Geomorfologia & Società

Geomorphologie & Gesellschaft

Géomorphologie & Société

Geomorphology & Society

Program & Abstracts

Congresso biennale 2019 della Società Svizzera di Geomorfologia (SSGm)

Jahrestagung 2019 der Schweizerischen Geomorphologischen Gesellschaft (SGmG)

Colloque bisannuel 2019 de la Société Suisse de Géomorphologie (SSGm)

Biennial conference 2019 of the Swiss Geomorphological Society (SGmS)

Bellinzona (Svizzera | Schweiz | Suisse | Switzerland)

4 – 6 settembre 2019

Welcome to Ticino, the Mediterranean soul of Switzerland!

Within the unique geomorphological and geohistorical framework constituted by the UNESCO World heritage town of Bellinzona, the Swiss Geomorphological Society (SGmS | SGmG | SSGm) welcomes you to its biennial conference 2019.

This conference welcomes contributions from research, applied research and practical studies in geomorphology in relation with society, including climate change impact on geomorphological landscapes, natural hazards assessment and mitigation, geoheritage management and geotourism. We will focus particularly projects and case studies carried out in Switzerland and neighbouring countries or regional studies worldwide carried out by Swiss institutions. We welcome the participation of young researchers.

More information on: http://www.geomorphology.ch/

Coming to Bellinzona

By train	regional and international trains stops in Bellinzona FFS railstation.
By car	high-street A2, exit 45 *Bellinzona-Nord* from the north; exit 47 *Bellinzona-Sud* from the south. Carpark *Piazza del Sole* in Bellinzona centre.

Sala del Consiglio Comunale	public conference of Wednesday 4th September
Ristorante Castelgrande	symposia of Thursday 5th September
Ponte della Torretta	meeting point for the excursion of Friday 6th September

General program

Wednesday 4th September 2019

Sala del Consiglio Comunale, Bellinzona (see map on page 2)

20.00 Bellinzona: fra antichi ghiacciai, laghi e “buzze”

Welcome by Christian Paglia (Municipal of Bellinzona and SUPSI, CH)

Public conference (in Italian) on the geomorphological history of Bellinzona and neighbouring region by Cristian Scapozza (SUPSI, CH). Will follow an aperitif in collaboration with the Società ticinese di scienze naturali (STSN) and Città di Bellinzona.

Thursday 5th September 2019

Ristorante Castelgrande (at Castelgrande Castle, see map on page 2)

8.30 Reception

9.00 Welcome & Introduction

9.15 Symposium Geoheritage & Geomorphological Landscapes

Input-Conference: Heidi Megerle (Hochschule für Forstwirtschaft Rottenburg, D)

11.00 Coffee break & posters

11.30 Symposium Alpine geomorphology

Input-Conference: Etienne Cossart (Université Jean Moulin Lyon 3, F)

13.15 Lunch in Ristorante Castelgrande

14.45 Symposium Historical landslides

Input-Conference: Massimo Ceriani (Regione Lombardia, I)

16.30 Coffee break & posters

17.00 General Assembly of the Swiss Geomorphological Society (SGmG | SSGm | SGmS)

Friday, 6th September 2019

9.00 Geomorphological excursion in town Bellinzona, from the Ticino river to the Sasso Corbaro Castle (landscape evolution, glacial and fluvial geomorphology, geoarchaeology).

Meeting hour and point: **8.45**, Ponte della Torretta (see map on page 2). End of the excursion: **ca. 15.00**, Sasso Corbaro Castle.

Special guests: Pietro Beffa, fluvial engineer (Andreotti & Partners); Moira Morinini Pè, archaeologist (Archaeological section, Ufficio dei beni culturali TI).

Symposia program

Thursday 5th September 2019

9.15 Geoheritage & Geomorphological Landscapes

***Chair**: Nikolaus J. Kuhn (Universität Basel, CH, president of the SGmS)*

INPUT-CONFERENCE: **Chancen, Herausforderungen und Risiken der Inwertsetzung des regionalen Geo-Erbes: Geotopschutz und Geotourismus im Spannungsfeld unterschiedlichster Interessen**
Heidi Megerle (Hochschule für Forstwirtschaft Rottenburg, D)

10.00 **Les régions « Géo-focus » de la Suisse : étude sur les valeurs géologiques d'importance internationales**
Géraldine Regolini

Le tourisme dans les sites géomorphologiques : opportunité ou menace ?
Jonathan Bussard

Jessour et habitats troglodytiques dans le Sud-est tunisien – un exemple de géomorphosites culturels
Emmanuel Reynard

La miniera d'oro di Sessa: ieri, oggi, domani
Mauro Poretti

Evolution of fluvial environments and history of human settlements on the Ticino River alluvial plain
Dorota Czerski

Assessment of the quality of models simulating carbon transfer by soil erosion on a global scale
Caroline Bolliger

Close-up imaging simulation in the Marslabor of the University of Basel
Nikolaus Kuhn

10.45 **General discussion and questions**

11.00 **Coffee break & posters**

11.30 Alpine geomorphology

***Chair**: Christophe Lambiel (Université de Lausanne, CH)*

INPUT-CONFERENCE: **Geomorphological (in)efficiency of sediments cascades: new insights from a network analysis**
Etienne Cossart (Université Jean Moulin Lyon 3, F)

12.15 **Semi-automated geomorphological mapping**
Elisa Giaccone

Quantifying the alpine sediment cascade using multi-temporal high-resolution topographical surveys: case studies from Mattertal and Col du Sanetsch (VS)
Hanne Hendrickx

The use of Unmanned Aerial Vehicle surveys for monitoring rock glacier kinematics: validation and accuracy assessment
Sebastián Vivero

Potentially frozen sediments presenting mass-wasting processes in glacier forefields in mountain permafrost environments (Swiss Alps)
Julie Wee

Rapid disappearance of glacier and implication for local multi-hazard risk assessment: Les Diablerets (western Swiss Alps)
Mauro Fischer

Co-evolution of morphological change and flood risk change in Swiss rivers
Andreas Paul Zischg

The world's largest debris-flow measuring system is back in operation - first experiences and measurement results from Illgraben
Christoph Graf

Simulating the effect of check dams on landscape evolution at centennial time scales
Mirjam Mertin

13.00 **General discussion and questions**

13.15 **Lunch in Ristorante Castelgrande**

14.45 Historical landslides
(in collaboration with the Interreg project A.M.A.L.Pi 18)

***Chair**: Christian Ambrosi (SUPSI, CH)*

INPUT-CONFERENCE: Grandi frane alpine e il progetto Interreg AMALPI18
Massimo Ceriani (Regione Lombardia, I)

15.30 **Topografie a confronto: Piuro 1618 – 2018**
Cristiana Achille

Estrazione di modelli digitali del terreno da TLS long range
Cristiana Achille

Distribuzione, attività ed evoluzione di grandi frane lente in ambiente alpino: analisi innovative a scala regionale e locale
Federico Agliardi

Deep-Seated Gravitational Slope Deformations (DSGSDs) and last glaciation in Chiavenna Valley: geomorphological evidences of chronological relations
Tiziana Apuani

La frana del Monte Crenone del 1513. Modello numerico e analisi geomorfologica.
Alessandro De Pedrini

The Cimaganda rockslide (2012): recent geomorphological evolution of the paleo-event
Andrea Morcioni

The Ralligen rockfall and the Lütschine River deviation recorded in the sediments of Lake Thun
Stefanie Wirth

Le esperienze dell'interferometria sui monitoraggi di Gallivaggio e Cataeggio
Luca Dei Cas

La rete lombarda di monitoraggio geologico
Maria Luisa Pastore

16.15 **General discussion and questions**

16.30 **Coffee break & posters**

17.00 **General Assembly of the Swiss Geomorphological Society (SGmG | SSGm | SGmS)**

Poster only

Geoheritage & Geomorphological Landscapes

Soapstones: fields and production laboratories between Ticino and Moesano
Filippo L. Schenker

A Cross-Comparison between a Traditional Portable Straight-Line Wind Tunnel and PI-SWERL over an Altitude Gradient
Cynthia C.E. van Leeuwen

Towards decadal hydro-glaciological forecasts for the hydropower sector
Davide Saurwein

Alpine geomorphology

Assessing the impact of ground ice degradation on high mountain lake environments (Lago Nero catchment, Swiss Alps)
Monica Bulgheroni

Les fluctuations des glaciers après le Petit Âge Glaciaire. Datation de cordons morainiques dans le Val Scaradra avec la méthode du marteau de Schmidt et l'analyse de cartes historiques
Chantal Del Siro

Assessing provenance, exposure timing and emplacement processes of large exotic boulders in central Himalayan river valleys
Marius L. Huber

Reconstructing deglaciation dynamics and environmental changes in the Italy-Switzerland transboundary area of the Val Viola Pass
Anna Masseroli

Historical landslides

Monitoring large alpine landslides with satellite SAR interferometry within the A.M.A.L.P.I. 18 project
Tazio Strozzi

Practical information

In order to give the opportunity to more authors to present their contribution and to improve the discussion, especially for young researchers, short talks can be associated with a poster. Questions to the speakers or general discussions on the presented topics will be grouped in the *General discussion and question* section closing every symposium.

Languages Short talks and posters can be in a Swiss National Language (German, French or Italian) or in English. Since there will not be simultaneous translation, it is desirable to use English for slides accompanying the short talks.

Short talks Maximum duration of **5 minutes**.
Please illustrate your talks with **only 5 slides**:
1. Title page and author names;
2. The problem;
3. The results;
4. The solution or the take home messages;
5. Acknowledgements.

Please send the slides of your presentation to cristian.scapozza@supsi.ch by Wednesday 4th September evening or upload it directly during the break preceding your symposium.

Posters Must be in a maximal size of 84.1 x 118.9 cm (A0), in **portrait** orientation.

Fees Please remember to pay the registration fees **before 31 August 2019**. See details on page 9.

Accommodation Will not be organised by the conference. You can select and book your accommodation on the tourism office homepage: https://www.bellinzonese-altoticino.ch/en/plan/accomodation.html
Bellinzona youth hostel: https://ostellomontebello.ch/en/home-e-2/

Lunch Aperitif on 4th September, lunch and coffee breaks on 5th September and refreshment during the excursion of 6th September are included in the registration fee. Those who have allergies or food intolerances, vegetarians or other food-related issues, please contact directly the Castelgrande restaurant during lunch.

Excursion Please take with you a lunch and beverages. There is the possibility to buy a lunch in city centre during the excursion.

Young geomorphologists' two-day excursion

Participants to the young geomorphologists' excursion of Saturday and Sunday 7th and 8th September 2019 will receive the detailed information directly from the organisers. For questions please contact elisa.giaccone@unil.ch

Costs and payment information

Biennial Conference

Public lecture: free for all

Conference with excursion for SGmS members:
> Students & PhD Candidates: 50 CHF
> Post docs & Others: 100 CHF

Conference with excursion for NOT SGmS members:
> Students & PhD Candidates: 80 CHF
> Post docs & Others: 130 CHF

No costs reduction for conference only without excursion

Excursion of the Young Geomorphologists

> Students & PhD Candidates members of the SGmS: free of charge
> Students & PhD Candidates NOT members of the SGmS: 30 CHF

Account of the SGmS

CCP: 80-46505-2 / IBAN: CH78 0900 0000 8004 6505 2
POFICHBEXXX / PostFinance SA, Mingerstrasse 20,
CH-3030 Bern

Please mention: Meeting 2019 + your family name

Payable until 31.08.2019

On behalf of the organizing committee:

Cristian Scapozza
Istituto scienze della Terra SUPSI
Campus Trevano
CH-6952 Canobbio
cristian.scapozza@supsi.ch

Géraldine Regolini
Bureau d'étude Relief
Chemin des Oisillons 9
CH-1860 Aigle
geraldine.regolini@bureau-relief.ch

Abstracts

(in alphabetical order)

Estrazione di modelli digitali del terreno da TLS long range

Achille Cristiana *, Fassi Francesco *, Teruggi Simone *, Cannata Massimiliano ** & Spataro Alessio **

* Politecnico di Milano, Dip. A.B.C. – 3DSurvey Group, Via Ponzio 31, 20133 Milano, Italia
** SUPSI, Istituto scienze della Terra, Dipartimento ambiente costruzioni e design, Campus Trevano, CH–6952 Canobbio

L'attività di ricerca in corso riguarda l'elaborazione e corretta gestione dei dati provenienti dall'attività di rilievo laser scanner al fine di produrre modelli del terreno utili alla ricostruzione degli effetti causati da eventi franosi, l'area di interesse è quella relativa al Comune di Piuro, sia la zona con l'abitato che il territorio che si estende sui due versanti limitrofi, nord e sud.

Il dato, acquisito con scanner Riegl Vz-4000, ha subito un primo filtraggio selezionando gli echo di ritorno del segnale, al fine di eliminare una componente di vegetazione e di elementi antropici. L'area acquisita è stata divisa in due zone omogenee, per caratteristiche orografiche, per essere sottoposta ad un processo di classificazione di dettaglio attraverso un uso appropriato del Cloth Simulation Filter. L'esito della classificazione ha prodotto come risultato i soli punti appartenenti alla superficie del terreno di tutta l'area. Il dataset (*.las) così ottenuto è stato successivamente elaborato con software GIS ed è stata ricavata la superficie del modello del terreno (TIN e raster).

La risoluzione del dato è di circa 30cm/pix nella parte della vallata e del Comune di Piuro; tale risoluzione degrada man mano ci si sposta sui versanti. Questo degrado è dovuto alla presenza di zone d'ombra, prodotte in particolare dalla vegetazione. Il dato raster (geotiff) ha una risoluzione che supporta una scala pari a 1:1000, su un modello di questo tipo si possono georeferenziare carte di pari livello di dettaglio e tutte le informazioni necessarie alla corretta comprensione e ricostruzione dell'evento franoso storico del 1618.

Topografie a confronto: Piuro 1618–2018

Achille Cristiana *, Castelletti Sergio ***, Fassi Francesco *, Teruggi Simone *, Cannata Massimiliano ** & Spataro Alessio **

* Politecnico di Milano, Dip. A.B.C. – 3DSurvey Group, Via Ponzio 31, 20133 Milano, Italia
** SUPSI, Istituto scienze della Terra, Dipartimento ambiente costruzione e design, Campus Trevano, CH–6952 Canobbio
*** Castelletti grafica immagine, Via Ceradello, 18 – 24020 Premolo (BG), Italia

Lo studio degli effetti degli eventi franosi storici non può prescindere da una attenta e dettagliata analisi dei documenti e delle informazioni che descrivono l'area oggetto di indagine prima della catastrofe e nel periodo immediatamente successivo.

