ACTA GEOLÒGICA HISPÀNICA, t. 18 (1983), n.º 3/4, pags. 153-160

Penecontemporaneous partial disaggregation and/or resedimentation during the formation and deposition of subglacial till

by A. DREIMANIS

Departament of Geology University of Western Ontario, London, Ontario, Canada N6A 5B7

ABSTRACT

Glacier ice has been always considered to be the geologic agent that forms and deposits till. However, the reality is more complex: meltwater and gravity participate to various degrees at the formation, deposition and penecontemporaneous redeposition of till, even though the glacier is the principal agent and the deposition of till takes place in contact or near-contact with glacier ice.

Boulton's (1980) and Lawson's (1981) criteria for the differentiation of "tills" from "nontills" are tested here, by using mainly their own data on glacial sedimentation and penecontemporaneous resedimentation at Breidamerkurjøkull, Iceland, and Matanuska Glacier, Alaska, but re-interpreting some of their conclusions or pointing out some discrepancies in their own conclusions.

A strict adherence to some of Boulton's (1980) and Lawson's (1981) criteria would not permit calling most of Matanuska Glacier's melt-out tills, and the Breidamerkurjøkull's lodgement till, particularly its dilated top portion, a true till. However, they may be considered tills, if the broad definition of: "Till is a sediment that has been transported and subsequently deposited by or from glacier ice, with little or no sorting by water" is applied instead.

RESUMEN

Al hielo glacial se le ha considerado siempre como el agente geológico que forma y deposita el till. Sin embargo la realidad es más compleja: el aque de fusión y la gravedad participan en distintos grados en la formación, deposición y redeposición penecontemporánea del till, incluso cuando el glaciar es el agente principal y el depósito del till tiene lugar en contacto o muy cerca del hielo glacial.

Se examinan aquí los criterios de Boulton (1980) y de Lawson (1981) para la diferenciación entre till y no-till, utilizando principalmente sus propios datos sobre sedimentación glacial y resedimentación pene-contemporánea en el Breidamerkurjøkull, Islandia, y en el glaciar de Matanuska, Alaska, pero reinterpretando algunas de sus conclusiones o puntualizando algunas discrepancias en sus propias conclusiones.

La observancia estricta de algunos de los criterios de Boulton (1980) y de Lawson (1981) no permitiría denominar como verdaderos tills a la mayoría de los "melt-out tills" del glaciar de Matanuska, ni al "lodgement till" del Breidamerkurjøkull, particularmente su amplia parte somital. Sin embargo pueden considerarse como tills si se aplica, en cambio, la definición más amplia: "Till es un sedimento que ha sido transportado y posteriormente depositado por, o desde, hielo glacial, con escasa o nula clasificación por el agua".

RESUM

Al gel glacial se l'ha considerat sempre com l'agent geològic que forma i deposita el till. Però la realitat es més complexa: l'aigua de fusió i la gravetat participen de distinta manera en la formació, deposició i redeposició pene-contemporània del till, fins i tot quan la glacera n'és l'agent principal i la deposició del till es produeix en contacte o molt a prop del gel glacial.

S'examinen els de Boulton (1980) i Lawson (1981) per a la diferenciació entre till i no-till, utilitzant principalment les seves pròpies dades sobre sedimentació glacial i resedimentació pene-contemporània en el Breidamerkurjøkull, Islàndia, i a la glacera de Matanuska, Alaska, però reinterpretant algunes de les seves conclusions o be puntualitzant algunes discrepàncies de les seves pròpies conclusions.

L'observança estricta d'alguns dels criteris de Boulton (1980) i de Lawson (1981) no permetria denominar com a veritables tills la majoria dels "melt-out tills" de la glacera de Matanuska, ni el "lodgement till" del Breidamerkurjøkull, particularment la seva àmplia part summpoden considerar si s'aplica, en canvi, la definifició més àmplia: "Till és un sediment que es estat transportat i posteriorment depositat per, o des de, gel glacial, amb una classificació escassa o nul·la deguda a l'aigua.

