as 70 m and constitute a net-like pattern with a total length of 1000 km (Mooers, 1989). In Denmark and northern Germany, the tunnel valleys are miniature fjords, up to 400 meters deep, filled with fluvial sediments and glacial till (Ehlers, 1981). Since tunnel valleys are associated with deglaciation features, glacial geologists have trouble explaining them. Some geologists have suggested catastrophic erosion by high-velocity subglacial meltwater (Wright, 1973; Boyd, Scott, and Douma, 1988; Gilbert, 1990). Unfortunately, they have trouble finding a source for the water. The catastrophic melting of the post-Flood ice sheets, likely with the aid of cavitation (Holroyd, 1990a, b), can provide a source for the water and a rapid erosional mechanism for tunnel valleys.

Given the observational and simulated model evidence for rapid deglaciation of the Scandinavian and Laurentide ice sheets, plus the new surficial data on likely catastrophic melting, why are the deglaciation rates postulated from varve chronology so low? To answer this question, we need to examine whether "varves" are really annual.

Are Varves Annual?

De Geer believed that each varve couplet was annual, based on the similarity to tree rings. De Geer's colleagues and students unquestioningly have followed his belief. Anderson and Dean (1988, p. 216) write:

> There was little questioning of the assumption of annual deposition for proglacial lake sediments because seasonally regulated melting and freezing was so obvious, and early investigations . . . were convincing.

But many modern investigators question this assumption, and many others are so concerned about it that they list reasons why they believe the layers are annual. Mackiewicz et al. (1984, p. 114) assert: ". . . the term varve has had a troubled history . . . the term 'varve' has become a catch-all term to describe any interlaminated glacial sediment, and it is confusing and misleading." Quigley (1983, p. 150) corroborates: "A single varve representing 1 year of deposition, consists of a couplet of summer silt and winter clay; this time framework is difficult to demonstrate however."

The time frame is very difficult, if not impossible, to prove because it is historical and not empirical. One troublesome problem is that rhythmites are complex and variable. The rhythmites displayed in Figure 1 are variable; they abruptly change thickness in the lower portion of the photograph. The character of lake rhythmites depends upon the quantity, grain size, and composition of the inflowing sediment, the size and bathymetry of the water body, the wind regime, the thermal and chemical stratification of the lake, the presence of burrowing organisms on the bottom, and other variables (Ludlam, 1979; Smith, Venol, and Kennedy, 1982, p. 206). Unlaminated sediments are sometimes intercalated within rhythmites.

Rhythmites also represent a great variety of depositional environments (Sturm, 1979a, b). Not only do presumed varves or varve-like layers form in pro-glacial lakes, but they also form in many non-glacial lakes (Boyko-Diakonow, 1979; Ludlam, 1979; Saarnisto, 1986; Anderson and Dean, 1988). Many of these non-glacial rhythmites are very thin couplets of diatoms, calcium carbonate, mineral matter, or organic sludge. These rhythmites are beyond the scope of this paper, which shall be confined to clastic rhythmites in which the majority of the sediment is supplied by rivers.

Some recently-formed rhythmites are indeed annual and hence true varves. For instance, a retreating glacier in Norway left behind a pro-glacial lake. The ice was in contact with the lake for 30 years. Cores taken from the bottom sediments revealed that the number of couplets at each location matched the years since the ice left that location. But to complicate matters, one location had twice as many layers as years of deposition (Ostrem, 1975, pp. 116,117). There were a total of 42 couplets. The lower 21 couplets in this one core were assumed to be annual, while the upper 21 couplets were to have been emplaced by slumping, although both sets appear almost identical.

Measurements of the clastic rhythmites in non-glacial lakes indicate that more than one pair of laminae can form each year. For instance, Lambert and Hsü (1979a, b) report that 300 to 360 laminae formed in 160 years in Lake Walensee, Switzerland. The number and thickness of laminae varied with the location, which should make correlation by couplet thickness hazardous. Generally, two layers a year had formed, but at some locations five layers were deposited in one year. This confirmed the long-overlooked findings of a Swiss engineer, W. Stumpf, who earlier this century measured five laminated couplets in one year.