Il modello-plastico, in scala 1:000, conservato presso il museo di Piuro ritrae il borgo prima della frana. Questo modello è stato realizzato sulla base dei documenti storici stampa Hardmeyer 1618 e dipinto di anonimo conservato presso il palazzo Vertemate – Franchi in Piuro. Questa ricostruzione assorbe anche tutte le indagini che a partire dal 1962 con il fotografo Hans Steiner di Berna (fondatore dell'associazione Italo-Svizzera scavi di Piuro) sono procedute fino al 1988. In tale occasione la campagna di scavi aveva dato ulteriori risultati che hanno permesso una ricostruzione grafica più accurata del territorio così com'era prima dell'evento franoso. Attività documentate attraverso le relazioni di scavo e le molte fotografie.

Questo plastico è stato acquisito con tecnica fotogrammetrica realizzandone così una copia digitale. Questo modello è stato confrontato con i dati acquisiti durante la campagna di rilievi laser scanner del 2018 che ha portato alla produzione di modelli DTM e DSM. Il modello digitale che ritrae Piuro prima della frana è stato volutamente confrontato con il DTM per permettere una lettura più chiara delle variazioni della morfologia, sottolineate dalla modifica della posizione dell'alveo del fiume Mera.

La continua evoluzione delle ricerche e la ripresa delle campagne di scavi, con il sostegno di istituti di ricerca, pone la necessità di disporre di un modello tridimensionale sul quale georeferenziare e confrontare analisi passate, presenti e future, e in questo senso queste ricostruzioni digitali si offrono come un supporto concreto.

Distribuzione, attività ed evoluzione di grandi frane lente in ambiente alpino: analisi innovative a scala regionale e locale

Agliardi Federico *, Crosta Giovanni Battista *, Frattini Paolo *, Crippa Chiara *, Spreafico Margherita * & Valbuzzi Elena *

* Università degli Studi di Milano-Bicocca, Dipartimento di Scienze dell'Ambiente e della Terra - DISAT (federico.agliardinimib.it)

Le grandi frane lente in roccia sono molto diffuse negli ambienti alpini. Esse evolvono lentamente per lunghi periodi, ma in determinate condizioni possono evolvere fino a collasso catastrofico. Queste frane hanno quindi un ruolo importante nel modellamento del paesaggio alpino (Agliardi *et al*. 2013) e costituiscono importanti minacce per le infrastrutture e la sicurezza di intere comunità. Prevederne evoluzione ed effetti è difficile, a causa della varietà delle condizioni geologiche e morfo-climatiche in cui si sviluppano e dei meccanismi e stili di attività che le caratterizzano.
Lo studio è stato quindi affrontato con un approccio multiscala. A scala di orogene, l'analisi statistica di un inventario originale (Crosta *et al*. 2013) permette di esplorare le condizioni favorevoli allo sviluppo di grandi frane e i loro impatti sul territorio. A scala regionale, una mappatura geomorfologica a scala di semi-dettaglio fornisce indicazioni distribuite su meccanismi ed attività dei fenomeni (Frattini *et al*. 2018). A scala locale, studi di dettaglio, monitoraggio e modellazione numerica consentono di quantificare gli aspetti evolutivi (Agliardi *et al*. 2018; Riva *et al*. 2018). I risultati forniscono utili indicazioni per una più ampia comprensione dei fenomeni, ma anche per stimolare la consapevolezza del pubblico per una più efficace riduzione dei rischi e una fruizione consapevole del territorio alpino.

REFERENZE

Agliardi F., Crosta G.B., Frattini P. & Malusà M.G. 2013. Giant non-catastrophic landslides and the long-term exhumation of the European Alps. *Earth & Planetary Science Letters* 365: 263–274.
Agliardi F., Riva F., Cola G., Spreafico M.C., Bourlès D., Braucher R., Crippa C., Rivolta C.,
Crosta G.B., Frattini P. & Agliardi F. 2013. Deep seated gravitational slope deformations in the European Alps. *Tectonophysics* 605: 13–33.
Frattini P., Crosta G.B., Rossini M. & Allievi J. 2018. Activity and kinematic behaviour of deep-seated landslides from PS-InSAR displacement rate measurements. *Landslides* 15(6): 1053–1070.
Riva F., Agliardi F., Amitrano D. & Crosta G.B. 2018. Damage-Based Time-Dependent Modeling of Paraglacial to Postglacial Progressive Failure of Large Rock Slopes. *Journal of Geophysical Research: Earth Surface* 123(1): 124–141.

Deep-Seated Gravitational Slope Deformations (DSGSDs) and last glaciation in Chiavenna Valley: geomorphological evidences of chronological relations

Apuani Tiziana *, Tantardini Davide ** & Bajni Greta *

* Università degli Studi di Milano, Dipartimento di Scienze della Terra "Ardito Desio" via Mangiagalli 34, 20133 Milano, Italy (tiziana.apuani@unimi.it)
** Paeb srl, Via Torino 5, 20096 Pioltello (MI), Italy

Deep-seated gravitational slope deformations (DSGSDs) are a common and widespread type of large slope instability in the Alps, affecting large portions of high-relief mountain slopes. DSGSD evolution is generally characterized by gravitational creep involving rock masses constituting the slope at slow rates (mm/year) (Apuani *et al*. 2007).
DSGSDs are significant natural hazards as they may damage local infrastructure, although it is the exceedance of a certain deformation threshold leading to a catastrophic collapse, that may endanger mountain communities (Chigira *et al*. 2010).
Characteristic morpho-structures of DSGSD include double ridges, trenches, tension cracks, counter scarps, and downthrown blocks in the upper sectors of slopes and buckling folds, toe bulging, enhanced rock fracturing and secondary mass movements in the middle and lower sectors (Panek 2016).
DSGSD space-time distribution can be related not only to the high relief potential energy but also to glaciation cycles action, deep groundwater flow, tectonic and locked-in stresses (Ambrosi & Crosta 2006).
In particular, in the literature, the "postglacial debuttressing" (i.e., the loss of the support provided from a last glaciation glacier to the slope because of its melting) is often considered as a major predisposing factor in the alpine environment (Dramis & Sorriso-Valvo 1994; Agliardi *et al*. 2001, 2009).
Detailed geomorphological field surveys carried out at a 1:10,000 scale in Valchiavenna (San Giacomo Valley and Bregaglia Valley) allowed to map the morphological evidences of a great number of DSGSDs, together with the deposits and landforms of structural, gravitational, glacial and periglacial origin. Among the many DSGSD phenomena in the area, some representative cases have been chosen to highlight relationships between the instability processes and the Last Glaciation phases and Maximum (LGM).
A relative dating has been carried out verifying the relationships between DSGSDs and glacial sediments/landforms relative to the last glaciation. The presence of tills, ice-contact deposits and glacial landforms filling and damming DSGSD trenches or covering DSGSD ridges has clearly shown that some DSGSDs in Valchiavenna have an age older than the LGM.

Moreover, it is unlikely that these DSGSDs formed during the glacial advance, when the slopes were progressively covered by the ice mass, reducing the potential gravitational energy. Thus, it can be reasonably inferred that DSGSDs started to settle previously than the last glaciation advance phase. The preglacial DSGSDs were hampered when glaciers became high enough to buttress the valley flanks. The postglacial debuttressing process, presented from various authors as one of the main predisposing factors of DSGSDs, can surely have occurred after the melting of the last glaciers: nevertheless, it did not act causing these DSGSDs, but inducing an acceleration of the process.
Recent progress in deciphering the temporal pattern of DSGSDs take advantage of the development of new methods (e.g. absolute dating methods and remote sensing techniques); however, field geomorphological surveys and direct observations of the territory still remain the benchmark to perform a robust analysis of the temporal cause-effect chain of these processes. The geomorphological and structural evidences and the stress field reconstruction during each geological step of the history of a slope are crucial to set up a coherent numerical modelling of the DSGSDs.

REFERENCES

Ambrosi C. & Crosta G. B. 2006. Large sackung along major tectonic features in the Central Italian Alps. *Engineering Geology* 83: 183–200.
Agliardi F., Crosta G. B. & Zanchi A. 2001. Structural constrains on deep–seated slope deformations kinematics. *Engineering Geology* 59: 83–102.
Agliardi F., Crosta G. B., Zanchi A. & Ravazzi C. 2009. Onset and timing of deep–seated gravitational slope deformations in the eastern Alps, Italy. *Geomorphology* 103: 113–129.
Apuani T., Masetti M. & Rossi M. 2007. Stress–strain–time numerical modelling of a deep-seated gravitational slope deformation: Preliminary results. *Quaternary International* 171–172: 80–89.
Chigira M., Wu X., Inokuchi T. & Wang G. 2010. Landslides induced by the 2008 Wenchuan earthquake, Sichuan, China. *Geomorphology* 118: 225–238.
Dramis F. & Sorriso–Valvo M. 1994. Deep–seated gravitational slope deformations, related landslides and tectonics. *Engineering Geology* 38: 231–243.
Pánek, T. & Klimeš, J. 2016. Temporal behavior of deep-seated gravitational slope deformations: A review. *Earth-Science Reviews* 156: 14–38.

Assessment of the quality of models simulating carbon transfer by soil erosion on a global scale

Bolliger Caroline * & Kuhn Nikolaus J. *

* University of Basel, Physical Geography, Environmental Sciences, Basel, Switzerland (nikolaus.kuhn@unibas.ch)

The impact of soil erosion on the global carbon cycle has been discussed controversially in recent years. On a global scale, erosion is considered to create a small carbon sink, while small-scale process studies tend to indicate a net release of Carbon. The 2014 IPCC report on climate change follows the global assessments, i.e. assumes a small sink. In this study, the literature used in the IPCC report and several additional recent studies with global assessments have been analyzed with the aim to identify why global and local assessments of carbon fluxes during erosion differ. Two key areas with significant methodological and information gaps have been identified. First, globally applied erosion models often simplify the processes involved in erosion and do not capture recent findings on the movement of eroded soil organic matter. Second, the scale of the raster cells used in the models is too large, leading to lower erosion values on the smoothed virtual slopes than in reality. Finally, the data used for calibrating and testing models do not represent the world's agricultural land adequately. For example, most field studies used to calibrate global models were done in Europe and North America, largely ignoring South America and Africa, where erosion leads to serious land degradation.

Assessing the impact of ground ice degradation on high mountain lake environments (Lago Nero catchment, Swiss Alps)

Bulgheroni Monica *, Scapozza Cristian *, Deluigi Nicola *, Pera Sebastian *, Pozzoni Maurizio *, Colombo Luca ** & Lepori Fabio *

* Institute of Earth Sciences (IST), University of Applied Sciences and Arts of Southern Switzerland (SUPSI), Campus Trevano, 6952 Canobbio, Switzerland (cristian.scapozza@supsi.ch)
** Department for Environment Constructions and Design (DACD), University of Applied Sciences and Arts of Southern Switzerland (SUPSI), Campus Trevano, 6952 Canobbio, Switzerland

We investigated the potential of local ground ice degradation to alter the water chemical composition at the outflow of the Lago Nero ("Black Lake") catchment, a high alpine basin located in the Southern Swiss Alps. The geomorphological characteristics of the area and the local permafrost distribution were assessed and coupled with measurements of ground surface temperatures and meltwater chemistry from an intact rock glacier and several perennial ice patches (Pozzoni *et al.* 2018). The local permafrost distribution in the catchment was in particular assessed thanks to machine learning modelling based on random forest algorithm, trained by the rock glaciers inventory of the Ticino Alps and 15 other environmental variables (Scapozza *et al.* 2019). The comparison of elemental concentrations between the cryosphere and the lake outflow unveiled the presence of high concentration of Nitrogen and Sulfur in the meltwater. Considering the temporal concordance between the recorded peak of atmospheric pollutants deposited between 1965 and 1980 and the last identified period of positive glacier mass balance occurred in the region (1961–1985; Huss *et al*. 2015), we assume that the enhanced melting of ground ice related to the recent severe warming is nowadays releasing "legacy" pollutants that have been stored in the cryosphere for several decades (Scapozza *et al.* 2019).

REFERENCES

Huss M., Dhulst L. & Bauder A. 2015. New long-term mass-balance series for the Swiss Alps. *Journal of Glaciology* 61: 551–562.

Pozzoni M., Bruder A., Bulgheroni M., Pera S., Scapozza C., Rioggi S., Domenici M. & Colombo L. 2018. Lago Nero: monitoraggio della risposta di un ecosistema all'inquinamento atmosferico e ai cambiamenti ambientali. *Bollettino della Società ticinese di scienza naturali* 106: 23–33.

Scapozza C., Deluigi N., Bulgheroni M., Pera S, Pozzoni M., Colombo L. & Lepori F. 2019. Assessing the impact of ground ice degradation on high mountain lake environments (Lago Nero catchment, Swiss Alps). *Aquatic sciences*: in press.

Le tourisme dans les sites géomorphologiques : opportunité ou menace ?

Bussard Jonathan *

* Institut de géographie et durabilité, Université de Lausanne (jonathan.bussard@unil.ch)

Un inventaire des géomorphosites du Parc naturel régional Gruyère Pays-d'Enhaut, dans les Préalpes de Suisse romande, a été réalisé en 2014 dans le but de mieux connaître ce patrimoine et de documenter la question de la protection de ces sites naturels d'intérêt (Bussard 2014). Ce travail a été motivé par le constat que la nature abiotique ne bénéficie pas du même niveau de reconnaissance que la nature vivante lorsqu'il s'agit de définir des zones protégées ou de restreindre certains usages comme le tourisme (voir notamment Reynard 2012). L'objectif est donc de renforcer les connaissances sur la géomorphologie régionale, de souligner l'intérêt scientifique des sites, leur valeur esthétique et écologique et d'analyser les usages et la gestion des sites en termes de protection et de valorisation touristique.

La documentation de 33 géomorphosites et des entretiens avec les principaux acteurs du tourisme et de la protection de la nature dans la région permettent de constater que :

(1) Le patrimoine géomorphologique est plutôt bien protégé, mais indirectement. Certains sites situés en dehors des périmètres de protection des biotopes sont menacés. Une meilleure reconnaissance du patrimoine abiotique dans les législations est donc nécessaire.

(2) Le patrimoine géomorphologique pourrait être bien mieux mis en valeur notamment pour le tourisme ou pour l'éducation à l'environnement, ce qui contribuerait aussi à une meilleure reconnaissance. La présence du Parc naturel régional peut certainement faciliter une mise en tourisme durable de certains sites.

