

Fig. 6. Snow stratigraphy and displacement patterns beside a 6 in [0.15 m] diameter, close-ended steel pile driven 10.1 ft [3.1 m] below the trench floor. The snow structure was highlighted by illuminating the snow from within a borehole behind the pile. The near-vertical dark line on the right side of the pile at about the middle of the composite photograph is a chain-saw cut.

a report on pile foundations by Kovacs (1976). The photographs presented here are only intended to give an indication of the results that can be obtained from first planing smooth the surface of a snow-pit wall and then applying a dye to reveal snow structure. Each investigator will need to develop, through trial and error, the procedure best suited to producing a good view of the snow structure.

In our field program, we did not obtain satisfactory results using a dye of methanol coloring in water. Freeze-up at the sprayer nozzle was one problem and the snow surface had a blemished appearance because of the addition of the water, which then froze. Freeze-up may not be a problem at elevated temperatures, say above about  $-3^{\circ}\text{C}$ . However, the addition of water to the surface may cause undesirable snow modification. A methylene-colored alcohol dye does not do this because much of the alcohol evaporates.

It should be pointed out that one should be careful when handling the methylene-dye powder, as it is a difficult dye to remove from hands and clothing.

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*The accuracy of references in the text and in this list is the responsibility of the author, to whom queries should be addressed.*

SIR,

*The use of computer-aided learning packages in glaciology and glacial geology*

One of the recent changes in computing has been the development of more user-friendly computer environments. One specific example is the development of HyperCard (discussed in detail in Nielsen (1990)), which provides development tools for interactive packages which are ideal for developing computer-aided learning (CAL) programmes. These have been developed for

many subjects (e.g. Geographical information systems: Raper and Green, 1992; Art history: Saywell, 1992; Computer-aided design, Delisle and Schwartz, 1986; English literature: Friedlander, 1988) but as yet there have been few within the field of glaciology and glacial geology. The latter includes one demonstrated by Morgan in 1992 at the annual conference of the Geological Society of America, and one produced by ourselves called "The analysis of glacial sediments" developed for the teaching of glacial sedimentology to university-level students (Hart and Martinez, 1992). We feel that there is great potential for creative CAL development in glaciology and glacial geomorphology, as it is easy (although time-consuming) to generate and provides a simulating learning experience for students. In this letter, we briefly outline the stages of production of a CAL program and the students' reaction to it, using our programme as an illustration.

There are two major proprietary systems for CAL programming; HyperCard, which runs on a Macintosh, and Toolbook (by Asymetrix) which runs on IBM PC compatibles (using Microsoft Windows). Our particular program was developed in HyperCard and runs on a Macintosh SI or above (with 2 megabytes of RAM). It includes colour images and so a system with a colour display, with at least 256 colours, is required. HyperCard (or Toolbook) can be used to make programs which are like interactive books (called *stacks*), comprising pages (*cards*) which can contain text, graphics and images.

Our CAL program uses photographs, animation and text to explain different aspects of glacial sedimentology. It illustrates graphical techniques to interpret different types of tills and related glacial sediments, and discusses in detail the different methods of till-fabric analysis. These techniques are taught through an interactive system that is, at every stage throughout the program the student is required to do something, in order to promote active learning instead of passive reading. This system is designed to be used by students at a variety of levels. Complete beginners can work through the stack progressively as there are specific "chapters" accessible through the index page (Fig. 1). Higher-level users can use the stack as a refresher course, or work through specific sections, e.g. how to plot till-fabric data in three-dimensional projections.

There are three stages to producing a CAL program: (i) planning, (ii) programming, and (iii) data input. The planning stage is very important as the contents and structure have to be chosen. The style of interactivity also has to be determined and this can determine how much programming will be required.

There are different levels of programming within the stack. HyperCard uses a programming language called HyperTalk (Goodman, 1990; Winkler and Kamins, 1990). The simplest level of programming (which is easy to learn) is the connection of one card to another, e.g. used when one presses the *forward* button (Fig. 2). If the

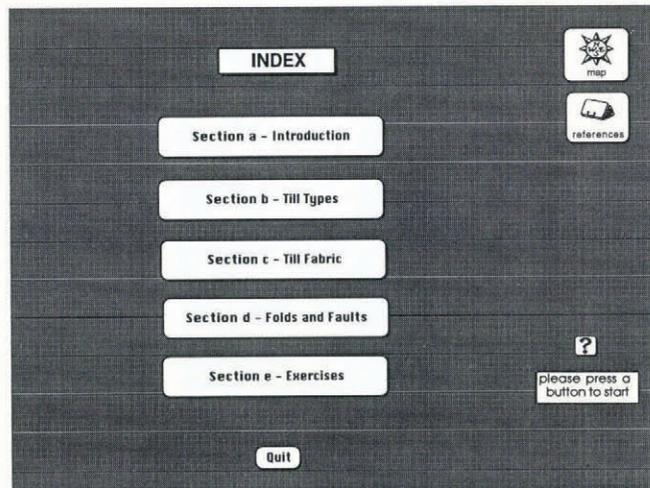


Fig. 1. The INDEX card showing the five sections within the stack, and the "quit", help ("?"), "map" and "references" buttons.

cards are displayed sequentially, they give the impression of animation; a simple example of this is the demonstration of a melting glacier and the resulting sediments. However, the more interesting interactivity requires a higher level of programming, which is more complex to learn but produces such good results that it makes the extra time-input worthwhile. At each stage of programming development, the functions have to be tested extensively to ensure that no sequence of actions can leave a card (or the users) in an unexpected state.

