Field Report 2009-10: AFI9/23

Hydraulics and sediment deformation beneath an ice stream: A multi-component geophysical AVO investigation

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1. Rationale

The dynamics of modern ice sheets are profoundly influenced by fast flowing ice streams. Geological evidence shows how ice streams have waxed and waned in the past and how large scale instabilities have had a major impact on oceans and climate. Modelling is currently directed to understanding the operation of modern ice streams and to forecast their future behaviour, but the lack of a physically-based basal boundary condition is a major limitation.

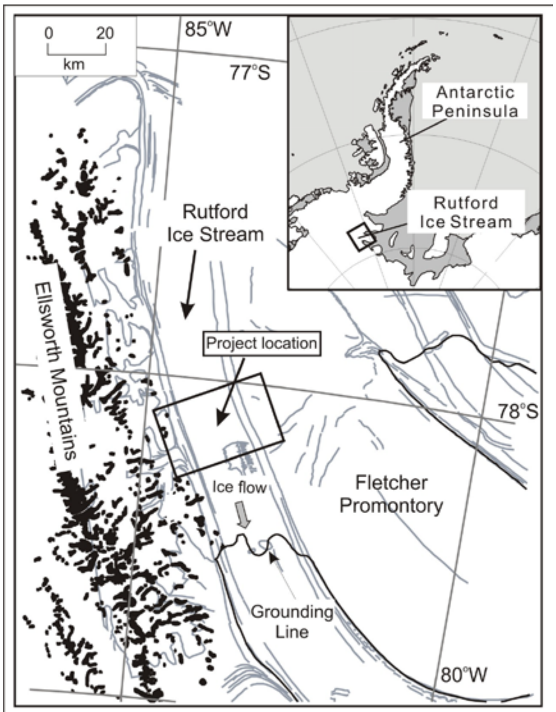

Fig. 1. Location map, AFI/9/23 fieldwork 2009/10.

Friction at the ice-bed interface generally depends upon effective pressure which itself depends on the geometry and efficiency of the hydrological drainage system. Resolving the structure of this drainage is therefore key to solving the basal boundary problem – and the nature of the bed is fundamental to understanding the drainage system.

This project's primary aim is to test the theory that sediment deformation is linked to drainage and subglacial hydraulic structure by deducing the hydraulic characteristics of the sediment beneath a fast-flowing West Antarctic ice stream. We will achieve this by determining a full set of geotechnical properties of the bed from seismic data. This will be complemented by an assessment of changes in the subglacial sedimentary and hydrological systems determined from complementary geophysical surveys.

2. Project Location: Rutford Ice Stream

The fieldwork was conducted on Rutford Ice Stream (Fig.1), a large glacier draining the West Antarctic Ice Sheet. Previous seismic work has shown the glacier is underlain by water-saturated sediment. Some of this sediment is actively deforming; elsewhere the ice is sliding over it. In one particular area, the overall spatial distribution of deforming vs non-deforming sediment is well known and this was the location for the project fieldwork.

3. Fieldwork

3.1. Overview A campaign of geophysical data acquisition was completed on Rutford Ice Stream during the 2009/10 season (Fig.2). The aims were to:

- Conduct Amplitude *vs.* Offset (AVO), and Amplitude *vs*. Azimuth (AVA) seismic experiments in areas of known basal characteristics (identified from seismic reflection and radar data).
- Acquire grids of radar and seismic reflection data to map bed topography and basal conditions.
- Monitor basal seismicity and ice motion throughout the seismic and radar work