INTRODUCTION

When hearing or reading about "till", we usually associate this term with glacial environment, more specifically with deposition by glacier ice. It would be very convenient, if glacier ice could be regarded as the *only* geological agent that can form and deposit till. Such a restriction, if applicable, would eliminate the controversies about "tills" and "nontills", discussed, for instance, by Boulton (1980a), Lawson (1981), Dreimanis (1982), Dreimanis and Lundqvist (1984). The main stumbling block for the consideration of glacier ice as the *only* depositional agent for till, is the participation of meltwater and gravity, to various degrees, at the formation, deposition and penecontemporaneous redeposition of till, while still in the glacial environment.

The participation of water in the formation and deposition of till can not be disregarded, since nearly all till-forming mechanisms involve meltwater. While discussing the glacier sole, under which the usually unquestioned varieties of primary or ortho-till, lodgement and the meltout tills, are deposited - Muller (1983b, p. 21) makes the following statement:

"...in ultimate analysis essentially all till is water deposited. The role of meltwater is essential to the movement of material through the glacier sole to the substrate. Whereas in some cases this involves only the briefest melting and regelation of ice at pressure points between clasts, much more often it results in a slurry, a dispersed sediment-water system the subsequent development of which determines the nature of the subglacial till."

Though Muller *(ibid.)* went to an extreme at the beginning of the above statement, in order to emphasize the role of water in the formation and deposition of till, he is not denying the glacier ice as the *principal* geological agent. What is important in the participation of water, is "...that the selective activity of water had played a *minimum part* (underlining mine) in its (till) deposition." (Flint, 1971, p. 148). Therefore, the broad definition of till (see p. 19) that had been adopted by the majority of the Till Work Group of the INQUA Commission on Genesis and Lithology of Quaternary Deposits in 1982 (Dreimanis, 1982, p. 21), stresses that till is formed and deposited "...with little or no sorting by water." This restrictive clause, admittedly, does not provide a sharp boundary between till as a glacial deposit and the sorted meltwater sediments, which occasionally may be also as poorly sorted as till (Lundquist, 1976, Fig. 1). This absence of a sharp boundary is not surprising, since nature often does not produce sharp boundaries, even though we would like to have them for strict classifications. This lack of sharp boundaries has been recognized repeatedly by various authors with broad field experience, for instance Flint (1971, p. 148): "No sharp dividing line separates till from stratified drift; one grades into the other." In such a situation, every dividing line will be arbitrary. Any narrow definition of till will just narrow the range of till and widen the range of stratified drift; any broad definition will do the opposite.

The following are the main arguments used for calling a glacial sediment a "nontill" and thus narrowing the range of sediments considered to be till.

(1) Disaggregation of the "...components ...brought into contact by the direct agency of glacier ice." (Boulton, 1980a, p. 11). It has two clauses: (a) how the components are brought together, and (b) their disaggregation.

(2) Disaggregation and resedimentation subsequent to the release of glacial debris from the glacier after their deposition directly by glacier ice (Lawson, 1981, p. 2).

The contentious processes that may turn a till into "nontill", in strict classifications, are essentially of secondary character. Primary processes are glacial, while related, gravity, water and wind, participate or dominate among the geological agents that produce secondary processes. Again, no sharp dividing line separates them, and the criteria for separating these processes in relation to glacigenic deposition, may vary from one author to another. For this discussion, let us take the criteria and their discussions from Lawson (1981, p. 2-3). They are the strictrest and should be tested by examination of several actual examples from the glacial environment in order to see how strictly "tills" can be separated from "nontills".

From a lengthy discussion in Lawson (1981, p. 2-3), I here quote three sentences (ibid., p. 2) that seem to condense his criteria for the differentiation of primary till-forming processes from the secondary ones that form nontills.

"The sedimentologic distinctions between primary and secondary processes are principally three: sediment source, uniqueness of the glacial environment, and ability to preserve glacial properties.

Primary processes derive their sediment only from debris in the glacier. Secondary processes mobilize, rework and resediment material previously deposited by primary or secondary processes and, less often, continue to transport and deposit debris immediately after release by a primary process.

...only sediments deposited by primary processes should be classified genetically as tills."

Another contentious issue may be the deformation, disaggregation, and resedimentation caused by glacial pressure upon the overridden substratum, since some of these effects are hard to differentiate from those which are caused by nonglacial secondary processes.

Let ut examine a few well known examples mainly of subglacial deposits that have been deposited essentially by primary processes (*sensu* Lawson, 1981), in order to see whether any of their parts have not been affected also by penecontemporaneous secondary processes.