Une thèse de doctorat démarrée en 2019 a pour but de donner suite à cette recherche en analysant dans le détail si le tourisme est compatible avec une protection adéquate du patrimoine géomorphologique. Surfréquentation de sites fragiles, dégradations, impacts paysagers, pollution, perturbation des dynamiques naturelles, etc. ; ces conséquences négatives peuvent-elles être limitées par une gestion durable du tourisme ? Si oui, dans quelles conditions ? Nous tenterons d'apporter des éléments de réponse par une comparaison de sites géomorphologiques « touristiques » dans différents contextes territoriaux.

REFERENCES

Bussard J. 2014. *Protection et valorisation du patrimoine géomorphologique du Parc naturel régional Gruyère Pays-d'Enhaut. État des lieux et perspectives* [Mémoire de master]. Lausanne : Université, Institut de géographie.

Reynard E. 2012. Geoheritage protection and promotion in Switzerland. *European Geologist* 34: 44–47.

Grandi frane alpine e il progetto Interreg AMALPI18

Ceriani Massimo * & Toffaloni Carlo *

* Regione Lombardia, Direzione Generale Territorio e Protezione Civile, Struttura Prevenzione Rischi Naturali, Piazza Città di Lombardia 1, 20124 Milano (I) (massimo_ceriani@regione.lombardia.it; carlo_toffaloni@regione.lombardia.it)

Gli studi e le analisi dei fenomeni di dissesto geo-idrologico (frane, valanghe, alluvioni) condotti in Lombardia, in Canton Ticino e nei Grigioni, negli ultimi 20 anni, sia a livello locale che regionale, hanno prodotto un quadro delle conoscenze decisamente significativo (solo in Lombardia oltre 140'000 frane mappate, oltre 30'000 valanghe censite, 2200 chilometri quadrati di aree alluvionabili individuate).
In realtà, al di là delle conoscenze acquisite, l'evoluzione dei territori montani passa, inevitabilmente, attraverso fenomeni franosi, anche di grandi dimensioni (oltre un milione di mc) che potrebbero generare danni enormi a cose e persone e modificare permanentemente la morfologia di una valle. Questi eventi estremi, ancorché rari, si sono manifestati nel passato e si ripresenteranno nel futuro.
La frana del Monte Crenone del 1513 con la "buzza" di Biasca del 1515, la frana di Piuro del 1618, la frana di Antronapiana del 1642, la frana di Gero e Barcone in Valsassina del 1762, la frana di Goldau del 1806, la frana del Sasso Rosso del 1898 sono alcuni esempi sulle Alpi, con distruzione anche di interi abitati, di ciò che è accaduto. Sono invece eventi dei nostri giorni le frane della Val Pola e del Torreggio (1987), di Randa (1991), la frana della Val Canaria (2009), la frana del Valegion di Preonzo (2012), le frane del Cengalo e di Bondo (2011–2017), la frana del Gallivaggio (2018) che grande ripercussione hanno avuto su questi territori. E ormai ci è chiaro che l'evoluzione di un territorio alpino, maestoso e grandioso avviene normalmente in maniera impercettibile ma, ogni qualche secolo, ogni qualche decennio, l'instabilità dei versanti si manifesta in maniera devastante.
Vie di comunicazione, abitati, infrastrutture e le grandi opere legate all'utilizzo delle acque possono, potrebbero essere interessate da questi eventi franosi estremi (rari ma non troppo!). Il progetto Interreg AMALPI18 (Alpi in Movimento, movimento nelle Alpi – Piuro 1618) vuole considerare le grandi frane quali elementi inevitabili e grandiosi del paesaggio e ha l'ambizione di promuoverne un turismo scientifico culturale con la creazione di un Centro Grandi Frane (*Alpine Landslide Research Centre*) a Chiavenna (SO) unito a un itinerario escursionistico che, dal Passo del Maloja al San Gottardo, attraverserà proprio i territori interessati nel passato e nel presente da questi importanti fenomeni di dissesto.

Evolution of fluvial environments and history of human settlements on the Ticino river alluvial plain

Czerski Dorota *, Mosetti Luisa **, Cardani Vergani Rossana **, Pellegrini Michele **, Federici-Schenardi Maruska **, Gillioz Mattia **, Nogara Giorgio ** & Scapozza Cristian *

* Institute of Earth Sciences, University of Applied Sciences and Arts of Southern Switzerland (SUPSI), Campus Trevano, 6952 Canobbio, Switzerland (dorota.czerski@supsi.ch)
** Section of Archaeology, Ufficio dei Beni Culturali del Cantone Ticino, Viale Stefano Franscini 30a, 6501 Bellinzona, Switzerland

In recent times many geomorphological and geoarchaeological studies were carried out at many locations on the Piano di Magadino (Scapozza & Opizzi 2013). The age and stratigraphy of the deposits were determined using the radiocarbon dating method on organic matter debris and charcoals. This, combined with an accurate sedimentological characterization of the deposit, archaeological observations and dating, allowed interpreting the palaeoenvironmental conditions and depositional context for the studied sedimentary and archaeological sequences. This contribution resumes dating and stratigraphy determined in the archeological sites in Progero (2'715'900/1'114'530, CH1903+ / LV95), Gudo (2'716'720/1'114'800) and Giubiasco–Palasio (2'721'902/1'114'942), for the last site the dating analysis is ongoing. The observations together with other historical information (Scapozza 2013) and results from other research projects on the Ticino river alluvial plain (Scapozza *et al.* 2017) highlighted eight phases of enhanced hydrosedimentary activity since the Bronze Age: 1500–1440 BC (Middle Bronze Age), 1285–760 BC (Late Bronze Age/Early Iron Age), 400–370 BC (Late Iron Age), 200–170 BC (Late Iron Age), 10–340 AD (Roman Period), 540–1000 AD (Early Middle Ages), 1178 AD (High Middle Ages) and 1690–1868 AD (Modern Epoch) (Scapozza & Czerski 2019).

REFERENCES

Scapozza C. 2013. L'evoluzione degli ambienti fluviali del Piano di Magadino dall'anno 1000 a oggi. *Archivio Storico Ticinese* 153: 60–92.
Scapozza C. & Oppizzi P. 2013. Evolution morpho-sédimentaire et paléo-environnementale de la plainde fluvio-deltaïque du Ticino pendant l'Holocène récent (Canton du Tessin, Suisse). *Géomorphologie : relief, processus, environnement* 19(3): 265–286.
Scapozza C., Castelletti C. & Czerski D. 2017. Nuove datazioni per la storia dell'evoluzione olocenica degli ambienti fluviali del Piano di Magadino (Cantone Ticino, Svizzera). *Bollettino della Società ticinese di Scienze naturali* 105: 97–102.
Scapozza C. & Czerski D. 2019. Geomorfologia della Svizzera italiana / Die Geomorphologie der Südschweiz. *Archeologia svizzera* 42(2): 8–13.

La frana del Monte Crenone del 1513. Modello numerico e analisi geomorfologica

De Pedrini Alessandro *, Scapozza Cristian * & Ambrosi Christian *

* Istituto scienze della Terra (IST), Scuola universitaria professionale della Svizzera italiana (SUPSI), Campus Trevano, 6952 Canobbio, Svizzera (alessandro.depedrini@supsi.ch)

La frana del Monte Crenone del 30 settembre 1513 è uno degli eventi naturali più catastrofici della Svizzera e di tutto l'arco alpino. L'enorme massa di roccia che si staccò dal versante occidentale del Pizzo Magn o Monte Crenone, stimata in 50-90 milioni di metri cubi, causò lo sbarramento completo del corso del Brenno, portando alla formazione di un bacino che si estese da Biasca fino a lambire il Castello di Serravalle a Semione (De Antoni *et al*. 2016). Il 20 maggio 1515 il bacino formatosi alle spalle dello sbarramento tracimò, dando origine a un'onda di altezza superiore ai 10 metri che portò devastazione nei territori a valle fino a raggiungere il Lago Maggiore (Scapozza *et al.* 2015).

In questo progetto, si analizza la dinamica della frana del 1513, cercando di ricostruire l'evento attraverso un modello numerico, calcolato con il software RAMMS::Debrisflow (RApid Mass Movement Simulation) fornito dall'Istituto federale per lo Studio della Neve e delle Valanghe (SLF/WSL).

La realizzazione del modello numerico è stata preceduta dalla ricostruzione della topografia precedente la frana. Questa prima fase di lavoro ha previsto un rilevo geologico sul corpo frana, l'analisi di dati digitali (ortofoto, carte topografiche digitali, modello ombreggiato derivato dallo swissALTI3D) e la raccolta di dati storici pregressi.

Fondamentale è stata l'osservazione dei dati stratigrafici ottenuti dai sondaggi 701.27 e 701.30 (parte degli studi geotecnici per l'autostrada Chiasso-San Gottardo) della banca dati GESPOS (GEstione Sondaggi, POzzi e Sorgenti) dell'Istituto scienze della Terra SUPSI.

Dalla prima fase di raccolta e interpretazione dei dati, si è passato quindi alla ricostruzione vera e propria del modello digitale del terreno precedente alla frana. Questa operazione è stata effettuata mediante software ArcGIS di ESRI, che ha permesso di ricreare molteplici modelli della topografia pre-evento e di trovare quindi la soluzione più realistica applicabile al successivo modello RAMMS.

REFERENZE

De Antoni S., Scapozza C., Tognacca C., Zucca M., Bernasocchi M., Bruni-Coduri Y. & Chiaravalloti E. 2016. *La Buzza di Biasca attraverso le immagini e i documenti. 1515–2015*. Biasca, Comune di Biasca, 128 p.

Scapozza C., Tognacca C., Ambrosi C. & Seno S. 2015. 20 maggio 1515: la "Buzza" che impressionò l'Europa. *Bollettino della Società ticinese di scienze naturali* 103: 79–88.

Le esperienze dell'interferometria sui monitoraggi di Gallivaggio e Cataeggio

Dei Cas Luca *

* ARPA LOMBARDIA UO Centro di Monitoraggio Geologico. Via del Gesù 17, I-23100 Sondrio (l.deicas @arpalombardia.it)

La tecnologia interferometrica è da anni utilizzata per il monitoraggio delle frane. Risulta interessante evidenziarne alcuni dati di velocità acquisiti, relativamente ai fenomeni osservati che sono evoluti fino al crollo (Cataeggio e Gallivaggio), o che, pur non collassando, hanno evidenziato fortissime accelerazioni (Ruinon). L'intervento sarà centrato sui due più recenti crolli in roccia avvenuti in provincia di Sondrio anche in relazione ai dati acquisiti mediante tecnica interferometrica SAR. Accenni sui dati acquisiti con tecnologia SAR durante l'ultimo fenomeno di accelerazione della frana di Ruinon in Valfurva.

Les fluctuations des glaciers après le Petit Âge Glaciaire. Datation de cordons morainiques dans le Val Scaradra avec la méthode du marteau de Schmidt et l'analyse de cartes historiques

Del Siro Chantal *, Lambiel Christophe * & Scapozza Cristian **

* Institut des dynamiques de la surface terrestre (IDYST), Université de Lausanne, UNIL Mouline, CH-1015 Lausanne (chantal.delsiro@unil.ch; christophe.lambiel@unil.ch)
** Institut Science de la Terre (IST), Ecole Universitaire Professionnelle de la Suisse Italienne (SUPSI), Via Trevano, CH-6952 Canobbio (cristian.scapozza@supsi.ch)

L'étude vise à reconstruire les fluctuations du glacier Vadrecc di Scaradra – qui se trouve au nord du Canton Tessin – après la fin du Petit Âge Glaciaire (PAG) ainsi que vérifier l'efficacité des différentes approches de la méthode de datation avec le marteau de Schmidt (Del Siro 2019). Les âges calibrés des stations de mesure placées sur les dépôts glaciaires ont été comparés à l'analyse des cartes topographiques et photos aériennes historiques. Les résultats obtenus ont été vérifiés et complétés ensuite avec l'évolution du Vadrecc di Bresciana et avec les données climatiques historiques. Les âges calibrés des cordons morainiques, à partir des valeurs-R du deuxième et troisième impact, se sont avérés plus précis que ceux obtenus avec les valeurs-R du premier impact, dont la calibration donne souvent des âges trop anciens par rapport à l'évolution réelle du glacier. L'évolution du Vadrecc di Scaradra à partir de la fin du PAG a été caractérisée par l'alternance de phases de stagnation ou de bref réavancement et d'importantes phases de retrait, avec la dernière qui est en cours et qui conduira probablement à la disparition complète du glacier. Vu la ressemblance des glaciers des Alpes de l'Adula au niveau de la taille (Scapozza 2014), la reconstruction des positions « post-PAG » du Vadrecc di Scaradra pourrait s'avérer intéressante pour la compréhension de l'évolution glaciaire dans cette région.

REFERENCES

Del Siro C. 2019. *Les fluctuations des glaciers après le Petit Âge Glaciaire. Datation de cordons morainiques dans le Val Scaradra avec la méthode du marteau de Schmidt et l'analyse de cartes historiques*. Travail de Bachelor, Université de Lausanne, 41 p.
Scapozza C. 2014. Appunti climatici e glaciologici sulle descrizioni della Valle di Blenio tra Settecento e Ottocento. *Archivio Storico Ticinese* 155: 38–63.

Rapid disappearance of glacier and implication for local multi-hazard risk assessment: Les Diablerets (western Swiss Alps)

Fischer Mauro *, ** & Keiler Margreth *, **

* Institute of Geography, University of Bern, Hallerstrasse 12, 3012 Bern, Switzerland (mauro.fischer@giub.unibe.ch)
** Oeschger Centre for Climate Change Research, University of Bern, Hochschulstrasse 4, 3012 Bern, Switzerland

This case study presents preliminary results of an in-depth application of state-of-the-art multi-hazard and risk assessment strategies to identify and assess present and future impacts, vulnerabilities and risks related to the currently observed rapid changes of the high-mountain cryosphere in the catchment of Glacier du Sex Rouge.

Glacier du Sex Rouge, a very small and rapidly shrinking glacier in the western Swiss Alps, is projected to completely disappear around 2030. The current glacier bed topography has been investigated based on close meshed ground penetrating radar (GPR) surveys and shows a trough-shaped structure, i.e. an overdeepening confined to all sides formed by past glacier erosion. Evidence for the potential formation of a future new lake can already be observed at the location of today's glacier terminus during summer.

