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GEOMORPHOCrew
Keep exploring the Alps

Internal structure and evolution of a small debris-covered glacier (Entre la Reille, Les Diablerets, Switzerland)

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1. Context of research

Picture 1. The debris covered glacier system of Entre la Reille

- Current context of global warming
- High sensitivity of Alpine cryosphere but with differentiated and complex response

➔ Critical issues (risk, water management, landscape, etc.) in mountain environments

Picture 2. The central part and the left morainic ridge

- Negative mass balance of glaciers can lead to their burial under debris : a few centimetres thick mantle leads to a partial insulation of the ice from atmosphere and reduces the melt rate
- Some debris-covered glaciers (DCG) are located within the periglacial belt (roughly above the isogeotherm -2°C) : glacier/permafrost interactions occur frequently and continuum of complex forms exists between DCG and rock glaciers
- Morainic dams (or bastions) with hypertrophied sedimentary accumulations result from Holocene climatic fluctuations

Picture 3. The central depression and the upper firns

➔ Complex ice/sediments accumulations exist in high mountain : How do they respond to global change? Is the stability of these ice/sediments accumulations disturbed?

2. Research area : Entre la Reille valley (ELR)

Location : 46°20'22" N / 7°13'11" E in Les Diablerets (Vaud, Switzerland, Fig. 1). The studied landform is located in the ski area of Glacier 3000 (Diablerets - Gstaad)

Topography : ELR valley is an hanging valley (corresponding to an recumbent syncline). The studied landform is oriented N-S between 2550 and 2350 m a.s.l. and dominated by the rock walls of a secondary summit of the Oldenhorn (2887m). It area is 0.05 km^2 and dimensions are 270m*200m

Climate and Geology: wet climate of the NW Alps (negative MAAT and more than 1800 mm of annual precipitations above 2400 meters, according to 1961-1990 MeteoSwiss data) / Helvetic geological domain (Limestone and marl)

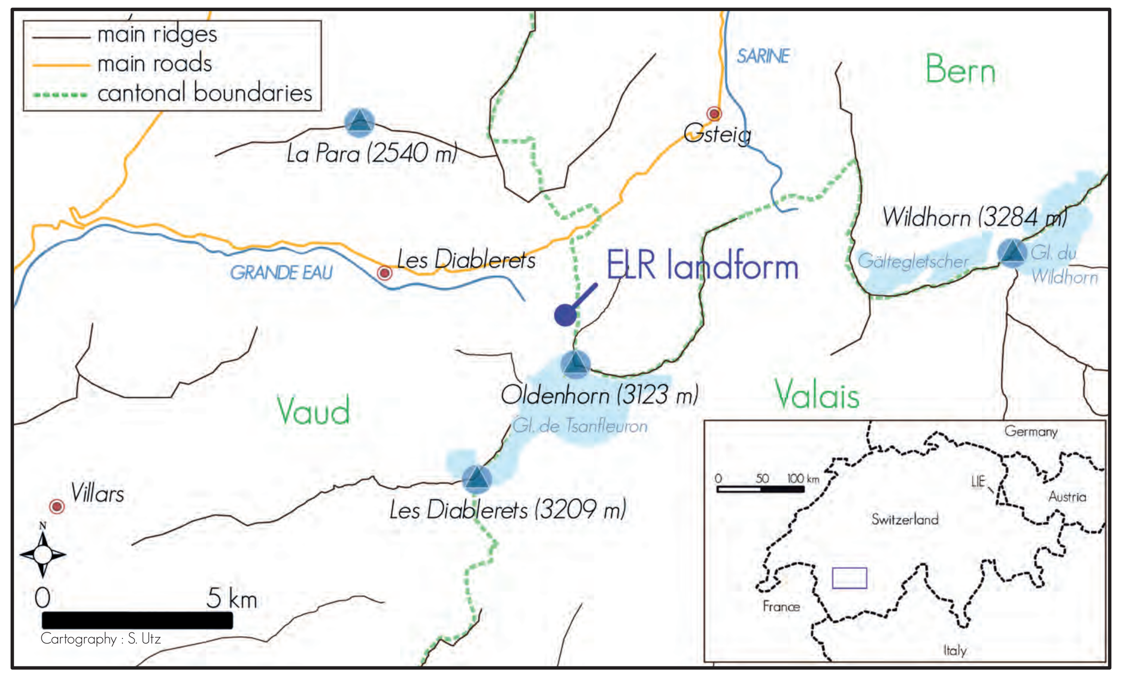

Figure 1. ELR regional context

Geomorphology : Entre-la-Reille landform presents a rock glacier morphology in the distal part (ridges and furrows, 20m high steep active front) and morainic ridges surrounding a central depression uphill, with outcrops of massive ice and permanent snowfields. A small relict protalus is located 50m downhill. Screes, rockfall deposits and embryonic rock glacier (protalus) can be found in the close slope

