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A MAJOR CALVING EVENT OF JAKOBSHAVNS ISBRÆ, WEST GREENLAND, ON 9 AUGUST 1982

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ABSTRACT. On 9 August 1982, the calving of a large ice mass, approximately 0.3 km × 1.5 km in size, from Jakobshavns Isbræ was filmed. The event, which took place as the tide was rising, is described by means of picture sequences from the ciné film. First, a large transverse crevasse opened in the glacier. The subsequently detached piece then split into large blocks which toppled forward one after the other in the direction of the fjord, so that finally large, clean ice slabs lay in front of the glacier terminus. The tilting ice blocks pushed the whole mass of fjord water, together with the ice debris which floated on it, in the direction of the sea. The tilting processes had terminated after approximately 8 min. Then a wave which had been reflected farther out in the fjord returned to the break-off zone, where it caused the formation of a large amount of ice debris and high jets of water.

ON the morning of 9 August 1982, I witnessed a major calving event of Jakobshavns Isbræ which terminates in Isfjord, east of Disko Bay, West Greenland. Weather conditions were superb. A large part of the calving was recorded by means of an 8 mm ciné camera. Since such events can only rarely be documented on ciné film, sequences of the film are presented below despite their relatively poor resolution (dimensions of the original frames: 5.3 mm × 4.2 mm). The sequence of events can be reconstructed on the basis of the shots taken at the times I–VIII. Times I, VII, and VIII were recorded directly (local time of Jakobshavn), whereas times II–VI were determined on the basis of positions on the film strip and estimated lengths of interruptions between the scenes.

Time		*Figure No.*
I	08 h 40 min	1
II	*c.* 08 h 42 min	
III	*c.* 08 h 42 min 10 s	3a
IV	*c.* 08 h 44 min 00 s	4a
V	*c.* 08 h 44 min 35 s	5a
VI	*c.* 08 h 49 min 30 s	5d
VII	08 h 50 min	2
VIII	08 h 55 min	

At times I, VII, and VIII, additional pictures were taken with a Leica 24 mm × 34 mm camera (Figs 1 and 2). Picture sequences starting at times III, IV, and V were enlarged from the ciné film. The time differences between Figures 3, 4, and 5 were determined to the nearest 1/8 s by counting frames. The ciné film initially advanced at a rate of 16 frames/s, but after time III at 8 frames/s.

At 08.00 h, I flew as a tourist on board a helicopter from Jakobhavn airport (Jlulissat) about 45 km west over Isfjord towards the front of Jakobshavns Isbræ. The calving front was at least 6 km long and lay at approximately long. 50°00′ W. The fjord was filled with numerous icebergs from its mouth in Disko Bay all the way to the glacier. Only in the middle section of the fjord was some open water visible between the icebergs. The rest of the water in the fjord was covered by a practically continuous layer of ice debris. The ice blocks were probably mostly clean and quite small; only occasionally could dirty patches be seen. Two types of iceberg were distinguishable: first, there were relatively large, tabular icebergs with almost vertical edges and dirty grey upper surfaces which had many vertical crevasses. These were clearly detached sections of the glacier front floating in their original vertical orientations. The second type were mostly clean with only very little morainic material, and were white to blue in colour. Smaller icebergs of this type had irregular shapes; the larger ones were frequently several hundred metres long and also had tabular shapes. After observing the glacier front, it became clear that the tabular icebergs of the second type were also originally vertical parts of the glacier tongue, but in this case had tilted after becoming detached from the glacier.

