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Basal conditions of Kongsvegen at the onset of surge: revealed using seismic vibroseis surveys

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Motivation

Kongsvegen is a well-studied surge-type glacier in the Kongsfjord area of northwest Svalbard (Fig. 1). Long-term monitoring has shown that the ice surface velocity has been increasing since around 2014 (Fig. 2); presenting a unique opportunity to study the internal ice structure, basal conditions and thermal regime, all of which play a crucial role in initiating glacier surges.

In April 2019, three-component seismic vibroseis surveys were conducted at two sites on the glacier, using a small Electrodynamic Vibrator source (ElViS). **The aim of the study is to image and quantify the basal conditions and sub-ice structure beneath the glacier at the onset of a surge phase**, with a view to better understanding the physical factors affecting ice dynamics.

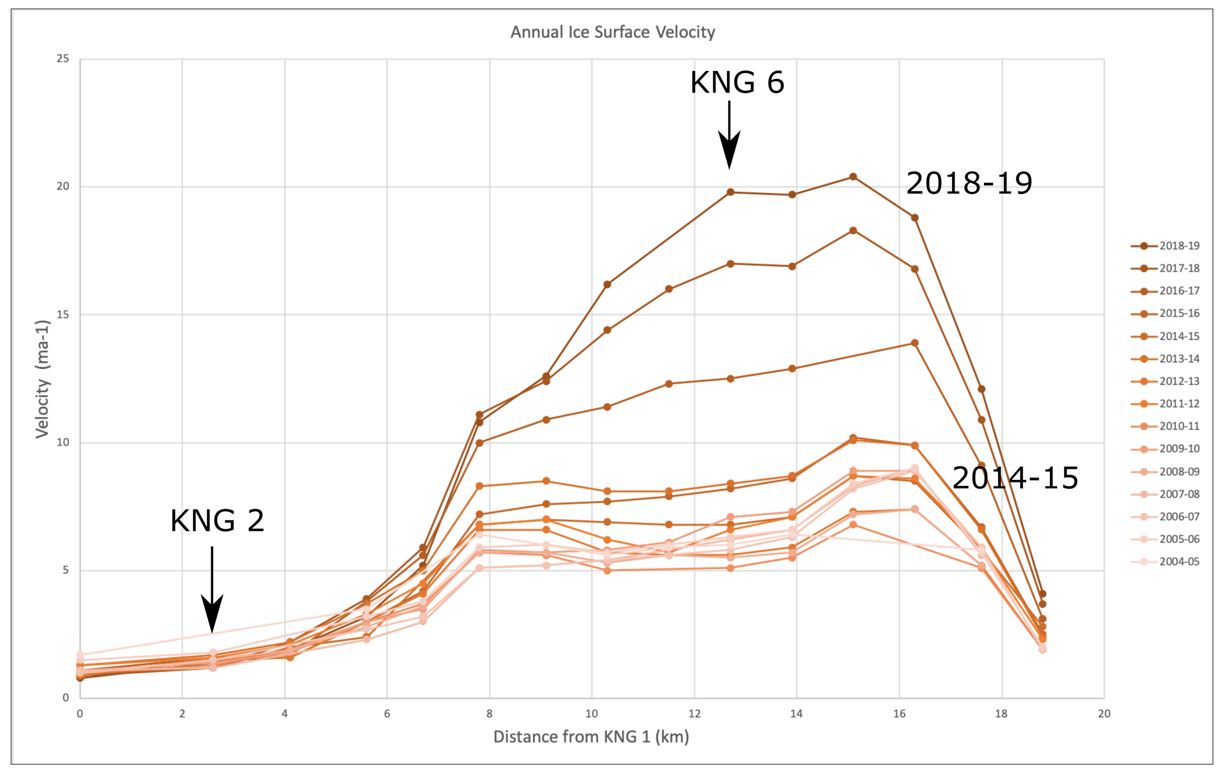

Figure 2: *Annual ice surface velocities of Kongsvegen from 2004- 2019, measured at a series of surface mass-balance stakes (Fig. 1). Rapid inscrease in ice surface velocity begins around 2014, with maximum increase around KNG 6 and almost no increase around KNG 2.*

Data: Seismic Vibroseis

Seismic vibroseis data were collected at two sites: site 1 near KNG 2 (Fig. 1) in an area where little change in ice surface velocity has been observed (Fig. 2) and site 2 near KNG 6, where the greatest change in ice velocity has been observed. Surveys were targeted at areas of the bed known to be flat from radar measurements.