MELT-OUT TILLS AT THE WESTERN TERMINUS OF MATANUSKA GLACIER, ALASKA

Lawson (1979) describes in considerable detail three sections of melt-out till in contact with stratified basal ice at Matanuska Glacier. Most of his data for surface melt-out tills are presented in his Figs. 23 and 24 and for basal melt-out till in his Fig. 25.

One of the tills (*ibid.*, Fig. 24) has been deposited without much interference of secondary processes, since

"...a subhorizontal, poorly-defined stratification, apparently inherited from the layers of the suspended subfacies concentrated at this level in the ice, was observed below the lenses of coarse sand." (*ibid.*, p. 37).

The other two tills are massive, without any preservation of the stratified debris-band structures encountered in the associated basal ice, and both tills are coarser textured than the glacial debris in the adjoining ice. Lawson (1979, p. 34) gives the following description of the coarse textured (mean size - 2.1 ø) surface melt-out till:

"The texture of the till, as indicated in Figure 23, is much coarser than the debris source. This difference appears to have resulted from the downslope migration of the fine-grained particles in the water released during melting. The stratification and textural variations in individual layers are not preserved in the till. It is also loose, with an open framework and a high void ratio."

According to Lawson's (1981) own criteria for the secondary processes and his own conclusion on the downslope migration of the fine-grained particles (see above), this till has been definitely affected by secondary processes that have washed most of silt and all clay-size particles out of it. Whether this happened during or shortly after its deposition, or even prior to its deposition, is hard to tell. Since the till layer is thin (less than 10 cm) and very coarse textured (ab. 65% of it is coarser than -1 ø or 2 mm) the pebble orientation inherited from the glacier ice has been preserved except for the plunge of their long axes: the plunge has flattened considerably - from 45° SE to 2° NW. No microfabric data are available to check on the possible remobilization of the till matrix around the pebbles.

The basal melt-out till (Lawson, 1979, Fig. 25) has also a coarser texture (mean size of 3 samples: 2.5-3.1 ø) than the debris in the stratified basal ice above it (3.4-3.5 ø, 2 samples), but the difference is not as great as in the surface melt-out till of Fig. 23 *(ibid.)*. It is interesting to note that the silt and clay percentage increases in the lowermost till sample to about 49% from 38% in the overlying sample (both percentages are read from Fig. 25 of Lawson, 1979); this increase may represent secondary accumulation of that silt and clay, which migrated downward from the overlying part of the till.

If the above interpretation of the textural differences in the basal till of Fig. 25 *(ibid.)* is correct, then this till has been affected by secondary processes, such as washing out of the fines from its top part and redeposition of these fines into its lower part by percolating meltwater. Admittedly, the washing out in this till has been less effective than in the surface melt-out till of Fig. 23 *(ibid.,)*. Thus, the basal melt-out till considered by Lawson (1979) to be deposited by primary processes only, has been also affected to some degree by secondary postdepositional, actually penecontemporaneous processes. Therefore, according to Lawson's own criteria of (1979, 1981), this melt-out till should not be considered till. More sections should be investigated, and experimental quantitative studies conducted, before drawing any generalized conclusion on how much a basal melt-out till may become affected by secondary processes. This may vary from place to place depending upon a variety of local factors, such as grain size composition, structure, permeability, pore water pressure, etc.

LODGEMENT TILL AND DEFORMED LODGEMENT TILL AT THE MARGIN OF BREIDAMERKURJØKULL, ICELAND

The ice-marginal area at Breidamerkurjøkull, Iceland, is chosen here for the discussion of lodgement till and other related varieties of subglacial tills, because this area has been studied extensively by G.S. Boulton and his associates, and visited by many glacial geologists including the author of this discussion.

Dilation and its consequences

Boulton *et al.* (1974) and Boulton and Dent (1974) discuss the particle-by-particle lodgement and the post-depositional changes of lodgement till at Breidamerkurjøkull which were caused by shearing while the till was still in contact with the glacier sole. Boulton *et al.* (1974, p. 137) write:

"The effect of the movement of ice over the underlying till thus produces shear strain and dilation in the till, opening up the structure of one of a relatively high void ratio."

The dilation has nearly doubled the void ratio and decreased the shear strength five times (Table 1) in the upper 50 cm of the lodgement till. Being in the water-saturated zone at the glacier edge, this weakened till behaves under stress like a viscous fluid (Fig. 1).