The extra-annual couplets were formed by turbidity currents caused by either melting snow or heavy rain storms. The implications of this research are stated by Lambert and Hsü (1979a, p. 454):

> Our investigations supported de Geer's first contention that sediment-laden flood-waters could generate turbidity underflows to deposit varves, but threw doubt on his second interpretation that varves or varve-like sediment are necessarily annual!

Rhythmites form by either underflows, interflows, or overflows, or by all mechanisms operating at different times. Underflows are more-or-less *continuous* turbidity currents that flow along the bottom. Interflows and overflows spread out from a river or stream at intermediate depths and at the surface, respectively. The level at which the inflowing sediment-water mixture flows depends upon its density compared to the lake density and stratification.

Turbidity currents are more technically defined as sporadic underflows or surge currents. Turbidites, the deposits laid down by turbidity currents, can occasionally mimic varves, especially at far or distal distance from the source of sediment. For instance, turbidites can alternate colors, similar to Pleistocene rhythmites (Kuenen, 1966). Crowell (1957, p. 1005) states: "Sandstone and mud sequences laid down by turbidity currents far removed from a glacial environment may be easily confused with varved sequences . . ." Hambrey and Harland (1981, p. 14) admit that common distal marine turbidites duplicate varve-like rhythmites. Some investigators believe that many supposed varves are in fact multiple turbidity current deposits with no seasonal control:

> It is very unfortunate from a sedimentological viewpoint that engineers describe any rhythmically laminated fine-grained sediment as 'varved.' There is increasing recognition that many sequences previously described as varves are multiple turbidite sequences of graded silt to clay units . . . without any obvious seasonal control on sedimentation. (Quigley, 1983, p. 151).

Silt settles in a matter of days, but clay, depending upon its grain size, can take years to settle in a quiet lake. However, a turbidity current or underflow rapidly transports clay as well as silt and sand to the bottom of the lake (Smith and Ashley, 1985). A cloud of clay particles would be left floating above the deposited silt or sand as the current diminishes. Then the clay will settle on top of the silt or sand in a relatively short time. Smith and Ashley (1985, pp. 198,199) state that the same thickness of silt and clay are expected in turbidity surges:

> As both clay and silt fractions are transported to the site of deposition at the same time, successive surge deposits are likely to have similar proportions of silt and clay. In other words, thick silt layers will have thick clay layers, and thin silt layers will have thin clay layers.

I doubt whether this is an absolute rule, but it indicates that turbidity currents or rapid underflows have no problem depositing clay rapidly above silt or sand.

Lambert and Hsü are not the only investigators to discover more than one annual couplet in a lake. Pickrill and Irwin (1983) analyzed rhythmic sediments from a deep glacial-fed lake in New Zealand. They had to depend on ^{210}Pb dating to ascertain the annual sedimentation rate, since each couplet looked similar. They found an average of three couplets per year and surmised that the extra two layers were deposited by floods and slumps.

In another instance, Wood (1947) describes three varve-like couplets deposited in a new reservoir. The couplets looked very much like varves and were formed by three peak river inflows caused by light showers. The layers were deposited in just two weeks! The average grain size of these layers was larger than in supposed Pleistocene varves because they were formed by settling in a reservoir only 0.5 mile in length. Ice Age rhythmites predominantly settled out in a larger lake and hence would have a finer average grain size.