The possible lake formation might change the hazard and risk potential for population and infrastructure in the area of Les Diablerets (1162 m a.s.l., a village situated 6 km from Glacier du Sex Rouge) or even further down-valley. Impact waves triggered due to rock fall from the steep northwest face of Oldehore/Becca d'Audon (3123 m a.s.l.) with occurring permafrost could potentially overtop the lake's rock dam and initiate a flood wave which might – considering the notable amount of loose debris currently accumulated in the forefield of Glacier du Sex Rouge – develop into a debris-flow by sediment entrainment along its flow path.

Semi-automated geomorphological mapping

Giaccone Elisa *, Mariéthoz Grégoire * & Lambiel Christophe *

* Institute of Earth Surface Dynamics (IDYST), University of Lausanne, UNIL Mouline, CH-1015 Lausanne (elisa.giaccone@unil.ch; gregoire.mariethoz@unil.ch; christophe.lambiel@unil.ch)

Conventional geomorphological maps are usually constructed by mapping features on the field or directly in Geographic Information Systems from topographic data and orthoimages. This approach is time-consuming and therefore only suitable for mapping relatively limited areas. For the mapping of larger areas, automatic procedures are needed, but to be efficient those need to be driven by geomorphological expertise.

To this end, we developed two different approaches that perform semi-automated geomorphological map (SAGM) guided by an already classified map from an analogue area. The first approach is based on the Direct Sampling (DS) algorithm, part of the multiple-point geostatistics framework that simulates a random variable (here the geomorphological categories) based on a training image (Mariéthoz *et al.* 2010; Vannametee *et al.* 2014; Mariéthoz & Caers 2015).

The second approach is based on the Random Forest algorithm (RF, Breiman 2001). It is a classification and regression method, able to elaborate decision trees and to weight predictors based on a permutation test. In this way, if a variable is not important, it will be dismissed without undermining classification accuracy (Conedera *et al.* 2015).

The SAGM and the RF are tested on a site located in the Western Swiss Alps, where a traditional geomorphological map is available for validation, and then applied to other alpine sectors.

REFERENCES

Breiman L. 2001. Random Forests. *Machine Learning* 45(1): 5–32.

Conedera M., Tonini M., Oleggini L., Vega Orozco C., Leuenberger M. & Pezzatti, G. 2015. Geospatial approach for defining the Wildland-Urban Interface in the Alpine environment. *Computers, Environment and Urban Systems* 52: 10–20.

Mariéthoz G. & Caers J. 2015. *Multiple-point geostatistics: stochastic modeling with training images*. John Wiley & Sons, Ltd, Chichester, UK, xi + 364 pp.

Mariéthoz G., Renard P. & Straubhaar J. 2010. The direct sampling method to perform multiple-point geostatistical simulations. *Water Resources Research* 46: W11536.

Vannametee E., Babel L.V., Hendriks M.R., Schuur J., de Jong S.M., Bierkens M.F.P. & Karssenberg D. 2014. Semi-automated mapping of landforms using multiple point geostatistics. *Geomorphology* 221: 298–319.

The world's largest debris-flow measuring system is back in operation – first experiences and measurement results from Illgraben

Graf Christoph *, McArdell Brian W. *, Boss Stefan *, Collet Marco **, Huguenin Pierre *** & Badoux Alexandre *

* Eidgenössische Forschungsanstalt für Wald, Schnee und Landschaft WSL, Birmensdorf (christoph.graf@wsl.ch)
** WSL-Institut für Schnee- und Lawinenforschung SLF, Davos
*** Institut fédéral de recherches WSL, Sion

In summer 2016, a debris-flow transporting huge boulders destroyed the measuring system installed in the Illgraben gully near Leuk (canton of Valais). The equipment, which is part of the automated debris-flow monitoring system operated by the Swiss Federal Institute for Forest, Snow and Landscape Research (WSL), has now been replaced with a technically superior version. On June 21, the upgraded facility successfully withstood its first large debris-flow and provided more accurate measurements and videos than the previous system, with a higher temporal resolution than ever.

Quantifying the alpine sediment cascade using multi-temporal high-resolution topographical surveys: case studies from Mattertal and Col du Sanetsch (VS)

Hendrickx Hanne *, Nyssen Jan *, Delaloye Reynald ** & Frankl Amaury *

* Department of Geography, Ghent University, Belgium (hanne.hendrickx@ugent.be)
** Department of Geography, Fribourg University, Switzerland

Climate change-induced permafrost degradation can affect the frequency and magnitude of mass wasting processes in high alpine environments, potentially altering sediment redistributions (Beniston *et al.* 2018). Talus slopes are one of the most common landforms in these environments, collecting debris through rock fall from adjacent rock walls, forming the first step in the alpine sediment cascade and can be a source for other geomorphic processes leading to sediment transfers. It is therefore important to study geomorphic change in talus slopes and their headwalls to increase our understanding of the driving environmental factors.
The main objective of this research is to contribute to the understanding of the overall sediment cascade in an alpine environment with specific focus on rock walls, talus slope, and rock glaciers as sediment conveyors. Monitoring of topographic changes is fundamental to studying sediment dynamics (Cucchiaro *et al.* 2018). Therefore, multi-temporal high-resolution data (5 ± 2 cm) from Terrestrial Laser Scanning (TLS) and Unmanned Aerial Vehicles (UAV) photogrammetry are gathered along with data of ground temperature, geophysical data, meteorological data and time-lapsed terrestrial photographs.
Geomorphic processes, such as rock fall, rock tilting, rock tumbling, and channel fill, can be detected and quantified in a timeframe of two years using UAV- and TLS-based point cloud acquisition. The integration of multi-year datasets will allow to understand the geomorphologic dynamics of the area and the driving environmental factors behind these sediment redistributions.

REFERENCES

Beniston M., *et al.* 2018. The European mountain cryosphere: A review of its current state, trends, and future challenges. *Cryosphere* 12(2): 759–794.
Cucchiaro S., Cavalli M., Vericat D., Crema S., Llena M., Beinat A., Marchi L. & Cazorzi, F. 2018. Monitoring topographic changes through 4D-structure-from-motion photogrammetry: application to a debris-flow channel. *Environ. Earth Sci.* 77(18): 632.

Assessing provenance, exposure timing and emplacement processes of large exotic boulders in central Himalayan river valleys

Huber Marius L. *, Lupker Maarten *, Gallen Sean F. **, Haghipour Negar *, Christl Marcus *** & Gajurel Ananta P. ****

* Geological Institute, Department of Earth Sciences, ETH Zurich, Sonneggstrasse 5, CH-8092 Zurich, now at University of Bern, Institute of Geological Sciences (marius.huber@geo.unibe.ch)
** Department of Geosciences, Colorado State University, Smith Natural Resources Building 327, Fort Collins, Colorado 80523, United States of America
*** Laboratory of Ion Beam Physics (LIP), Institute for Particle Physics, Department of Physics, ETH Zurich, Otto-Stern-Weg 5, CH-8093 Zurich
**** Department of Geology, Tri-Chandra Campus, Tribhuvan University, Ghantaghar, Kathmandu, Nepal

Tectonically active landscapes develop equilibrium and steady state topography by balancing rock uplift and erosion over long timescales (>1 Ma) (e.g. Willett & Brandon 2002). On shorter timescales (≤ 10^5 a) landscape evolution is characterized by phases of erosion and aggradation induced by changes in climatic forcing and threshold behaviour (e.g. Schumm 1979).
In central Himalayan river valleys, numerous large boulders (>10 m in diameter) lie on or are contained within Quaternary river terraces, active floodplains or the modern river bed. Their lithology frequently differs from the surrounding bedrock and reveals that they are derived from rock units outcropping >10 km of kilometres upstream. The large boulders show evidence of fluvial rounding, crescentic percussion marks and are located 2000 m lower in elevation than the terminal moraines associated with the last glacial maximum (LGM) (e.g. Owen & Benn 2005). The exact transport mechanisms of such exceptionally large grain sizes remain unknown and may be linked to reoccurring catastrophic mass-wasting events. This study aims to constrain the timing and processes that lead to emplacement of these exotic boulders.

(1) The boulder size of 16 boulders was used to estimate paleo-discharges in two valleys of central Nepal (Trishuli & Sunkoshi) based on different literature fluid flow approaches (e.g. Alexander & Cooker 2016). These estimates indicate discharges in the order of 10^4 to 10^5 m^3/s are necessary to mobilize the surveyed boulders.

(2) ^{10}Be exposure ages of these boulders show ages up to 10.2–14.2 ka BP for two boulders in the Sunkoshi but also show clustering of emplacement at ca. 4.5–5.5 ka BP in both

valleys. Exposure dating implies a reoccurrence interval >10^3 a for such large magnitude events.

The ages documented in this study were compared to dated glacial landforms, alluvial deposits and earthquake occurrence in central Himalaya (e.g. Abramowski *et al*. 2003; Pratt-Sitaula *et al*. 2004; Bollinger *et al*. 2014) as well as terrestrial climate records of the Indian monsoon influenced region (e.g. Thompson *et al*. 1997; Herzschuh 2006; Sarkar *et al*. 2015). Correlation between boulder exposure ages, shift on monsoon governed climate regime, and glacial retreat suggests linkage of emplacement to mid Holocene climate transition after an Early Holocene climate optimum (EHCO). We reason that the mid-Holocene weak monsoon induced wide-spread glacier retreat and may have led to high magnitude Glacial Lake Outburst floods (GLOFs) responsible for large scale boulder emplacement in central Himalayan river valleys. We therefore propose that large floods causing valley aggradation may occur during onsets of weak monsoon phases and may be linked to glacier dynamics.

REFERENCES

Abramowski U., Glaser B., Kharki K., Kubik P. & Zech W. 2003. ABHANDLUNGEN-Late Pleistocene and holocene paleoglaciations of the Nepal Himalaya: 10be surface exposure dating. With 5 figures. *Zeitschrift fur Gletscherkunde und Glazialgeologie* 39: 183–196.

Alexander J. & Cooker M.J. 2016. Moving boulders in flash floods and estimating flow conditions using boulders in ancient deposits. *Sedimentology* 63(6): 1582–1595.

Bollinger L., Sapkota S.N., Tapponnier P., Klinger Y., Rizza M., Van Der Woerd, J., Tiwari D., Pandey R., Bitri A. & Bes de Berc S. 2014. Estimating the return times of great Himalayan earthquakes in eastern Nepal: Evidence from the Patu and Bardibas strands of the Main Frontal Thrust. *Journal of Geophysical Research: Solid Earth* 119(9): 7123–7163.

Herzschuh U. 2006. Palaeo-moisture evolution in monsoonal Central Asia during the last 50,000 years. *Quaternary Science Reviews* 25(1): 163–178.

Owen L.A. & Benn D.I. 2005. Equilibrium-line altitudes of the Last Glacial Maximum for the Himalaya and Tibet: an assessment and evaluation of results. *Quaternary International* 138: 55-78.

Pratt-Sitaula B., Burbank D.W., Heimsath A. & Ojha T. 2004. Landscape disequilibrium on 1000–10,000 year scales Marsyandi River, Nepal, central Himalaya. *Geomorphology* 58(1): 223–241.

Sarkar S., Prasad S., Wilkes H., Riedel N., Stebich M., Basavaiah N. & Sachse D. 2015. Monsoon source shifts during the drying mid-Holocene: Biomarker isotope based evidence from the core ‘monsoon zone’(CMZ) of India. *Quaternary Science Reviews* 123: 144–157.

Schumm S.A. 1979. Geomorphic thresholds: the concept and its applications. *Transactions of the Institute of British Geographers* 4(4): 485–515.

Thompson L.o., Yao T., Davis M., Henderson K., Mosley-Thompson E., Lin P.-N., Beer J., Synal H.-A., Cole-Dai J. & Bolzan, J. 1997. Tropical climate instability: The last glacial cycle from a Qinghai-Tibetan ice core. *Science* 276(5320): 1821–1825.

Willett S.D. & Brandon M.T., 2002. On steady states in mountain belts. *Geology* 30(2): 175–178.

Close-up imaging simulation in the Marslabor of the University of Basel

Josset Jean-Luc **, Bontognali Tomaso *, **, Hofmann Beda ***, Meister Yardena * & Kuhn Nikolaus J. *

* University of Basel, Physical Geography, Environmental Sciences, Basel, Switzerland (nikolaus.kuhn@unibas.ch)
** Space Exploration Institute, Neuchâtel, Switzerland,
*** Natural History Museum, Bern, Switzerland

Close-up imagers such as MAHLI or CLUPI are often described as the equivalent of a geoscientist's hand lense mounted on a rover. Compared to the use of a hand lense by a geoscientist in the field, the use of such imagers for extracting information, e.g. on rock properties, rock formation or their potential to contain biosignatures, is biased. The difference between the tools is caused by the resolution and spectral recording capacity of the imager, as well as the environmental conditions when an image is taken. During rover missions, ideal conditions to take close-up images are rare or require extra time, energy and data transmission volume. Preparing the use of close-up imagers during a mission is therefore essential for maximizing the scientific output of rover operations. The Marslabor of the University of Basel aims at providing the opportunity to test the operations of close-up imagers in situations that resemble those during a rover mission to another planetary body. The main elements of the Marslabor are a Marsyard with variable surface conditions, in particular surface color and roughness, lighting simulating different positions of the sun at various degrees of intensity and atmospheric diffusion, and a small rover carrying a commercial camera with macro-lense offering a field of view similar to the ExoMars Close-up Imager (CLUPI). The aims of the tests conducted in the University of Basel's Marslabor are (i) the identification of the best lighting for the recognition of biosignatures, (ii) rock identification from the furthest possible distance during rover drives, and (iii) integration of close-up imagers in rover exploration cascades.

Reconstructing deglaciation dynamics and environmental changes in the Italy-Switzerland transboundary area of the Val Viola Pass

Masseroli Anna *, Cerrato Riccardo **, Azzoni Roberto Sergio ***, Pellegrini Marco *, Vezzola Laura *, Bollati Irene *, Giaccone Elisa ****, Viani Cristina *****, Scapozza Cristian ******, Zerboni Andrea * & Guglielmin Mauro *******

* Università degli Studi di Milano, Dipartimento di Scienze della Terra (anna.masseroli@unimi.it)
** Università di Pisa, Dipartimento di Scienze della Terra
*** Università degli Studi di Milano, Dipartimento di Scienze e Politiche Ambientali
**** University of Lausanne, Institute of Earth Surface Dynamics
***** Università di Torino, Dipartimento di Scienze della Terra
****** Scuola Universitaria Professionale della Svizzera Italiana (SUPSI), Istituto scienze della Terra
******* Università degli Studi dell'Insubria, Dipartimento di Scienze Teoriche e Applicate

The deglaciation following the Last Glacial Maximum (LGM) is one of the most important climate-driven surface processes that occurred in the Alps. The deglaciation contributed to shape the landscape of high-mountain areas. In the Lateglacial and during the Holocene, water-related, slope, and periglacial processes have interplayed with pedogenesis, shaping the landscape of the deglaciated alpine valleys.