The dilated till investigated by Boulton *et al.* (1974) contains nearly twice as much silt and clay as the compact lodgement till underneath it or the basal debris in the glacier ice immediately above it (Table 1). Boulton *et al.* *(ibid.)* hypothesize that this increase in fines has been produced by in situ interparticle crushing, due to subglacial shearing. However, such a vigorous crushing, that would double the silt and clay percentage (see Fig. 7 of Boulton *et al.*, 1974) is very questionable for the following reasons:

(1) The predominantly igneous rocks and minerals that make up the lodgement till would be much more resistant to crushing thant the streaked-out clalk from Norfolk, England, mentioned in Boulton *et al.* (1974, p. 144) as a supporting evidence.

(2) If silt and clay were produced by crushing in the dilated till, at least some freshly broken rock fragments should also be visible in the dilated till. I do no remember having seen any on the field trip to Breidamerkurjøkull, guided by G.S. Boulton in 1977, and could not see any in the close-up photos

Figure 1. Dilated lodgement till flows out from underneath tne snout of Solheimajøkull, Iceland. Note the grooved sole of the glacier ice. Dr. Max Deynoux on the right. (Photo by A. Dreimanis, 1977)

taken at that time. My photos show evidence of the reorientation of the pebble alignment, but no visible products of crushing (see Fig. 2 as an example). The two tracings of clasts from close-up photos of some other dilated lodgement tills in Iceland by Derbyshire (1980, Fig. 3) also do not show any indication of visible crushing.

(3) An alternate source for the silt and clay would be the meltwater from the contact of the glacier sole and bedrock containing mainly silt-sized rock flour (Boulton, 1978). As demonstrated by Boulton and Dent (1974, Fig. 6) the silt and clay sized particles continued to move through the voids of the consolidated till surface part, after it had been exposed for years, and some of the fines even entered the top of the underlying compact lodgement till. It would be logical to expect that the increased void space in the dilated till would make it even easier for subglacial meltwater to carry silt and clay particles into the dilated till, gradually filling the voids with these additional fines, as graphically shown in Figs. 5 and 6 of Boulton and Dent (1974).

Table 1. Selected characteristic properties of glacial debris and till at the western margin of Breidamerkurjøkull (after Boulton et al., 1974, Table 1 and Boulton and Dent, 1974, Fig. 6)

	Mean % silt-clay <0.06 mm	Mean void ratio	Field shear strength
Basal debris-rich ice	20		
Dilated till, topmost 50 cm.	39	0.68	0.075
Compact lodgement till, below 50 cm	24	0.38	0.325

Figure 2. Fluted subglacial till exposed in a drainage rill at the front of Breidamorkurjøkull, with a flute on the right side. The section, at right angles to the flute, exposes 25 cm of dilated till over 5-10 cm of compact fissile lodgement till, over coarse gravel. The blade of a knife, 10 cm long, is at the contact of the dilated and undilated tills. (Photo by A. Dreimanis, 1977)

Figure 3. A short flute on the lee side of a boulder at the tront of Breidamorkurjøkull. Dr. G.S. Boulton (first on the right) explains the origin of the flute. (Photo by A. Dreimanis, 1977)

The lower the hydraulic transmissability of a subglacial till, the deeper it may become dilated and deformed in the marginal zone of the glacier. At the edge of Breidamerkurjøkull visited in 1977, a thin lodgement till covered permeable gravels; the depth of dilation was only down to 0.3-0.5 m (Fig. 2). At the front of the Solheimajøkull, Iceland, where he lodgement till covered a relatively impermeable bedrock, the dilation extended for about 1-1.5 m downwards (Fig. 1), and it could be even deeper under favourable conditions (for more details on dilation as a result of shear see Boulton *et al.*, 1974).

As already mentioned, dilated till has a low shear strength. At Breidamerkurjøkull the water-saturated dilated till had been intruded by glacial pressure into tunnels which tend to develop on the lee side of large boulders and other subglacial obstacles (Boulton, 1976) (see Fig. 3). These intrusions form flutes -"...long parallel-sided ridges which reflect accurately the direction of ice movement..." (*ibid.*, p. 287) This generally accepted mechanism of the formation of most flutes is actually a resedimentation of glacial materials, but it is glacially induced.