Most geologists assume the coarse layer of a "varve" couplet was deposited in summer and the fine layer settled slowly in winter. However, sand or silt layers can be deposited in winter as well, interrupting clay deposition. This will cause many extra years to be counted when every couplet is assumed annual. For example, Pickrill and Irwin (1983, pp. 70-73) discovered that winter couplets form by the slumping of river delta deposits. A delta may become oversteepened due to summer sedimentation and slump during winter. Shaw and Archer (1978) report sand layers sandwiched within presumed winter clay in Ice Age lake sediments from the Okanagan Valley, British Columbia. Coarse layers in presumed winter clay have also been observed in Swedish rhythmites (Shaw, Gilbert, and Archer, 1978, p. 692), and in ancient Lake Hitchcock in New England (Sturm, 1979b, p. 284). Lake Hitchcock is a postulated north-south orientated lake that filled the Connecticut Valley from central Connecticut to northern Vermont after the ice sheet melted in the area. Figure 4 shows the location of this ancient lake, which for the purposes of this paper includes ancient Lake Upham. The total length of the postulated lake is about 400 km.

In modern pro-glacial lakes, discharge from a glacier often continues during winter, although in reduced volume (Gustavson, 1975, p. 252; Smith and Ashley, 1985, p. 198). So, rhythmite deposition may continue well into the cold months. Quigley (1983, p. 152) writes:

> In many cases where large ice lobes or glaciers sit or float in lakes, there is year round delivery of sediments and turbidite activity occurs almost continually resulting in graded laminae that are not true varves.

The reason for continued river discharge is due to bottom melting and draining of water-filled fractures and tunnels in the ice sheet during winter.

Besides continuous river discharge, winter coarse layers are caused by several other mechanisms and are not rare. Potential controls over the occurrence of winter underflows are winter storms, delta failures, and jökulhlaups, which are floods caused by the breaching of an ice-dammed lake. Shaw, Gilbert, and Archer (1978, p. 698) summarize the implication of these winter coarse layers:

> Misinterpretation of these coarse-grained units as summer deposits leads to an over-estimate of the length of time represented by a particular glaciolacustrine sequence. Our review shows such misinterpretation to be common.

Actually, it is not known for certain that the coarse layers described above were formed in winter. They could simply be regular couplets in which the coarse layer is thin. Such layers could have been formed at distal locations in summer, during a dry year, or during a complex deposition of rhythmites. Therefore, couplets that would be interpreted as varves can be laid down rapidly any time of the year.

Scientists have been studying the glaciers of southern Alaska for years. One glacier in particular, the Muir Glacier, has been receding about 410 m / yr up a fjord. This glacier simulates in many ways the melting of the ice sheet at the end of the Ice Age. Investigators have discovered that debris from the base of Muir Glacier and other glaciers in Muir Inlet is continuously fed into the fjord. The debris often forms rhythmites that are similar to varves in glacial lakes (Mackiewicz, et al., 1984, p. 115). The rhythmites are formed mostly by interflows and overflows because of the higher density of the brackish water in the inlet. The sedimentation rate in the fjord varies from 13 m / yr at the terminus of one glacier to about 1 m / yr at ice-distal locations (Mackiewicz, et al., 1984; Cowan, Powell, and Smith, 1988, p. 409). Most of this sediment is finely laminated silt and mud, and many couplets are deposited each year.

The rhythmites in Muir Inlet are formed by combinations of semidiurnal tides, diurnal meltwater discharges, baroclinic waves resulting from water density differences in the estuary, heavy rain storms, and random debris flows (Mackiewicz, et al., 1984; Cowan, Powell, and Smith, 1988). Smith, Phillips, and Powell (1990) discovered that large diurnal meltwater variations, combined with twice-a-day tides (especially the large spring tides) form two rhythmite couplets a day below deltas in Muir Inlet. Each couplet averages half a centimeter thick, and the sequence superficially looks like varves. Seiches, standing wave oscillations in an enclosed water body caused by earthquakes or strong winds, can also cause rhythmites (Ludlam, 1979). Some of these variables would also operate to cause rhythmites in lakes.