At about 08.30 h we landed on the ridge 1.5 km north-west of the glacier terminus. Here, at about 200 m a.s.l., the view towards the south-south-east was as shown in Figure 1. The distance to the farther glacier margin (centre of the picture) is approximately 14 km. The nearer, northern margin is hidden behind the ridge in the foreground. However, the near margin could be seen from position A. The calving front is, according to Anon. (1985),

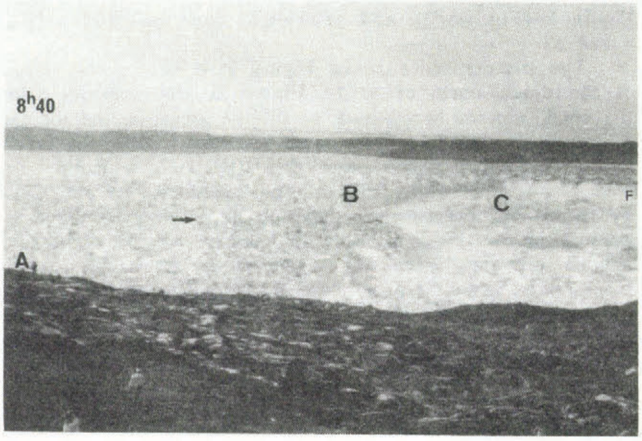

Fig. 1. Leica photograph at 08.40 h. View towards the south-south-east across Jakobshavns Isbræ. Distance to far glacier margin is approximately 14 km. During the subsequent calving, the piece of glacier in front of the crevasse between B *and* A *became separated. The wall* B–C *is approximately 70 m high. To the right is the fjord surface covered with ice debris. The northern, near margin of the glacier is hidden behind the ridge in the foreground.*

approximately 70 m high and trends in a roughly north–south direction in the section B–C. Starting at C, the front trends in an east–west direction for some distance, and it was estimated to be 100 m high in this section.

At 08.40 h, a crevasse became visible which started at the angle B in the calving front and extended in a northerly direction as far as the arrow in Figure 1. The crevasse formed a continuation of the front segment B–C. During the next 10 min, the crevasse lengthened rapidly towards the north. Subsequently, the part in front of the crevasse separated from the glacier. Figure 2 shows the situation at 08.50 h, as seen from position A. Close to the

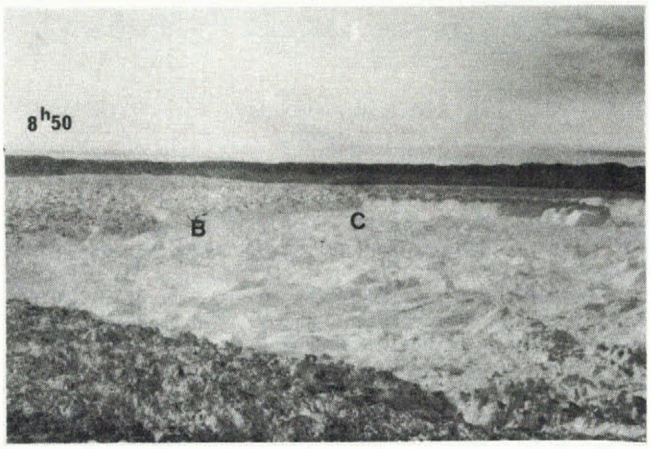

Fig. 2. Leica photograph at 08.50 h taken from position A. *The part of the glacier which was still intact in Figure 1 has now disintegrated into large blocks. These toppled over during an 8 min time interval and can now be seen as clean slabs lying next to each other in the water of the fjord.*

near glacier margin, a section of the glacier remained (lower left). Behind this, a 300 m × 1500 m large block had "disappeared". The sequence of events was as follows: at about 08.42 h, loud bangs resembling cannon shots were heard and, in the fracture zone north of B, movements could be seen (cracks becoming larger, pieces falling from the cliff). In addition, the crack lengthened rapidly and white jets (water or water–ice mixture?) shot out from it. From this moment in time (III) onwards, sections of the events were filmed, first from the same position as that in Figure 1 (Fig. 3a–d), and afterwards from position A (Figs 4 and 5).