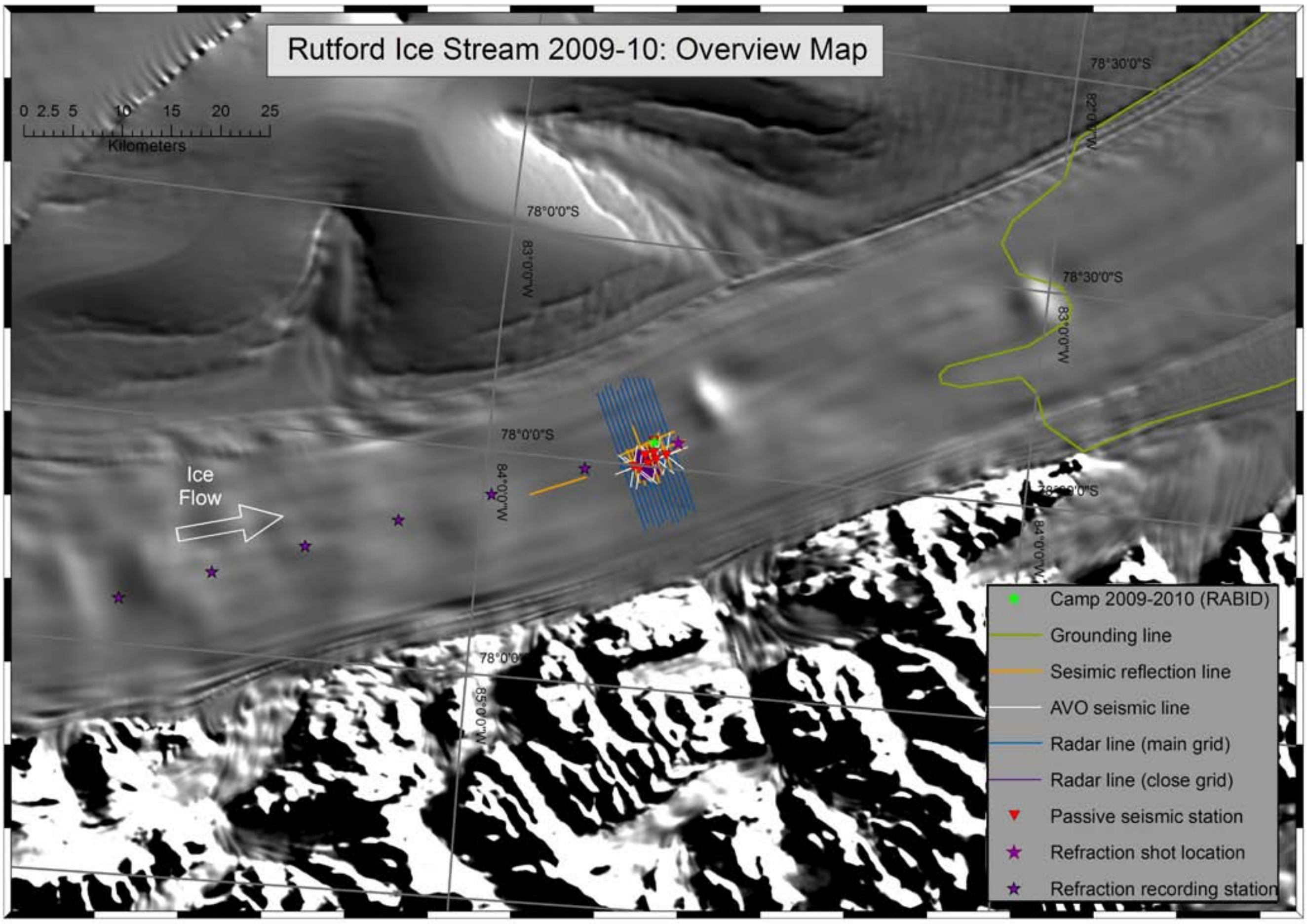

Fig. 2. Overview map of field activities.

Personnel and equipment were deployed in the field area between 21 Nov. 2009 and 10 Feb. 2010. Overall, the weather was favourable (Fig.3). Some calm, sunny periods alternated with weather which was much poorer, but did not stop the work. Only 6 days were un-workable due to bad weather. Mean temperature during the field project was -10°C; mean wind speed was 3 m s^{-1} (~6 knots).

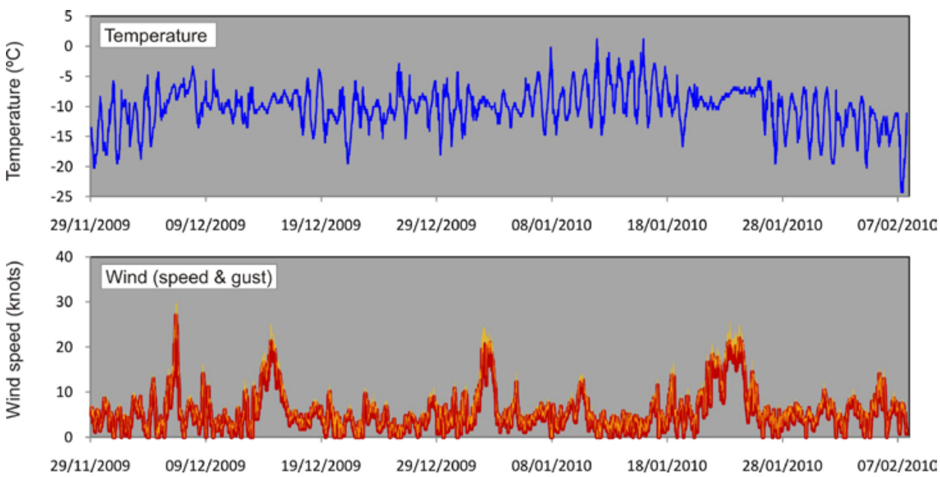

Fig.3. Temperature and wind speed data

3.2. Data acquisition (Figs. 3-5)

- 12 AVO experiments were completed at four different locations. At each location, three AVOs were acquired, orientated at 60º to each other about a common central point (Fig.5), thus forming 4 separate AVO-AVA "stars"
- 52 km of seismic reflection data were acquired
- 1200 km of radar data were acquired
- Passive seismic stations were established at 8 locations. Four were maintained throughout the fieldwork, each of the other four operated for approximately half the time.
- A continuous record of ice motion was acquired using GPS receivers at the camp
- A single seismic refraction experiment was conducted with recording stations aligned in the direction of ice flow, out to a maximum offset of 60 km.