3. Methods

We adopted several methods to study ELR landform's characteristics in addition to geomorphological mapping and analyses :

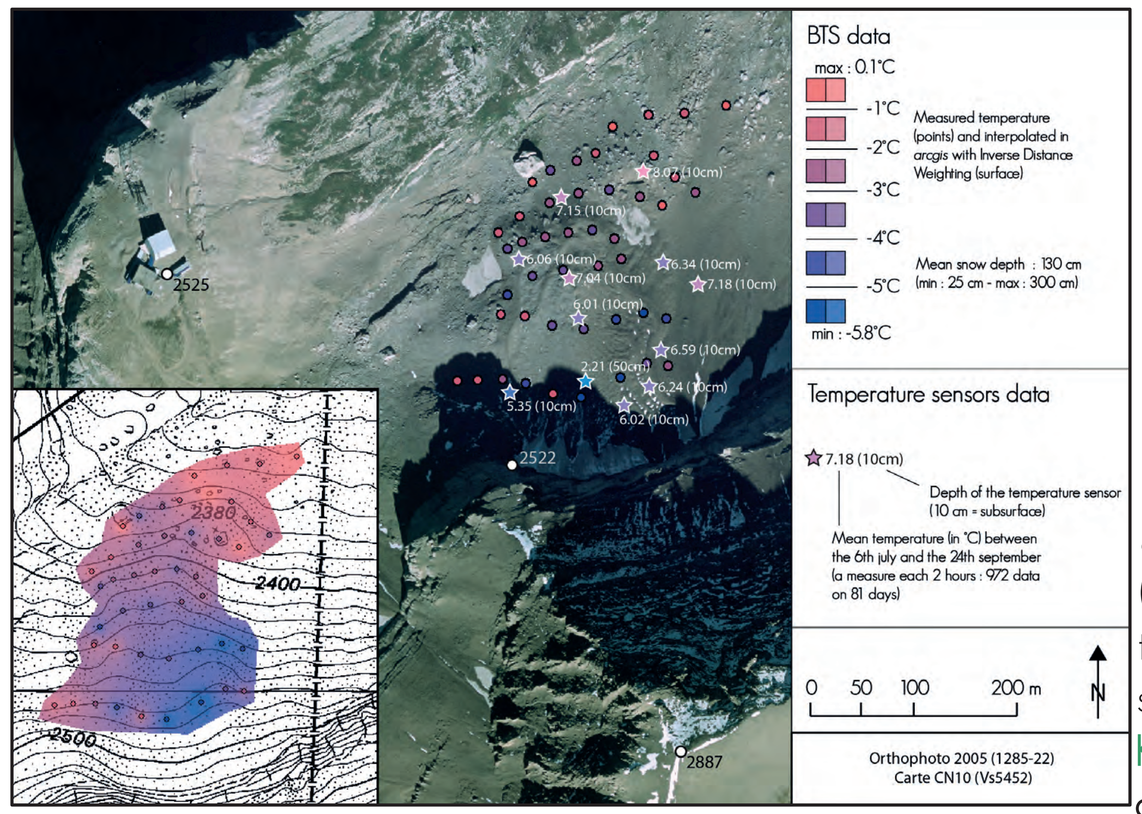

Figure 2. Ground surface thermal data. Temperature sensors are I-buttons DS1922 L/T (0.065°C precision).

Ground surface thermal state (GST°) : BTS (Bottom Temperature of Snow-Cover) campaign in March 2011 : 46 measurements. 12 temperature sensors installed in subsurface in July 2011 : Summer 2011 data

Internal structure : ERT (Electrical Resistivity Tomography) survey in July 2011 : one 72 electrodes' longitudinal profile (4m spacing) and two 48 electrodes' transversal profiles (4m spacing)

Kinematics : Differential GPS campaign : 67 embedded blocks 3D data between July and September 2011

4. Results

BTS (fig. 2) : • Heterogeneous thickness of the snow cover (25-300 cm) : we should be carefull with these data (possible influence of air T° on ground T°?)

