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Physical and mechanical behaviour of till in recently deglaciated areas: the GlaRiskAlp project

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The project

GlaRiskAlp is a project in the frame of ALCOTRA program, funded by ERDF. The project was registered in 2008 and started in January 2010. The partners are: Fondazione Montagna sicura (lead partner), the regional Agency for environment protection (ARPA) of Aosta Valley, CNR-IRPI, Université de Savoie (Laboratoire LISTIC) and CNRS France (Laboratoires LGGE, GIPSA, EDYTEM).

In the frame of this project, surveys on recently deglaciated areas have been carried out in order to assess their susceptibility to hydrogeologic phenomena. Two test-sites have been selected in Aosta Valley, and physical and mechanic characteristics of the till deposits have been investigated.

Study area

Study sites are located in Aosta Valley (Italy): the first site is just below the front of Tzanteleina Glacier, Rhêmes Valley; the second site is the proglacial area of Verra Grande Glacier, Ayas Valley.

Image above: test-site Tzanteleina Glacier (Rhêmes Valley)
Image on the right: test-site Verra Grande Glacier (Ayas Valley)

Both sites (red circles) are located in the proglacial area of a glacier and are covered by till, showing different lythology. Tzanteleina site shows mainly Triassic limestones and dolomites, while in Verra Grande area, metabasites amphibolites and eclogites are found.

Surveys and tests

Tzanteleina test-site.

GPR surveys have been carried out since 2010, in order to investigate deposit thickness as well as physical parameters, such as granulometry and permafrost. An automatic weather station (AWS) has been installed in October 2010, NW of Tzanteleina lake below the glacier front, 2695 m a.s.l. The station is equipped with sensors for the following parameters: wind velocity and direction, relative humidity, air temperature, rainfall, snowpack thickness, solar radiation. The following properties of soil are also measured and acquired by the station:

- TDR (Time Domain Reflectometry) and WCR (frequency domain reflectrometry), in a depth range between 0 and 60 cm to measure physical properties and water percolation;
- Thermistors in a depth range between 0 and 60 cm;
- Heat flux sensors. Two seismic surveys have been carried out, in June and November 2011 respectively, in order to assess seismic properties (waves velocity) and their variation depending on frozen soil.

A calibrated photographic survey has been done in September 2011; this was aimed to assess the granulometric classification of the coarse fraction of the deposits. Fine fraction was analyzed in laboratory test, thus obtaining a complete classification of the deposits.

Moreover the following laboratory tests have been done:

- tilt-test on dry sample;
- uniaxial compressive strength tests on saturated and frozen samples (to assess influence of temperature on strength);
- ultrasonic test to assess P and S waves velocity in frozen samples at different temperatures, to assess the influence of temperature on physical properties.

Verra Grande test-site.

The same surveys have been carried out on Verra Grande test-site. In this site, however, the weather station is not installed.

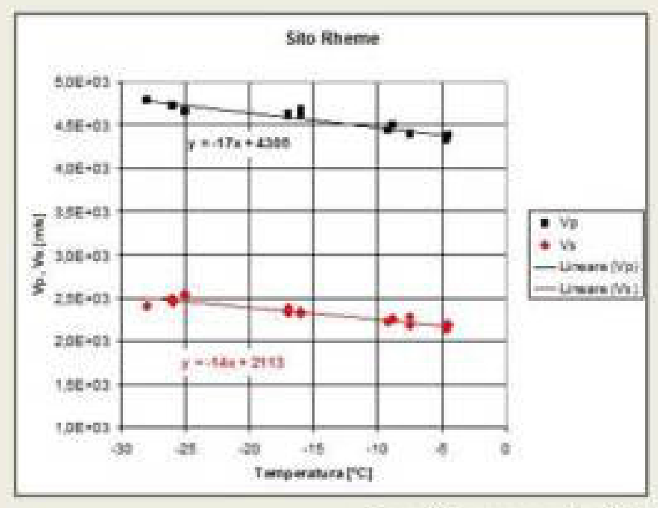
Image above: AWS on Tzanteleina test-site. On the right: Detail of WRC sensors. On the left: seismic survey in November 2011.