The picture sequence in Figure 3a–d shows the section of the crack north of B. In Figure 3a jets spouting from the crack can be recognized as diffuse areas in the picture. A transverse lamella of ice was observed within the crack, and Figure 3b–d shows how this lamella subsequently fell over towards the right. This motion can easily be pinpointed by comparing the lamella's position in relation to the fixed point D on the stable part of the glacier. At the same time, another crevasse opened at E across the near side of the main crack. Simultaneously, the block of ice H to the right of the new crevasse first shot up vertically (Fig. 3a–d) and then toppled over to the right (Fig. 4a–d). Its original upper surface (rough and moraine-covered) tipped over into a vertical orientation; the crevasse wall became a horizontal, snow-white, tabular surface. During the opening of this crevasse, smaller sections of the wall continued to fall down. Rocks and smaller morainic debris slid off the old glacier surface at H which became steeper and steeper.

During the rotation of block H, more crevasses opened in the newly separated section of the glacier and, as a result, blocks J and K became free (Fig. 4). These then fell over, one after the other, like falling dominoes; their rotational axes were slightly different from each other (Fig. 4b–d). Within 2 min 40 s (Figs 3a–5b), block H had rotated completely by 90° and now lay flat. Even faster was the rotation of block L (Fig. 5), whereas block J tipped