In summary, rhythmites that are believed to be varves may be annual, but several mechanisms operate to produce more than one couplet in a year. It is difficult to distinguish between these mechanisms. Consequently, presumed varves from the Ice Age may not be annual. Many couplets may have formed in one year.

Possible Diagnostic Criteria for Varves

Because of the various mechanisms depositing rhythmites, geologists have attempted to develop diagnostic criteria that determine the annual cycle. In reference to rhythmites formed by underflows, Smith and Ashley (1985, pp. 197, 198) discuss the problem:

> A pervasive and recurring controversy concerning glacial lake sedimentation is the underlying control of rhythmicity: randomly occurring slump-generated surge currents vs. regularly alternating (seasonal) sedimentary processes . . . The difficult problem is distinguishing varves formed predominantly by quasi-continuous underflow from surge-current deposits, because they share similar characteristics . . . Superficially the two deposits may appear similar.

The authors present three diagnostic criteria that hopefully characterize varves: 1) a sharp break between the coarse sublayer and the overlying fine sublayer; 2) biogenic marks, usually in the fine-grained layer; and 3) the same thickness for the fine-grained layer throughout the lake basin.

The first criterion is not absolute, so cannot be applied with certainty. Flint (1975, p. 125) infers that the break between the coarse sublayer and the overlying fine sublayer in presumed varves from ancient Lake Hitchcock is not always sharp. Ashley (1975, p. 304) contends that sharp breaks occur in more than 75% of the rhythmites in Lake Hitchcock. Therefore, a minor, but significant proportion of the rhythmites display a gradual transition from silt to clay in this particular lake.

Eden (1955) also indicates that Ice Age "varves" are variable. The varves at Steep Rock Lake in Ontario, Canada show a sharp boundary between the coarse sublayer and the overlying clay sublayer. However, the clay itself is not vertically graded, which is unusual if the clay settled out during winter. The only apparent explanation is that the clay settled quickly due to coagulation of the grains by ions in the water, which *does* occur in fresh water lakes. Such clay deposition can occur even in summer on top of underflow or turbidity current deposits. Eden's analysis indicates that many layers exhibiting sharp breaks between sublayers can form in one year.

Antevs (1951) came to a similar conclusion for rhythmites in Steep Rock Lake. He crudely estimated the annual layer as the top of the thickest clay layer. The rhythmites from Steep Rock Lake consisted of many couplets of various sizes, and the presumed annual group often contained many of these couplets, up to 25. Antevs could not distinguish any difference between the supposed winter and summer clay layers.

At a second location in Toronto, Canada, Eden (1955, p. 666) discovered that the coarse sublayer graded gradually into the overlying fine sublayer. So, the proportion of couplets that show sharp boundaries may depend upon the particular lake, and thus upon different variables. Tauber (1970, p. 174) states: "Many transitional forms of gradation exist, and even well-graded varves (diatactic varves) may contain various patterns of microlamination."

To complicate the matter further, thick turbidites that simultaneously deposited multiple layers show a sharp separation between the coarse and fine sublayers. This possibly indicates a type of segregation process of "like attracting like" (Kuenen, 1966). Bridge (1978) attributes this separation process to variable hydrological processes.

The activity of organisms, the second distinguishing criterion, is found on clay layers from ancient Lake Hitchcock. However, most layers do not show any evidence of organisms. Ashley (1972, p. 89) shows a picture of a varve sequence in which irregular contacts may be caused by other mechanisms, and the irregularity was only at the *top* of the clay layer. It seems that if the clay settled throughout the winter, the clay layers would be disturbed throughout. Possibly, such disturbances cannot be seen. And what are we to make of the one out of six clay layers that show disturbances? Would the annual cycle be six couplets? In the Swedish rhythmites, evidence of activity by organisms is rarely observed. Therefore, it is difficult to apply the second criterion, especially to the classical Swedish Time Scale.