Fig. 3. Field Camp

Fig. 4. Seismic shot

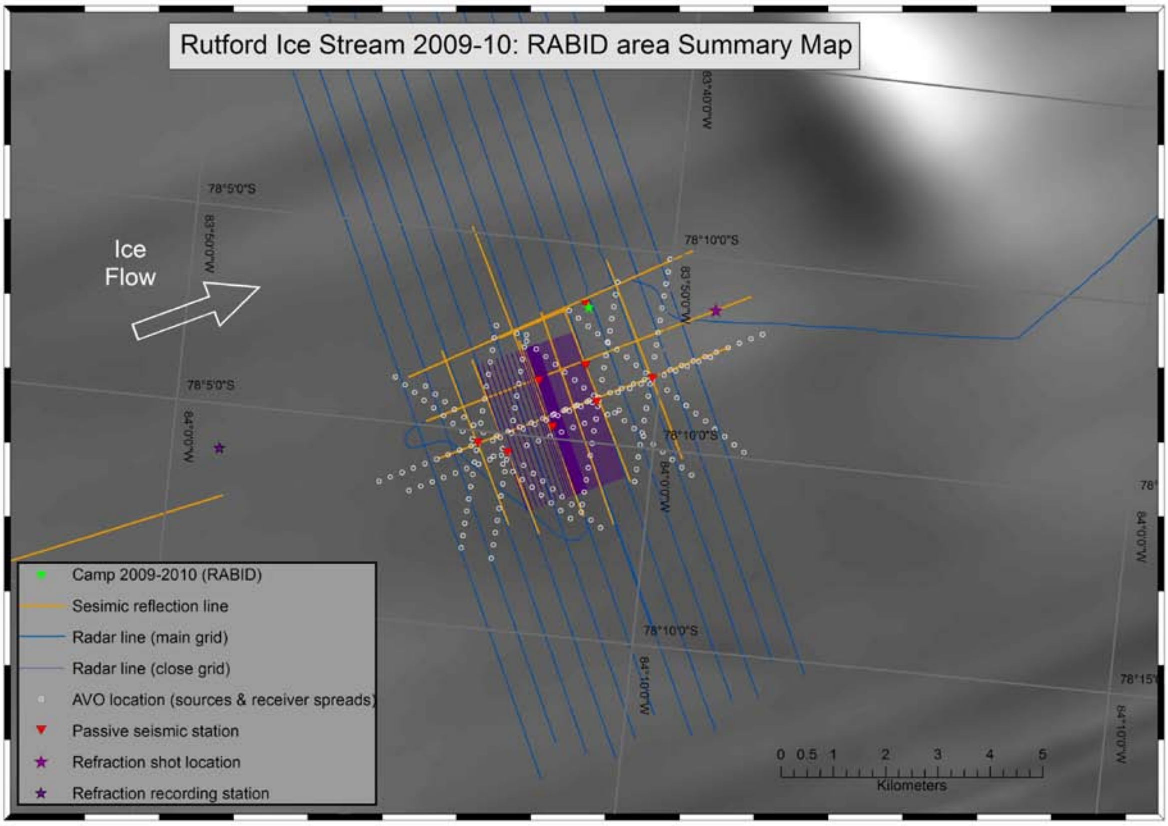

Fig. 5. Summary of completed seismic, radar and GPS achievements in the main work area.

The locations for all the geophysical work were guided by knowledge of the ice stream bed topography and basal conditions. Previous seismic and radar work had identified the location, geometry and orientation of elongated mounds of water-saturated deforming sediment beneath the ice (drumlins and mega-scale glacial lineations), as well as adjacent regions of basal sliding (non-deforming sediment at the bed). The AVO-AVA stars were positioned specifically to sample the different basal regimes. Fig. 6 shows the locations of the main survey lines and monitoring stations overlain on the bed topography determined from an earlier radar survey (E.C. King in 2007/08; see King et al, 2009; *Nat. Geosc*, doi: 10.1038/NGEO581). The regional topography has been removed to emphasise the bedform features. Brown colours are highs; blue colours are lows; stongest colours are maxima in each case. For example, the dark brown feature labelled "MSGL ("The Bump")" is an elongated mound of sediment, ~10-15 km long, 500 m wide and 50 m high, flanked by deep troughs, coloured dark blue.