a
b
c
d

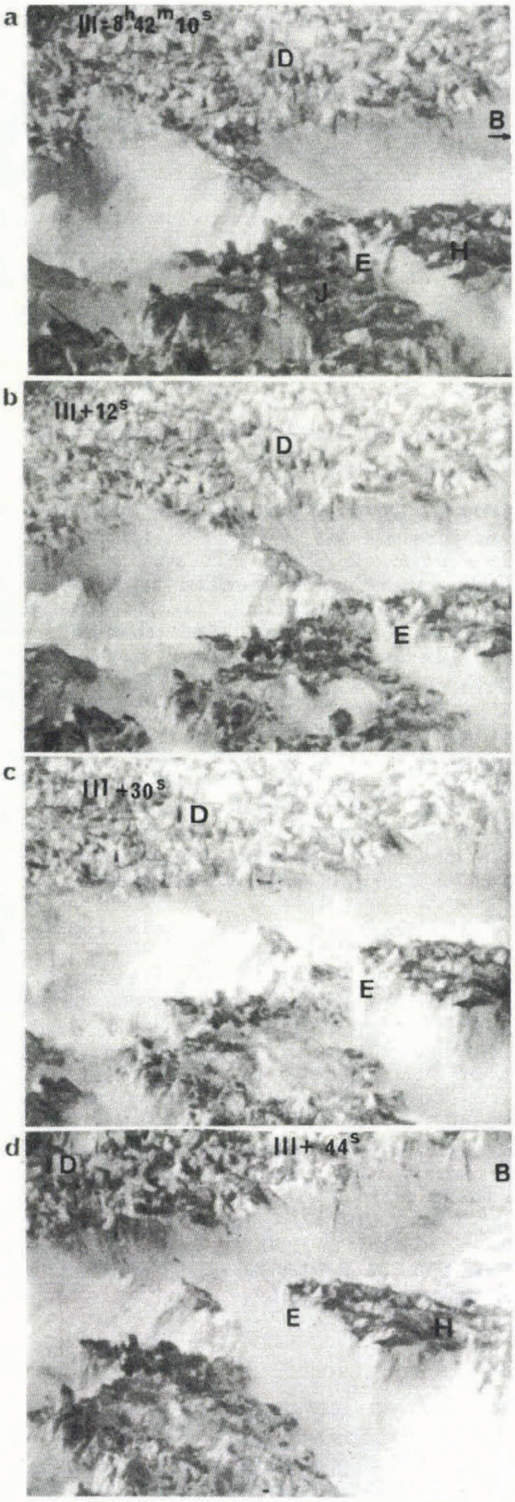

Fig. 3. Picture sequence from the ciné film (original frame size 5.3 mm × 4.2 mm). Areas to the immediate north of point B *(cf. Fig. 1), taken from position* A. *Upper half of image: stable glacier; from right to left: transverse crevasse opening, in which can be seen a cross wall (Fig. 3a) that tilts slowly towards the right (Fig. 3b–d); note the fixed point* D*). The right-hand section of the near part of the glacier is also divided by a crevasse. The ice block* H *on the right with the corner* E *first shoots up to at least 70 m (Fig. 3b and c) whereupon it starts to tilt towards the right. Water jets rise from the crevasses. The time intervals between the frames were determined from the speed of the ciné film (Fig. 3a = time III = 08 h 40 min 10 s; Fig. 3d = 44 s later).*

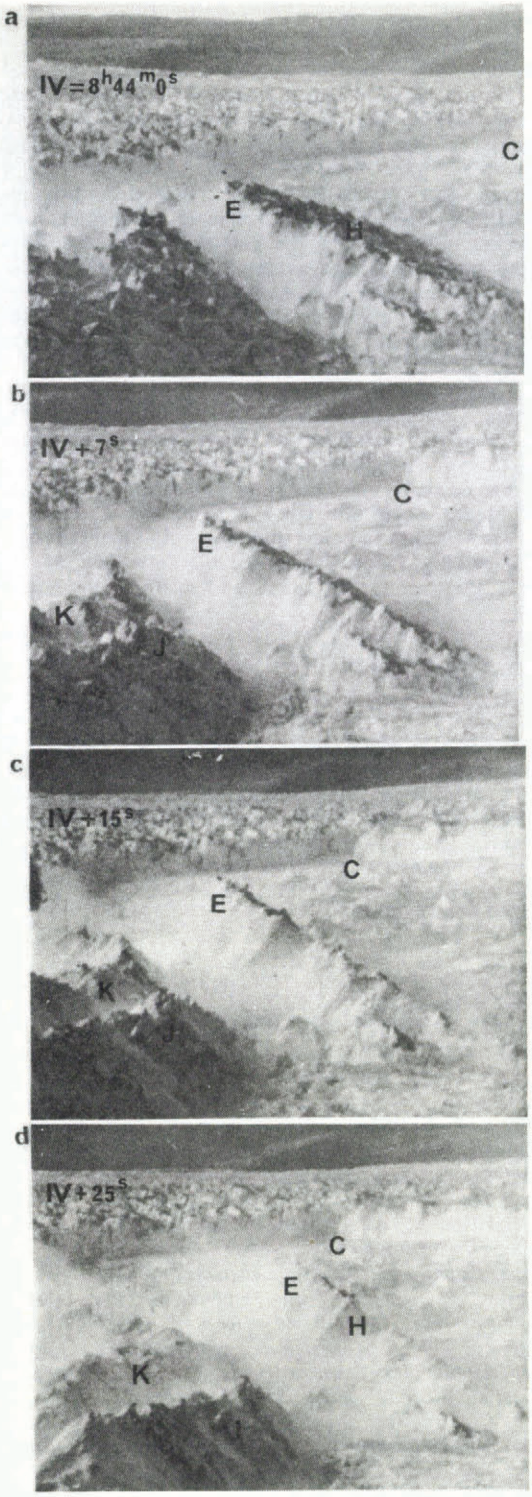

Fig. 4. Position as in Figure 3 but about twice the angle of view. Figure 4a: 76 s after Figure 3d. Block H *continues to tilt towards the right. Simultaneously, more crevasses form in the near-left area of the glacier. Formation of the blocks* J, K, *and* L *which also begin to tilt.*

relatively slowly. Within about 7 min, not only did the part which had become separated from the glacier by the main fissure disintegrate into blocks, but these blocks had also toppled over. Afterwards, they all lay as large white slabs, several hundred metres across, closely packed together in the fjord (Fig. 2). Their surfaces were relatively smooth and very clean. Quite a small piece originating from the glacier margin (lower right in Figure 2) moved out into the fjord without tipping over.