Another glacially induced change is reorientation of till fabric. While discussing the implications of subglacial deformation, Boulton *et al.* (1974, p. 143) mention that "...significant reorientation of small (< 1 cm) particles took place along the shear plane..." in the direct shear tests undertaken by them. The fabric reorientation was observed by Boulton along the surface of the flutes at Breidamerkurjøkull. Boulton (1976, p. 298) states:

"The parallel orientation in the surface horizons predominantly reflect re-alignment of the fabric in response to the shearing imposed by the movement of ice over the flute surface."

In summary - the top portion of a lodgement till may become sheared and dilated by the same glacier that lodged it. This deformation may reach down to various depths depending upon a variety of factors discussed in Boulton et al. (1974).

The increased void ratio in the dilated till permits silt and clay to enter the voids and to modify the granulometric composition of the dilated portion of a lodgement till.

The dilated till, particularly when water-saturated, has a low shear strength and it may become easily deformed by the very same glacier that deposited it. The result of such glacially induced deformation may be reorientation of fabric and formation of flutes.

A question arises: is the dilated lodgement till a "till" or a "nontill" according to the criteria proposed by Boulton (1980a, p. 11) and Lawson (1981, p. 2)?

The dilated lodgement till would not meet the standards of Lawson (1981, p. 2) because of the following reasons:

(a) The added silt and clay particles have been transported and deposited by secondary processes subsequently to the lodgement of till.

(b) Differences in opinions, however, may exist about the resedimentation of the dilated till by glacial pressure, intruding it into the lee-side tunnel: is this a primary or a secondary process? It is postdepositional in sequence - subsequent to the release of glacial debris from the glacier, but some may call it primary, because the resedimentation was accomplished by the glacier. Most subglacial debris probably goes through multiple cycles from entrainment to its final resting place anyway.

Boulton *et. al.* (1974) call the dilated upper horizon of lodgement till a till. However, if the addition of silt and clay was accomplished by the percolation of meltwater through the widened voids in the dilated till, then the following condition stipulated in the Boulton's (1980a, p. 11) definition of till would not be met: "...components are brought into contact by the direct agency of glacier ice." Thus, according to Boulton's criteria *(ibid.)* the dilated till, if it contains silt and clay particles infiltrated by meltwater, would no longer qualify as till.

Subglacial deposition in lee-side cavities

The intrusion of dilated till into subglacial lee-side cavities as the principal mechanism for the formation of flutes was already discussed above. In addition, free fall and flowing of debris from the glacier sole is listed by Boulton (1980b) as another mechanism of glacial deposition in subglacial cavities. A photograph of a subglacial cavity of Nordenskioldbreen, Spitsbergen, where three flutes had been formed (Boulton, 1976, Fig. 6) portrays the ice roof and the till surface underneath it. Both surfaces show so many loose fragments or lumps of debris, that their release from the ice roof to the till suface is highly probable. Some odd fabric clusters that do not match the general fabric patterns in the microfabric diagrams from flutes at Breidamerkurjøkull (Boulton, 1976, Figs. 9 and 12) may have been derived from such fallen debris not discussed in Boulton (1976), but listed as examples of observed mechanisms for debris accumulation in subglacial cavities in Boulton (1980b). While Boulton (1980b, p. 1) lists "...falling of debris or debris-rich ice from the glacier onto the floors of subglacial cavities" as a glacial depositional process *(sensu stricto),* Boulton (1980a, p. 9) states that "...sediment ceases to be till if inter-granular stresses are reduced to the point where independent grain movement occurs..., or if this has occurred at some time in the aggregates "history". An obvious contradiction exists in these two statements, if applied to the fallen debris in subglacial cavities as constituent of the underlying diamict. According to Boulton (1980b), such debris would form till, but according to Boulton (1980a), it would not.

According to Lawson's (1981, p. 2) criteria, the debris fallen from the ice roof into a subglacial cavity would from a "nontill."

Is lodgement till a till at all?

The INQUA Till Work Group (at the Commission No. 2) defines lodgement as:

"...deposition of till from the sliding base of a dynamically active glacier by pressure melting and/or other mechanical processes." (Dreimanis, 1982, p. 24),

and all the other published definitions of lodgement or lodgement till *(sensu stricto)* are similar.

Though some glacial geologists have been questioning the lodgement process as a reality (for instance, at a till workshop meeting, Madison, Wisconsin, April 29, 1983), nobody, as far as I know, has expressed doubts about lodgement till being a true till.