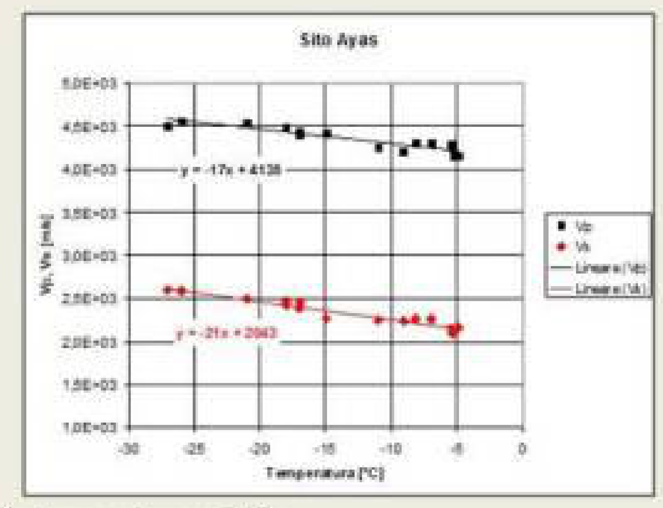
Results

A GPR survey was carried out in June 2010 on Tzanteleina test-site. Large-scale bedrock morphology, as well as debris-covering thickness, have been detected.

Strain properties and seismic velocity of materials show a constant variation with temperature, both in in-situ tests and laboratory tests on frozen samples.

Laboratory tests were carried out within a temperature range between -5 °C and – 30 °C, on frozen cylindrical samples, 100 mm diameter and 200 mm high, made of selected granular materials (less than 50 mm). Test results show seismic velocity increasing with lowering temperature in both sites samples. Strength of samples decreases with increasing temperature. This means that mechanical properties of materials change with temperature, and that slope stability is strongly affected by thermic condition of materials.





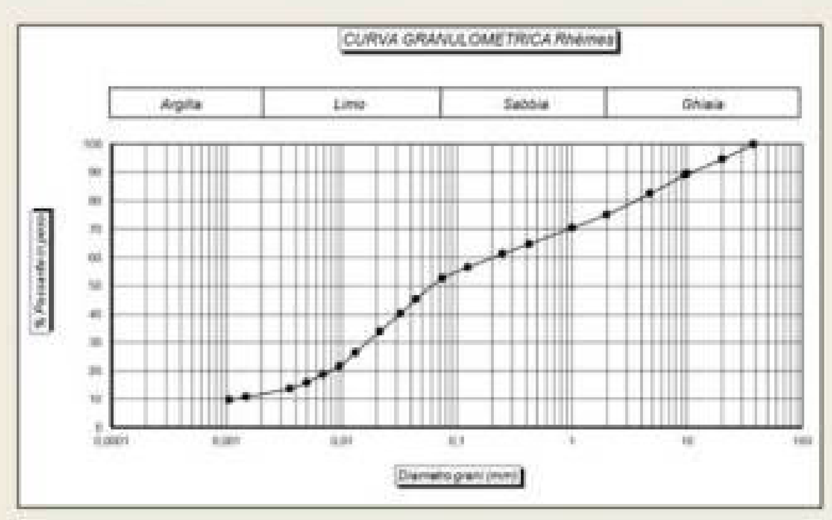
P and S waves velocity trend with temperature variation.

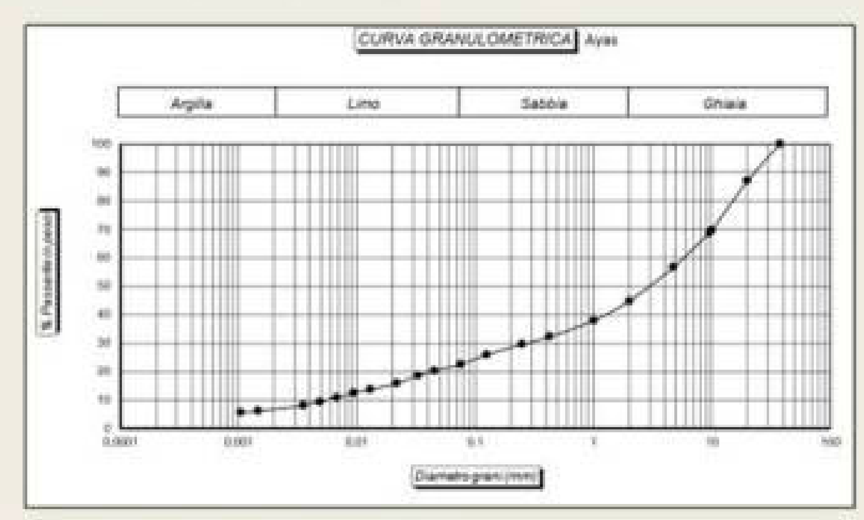
The following items have been pointed out from in situ measurements:

- air temperature range was between + 17° C (June 2011) and -20°C (February 2012);
- snowpack maximum thickness was 1.5 m in 2011 and 2.0 m in 2012;
- internal temperature of deposits is strongly affected by snowpack; in winter 2010/11 and 2011/12, soil temperature (2 cm depth) was almost 0°C, while at 50 cm depth temperature was above 0 °C all period long;
- heat flux is directed from bottom to top below 30 cm depth (geothermal flux); in the surface layer heat flux is strongly affected by snowpack and air temperature; in summer the process is inverted;
- soil humidity is constant in winter, while in spring is strongly affected by temperature of surface layer (some cm thick); when this increases above 0°, soil humidity increases down to 30-40 cm depth, with daily variation, as a result of snow melting; in summer humidity mainly depends on rainfall: surface layer is fast saturated, while deeper soil is saturated only after long-lasting rainfall.

Granulometric classification has been carried out by photographic technique for coarser fraction, and by sieving for the fine fraction. In Verra Grande test-site, till is over 70% sand and gravel, while silt and clay fraction in less than 20 %. On the contrary, in Tzanteleina test-site over 50% in weight of the deposit is silt and clay, while sand and gravel are the remaining part.

This confirm the assumption that lithology of bedrock and outcrops strongly affects the characteristics of deposits: carbonatic rocks debris (Tzanteleina test-site) originates a mainly silty and sandy till with less gravel; on the contrary, massive igneous rock debris (Verra Grande test-site) turns into a mainly sandy and gravel till.





Till granulometric curve in both test-sites (weight percentual on grain size).

Tilt tests have been carried out on different samples prepared with increasing compaction, thus obtaining geotechnical parameters of the deposits.