- Cold T° (< -4,5°C) of the upper part correspond to 40-60 cm of snow depth
- In general, T° are little warmer with a snow depth thicker than 100cm

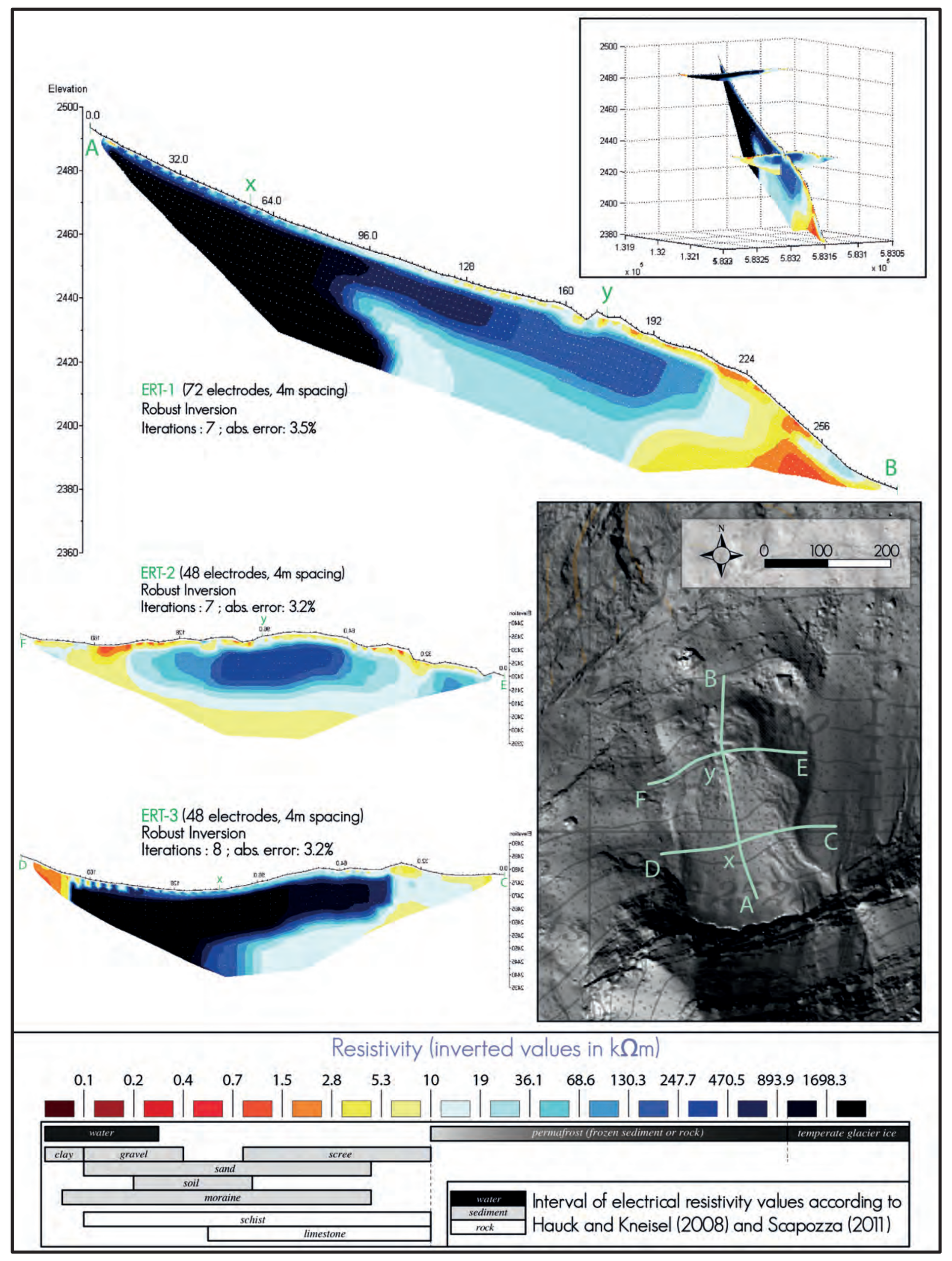

Figure 3. Results of Electrical Resistivity Tomography survey. With a SYSCAL Pro (Schlumberger configuration), we measured the apparent resistivity on three profiles. To treat apparent resistivity and obtain a true geoelectrical tomography, 2D inversions were done with Prosys II and RES2Dinv softwares.