Seismic Source: ElViS - small electrodynamic vibrator (Fig. 3), sweep frequency 30-360 Hz, shot point interval 5 m (inside array) and 10 m (at far offsets).

Receivers: 24 x 3-component geophones, 5 m geophone interval.

Recording Parameters: 10s sweep time + 2s listening time, sample interval 0.05 ms.

Figure 3: *Electrodynamic Vibroseis source - ElVis. Seismic waves are trabsmitted inot the ground via a vibrating plate (red arrow). Once a sweep has been made the source is moved forward by lifing the plate and pushing forward, much like a wheel barrow*

Location

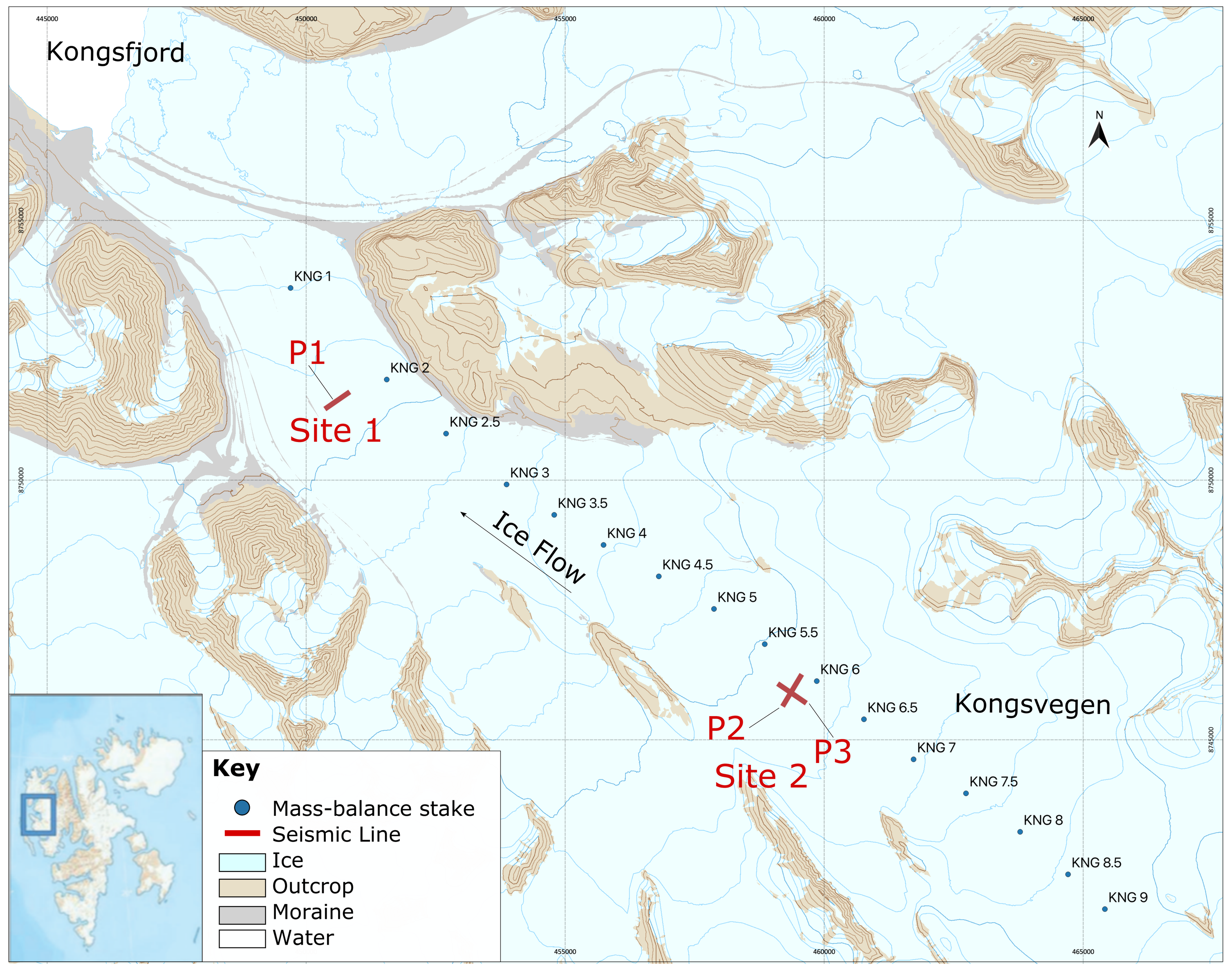

Figure 1: *Location of survey on Kongsvegen, Svalbard. Kongsvegen is a marine terminating glacier that flows out into Kongsfjord. Mass-balance measurements have been made here since 1987, current stake locations are shown (blue points). Seismic profiles were acquired at two sites. At site, a single cross-flow profile was made (P1) and at site 2 both cross-flow (P2) and along-flow (P3). Profile locations are shown as red lines.*