In order to reconstruct the deglaciation history and environmental changes occurred in the Val Viola area (Upper Valtellina-Poschiavo Valley), we used a multidisciplinary approach including a detailed geomorphological mapping of the area (Bollati *et al*. 2018) and field and laboratory characterization of post-LGM deposits and soils. As regards the analysis of deposits and soils, six soil profiles were sampled and analysed along an altitudinal transect between 2325 m and 2430 m a.s.l.; this helped elucidating the process of soil development and detecting the presence of different pedological units. Moreover, Schmidt's hammer measurements were performed in order to establish the degree of surface weathering and thus the exposure-age of rock glacier debris and bare rock surfaces. Debris and rock surfaces suitable for Schmidt's hammer exposure dating were selected according to the results of geomorphological mapping. Finally, two peat bog deposits and charcoals found in one soil profile were dated with AMS-14C dating. Analyses of soil profiles allowed the identification of the occurrence of different slope instability phases, which are recorded as buried surfaces, suggested by the presence of stone lines and/or granulometric discontinuity. A pristine phase of surface stability, likely characterized by increasing soil forming processes, is dated at 9130–9000 cal BP (95.4%) (8120 ± 30 BP), corresponding to the radiocarbon date of the bottom of a peat bog. Subsequently, this phase of stability has been affected by rexistasy phase probably due to the worsening of climate conditions. This instability phase occurred after the 5466–5345 cal BP (95.4%) (4650 ± 30 BP), radiocarbon date of the charcoal found in a soil horizon buried below a stone line. A similar radiocarbon age (4960–4925 cal BP; 95.4%; 4320 ± 30 BP) was found also at the bottom of a second peat bog. Above the stone line, covering the charcoal, a more recent soil unit testifies the occurrence of new environmental conditions promoting pedogenesis. In nearby areas, Schmidt's Hammer was used to date bare surfaces (e.g. Scotti *et al*. 2017), and the regression lines obtained by the authors were used to calibrate rebound values collected in our study area. The data show that the rock weathering processes on the top of two exharated granitic gneiss outcrops started around 17 ka BP being in accordance with the timing of deglaciation since the Last Glacial Maximum and with soil developments. Schmidt's hammer rebound values and soils analysis provided additional data useful for reconstructing the landscape evolution of the region.

REFERENCES

Bollati I. M., Cerrato R., Crosa Lenz B., Vezzola L., Giaccone E., Viani C., Zanoner T., Azzoni R.S., Masseroli A., Pellegrini M., Scapozza C., Zerboni A. & Guglielmin M. 2018. The geomorphological map of the Val Viola Pass (Italy-Switzerland). *Geografia Fisica e Dinamica Quaternaria* 41(2): 105–114. https://doi.org/10.4461/GFDQ.2018.41.16

Scotti R., Brardinoni F., Crosta G.B., Cola G. & Mair V. 2017. Time constraints for post-LGM landscape response to deglaciation in Val Viola, Central Italian Alps. *Quaternary Science Reviews* 177: 10–33.

Simulating the effect of check dams on landscape evolution at centennial time scales

Mertin Mirjam *, **, Ramirez Jorge Alberto *, **, Zimmermann Markus *, **, Skinner Chris *** & Keiler Margreth *, **

* Institute of Geography, University of Bern, Hallerstrasse 12, CH-3012 Bern
** Oeschger Centre for Climate Change Research, Mobiliar Lab of Natural Risks, Hallerstrasse 12, CH-3012 Bern (mirjam.mertin@giub.unibe.ch)
*** Energy and Environment Institute, University of Hull, Cottingham Rd, UK-HU6 7RX Hull

Check dams are structures that stabilize mountain rivers by decreasing flow velocity and reducing channel incision (Piton *et al*. 2017). Over long time scales (100 years), a series of check dams constructed in a particular river reach can have significant effects on sediment and water dynamics and river channel responses (Bombino *et al.* 2009). The maintenance, repair or replacement of check dams is costly over time (Piton *et al*. 2017). Given the drawbacks of check dam maintenance, the question arises as to what would happen geomorphologically if check dams were no longer maintained and allowed to structurally deteriorate. To provide insight about this question, a landscape evolution model (CAESAR-Lisflood) was applied to the Guerbe torrent containing 73 check dams. These longstanding structures afford a sense of security for downstream communities by mitigating small- and mid-scale flood and debris flow hazards. Using CAESAR-Lisflood future scenarios of the river development at centennial time scales were simulated. Scenarios considered the quantity and location of check dams that were neglected, subsequently collapsed, and released large amounts of sediment. This allowed us to understand how the neglect of check dam cascades through the catchment and provided information about optimal check dam placement and amount. The relevance of including geomorphic processes (e.g. sediment dynamic, erosion, deposition) into flood modeling was clearly supported by the current findings.

REFERENCES

Bombino G., Gurnell A.M., Tamburino V., Zema D.A. & Zimbone S.M. 2009. Adjustments in channel form, sediment calibre and vegetation around check-dams in the headwater reaches of mountain torrents, Calabria, Italy. *Earth Surface Processes and Landforms* 34(7): 1011–1021.
Piton G., Carladous S., Recking A., Tacnet J.M., Liébault F., Kuss D., Queffèléan Y. & Marco O. 2017. Why do we build check dams in Alpine streams? An historical perspective from the French experience. *Earth Surface Processes and Landforms* 42(1): 91–108.

The Cimaganda rockslide (2012): recent geomorphological evolution of the paleo-event

Morcioni Andrea *, Bajni Greta * & Apuani Tiziana *

* Università degli Studi di Milano, Dipartimento di Scienze della Terra "Ardito Desio" via Mangiagalli 34, 20133 Milano, Italy. (andrea.morcioni@unimi.it)

The San Giacomo Valley (Sondrio, Italy), as many alpine areas, is quite frequently affected by rock slope landslides at different scales, due to its geological and morphological features. Their interaction with anthropic activities represents one of the main natural risk along the Valley. The analysis and understanding of slope instability processes are thus so crucial to forecast landslide events, and to plan risk mitigation and civil protection actions.
This work deals with the study of the Cimaganda rockslide, occurred in September 2012 after some days of persistent rainfall. It involved a rock volume of about 20.000 m^3, blocking the main road (SS36) and isolating the municipality of Madesimo and Campodolcino in the upper Valley. The rockslide developed in an active geomorphological context, along the right flank of the historical Cimaganda landslide, dated at least to the 17th century with a volume involved valued in 7.5 million of m^3.
Following a procedural scheme including field surveys, remote sensing and geomechanical laboratory tests, this work develops an accurate characterization of the slope, that lead to a solid geological and geomechanical conceptual model extended to the slope directed involved in the 2012 event and to the surrounding area of the historical large landslide. Geological, geomorphological and geomechanical surveys allowed to recognize typical features of deep-seated gravitational deformations and largescale stress release: trenches and counter-slopes at the crown of the ancient landslide, sub-vertical tensile fracturing along the slope and shear planes mainly along the right flank.
Using Finite Element Method (FEM) the conceptual model was built specifying the joint network orientation and the elasto-plastic properties of rock and joints. Hydraulics properties and anisotropy conductivities of rock mass, necessary to simulate hydrogeological flow, were calculated based on joint features of each discontinuity set. First, the numerical modelling, developed to simulate the slope scenarios before the landslide event, was able to reproduce a deformation pattern coherent with filed observations. Then, the introduction of a rainfall infiltration process, as triggering factor, with a semi-coupled hydro-mechanical analysis, allowed to simulate the evolution of the 2012 rockslide.
This work represents a solid base to improve the analysis of the Cimaganda paleo-landslide and explore instability-forecasting scenarios in order to enhance rockslide risk management.

La rete lombarda di monitoraggio geologico

Pastore Maria Luisa *

* ARPA LOMBARDIA Settore Tutela dei Rischi Naturali. Via Rosellini 17, Milano (m.passtore@arpalombardia.it)

Il Centro di Monitoraggio geologico di ARPA Lombardia ha recentemente subito una forte ristrutturazione che lo ha portato ha gestire oltre 40 reti di monitoraggio geologico distribuite sul territorio dell'intera Lombardia. Molti di queste reti vengono gestite con finalità di allertamento per la Protezione Civile. L'intervento illustrerà la situazione dei monitoraggi geologici gestiti da ARPA Lombardia con particolare riferimento alle differenti sensoristiche utilizzate ed all'organizzazione del Centro di Monitoraggio.

Les régions « Géo-focus » de la Suisse : étude sur les valeurs géologiques d'importance internationale

Regolini Géraldine *, Meyer Jürg ** & Buckingham Thomas ***

* Bureau Relief, Ch. des Oisillons 9, 1860 Aigle (geraldine.regolini@bureau-relief.ch)
** Rundumberge, Bergwaldweg 5, 4933 Rütschelen (ibex@gmx.ch)
*** UNESCO-World Heritage Swiss Tectonic Arena Sardona, Städtchenstrasse 45, 7320 Sargans (thomas.buckingham@unesco-sardona.ch)

Quelles sont les valeurs géologiques d'importance internationale en Suisse? Voici la question de départ d'une étude commandé par l'Office fédéral de l'environnement (OFEV) en 2018. Les auteurs, tous membres du groupe de travail Géotopes de l'Académie suisse des sciences naturelles (SCNAT), en collaboration avec d'experts de différents disciplines géoscientifiques ont répondu par la sélection de 20 régions « Géo-focus » (Geo-Fokus-Gebiete). Elles sont ni géotopes, ni sites candidats au patrimoine mondiale, mais représentent des régions exemplaires de par les géo-phénomènes que l'on peut y observer (p.ex. la région Aletsch–Sierre pour l'évolution postglaciaire du paysage); pour la représentativité de certaines géo-thématiques (p.ex. la minéralogie dans le Binntal); pour leur géodiversité (p.ex. Région du Gothard) ou encore pour leur importance historique dans le développement des géosciences (p.ex. la région Sardona-Alpstein-Rätikon avec le chevauchement principal de Glaris). Les 20 régions « Géo-focus » ont été décrites avec l'aide des experts et cartographiés à l'échelle de la Suisse. La comparaison entre les régions Géo-focus et les périmètres des parcs naturels régionaux (PNR), les réserves de biosphères et les sites UNESCO a révélé d'intéressantes superpositions qui mériterait d'être explorées pour mettre en valeur davantage cette richesse patrimoniale.

Jessour et habitats troglodytiques dans le Sud-est tunisien – un exemple de géomorphosites culturels

Reynard Emmanuel *, Ben Fraj Tarek **, Ghram Messedi Aziza ***, Ben Ouezdou Hédi ***, Boukhchim Nouri **** & Calianno Martin *

* Institut de géographie et durabilité, Université de Lausanne, Géopolis, 1015 Lausanne (emmanuel.reynard@unil.ch)
** Faculté des Lettres et des Sciences Humaines, Université de Sousse et Laboratoire CGMED, Université de Tunis
*** Faculté des Sciences Humaines et Sociales et Laboratoire CGMED, Université de Tunis
**** Faculté des Lettres et des Sciences Humaines, Université de Kairouan et Laboratoire LMAIM, Université de Tunis

Les géomorphosites culturels sont des sites patrimoniaux qui présentent une symbiose entre un patrimoine géomorphologique et un patrimoine culturel (Reynard & Giusti 2018). C'est le contexte géomorphologique qui a permis le développement du site culturel.

Le plateau du Dahar, dans le Sud-est tunisien, est caractérisé par des conditions climatiques arides et une morphologie de cuestas, recouverte partiellement de dépôts quaternaires (loess, remplissages fluviatiles). Les sociétés ont développé des formes d'adaptation à ce contexte morphoclimatique. Les *Jessour* (pluriel de *Jesr*) sont des systèmes de barrages installés le long des talwegs des oueds et dans les ravins afin de capter les eaux de ruissellement et les sédiments dans le but de réduire l'érosion et d'améliorer les conditions agricoles; ces systèmes ont permis de cultiver l'olivier bien au-delà des limites écologiques contraintes par la sécheresse (Bonvallot 1986; Ben Ouezdou 2000; Calianno *et al.* submitted). Afin de se prémunir des hautes températures (et également des ennemis), des habitats troglodytiques ont également été développés. Deux formes principales ont été utilisées en tenant compte du contexte géomorphologique (Boukhchim *et al.* 2018) : le système latéral est typique des situations de front de cuesta, où les grottes sont creusées dans les niveaux tendres, alors que le système vertico-latéral a été préféré dans les cuvettes de remplissage loessique.

Ces deux cas sont d'excellents exemples de sites géoculturels. A côté de sites paléontologiques et stratigraphiques documentant l'ouverture de la marge sud de la Téthys, ils sont au coeur d'un projet de géoparc dans le Sud-est tunisien et constituent la base pour le développement du tourisme culturel, en complément au tourisme balnéaire et saharien. Cette communication propose une analyse géomorphologique des différents types d'aménagement et présente la méthodologie développée pour analyser et sélectionner les sites les plus représentatifs.

REFERENCES

Ben Ouezdou H. 2000. Les aménagements de petite hydraulique dans le Sud Tunisien, un savoir-faire traditionnel au service du développement durable. *Séminaire international (Hammamet-Tunis)*, pp. 45–54.

Bonvallot J. 1986. Tabias et jessour du Sud tunisien: Agriculture dans les zones marginales et parade à l'érosion. *Cahiers ORSTOM*, Série Pédologie, 22, 163–171.

Boukhchim N. , Ben Fraj T. & Reynard E. 2018. Lateral and BVertico-Lateral^ Cave Dwellings in Haddej and Guermessa: Characteristic Geocultural Heritage of Southeast Tunisia. *Geoheritage* 10: 575–590.

Calianno M., Fallot J.-M., Ben Fraj T., Abbassi M., Adatte T., Ben Ouezdou H., Milano M. & Reynard E. Submitted. Benefits of water-harvesting systems (Jessour) on soil water retention in Southeast Tunisia. *Water* (in review).

Reynard E. & Giusti C. 2018. The landscape and the cultural value of geoheritage. In: E. Reynard & J. Brilha (eds.), *Geoheritage. Assessment, Protection, and Management*. Amsterdam (NL), Elsevier, pp. 147–166.