➔ March 2011 GST° : colder than -3,5°C for the upper central and East sector / between -2 and -4°C for the west slope and central sector/ warmer than -2°C for the distal sector

Temperature sensors (fig. 2) : • Depth and proximity of massive ice both seems to explain the cold mean (2.21°C) of sensor located in the central upper depression

➔ Summer 2011 GST° means : around 6.25°C for the upper part / around 7°C in the distal part

ERT (fig. 3) : • Low resistivity values (<10 kΩm) in the surface layer (thickness of 6m upon the front which decreases progressively upslope)

- Extreme resistivity values (<900 kΩm) for the body in the upper central part. Dimensions are around 140*100m and 15-35m thick
- This body is related downslope to a resistive lenticular masse in the central part (70-900 kΩm). Dimensions are around 60*110m and 20m thick

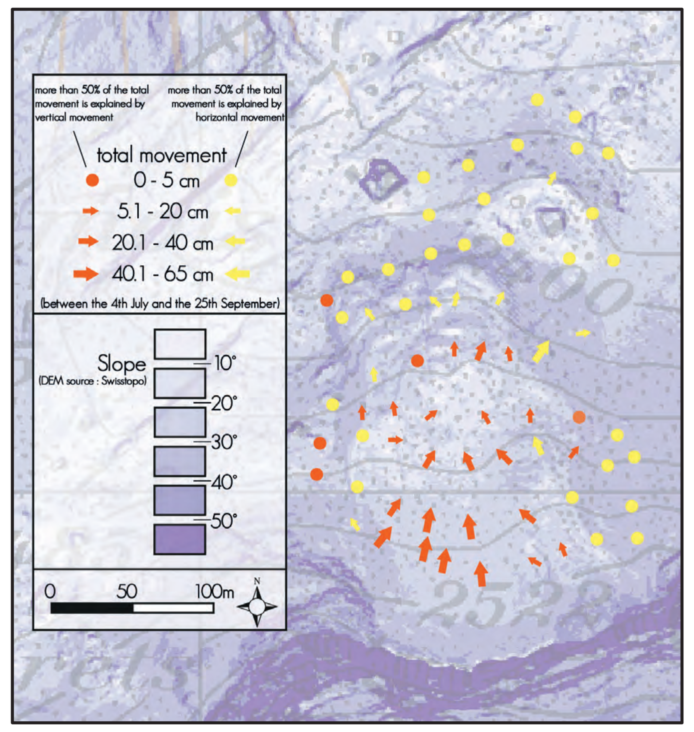

Figure 4. Results of DGPS (Leica SR500, precision of 3-5 cm) campaign.

- Low resistivity values (<20 kΩm) in the front
- Moderate resistivity values (3-20 kΩm) for the upper right bulge. It is extended downslope by a resistive body (35-130 kΩm) which dominates the relict protalus

➔ According to resistivity values : Massive ice body in the central upper depression, surrounded downslope and on the right by ice-cemented sediments. Sporadic permafrost in the front part

DGPS (fig. 4) : • Centimeters to pluri-centimeters movements were measured, values are not correlated with slope angle

➔ Differential kinematics : Significant values of the upper part have high vertical components, probably in relation with massive ice melt out / Low to zero values in marginal part seem linked with subhorizontal flow