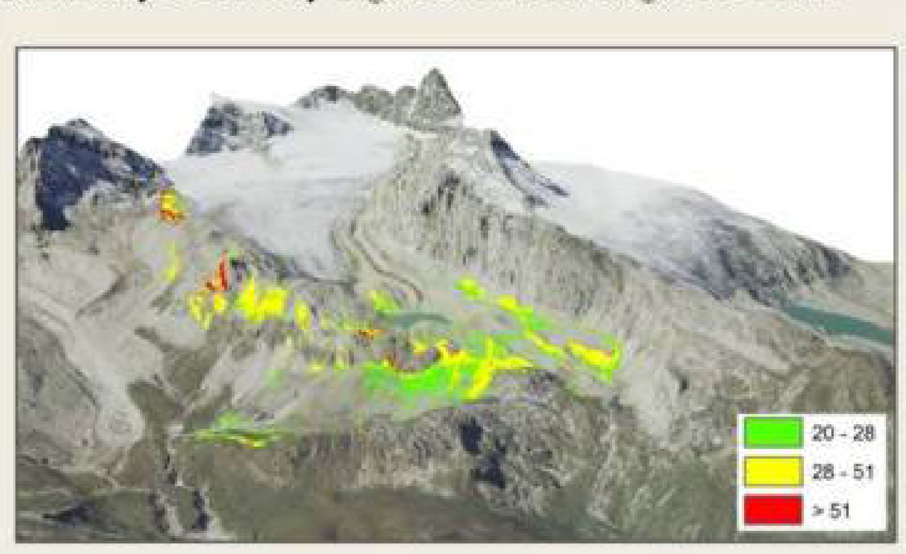
	Compattazione 0			Compattazione 1			Compattazione 2			Compattazione 3		
Massa scatola inf. (Kg) solo terreno	4,620	4,245	4,420	11,05	11,09	10,96	11,482	10,667	11,427	11,47	12,06	11,06
Massa scatola sup. (Kg) solo terreno	10,305	10,480	10,420	9,15	8,90	9,15	9,205	9,995	9,170	9,14	8,80	9,56
Battente sul piano di scorrimento [m]	0,1050	0,1050	0,1050	0,08	0,08	0,08	0,0800	0,0850	0,0800	0,08	0,08	0,08
Volume occupato dal terreno [m3]	0,0087	0,0087	0,0087	0,01	0,01	0,01	0,0108	0,0111	0,0108	0,01	0,01	0,01
Altezza Y di inizio movimento [cm]	13,50	12,80	13,00	19,50	19,00	20,00	23,90	22,50	24,00	25,90	26,60	26,30
Altezza Y misurata [cm]	15,70	14,40	15,90	21,60	20,50	21,90	25,00	23,60	24,60	26,80	29,80	27,00
Angolo di inizio movimento [°]	28,08	26,84	27,20	37,62	36,91	38,33	43,37	41,65	43,49	45,67	46,43	46,11
Angolo di scivolamento [°]	31,82	29,65	32,15	40,49	39,02	40,88	44,66	43,01	44,20	46,65	49,67	46,86
Delta angolo [°]	3,74	2,81	4,95	2,87	2,11	2,55	1,29	1,36	0,71	0,98	3,23	0,75
W (N)	101,05	102,77	102,18	89,72	87,22	89,72	90,26	98,01	89,92	89,63	86,29	93,75
W+ (N)	85,86	89,31	86,51	68,24	67,77	67,84	64,21	71,67	64,47	61,53	55,85	64,10
σ (N/m2)	1431,03	1488,56	1441,87	1137,31	1129,50	1130,66	1070,10	1194,50	1074,49	1025,43	930,82	1068,32
τ (N/m2)	888,03	847,24	906,16	970,98	915,20	978,71	1057,41	1114,24	1044,76	1086,22	1096,58	1140,11
Volume occupato dai grani [m3]	0,0053	0,0052	0,0053	0,0072	0,0071	0,0071	0,0073	0,0073	0,0073	0,0073	0,0074	0,0073
e indice vuoti	0,64	0,66	0,65	0,52	0,53	0,51	0,47	0,51	0,48	0,44	0,42	0,48
Componente di taglio della scatola τ (N/m2)	132,62	124,42	133,84	163,32	158,35	164,62	176,79	171,57	175,34	182,90	191,74	183,54
τ compresa come scatola (N/m2)	1020,66	971,66	1039,99	1134,30	1073,55	1143,33	1234,20	1285,81	1220,10	1269,12	1288,12	1323,65
Angolo d'attrito φ [°]	35,5	33,1	35,8	44,92	43,55	45,32	49,1	47,1	48,6	51,06	54,15	51,09