The third criterion is an even thickness of clay deposited throughout the entire basin. This criterion is difficult to apply in practice, since rhythmite sections collected from the entire basin for the exact time of deposition are required. I doubt whether this has been accomplished in sufficient detail in any ancient or modern lake. Besides, there are reasons, discussed in Part II, why presumed winter clay deposition should not be uniform over the whole lake basin. In ancient Lake Hitchcock, the clay sublayers, as well as each rhythmite unit, display lateral variability in thickness (Ashley, 1972, 1975). In fact, clay is completely absent on some topographic highs on the lake bottom (Ashley, 1972, p. 26). This is very unusual for true varves, and indicates that deposition of the rhythmites, including the clay layer, was very likely due to turbidity currents or semi-continuous underflows.

No set of diagnostic criteria can absolutely delimit the annual layer in a sequence of rhythmites. Several other processes can duplicate varve-like layers, and many couplets can form in one year. Francis (1975, p. 63) maintains:

> Many glacial rhythmites are not varves and consist of laminated sediments in which the layers are alternately lighter-coloured fine sand or coarse silt and darker fine silt or clay . . .

Summary

The foregoing sections have endeavored to describe varves and whether they are annual or not. The correlation of these varves is the basis for the first "absolute" chronology, developed in Sweden and called the Swedish Time Scale. This time scale dated the beginning of deglaciation in southern Sweden at 13,000 years ago and ending 9,000 years ago in central Sweden. The chronology was considered so exact that it was used to date other cyclic phenomena from anywhere in the world.

Observational evidence from modern glaciers and the results of climate simulations show that ice sheets melt rapidly—much faster than indicated by uniformitarian models and varve dating. The treatment given here shows that a varve chronology is not scientifically sound. Varves have been assumed to be annual accumulations in pro-glacial lakes, but such deposits form in many types of lakes, and mechanisms have been discovered that deposit varve-like couplets quickly. Several investigators have attempted to devise criteria to distinguish between annual and non-annual rhythmites, but these criteria cannot be applied with certainty.

In Part II, I will examine closely the method of varve correlation. Then the post-Ice Age rhythmites in the Angermanälven River in central Sweden will be analyzed. The paper will conclude with a discussion of the results and the possible contribution to future research.

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KEYWORD INDEX TO VOLUME 28

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*Glen W. Wolfrom, Ph.D., is Membership Secretary of the Society. For multi-page items, the reference is to the first page only. Letters following numbers indicate: a = article; L = letter; p = panorama; r = reviews; and n = note.

QUOTE

Those who, like Lewis in *The Abolition of Man,* have seen the figure of Dr. Faustus as possessing a profound mythic significance for Western self-understanding have certainly been right. For Faust wanted no thing, no vocation, no possession, merely the unfettered expression of his own will. And from Faust to Bacon the road runs broad and straight, for in a Faustian world the purpose of science is not noetic, is neither wisdom nor knowledge of the natures of things, but that successful production, at any cost and by any means, of those fruits desired by mankind. For not only does man have no nature and fail of existence as a creature or being having self-identity and relatedness, but nature itself loses its very forms. Bacon's *Novum Organum* required as a companion piece Hume's *Treatise of Human Nature,* for the assertion of technological transcendence over man and nature cannot be pursued successfully unless the world has been swept clean of those forms that imply, indeed require, the existence of order and a certain profound respect for the integrity of beings. Thus the metaphysical platform of modernity, pursued from Occam to the English positivists, has had as its central project the extirpation of the Aristotelian-Platonic notion of form or natures or essences and the propagation of the thesis that the individuality of every being is merely subjective and conventional. Thus it is hardly surprising that at the end of this process there exists a populous race who, obedient to the folk Darwinism of their teachers, are willing to believe that no being has a determinate form, but that each may enjoy an indeterminate number of natures, passing down the interminable evolutionary corridor first as one creature then another. And at the end imagination is gripped by the paradox that everything is everything else, nothing itself. Persons as such, rational individuals capable of contracts, loyalties, politics, and faith, cease to exist.

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