However, if we strictly apply the criteria of Boulton (1980a) and Lawson (1981) to all the complexities of the formation of lodgement till, without even considering its postdepositional deformation possibilities, some doubts may be raised whether lodgement till is a true till, by applying their criteria. The crucial issue is in the participation of secondary resedimentation processes during lodgement.

While Boulton *et al.* (1974) discuss the dilation of lodgement till as a postdepositional process, Muller (1983a, p. 14) draws attention to the presence of dilated material continuously during the lodgement:

"Lodgement process is conceived as being multidimensional in that it takes place progressively through the interval of time and the thickness of the zone of deformation in which the dilatant debris-water system is transformed into lodgement till."

Muller (ibid., p. 17) concludes:

"Lodgement involves not only embedding clastic particles in a plastic substratum, but also the immobilization and collapse of a dilatant system through expulsion and escape of interstitial water."

As the interstitial water moves through the interconnecting pore channels,

"The result may be washing and sorting of the matrix immediately in contact with enclosed clasts. Thus Boulton (1975: 297), for instance noted an enrichment in fines immediately adjacent to large clasts in undisturbed lodgement till at Breidamerkurjøkull."

Boulton *et al.* (1974, p. 137-138, Figs. 2 and 3) demonstrate that dilation may occur during the lodgement of clasts against the surface of the underlying till, and cavities develop behind the clasts. Subglacial meltwater subsequently fills these cavities with rock flour, as I have seen in several sections of Pleistocene tills, and some of these fines may also fill the nonvisible voids in the adjacent dilated till.

Haldorsen (1983, p. 24) makes the following statement resulting from mineralogic and geochemical investigation of basal tills.

"All basal deposition of till, even by lodgement, obviously includes a melt-out process which results in the production of water. Each meltwater component may affect a winnowing of fine-grained till material, even in cases where no sorting is visible. The meltwater influence is then a syngenetic process clearly related to the till deposition."

If meltwater participates by washing or resedimentation during the lodgement of till, then neither of the following strict conditions stipulated by Boulton or Lawson would permit calling the lodgement till a till:

(1) Boulton (1980a, p. 11): "Till is a sediment whose components are brought into contact by the direct agency of glacier ice."

(2) Lawson (1981, p. 2): Till is "...sediment deposited directly by the glacier ice that has not subsequently undergone disaggregation and resedimentation."

CONCLUSIONS

The basal melt-out and lodgement tills from present-day glaciers discussed in this paper have been deposited essentially by primary glacial processes as defined by Lawson (1981). However, some fines of their matrix, particularly silt and clay particles, either have been washed out or infiltrated from the subsole meltwater, or moved from one part the till to another penecontemporaneously, probably mainly shortly after the deposition of the older parts of the subglacial tills discussed. Since the deposition of both basal melt-out till and lodgement till is time-transgressive, the participation of the secondary processes may continue during the entire deposition of the till unit, or may be disrupted by conditions that inhibit the participation of the secondary "non-glacial" processes.

In the more specific case of the formation of flutes along the surface of lodgement till, glacially induced flow of the dilated water-saturated till under the pressure of the overriding glacier ice is probably the main mechanism for this post-depositional redeposition of till. Falling or flowing of glacial debris into the flute-forming cavity may have contributed to the formation of the flutes. While the glacially induced flow of the dilated till may be considered as a result of primary process (the opinions as to its primary or secondary nature may differ), the falling and flowing of glacial debris into the cavity and the probable infiltration of fines into the dilated till in the flute are caused by secondary processes.

Thus we can not exclude the possibility of participation of secondary processes during the formation and penecontemporaneous resedimentation of the lodgement and melt-out till. The theoretical criteria proposed by Boulton (1980a) and Lawson (1981) for the separation of "tills" from "non-tills" may apply to some end-members of the tills where the participation of secondary processes is absent or near-absent. However, the results of their own investigations of glacial deposition at the present-day glaciers demonstrate that their criteria for the differentiation of "tills" from "non-tills" are too rigid to be generally applicable. The uniqueness of the glacial environment, emphasized by Lawson (1981, p. 2) is most probably not represented by the exclusive activity of the primary glacial processes, but the primary glacial processes are also supplemented with secondary non-glacial ones to various degrees. The emphasis should be placed more on their interrelationship in a *glacial environment*, in contact or near-contact with a glacier.