Towards decadal hydro-glaciological forecasts for the hydropower sector

Saurwein Davide *

* Institute of Earth Sciences, University of Applied Sciences and Arts of Southern Switzerland (SUPSI-IST), Campus Trevano, Via Trevano, 6952 Canobbio (davide.saurwein@supsi.ch)

Hydropower and water resources management are an important issue in most countries of the world, included Switzerland. The scientific community is currently engaged to produce numerical models and simulations which aim at understanding the most important climate factors with the support of tools at a variable scale. The aim is to simplify reality while reducing uncertainty at the same time (Beven 2012).
The aim of this work is to investigate the propagation of uncertainties from the input meteorological forecasts to the resulting streamflow predictions. A weather generator has been used to create synthetic weather decadal forecasts (Ailliot *et al.* 2015). These forecasts have been fed into the hydrological model HBV, and simulations have been run in order to obtain corresponding runoff forecasts. The accuracy of the meteorological and runoff forecasts has been calculated with statistical metrics defined as "skill scores" (Hamill & Juras 2006). The experiment was performed for two glacierized catchments both located in the Swiss Alps, Findelen and Gries, by assuming different scenarios of glacier extent in order to observe the relation between skill transfer and the amount of ice.
It has been observed that the influence of precipitation and runoff forecasts is lower than the one of temperature for highly-glacierized catchments. This influence increases with diminishing glacierization. In a hypothetical ice-free catchment, the effect of precipitation on skill transfer tends to become more relevant, for both Findelen and Gries catchments. Other important factors of skill transfer are the lead time from which a forecast is produced, the variable model settings and also the morphological and topographical features of the catchment.

REFERENCES

Ailliot P., Allard D., Monbet, V. & Naveau P. 2015. Stochastic weather generators: an overview of weather type models. *Journal de la Société Française de Statistique* 156: 101–113.
Beven K. 2012. *Rainfall-Runoff Modelling (2nd edition)*. Wiley-Blackwell Editors, Lancaster University, UK.
Hamill T.M. & Juras J. 2006. Measuring forecast skill: is it real skill or is it the varying climatology? *Quarterly Journal of the Royal Meteorological Society* 132: 2905–2923.

Bellinzona: fra antichi ghiacciai, laghi e "buzze"

Scapozza Cristian * & Czerski Dorota *

* Istituto scienze della Terra (IST), Scuola universitaria professionale della Svizzera italiana (SUPSI), Campus Trevano, 6952 Canobbio, Svizzera (cristian.scapozza@supsi.ch)

Al culmine dell'Ultimo massimo glaciale, datato a Sud delle Alpi fra 27.3 e 22.9 ka b2k (b2k = *before 2000* = "prima del 2000"), l'insieme del territorio della Svizzera italiana era ricoperto dai ghiacci fino alle più alte cime e i fronti glaciali si spingevano fino alla Pianura Padana. La conformazione territoriale odierna ha preso forma a seguito del ritiro di queste grandi masse di ghiaccio durante il Tardoglaciale (19.0–11.7 ka b2k), fenomeno che ha liberato i fondivalle e ha iniziato a riempirli con depositi fluvioglaciali, lacustri e fluviali. Alla fine dell'Ultima grande glaciazione, verso 14.5 ka b2k, il paesaggio era dominato da numerosi bacini lacustri che si spingevano all'interno delle principali valli alpine. Nel Sopraceneri, il Lago Maggiore arrivava a una quota di 210-220 m, con un'estensione massima che raggiungeva Giubiasco a monte del Piano di Magadino. A nord di Bellinzona, i grandi conoidi di deiezione che già all'epoca sbarravano quasi completamente il fondovalle avevano creato due laghi ben documentati sia a Castione sia fra Claro e Biasca (Scapozza & Czerski 2019). Questi laghi scomparvero probabilmente negli ultimi millenni del Pleistocene. La colonizzazione del territorio e lo sviluppo di insediamenti stabili è stata probabilmente favorita anche dalla dinamica fluviale particolarmente calma durante l'insieme del Massimo Termico dell'Olocene (ca. 9.5–6.3 ka b2k), quando sono documentati anche i primi insediamenti nella Svizzera italiana. L'attività fluviale divenne più intensa dopo 5.0 ka b2k, come si può ricavare dalle velocità di accumulo di depositi fluviali nei fondivalle e dai tassi di progradazione dei delta del Ticino/Verzasca (Scapozza 2019). L'evoluzione della dinamica fluviale e fluvio-deltizia, originariamente basata su sondaggi profondi nei depositi fluviali di fondovalle o in conoidi di deiezione, è stata di recente affinata grazie a numerose osservazioni e datazioni compiute in cantieri archeologici (Czerski *et al.* 2019).

REFERENZE

Czerski D., Mosetti L., Cardani Vergani R., Pellegrini M., Federici-Schenardi M., Gillioz M., Nogara G. & Scapozza C. 2019. Evolution of fluvial environments and history of human settlements on the Ticino river alluvial plain. *This volume/Questo volume*.

Scapozza C. 2019. Esempi di corrispondenze della suddivisione formale della Serie/Epoca dell'Olocene nella Svizzera italiana. *Bollettino della Società ticinese di scienze naturali* 107: 27–32.

Scapozza C. & Czerski D. 2019. Geomorfologia della Svizzera italiana / Die Geomorphologie der Südschweiz. *Archeologia Svizzera* 42(2): 8–13.

Soapstones: fields and production laboratories between Ticino and Moesano

Schenker L. Filippo * & Scapozza Cristian *

* Institute of Earth Sciences, University of Applied Sciences and Arts of Southern Switzerland (SUPSI), Via Trevano, CH-6952 Canobbio (filippo.schenker@supsi.ch; cristian.scapozza@supsi.ch)

The soapstone fields known along the Alpine mountain range in the territory of France, Italy and Switzerland are about ~400 of which 120 are located in Southern Switzerland (Ticino and Moesano) together with 14 production laboratories. The extraction, the use and the function of soapstone manufactories have influenced the historical and economical evolution of Alpine etnographic contexts since the Iron Age, with a peak of production of pots ("laveggi") between the last centuries of the Roman Empire and the Late Middle Ages. The recovery of this historical identity is based on the study of archeological artifacts and on the reconstruction of historical commercial networks. For this purpose, tracing back the extraction site of an archeological artifact becomes fundamental to reconstruct the ancient commercial roads across the Alps. The mineralogical content of soapstone artifacts has successfully been used to distinguish the provenance of artifacts coming from the Valtellina or from the Val d'Aosta. However, the petrographic method shows some limits because several types of soapstone can be found in more than one Alpine region. Here, we present (i) a database of soapstone fields and production laboratories updated after Mannoni *et al.* (1987) that includes new findings and (ii) new bulk-rock geochemical analyses to support the petrographic characterization of soapstones. The small differences in mineral and in major- and trace-elements compositions should help to localize the fields.
Eight types of soapstone can be distinguished in southern Switzerland; some of them are characteristic of a specific area. The preliminary geochemical results show that the chemical composition can be significantly different even between the same type of soapstone and that H_2O and CO_2 (LOI), U and Cr can be tentatively linked to the metamorphic grade and the mineralogy of the soapstone (Schenker & Scapozza 2019), permitting to better reconstruct the geological framework of the rock and therefore also the location from which it has been extracted.

REFERENCES

Mannoni T., Pfeifer H.R., & Serneels V. 1987. Giacimenti e cave di pietra ollare nelle Alpi. *Archeologia dell'Italia Settentrionale* 5: 7–46.
Schenker F.L. & Scapozza C. 2019. La pietra ollare: giacimenti e laboratori di produzione/Speckstein: Lager- und Werkstätten. *Archeologia Svizzera* 42(2): 28–33.

Monitoring large alpine landslides with satellite SAR interferometry within the *A.M.A.L.P.I.* 18 project

Strozzi Tazio*, Caduff Rafael *, Manconi Andrea * & Ambrosi Christian **

* Gamma Remote Sensing, Gümligen (BE), Switzerland (strozzi@gamma-rs.ch)
** SUPSI, Trevano (TI), Switzerland

The A.M.A.L.P.I. 18 project has as its main objective the research, enhancement and promotion of large alpine landslides between Val Bregaglia and Canton Ticino to be included in tourist itineraries. It is however of outstanding importance to also continuously monitor the current rate of motion of landslides for the assessment of their hazard and the survey of their activity with time. Satellite Synthetic Aperture Radar (SAR) interferometry (inSAR) is one option for surface deformation monitoring over large areas, now entering an operational phase with the regular availability of Sentinel-1 data since 2014, see various nation-wide maps of land deformation recently released in Norway, Germany and the United Kingdom. Also in the transboundary Swiss-Italian region there is a high interest on deformation maps and time series of surface motion from InSAR. Within the A.M.A.L.P.I. 18 project Radarsat-2 data between 2011 and 2017 and Sentinel-1 data since 2015 are analysed.

In our contribution, we discuss, based on results various large landslides in Canton Ticino, potential and limitations of current satellite SAR data with different carrier frequencies (L-, C- and X-band), ground resolutions (around 10, 20 and 2 meters), time intervals (46, 6, 34 and 11 days) and acquisition strategies (global versus on-demand, free versus commercial data) for the monitoring of very slow landslides (i.e. rates of motion of a few cm/year). Multi-temporal interferometric approaches using large data stacks are applied over this mountainous area, where sparse urbanization, large vegetated areas, snow-cover, layover/shadow, and atmospheric stratification and summer turbulences are introducing special processing challenges.

A Cross-Comparison between a Traditional Portable Straight-Line Wind Tunnel and PI-SWERL over an Altitude Gradient

van Leeuwen Cynthia C.E. *, Cammeraat L.H. *, Kuhn Nikolaus J. **, Fister Wolfgang ** & Vos Heleen C. **

* Institute for Biodiversity and Ecosystem Dynamics, Ecosystem and Landscape Dynamics Group, University of Amsterdam, PO Box 94240, Amsterdam 1090 GE, The Netherlands (cce.vanleeuwen@gmail.com)

** Physical Geography and Environmental Change, University of Basel, 4056 Basel, Switzerland

Dust emissions by soils, primarily originating from hot and cold (semi-) deserts, can have a large effect on the Earth's system. Long distance transport of suspended dust potentially affects air circulation systems, biogeochemical cycles of oceanic and terrestrial ecosystems, soil characteristics and geomorphology. To generate dust emission, a particular wind velocity must be exceeded: the threshold friction velocity. Most research focused on the relation between wind velocities and dust emission has been carried out at sea level, where a high air pressure, and thus high air density, is present. Studies on the effect of low air density conditions are primarily focused on extra-terrestrial environments. However, more recent research demonstrated that the intensity of wind erosion on Earth decreased with decreasing air density. These findings form the basis for this research, which aims to *establish the relationship between threshold friction velocities and PM_{10} dust emission, taking changing air density into account, while comparing two types of instruments: a traditional portable straight-line wind tunnel, and a new type of instrument, the PI-SWERL.* The research is divided into two components: 1) a cross-comparison between a traditional portable straight-line wind tunnel and the PI-SWERL, and 2) a study on the influence of decreasing air density on the threshold friction velocity for PM_{10} emission by employing the PI-SWERL in the field. It was found that compared to the wind tunnel, the PI-SWERL measured significantly different threshold friction velocities for one of the materials, which can possibly be attributed to the experimental set-up. To obtain data about the effect of changing air density on the threshold friction velocity and dust emission potential of soils, four field locations at different altitudes in Switzerland were chosen to create an altitude gradient. When testing the PI-SWERL in the field, a highly significant positive linear relationship between the threshold friction velocity for PM_{10} emission and air density was found. Furthermore, a significant negative linear relationship between the PM_{10} emission potential and air density was found, as the PM_{10} emission decreased with decreasing air density. Despite the different measured thresholds for PM_{10} emission, it is believed that the PI-SWERL can be used to study certain aspects of wind erosion. For future research, several adjustments need to be done to the experimental design to reduce variance between replicates and improve reproducibility.

The use of Unmanned Aerial Vehicle surveys for monitoring rock glacier kinematics: validation and accuracy assessment

Vivero Sebastián * & Lambiel Christophe *

* Institute of Earth Surface Dynamics (IDYST), University of Lausanne, Bâtiment Géopolis UNIL Mouline, CH-1015 Lausanne (sebastian.viveroandrade@unil.ch)

This study presents a rigorous procedure to quantify rock glacier kinematics and their associated uncertainties derived from sequential Unmanned Aerial Vehicles (UAV) surveys. This method is applied to six consecutive UAV surveys of Tsarmine rock glacier, Switzerland. This tongue-shaped rock glacier is about 500 m long and spans an elevation range of 2460–2680 m a.s.l. Since 2004, around 50 blocks are measured biannually with a differential GNSS equipment, reaching an overall uncertainty of ca. 2 ± cm horizontally. In 2016, we started UAV surveys with a SenseFly eBee RTK device concomitant with the terrestrial geodetic surveys. Sequences of orthomosaics and Digital Elevation Models (DEMs) with pixel sizes of 5 cm were produced for Tsarmine and its environs using Structure-from-Motion (SfM) techniques. Digital image co-registration and cross-correlation methods were implemented on the multitemporal orthomosaics and DEMs. Results indicate a good overall fitness between in-situ and UAV-derived displacements, where the flow structure of Tsarmine displays a regular profile of increasing velocities towards the terminus (up to 7 m/a). Furthermore, the general assessment of the 3D-models allows quantifying not only horizontal displacements but also vertical changes with a good level of confidence. UAV monitoring approaches can be advantageous for accessing remote and difficult terrain, as they can be easily customised to provide high resolution and frequency of observations in comparison with other remote sensing or ground survey techniques.

Potentially frozen sediments presenting mass-wasting processes in glacier forefields in mountain permafrost environments (Swiss Alps)

Wee Julie *, Barboux Chloé * & Delaloye Reynald *

* Geography, Dept. Geosciences, University of Fribourg, Chemin du Musée 4, CH-1700 Fribourg (julie.wee@unifr.ch)

Little Ice Age (LIA) glacier forefield located within the belt of discontinuous permafrost are complex systems sitting astride the glacial, paraglacial, periglacial research frontier. These recently deglaciated environments have been characterized as transient systems pursuing a state of equilibrium by adjusting to non-glacial conditions, and are therefore subject to intense geomorphological activity, especially under the current conditions of a warming climate (Bosson *et al*. 2014). Present-day landforms existing in these systems are legacies of the interrelations between glacial and periglacial morphodynamics, and are therefore precious proxies for the understanding of the spatio-temporal evolution of permafrost in glacier forefield systems. In this context, the aim of this study is to inventory potentially frozen sediments presenting mass-wasting processes located in glacier forefield within the belt of permafrost, as they serve as indicators of the kinematic and thermal evolution of these particular environments. For that purpose, existing, partly updated inventories of moving landforms in the Swiss Alps based on differential SAR interferometry (dInSAR) technique (Barboux *et al*. 2014) along with aerial photographs were used to detect and characterize the occurrence of mass-wasting processes such as permafrost creep or subsidence in glacier forefields within the belt of permafrost.