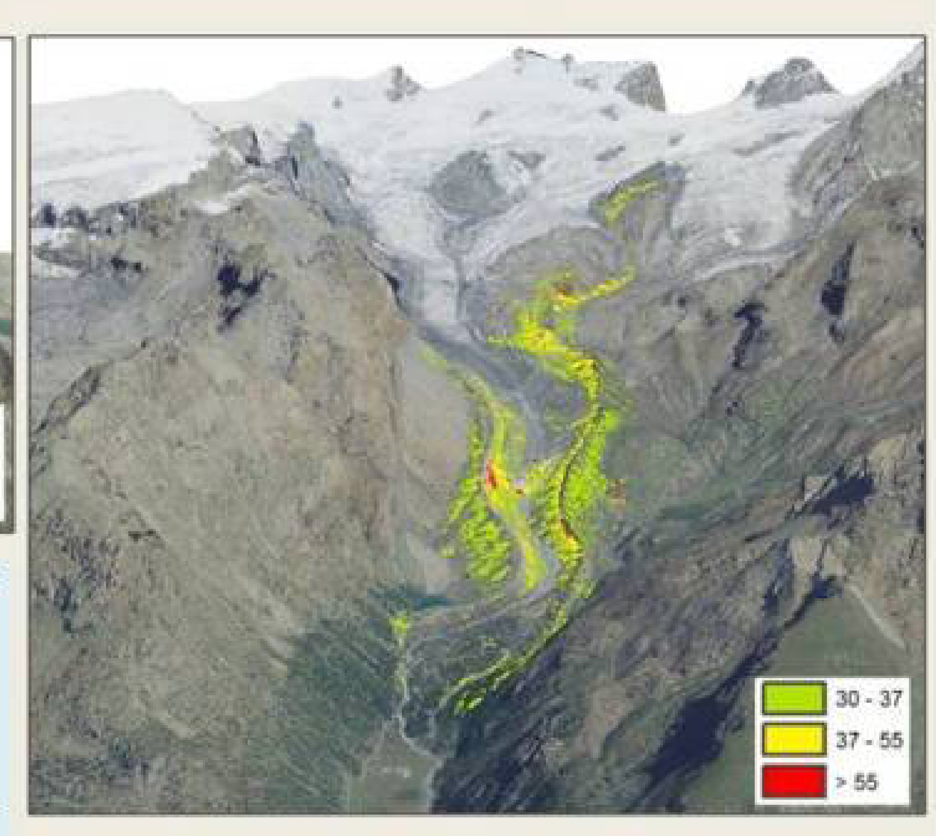
	Compattazione 0		Compattazione 1			Compattazione 2		Compattazione 3		
Massa scatola inf. (Kg) solo terreno	7,78	7,72	8,17	8,06	8,20	8,51	8,51	9,01	8,73	8,71
Massa scatola sup. (Kg) solo terreno	10,72	10,82	10,33	10,37	10,26	9,94	9,95	9,45	9,79	9,72
Battente sul piano di scorrimento [m]	0,11	0,11	0,10	0,10	0,10	0,09	0,09	0,09	0,08	0,09
Volume occupato dal terreno [m3]	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01
Altezza Y di inizio movimento [cm]	12,20	12,00	15,50	15,00	14,50	17,50	17,00	23,00	23,50	23,50
Altezza Y misurata [cm]	15,30	14,90	17,00	16,30	16,10	18,50	18,40	24,70	25,50	25,30
Angolo di inizio movimento [°]	30,88	30,47	37,23	36,33	35,40	40,62	39,81	48,43	49,04	49,04
Angolo di scivolamento [°]	36,87	36,14	39,81	38,63	38,28	42,20	42,05	50,45	51,34	51,12
Delta angolo [°]	3,10	2,90	2,58	2,30	2,88	1,58	2,24	2,02	2,30	2,08
W (N)	105,12	106,05	101,30	101,69	100,56	97,47	97,52	92,62	96,00	95,31
W+ (N)	84,10	85,64	77,82	79,44	78,94	72,20	72,42	58,98	59,97	59,83
σ (N/m2)	1401,60	1427,35	1296,96	1324,05	1315,64	1203,39	1206,93	982,98	999,52	997,13
τ (N/m2)	1051,20	1042,52	1080,80	1057,94	1038,32	1095,31	1068,60	1190,18	1249,40	1236,64
Volume occupato dai grani [m3]	0,00676	0,00678	0,00676	0,00674	0,00675	0,00675	0,00675	0,00675	0,00677	0,00674
e indice vuoti	0,68	0,66	0,59	0,59	0,59	0,52	0,52	0,46	0,43	0,44
Componente di taglio della scatola τ (N/m2)	150,91	148,35	161,02	157,01	155,82	168,97	168,46	193,93	196,41	195,80
τ compresa come scatola (N/m2)	1202,12	1190,88	1241,82	1214,95	1194,14	1260,27	1257,07	1384,11	1445,81	1432,44
Angolo d'attrito φ [°]	40,62	39,84	43,76	42,54	42,23	46,32	46,17	54,62	55,34	55,16

Geotechnical parameters of till: Tzanteleina test-site results on the left, Verra Grande test-site on the right.

Further development

This research pointed out a strong correlation between lythology of bedrock and physical characteristics of till. Glacial deposits coming from different lythologies show different granulometry and mechanical behavior, thus affecting slope stability. From a wider and representative number of analyses on different sites, a correlation between local geology and instability of recently deglaciated areas might be found.





Assessment of potential slope instability by crossing mechanical characteristic of the deposit with slope:
- Red: high potential instability;
- Yellow: medium potential instability;
- Green: low potential instability.

Image above: Tsanteleina test-site; on the right: Verra Grande test-site.

CONTACT

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