During the formation of the blocks and the tilting processes a loud noise was heard, accentuated by thunder claps which were probably caused by the opening of the crevasses. Many white jets of water shot up here and there, especially at the calving front C–B (Fig. 5b and c), where they reached heights of at least 200 m.

At the same time as the rotational movements of the blocks became prominent, the layer of ice debris in the fjord in front of the original glacier front started to move.

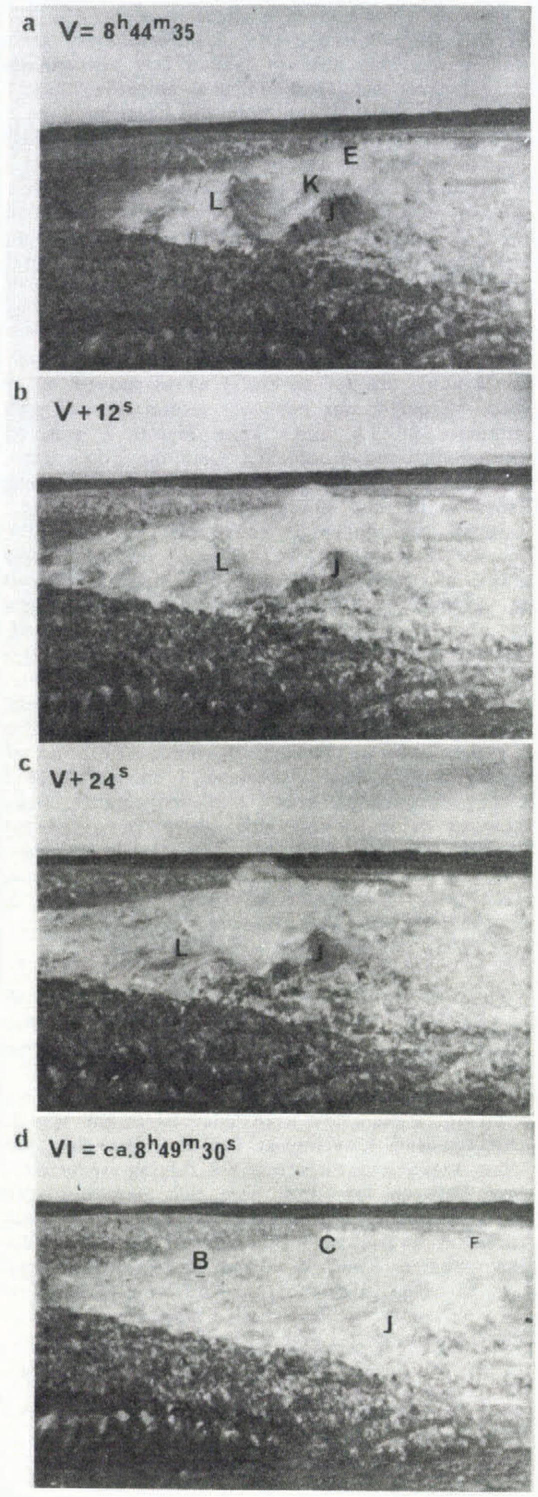

Fig. 5. Position as in Figure 3. Angle of view considerably larger than in Figure 3. Block H *tilts further, and 2.5 min after its separation has already rotated by 90° (Fig. 5b). The picture sequence in Figure 5a–d shows that the blocks* H *(with corner* E*),* J, K, *and* L *tip over with somewhat differently oriented horizontal axes. Block* L *rotates very rapidly, block* J *most slowly. Figure 5b shows a water jet at the former calving front* B–C. *Figure 5d was taken 0.5 min before Figure 2.*

The motion was (a) quite turbulent in the vicinity of the tilting processes, and (b) homogeneous, almost like a continuous, rigid carpet in a direction further out towards the fjord. The ciné film shows that the carpet of ice debris (which was already present before the start of these events) had not piled up in front of the moving blocks. This means that the blocks did not exert a ploughing action on the ice debris but rather that they worked on the water in the fjord, pushing it forward as a single mass.