Key Findings

- Site 1 - ice is 220 m thick (Fig. 4), bed is relatively flat and uniform, underlain by sediment package ~60 m thick.
- Site 2 - the ice is 390 m thick (Fig. 5), cross-cutting layers below bed, reflections in the 100 m above the bed indicate there could be shearing or sediment entrainment.
- Site 2 - Internal ice reflection at around 150 m depth could indicate ice fabric or temperature transition (Fig. 5)
- Site 2 - Possible change in bed reflection polarity – suggesting water or very wet sediment (Fig. 5).
- Seismic source works well on glacier, able to reach depths of over 500 m through ice, into the bed material.

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Results

Seismic P-wave data recorded on the vertical geophone component were filtered to remove surface waves before being stacked and depth converted, using a seismic velocity of 3600 m/s. Initial data processing shows exciting results - further work on these data promises to reavel much more! All data shown here are unmigrated, depth converted, stacked sections.

Site 1 - area of little change in surface velocity

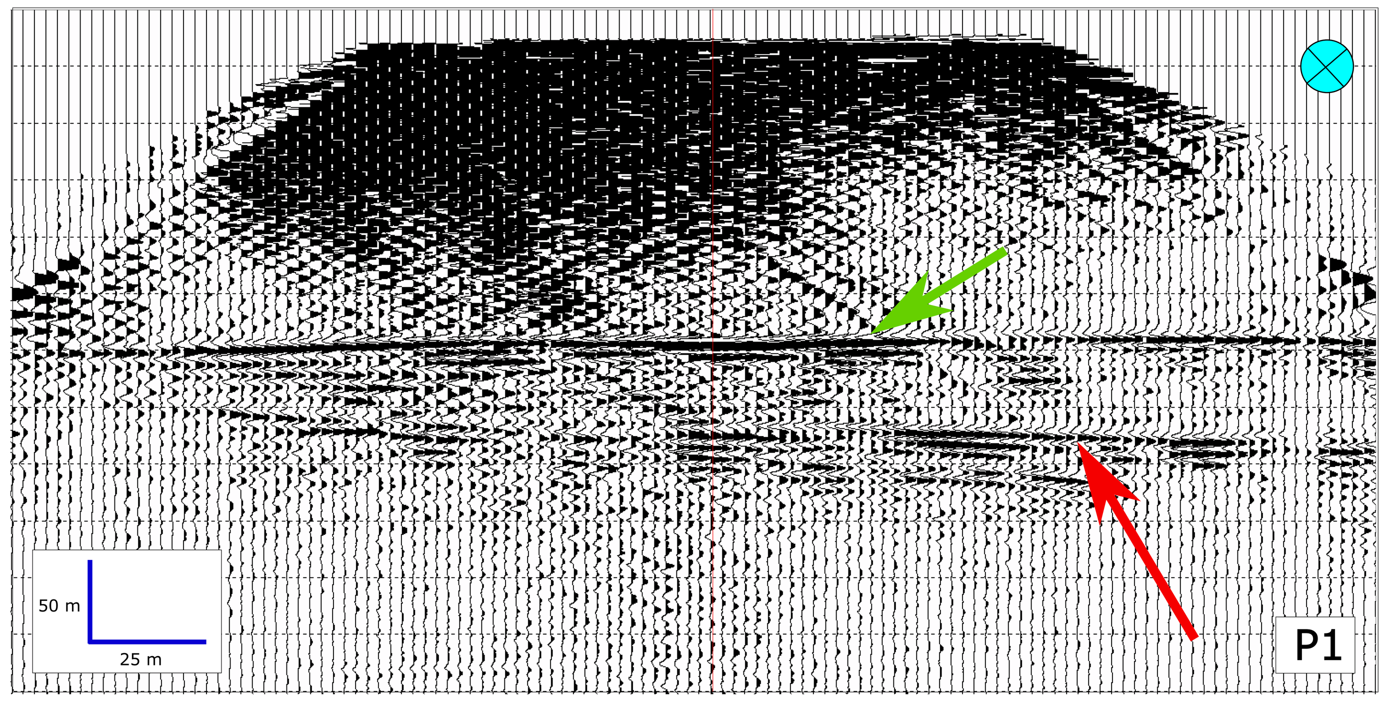

Figure 4: *Seismic stacked and depth converted section of cross-flow profile P1 at site 1. A clear bed reflection at 220 m is seen (green) with a second reflection 60 m below this (red) - interpreted as the base of a sub-glacial sediment package.*