The results obtained from the inventory of potentially frozen sediments presenting mass-wasting processes located in glacier forefields within the belt of permafrost in the Swiss Alps reveal that the spatial configuration of mass-wasting frozen sediments in such particular environmental context strongly differs from a glacier forefield to another. This diversity is mainly a function of sediment yield, of ground ice distribution and of past and present glacier dynamics, driven by the topo-climatic context of each site. This implies different dynamical behaviour and evolution for each system, steered by site-specific processes such as permafrost creep (back-creeping) or ice melt induced subsidence (thawing ground ice).

REFERENCES

Barboux C., Delaloye R. & Lambiel C. 2014. Inventorying slope movements in an Alpine environment using DInSAR. *Earth Surface Processes and Landforms* 39/15: 2087–2099.

Bosson J.-B., Lambiel C., Deline P., Bodin X., Schoeneich P., Baron L. & Gardent M. 2014. The influence of ground ice distribution on geomorphic dynamics since the Little Ice Age in proglacial areas of two cirque glacier systems. *Earth Surface Processes and Landforms* 40: 666–800.

The Ralligen rockfall and the Lütschine River deviation recorded in the sediments of Lake Thun

Wirth Stefanie *, Kremer Katrina ** & Schulte Lothar ***

* Centre for Hydrogeology and Geothermics, University of Neuchâtel, Neuchâtel, Switzerland (stefanie.wirth@unine.ch)
** Swiss Seismological Service, ETH Zurich, Zurich, Switzerland
*** Department of Geography, University of Barcelona, Barcelona, Spain

New ~10 m-long sediment cores from Lake Thun allow us to date the Ralligen rockfall that occurred at the northern shore of Lake Thun and to study the gradual deviation of the Lütschine River towards Lake Brienz.

In the reflection seismic data the Ralligen rockfall is evident by a large deposit with a chaotic/transparent facies whose surface structure still affects today's lake-bottom morphology (Wirth *et al.* 2011; Fabbri *et al.* 2018, map.geo.admin.ch → swissBATHY3D). Using macrofossils from the new sediment core just overlying the rockfall deposit for radiocarbon dating we have now evidence that the rockfall is prehistoric.

Another sediment core positioned in front of the inflow of the Aare River allows us to track sedimentary changes related to the early works on the Lütschine River. Around 1100 AD, contemporaneously with the foundation of the monastery of Interlaken and thus with the first documented human interference with the Lütschine, we observe a clear decrease of the sedimentation rate and the carbonate input. For improving the link between these first findings and the Lütschine deviation, we are currently further characterizing the sediment core and are combining with historical and geomorphological information from the Bödeli (e.g. Schulte *et al.* 2009)

REFERENCES

Fabbri S.C., Buechi M.W., Horstmeyer H., Hilbe M., Hübscher C., Schmelzbach C., Weiss B. & Anselmetti F.S. 2018. A subaquatic moraine complex in overdeepened Lake Thun (Switzerland) unravelling the deglaciation history of the Aare Glacier. *Quaternary Science Reviews* 187: 62–79.
Schulte L., Veit H., Burjachs F. & Julià R. 2009. Lütschine fan delta response to climate variability and land use in the Bernese Alps during the last 2400 years. *Geomorphology* 108: 107–121.
Wirth S.B., Girardclos S., Rellstab C. & Anselmetti F.S. 2011. The sedimentary response to a pioneer geo-engineering project: Tracking the Kander River deviation in the sediments of Lake Thun (Switzerland). *Sedimentology* 58: 1737–1761.

Co-evolution of morphological change and flood risk change in Swiss rivers

Zischg Andreas Paul * & Keiler Margreth **

* Institute Of Geography, Oeschger Centre for Climate Change Research, Mobiliar Lab for Natural Risks, University of Bern (andreas.zischg@giub.unibe.ch)
** Institute Of Geography, Oeschger Centre for Climate Change Research, Mobiliar Lab for Natural Risks, University of Bern (margreth.keiler@giub.unibe.ch)

Flood risk to population and infrastructure relates among others on the morphology of river reaches and on the spatial pattern of human exposure to floods. Both factors co-evolve in time. In past centuries, river morphology had been remarkably altered by river engineering measures such as the construction of lateral levees. As a consequence of river narrowing by dikes and the regulation of flows, flow velocities and incision rates increased and morphological diversity decreased. In parallel, settlements tended to locate near the rivers and so the exposure to floods increased. Thus, most rivers and their floodplains nowadays are anthropogenically modified systems. Today, river engineering aims at revitalizing rivers and giving them more space. Human interventions on rivers thus increasingly follow nature-based solutions. This vice versa coevolves with other drivers of flood risk change, e.g. climatic changes. In this presentation, we will shed light on the relationship between (past and future) morphological changes in rivers due to anthropogenic interventions and flood risk change. We show this on the example of a web-based visualization platform (https://risikodynamik.hochwasserrisiko.ch/). Moreover, we analyse which type of river morphology (natural rivers, river corrections of the 19th century, or revitalized rivers) are sensitive to an expected increase in river discharge due to climatic changes. We show that changing river morphology is one of the main drivers of flood risk change.

Excursion field guide

References about the geomorphological history of the Ticino valley

BEATRIZOTTI G. 1985. La geodinamica ed il suo impatto sull'uomo. *Bollettino della Società ticinese di scienze naturali* **73**: 31–36.

SCAPOZZA C. 2016. Evidence of paraglacial and paraperiglacial crisis in Alpine sediment transfer since the Last glaciation (Ticino, Switzerland). *Quaternaire* **27**(2): 139–155. DOI: 10.4000/quaternaire.7805

SCAPOZZA C. & AMBROSI C. 2016. Between glaciers, rivers and lakes: the geomorphological landscapes of Tessin. In: E. Reynard (ed.), *Landscapes and Landforms of Switzerland*. Springer, Dordrecht, in press.

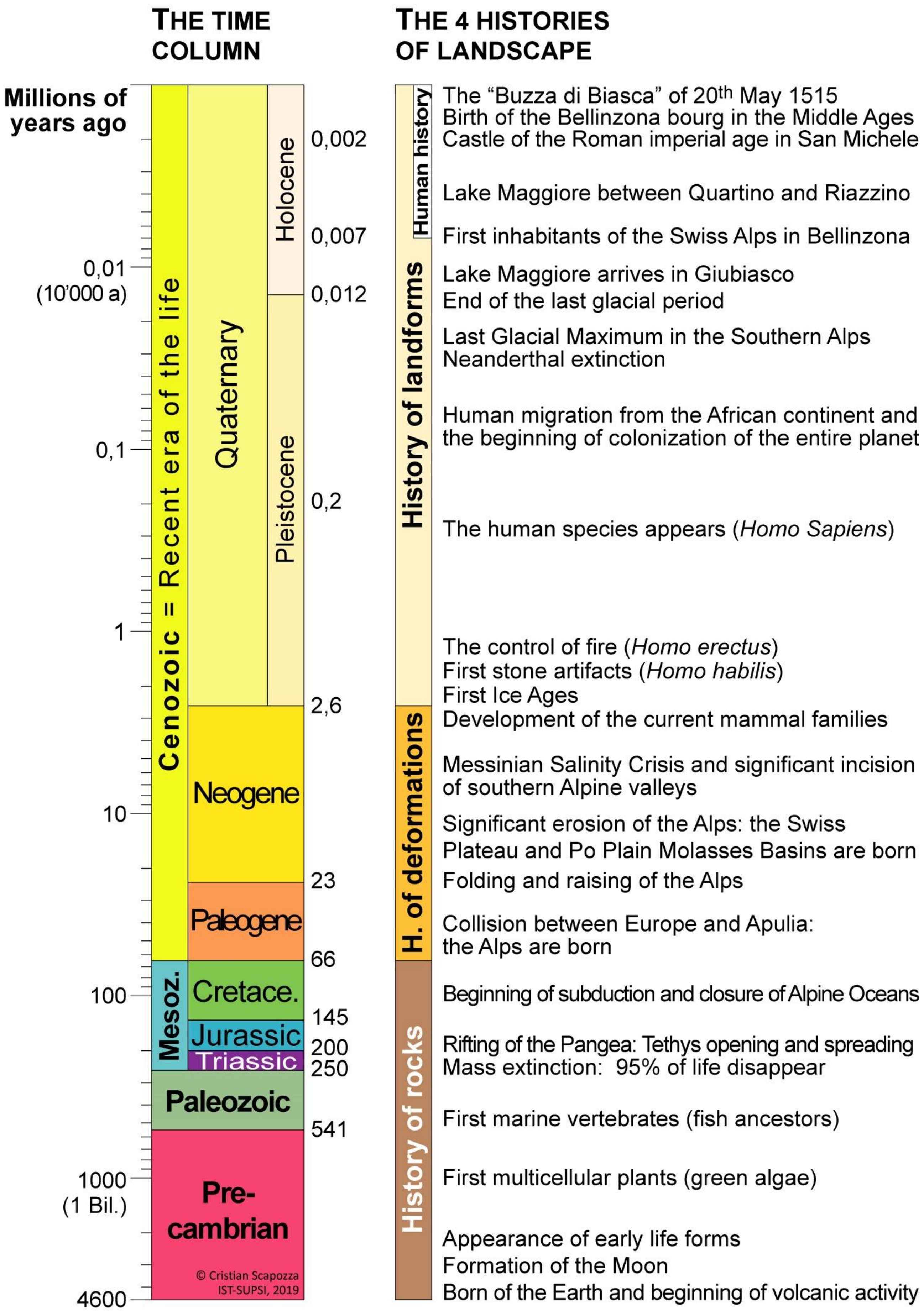
SCAPOZZA C. & CZERSKI D. 2019. Geomorfologia della Svizzera italiana / Die Geomorphologie der Südschweiz. *Archeologia svizzera / Archäologie Schweiz* **42**(2): 8–13.

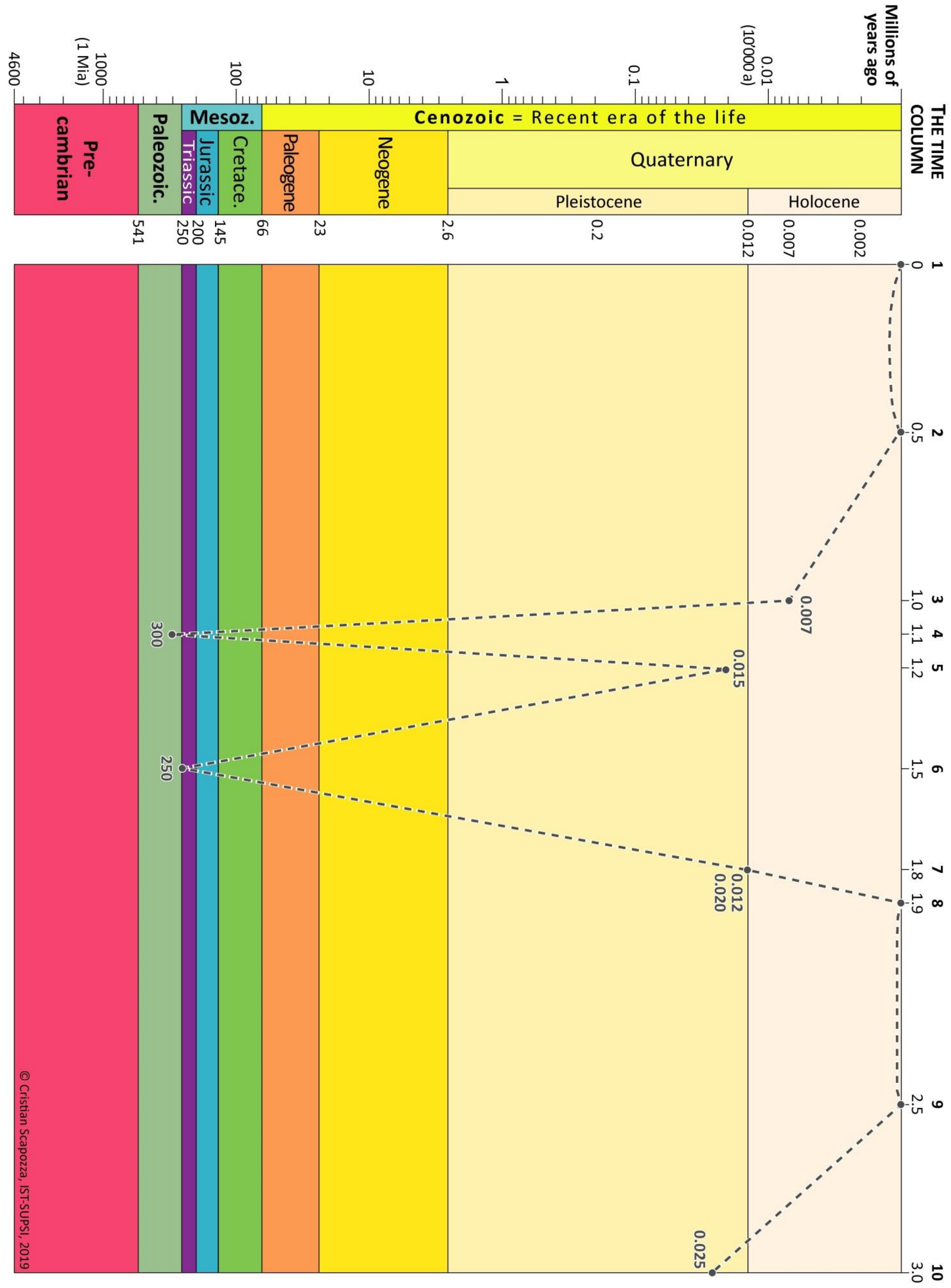
SCAPOZZA C. & OPPIZZI P. 2013. Evolution morpho-sédimentaire et paléo-environnementale de la plaine fluvio-deltaïque du Ticino pendant l'Holocène récent (Canton du Tessin, Suisse). *Géomorphologie : relief, processus, environnement* **19**(3): 37–58. DOI: 10.4000/geomorphologie.10289

SCAPOZZA C., ANTOGNINI M., OPPIZZI P. & PATOCCHI N. 2012. Stratigrafia, morfodinamica, paleoambienti della piana fluvio-deltizia del Ticino dall'Ultimo Massimo Glaciale a oggi: proposta di sintesi. *Bollettino della Società ticinese di scienze naturali* **100**: 89–106. http://repository.supsi.ch/2146/