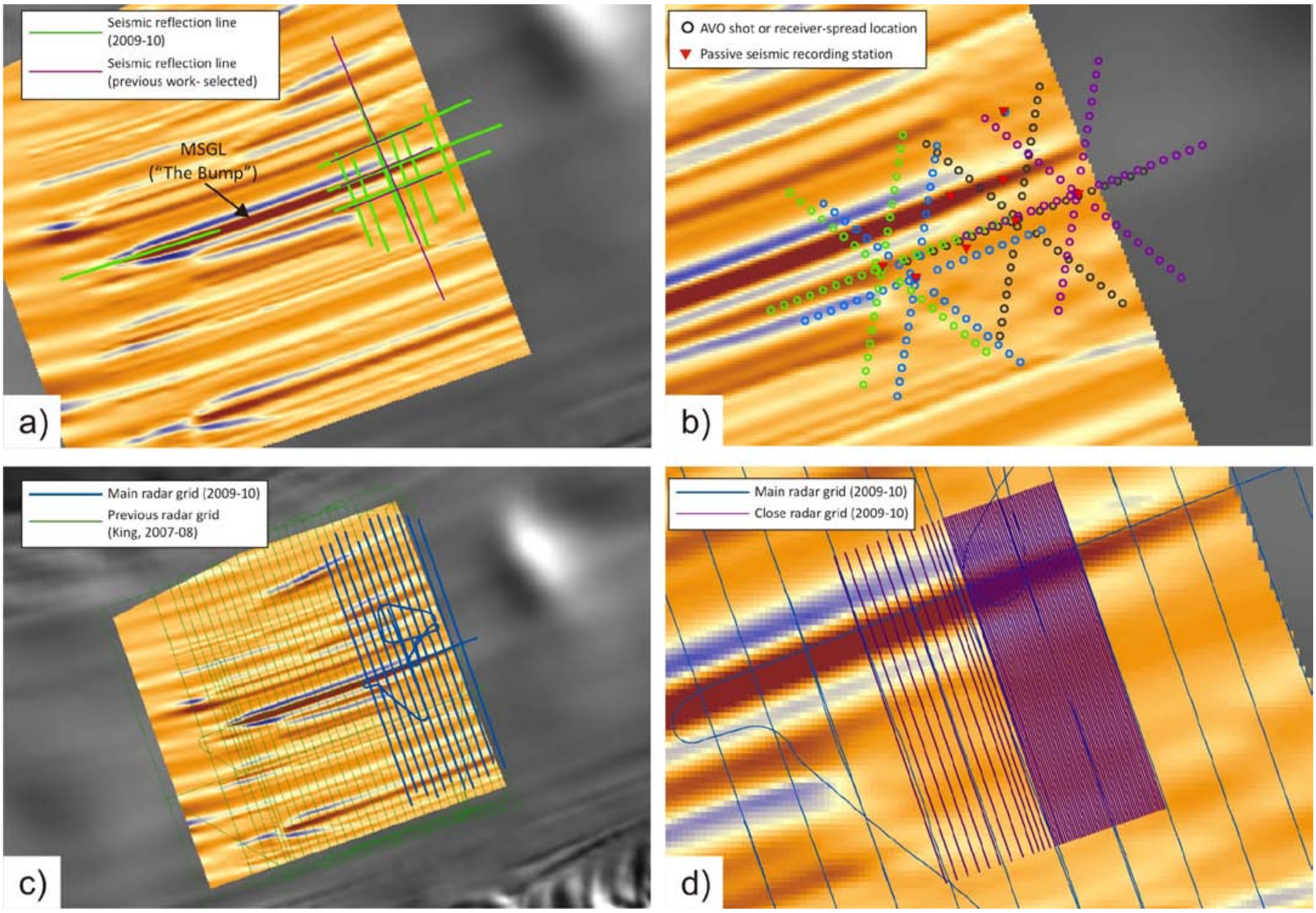

Fig.6. Location of survey lines and experiment locations. **a)** Seismic reflection lines. **b)** AVO experiments and posive seismic stations. **c)** Main radar grid. **d)** Closely-spaced radar grid.

Passive seismic stations were located at the centre of each star (as well as at other specific sites) to monitor basal activity, especially during the acquisition of the AVO data. Seismic reflection lines and the main radar grid were located to aid interpretation of the AVO experiments, to map new features, or to detect any changes. A closely-spaced grid of radar lines (Fig. 6d) was located over the downstream end of one bedform feature to map its morphology and bed reflectivity in detail.

Acknowledgements
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