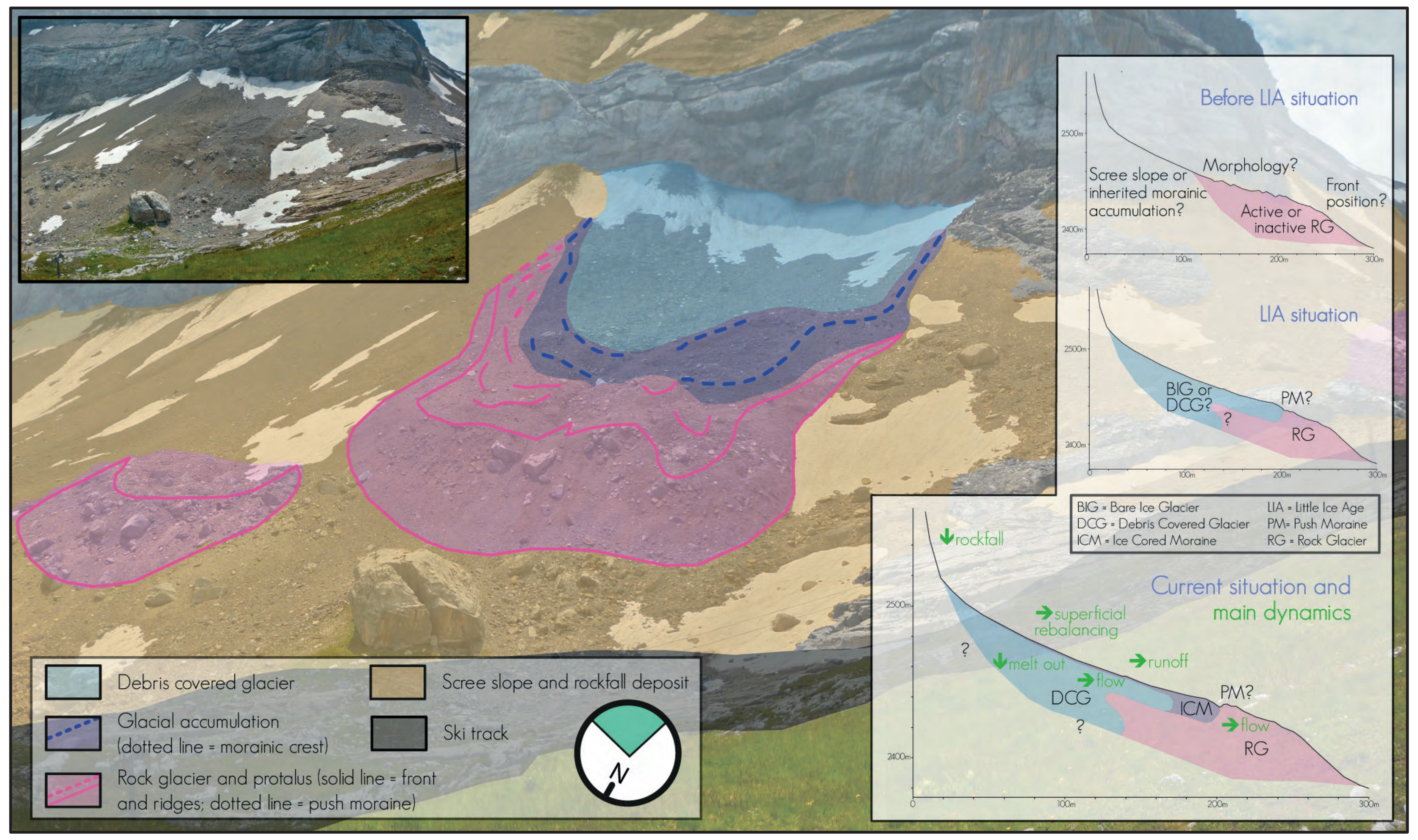

Figure 5. Analysis of current morphology of ELR debris covered glacier system and morphogenesis assumption

5. Discussion

- GST° : Upper central depression = the coldest area (ground heat flux, altitude and shadow effect?)
- Internal structure : Continuum between upslope ice-cored buried body and ice-cemented sediments
- Kinematic: Contrast between upslope melt-out linked rebalancing and marginal subhorizontal flow ?
- Geomorphology (fig. 5): Continuum between DCG (depression, sharp ridges), marginal ice-cored moraines (rounded ridges = push moraines?) and rock glacier (ridges and furrows, steep front) morphology

➔ ELR landform is a complex ice/sediment accumulation. Atypical but not uncommon landform (i.e. Ackert 1998, Delaloye 2004, Monnier 2007). Morphogenesis linked with Holocene history (Ribolini et al. 2010, Bosson 2012) and inefficiency of sediment transfer from glacier/interstitial ice to meltwater (Shroder et al. 2000)

➔ Response to global change : current thinning of the DCG / Rock glacier dynamics : fossilisation vs. crisis ? / The stability of the whole landform seems not disturbed ➔ study in progress...

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- Map and DEM : Swisstopo, 2012

Graphisme: Mariano Bonriposi & Lucien Grangier | IGUL - 2011