Acquiring the images and graphics required can be a long process. Colour slides were scanned using a Nikon LS3500 slide scanner and Photoshop. After scaling, retouching and cropping, these were compressed from 24 bit colour to 256 selected colours (by the adaptive-diffusion technique) and saved as PICT files. This is necessary, because most colour Macintoshes can only display 256 colours, but it also makes the files one-third the size and hence faster to display. Some monochrome diagrams were scanned with a grey-scale Apple flat-bed

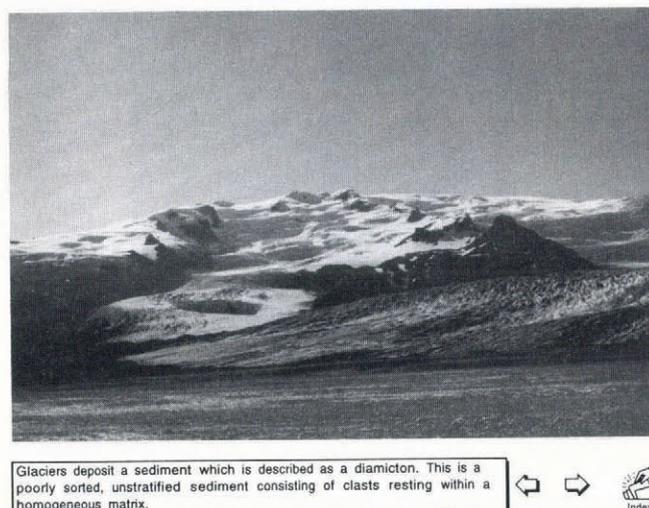


Fig. 2. The first card in the INTRODUCTION section, showing the general lay-out of the cards, with the card name in the top lefthand corner (card introduction 1), the forward and backward buttons and the index button. This is a colour photograph in the stack.

\*Details of the stack discussed in this letter are available in the "public domain" and available on request.



hopefully encourage students to develop a further interest in studying glaciology and glacial sedimentary processes.

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SIR,

### *Ice blisters and ice dolines*

In a recent letter to the Editor of *Journal of Glaciology*, Kovacs (1992a) gave a very comprehensive review of observations and morphology of ice blisters on glaciers, sea ice and rivers. Kovacs (1992a, b) gave many examples of ice blisters from Alaska and Antarctica, where they are generally observed in association with the ready availability of liquid water (Fig. 1). Ice blisters are usually 5–20 m across and 1–3 m high, although Echelmeyer and others (1991) estimated that some of the examples they observed on Jakobshavn Isbræ, West Greenland, were up to 8 m high. Kovacs (1992b) discussed their formation by the freezing of water trapped within ice which expands and forces up the ice cover, in an analogous way to the cream on top of a frozen bottle of milk. Many ice blisters are hollow inside with evidence for the release of water provided by the presence of refrozen water-icings around the ice blister. The drilling of many blisters reveals the presence of liquid water in their core.



*Fig. 1. Ice blister in a melt pool on the Koettlitz Glacier Ice Tongue (McMurdo Sound, Antarctica) surrounded by summer meltwater. The ice blister is about 12 m across and 0.5 m high. (Photograph by courtesy of A. Kovacs, CRREL.)*

I should like to draw attention to a class of features, ice dolines (sometimes known as ice calderas) that appear to be very similar to ice blisters, except that they are much larger, being of the order of kilometres in diameter and perhaps tens of metres deep. Mellor (1960) suggested the term doline for the features from their similarity to subsidences which occur in karst country after the collapse of underground chambers. Several examples of this type of feature were seen on George VI Sound, West Antarctica, in 1936 during the British Graham Land Expedition. Stephenson and Fleming (1940) described the largest doline as being a bowl “nearly a mile across, bordered by ice cliffs 100 ft high”; they suggested the term “ice caldera” for the feature (Fig. 2). The bottom of the bowl contained piles of angular ice blocks up to 12 m high. Fleming and others (1938) described the mounds of material in the caldera as consisting of “slabs of radially cracked ice tilted upwards to meet in a point”. Stephenson and Fleming (1940) stated that “it looked as if there had been an enormous hollow dome that has suddenly collapsed”. Similar features were also seen in that area by Byrd (1947), who suggested that they may have formed by the explosion of gas trapped within the ice. There is no generally agreed explanation for the origin of ice dolines, one explanation being that they are impact craters, another that they are melt lakes that drain intermittently to the sea beneath the ice shelf (Swithinbank, 1988). The ice shelf in the area near the doline is about 175 m thick (Crabtree, 1983), if the bottom of the doline was about 30 m below the surrounding ice shelf as has been suggested by the observations of Stephenson and Fleming (1940), then assuming the ice shelf is in hydrostatic equilibrium, the bottom of the doline would have been below sea level, allowing for drainage through basal fractures. Reynolds (1983) believed that the largest doline on George VI Ice Shelf described by Stephenson and Fleming (1940) was mapped in 1949 (Searle, 1960) and was roughly circular with a diameter of 1.5 km. Further observations of this feature in the 1960s and 1970s showed a gradual deterioration of surface definition and, by 1979, only the outline of the doline was clearly visible