At this stage in the events, I unfortunately ran out of film and I was only able to take a few still photographs. These document that from 08.50 h onwards there was a relatively quiet phase in the break-off/rotation zone. Shortly before the return flight, one last picture was taken (time VIII). This shows that at 08.55 h there was again intense movement in the debris area. In the vicinity of blocks J, K, and L, large displacements of the icebergs can be observed compared to Figure 2 (08.50 h). In addition, high wide clouds from water jets can be seen in the area south of B and west of C. These phenomena document the terminal stage of the events but I was unable to observe it sufficiently accurately.

Shortly after the widening of the main crack (i.e. around 08.42 h), one (or several?) waves moved out through the fjord. Its height was probably several tens of metres. At approximately 08.53 h, soon after Figure 2 was taken, a high but shallow wave returned from the outer part of the fjord. When it reached the calving front, the water level there rose to at least 30 m, approximately half-way up the front. Spray jets shot high above the front (08.55 h). The wave caused the tilting blocks to crash into each other, and the sound of ice being ground into fine debris was most evident. Therefore, it appears that the fine ice debris was formed mainly in the final stage by the reflected wave. This reflection of the wave might have occurred at the ice barrier at the mouth of the fjord.

It is interesting to note that calving events from tide-water glaciers can be initiated by tidal variations in sea-level, which exert a varying buoyancy force on the ice. During my stay in West Greenland, I unfortunately did not gather any information about tidal movements. Because of the lack of a registering tide gauge in Jakobshavn, no records are available. However, Mr D. Christensen of the Nautical Department of the Meteorological Institute of Denmark later calculated the tidal movements on 8–9 August 1982 for me. The following deviations from normal sea-level (0 m) at Jakobshavn were calculated:

8 August 1982:	high tide at 23.04 h;	1.20 m above 0 m;
9 August 1982:	low tide at 05.16 h;	0.85 m below 0 m;
	high tide at 11.20 h;	0.45 m above 0 m.

Therefore, during the night before the calving event described above, a relatively high tidal maximum was followed by a surface-level lowering of 2.05 m. After this, the water level rose again, and therefore the calving occurred roughly half-way between low and high tide. Possibly, the crack visible in Figure 1 and north of B had formed during the marked water-level change the night before. I was unable to establish whether, and to what extent, the water-level changes at the calving front differed from those in Jakobshavn. Contrary to the earlier view that Jakobshavns Isbræ flows over bedrock all the way to the calving front (e.g. Bauer, 1968), it now appears certain that the lower parts of this glacier are afloat for several kilometres. Kollmeyer (1980) was able to measure half-daily vertical oscillations of the glacier surface of up to 1.8 m at a distance of 1 km up-glacier from the calving front. Echelmeyer and Harrison (1985) established tide-induced surface-altitude variations of 1.5–3 m at the glacier terminus. The vertical movements of the glacier surface, therefore, are about the same magnitude as the tide-water level variations. This supports the fact that the end of the glacier tongue is afloat. Since the glacier surface displays many transverse crevasses, conditions are good for the widening of these into large calving fissures. The tide-induced stresses at the ends of the crevasses are periodically reversed – a process which can, according to the laws of fracture mechanics, lead to sudden extensions of these cracks. According to Kollmeyer (1980), Jakobshavns Isbræ is probably cold. Ice below the pressure melting-point is brittle, so that smooth vertical breaks occur through the glacier as a whole. Bauer (1968) gave 750 m as the thickness of Jakobshavns Isbræ near the calving front. Therefore, the formation of tabular-shaped icebergs, several hundred metres high, is quite possible.

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