We may still not be aware of all the mechanisms that participate in the formation and deposition of till. Therefore it is preferable, for now at least, to adhere to a general definition of till that is in agreement with our present day knowledge on glacial sedimentation and has some flexibility, such as the definition adapted by the Till Work Group of the INQUA Commission on Genesis and Lithology of Quaternary Deposits (Dreimanis, 1982, p. 21), with the word "subsequent" added for greater clarity on the transition from the transport to the deposition:

"Till is a sediment that has been transported and (subsequently) deposited by or from glacier ice, with little or no sorting by water."

Still, a question may be asked: what specific genetic name to assign to the till in the flutes? That is beyond the scope of this topic, but whatever name is assigned, this till is part of subglacial or basal till category in the English language terminology.

REFERENCES

BOULTON, G.S., 1975: "Processes and patterns of subglacial sedimentation: a theoretical approach". *In* A.E. Wright and F. Moseley, eds. *Ice ages ancient and modern,* Liverpool, Sul House Press, pp. 7-42.

–, 1976: "The origin of glacially fluted surfaces observations and theory". *Journal of glaciology,* 17: (76): 287-309.

–, 1978: "Boulder shapes and grain size distribution of debris as indicators of transport paths through a glacier and till genesis" *Sedimentology,* 25: (6): 773-799.

–, 1980a: "Classification of till" *Quaternary Newsletter,* (31): 1-12.

–, 1980b: "Subglacial processes and the development of glacial bedforms", *in* R. Davidson-Arnott, W. Nickling, B.D. Fahey, eds., *Research in glacial, glacio-fluvial, and glacio-lacustrine system,* Proceedings of the 6th Guelph Symposium on Geomorpohology, 1980, Norwich, Geo Books, p. 1-31.

–, and Dent, D.L., 1974: "The nature and rates of post-depositional changes in recently deposited till from south-east Iceland" *Geografiska Annaler,* 56: ser. A: 121-134.

–, Dent, D.L. and Morris, E.M., 1974: "Subglacial shearing and crushing, and the role of water pressures in tills from South-East Iceland: *Geografiska Annaler,* 56, ser. A: 135-145.

DERBYSHIRE, E., 1980: "The relationship between depositional mode and fabric strength in tills: shema and test from two temperate glaciers", *in* W. Stankowski, ed., *Tills and glaciagene deposits,* Univ. A. Mickiewicza W. Poznaniu, Ser. Geografia, 20: 41-48.

DREIMANIS, A., 1982: "Genetic Classification of Tills and Criteria for their Differentiation: Progress report on activities 1977-1982, and definitions of glaciogenic terms", *in* Schluechter, Ch., ed., *INQUA Commission on Genesis and Lithology of Quaternary Deposits,* Report on Activities 1977-1982, Zuerich, ETH, p. 12-31.

–, and Lundquist, J., 1984: "What should be called tills?", *in* L.K. Konigsson, ed., *Ten years of nordic till research, Striae,* 20: 5-10.

FLINT, R.F., 1971: "Glacial and Quaternary Geology", New York, John Wiley and Sons, 892 p.

HALDORSEN, S., 1983: "Mineralogy and geochemistry of basal till and their relationship to till-forming processes", *Norsk Geologisk Tidskrift,* 63: 15-25.

LAWSON, D.E., 1979: "Sedimentological analysis of the western terminus region of the Matanuska Glacier, Alaska", CRREL Report 79-9, 112 p.

–, 1981: "Sedimentological characteristics and classification of depositional processes and deposits in the glacial environment", CRREL Report 81-27, 16 p.

LUNDQUIST, J., 1976: "Significance of investigation in glacial deposits, *in* W. Stankowski, ed., *Till, its genesis and diagenesis,* Univ. A. Mickiewicza W. Poznaniu, *Ser. Geografia,* 12: 178-180.

MULLER, E.H., 1983: "Dewatering during lodgement of till", *in* E.B. Evenson, Ch. Schluchter, J. Rabassa, eds., *Tills and related deposits,* Rotterdam, A.A. Balkema, p. 13-18.

–, 1983b: "Till genesis and the glacier sole", *in* E.B. Evenson, Ch. Schluchter, J. Rabassa, eds., *Tills and related deposits,* Rotterdam, A.A. Balkema, p. 19-22.