Site 2 - Area of increased surface velocity

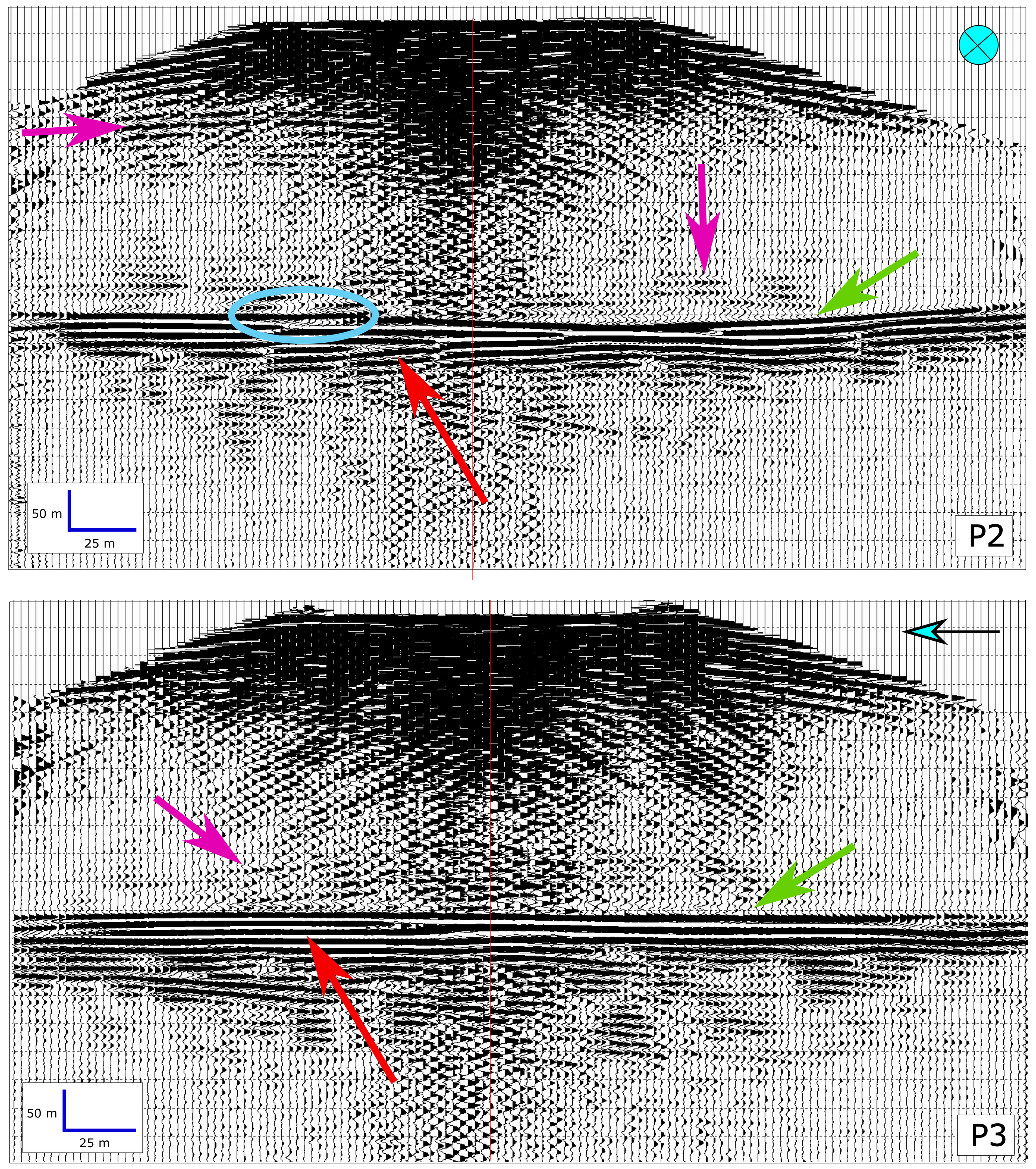

Figure 5: *Seismic stacked and depth converted sections of profiles at site 2. A strong bed reflection (green) at 390 m is seen in both profiles. Cross-cutting bedding below this (red) is clearly imaged. Cross-flow profile P2 shows a possible change in poarity (blue circle) of the bed reflection. Also seen are reflections directly above the bed and a clear englacial reflection at 150 m depth (both purple). Along-flow profile P3 shows a flat bed with uniform reflection polarity.*