SCAPOZZA C., CASTELLETTI C., SOMA L., DALL'AGNOLO S. & AMBROSI C. 2014. Timing of LGM and deglaciation in the Southern Swiss Alps. *Géomorphologie : relief, processus, environnement* **20**(4): 307–322. DOI: 10.4000/geomorphologie.10753

SCAPOZZA C., TOGNACCA C., AMBROSI C. & SENO S. 2015. 20 maggio 1515: la "Buzza" che impressionò l'Europa. *Bollettino della Società ticinese di scienze naturali* **103**: 71–80. http://repository.supsi.ch/7111/


THE TIME COLUMN
THE 4 HISTORIES OF LANDSCAPE
Millions of years ago
0,01 (10'000 a)
0,1
1
10
100
1000 (1 Bil.)
4600
Cenozoic = Recent era of the life
Mesoz.
Quaternary
Neogene
Paleogene
Cretace.
Jurassic
Triassic
Paleozoic
Pre-cambrian
Holocene
Pleistocene
0,002
0,007
0,012
0,2
2,6
23
66
145
200
250
541
© Cristian Scapozza IST-SUPSI, 2019
Human history
History of landforms
H. of deformations
History of rocks
The "Buzza di Biasca" of 20th May 1515
Birth of the Bellinzona bourg in the Middle Ages
Castle of the Roman imperial age in San Michele
Lake Maggiore between Quartino and Riazzino
First inhabitants of the Swiss Alps in Bellinzona
Lake Maggiore arrives in Giubiasco
End of the last glacial period
Last Glacial Maximum in the Southern Alps
Neanderthal extinction
Human migration from the African continent and the beginning of colonization of the entire planet
The human species appears (Homo Sapiens)
The control of fire (Homo erectus)
First stone artifacts (Homo habilis)
First Ice Ages
Development of the current mammal families
Messinian Salinity Crisis and significant incision of southern Alpine valleys
Significant erosion of the Alps: the Swiss Plateau and Po Plain Molasses Basins are born
Folding and raising of the Alps
Collision between Europe and Apulia: the Alps are born
Beginning of subduction and closure of Alpine Oceans
Rifting of the Pangea: Tethys opening and spreading
Mass extinction: 95% of life disappear
First marine vertebrates (fish ancestors)
First multicellular plants (green algae)
Appearance of early life forms
Formation of the Moon
Born of the Earth and beginning of volcanic activity

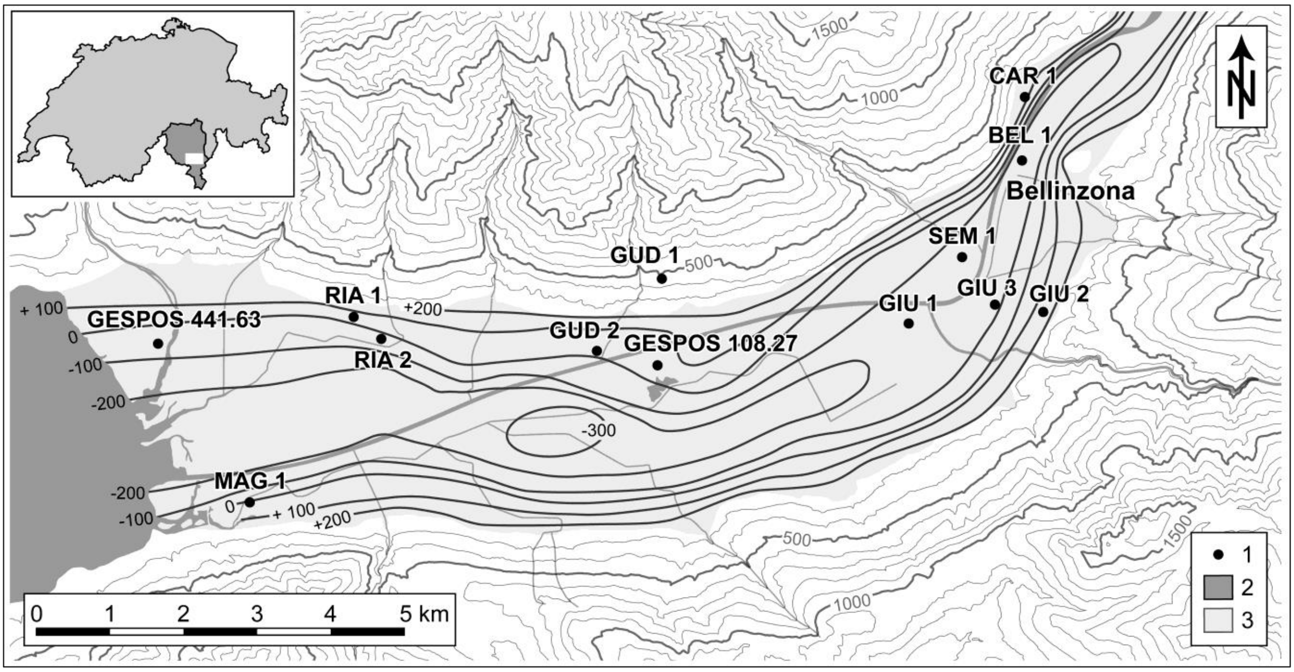


1 Ponte della Torretta (from 20.05.1515 to today)
2 La Murata (AD 1457)
3 Colle di San Michele (7280-7150 cal BP)
4 Castel Grande (from 300 Ma ago to AD 1250-1500)
5 Torre Bianca of Castel Grande (14’900-14’080 cal BP)
6 Piazza Collegiata (from 250 Ma ago to 06.05.1515 and AD 1785)
7 Colle di Montebello (from 20’450 to 10’700-10’490 cal BP)
8 Castello di Montebello (first mention in AD 1313)
9 Vineyards on the hill of Sasso Corbaro (AD 1910)
10 Castello di Sasso Corbaro (from 27’300-22’900 cal BP to AD 1478)

Artistical representation of the Piano di Magadino between Locarno and Bellinzona after the Last Glacial Maximum

Silvano Gilardi, *Lavorìo*, watercolour on paper, 19.5 x 41.5 cm, 1992, ©Ufficio dei beni culturali, Bellinzona.

Source: SCAPOZZA & CZERSKI (2019)



The lower Ticino Valley infilling.

Location of boreholes and excavations with dated material and archaeological findings and bedrock contour lines from BEATRIZOTTI (1985). Modified from SCAPOZZA *et al*. (2012). 1/ Borehole or archaeological finding, 2/ Hydrography, 3/ Fluvio-deltaic deposit. Holocene cold climate oscillations: GH 8.2/ Holocene Greenland Stage 8.2 cal. ka BP, Pi/ Piora, Lö/ Löbben, Gö/ Göschenen, LIA/ Little Ice Age. Chronozones: B/A/ Bølling/Allerød, YD/ Younger Dryas, PB/ Preboreal.

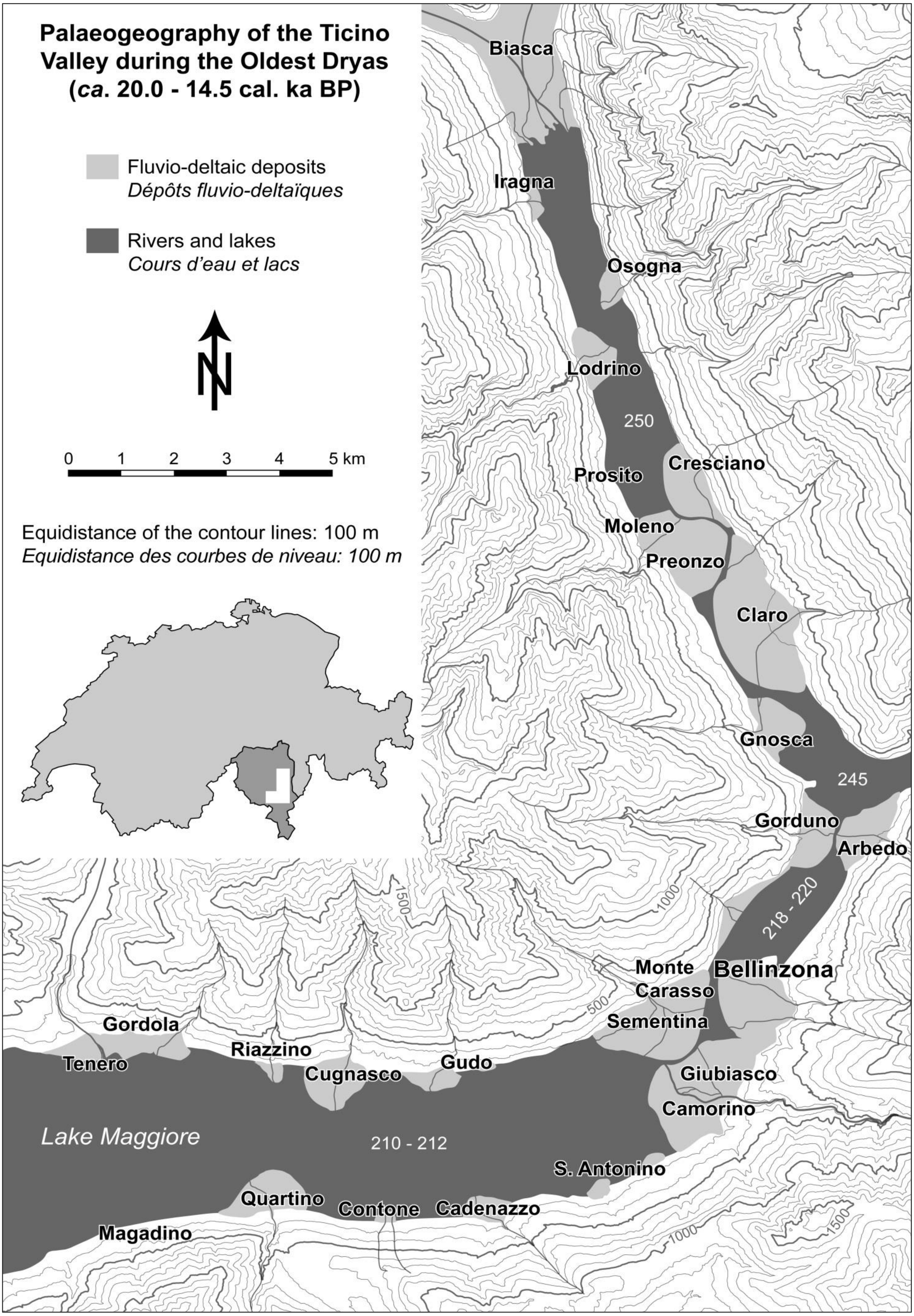
Source: SCAPOZZA (2016).

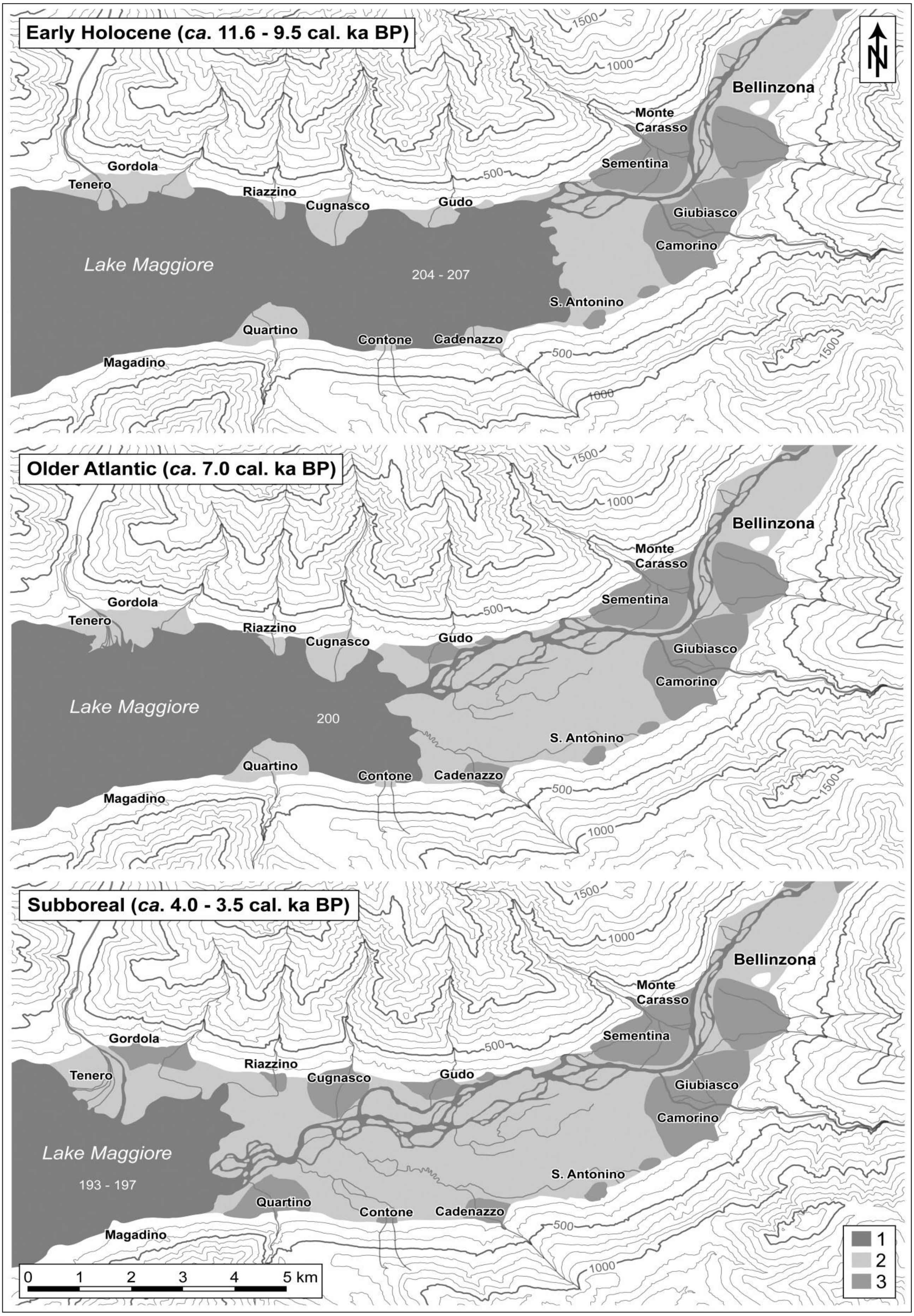
(Page 17) Palaeogeography of the Ticino Valley after the deglaciation.

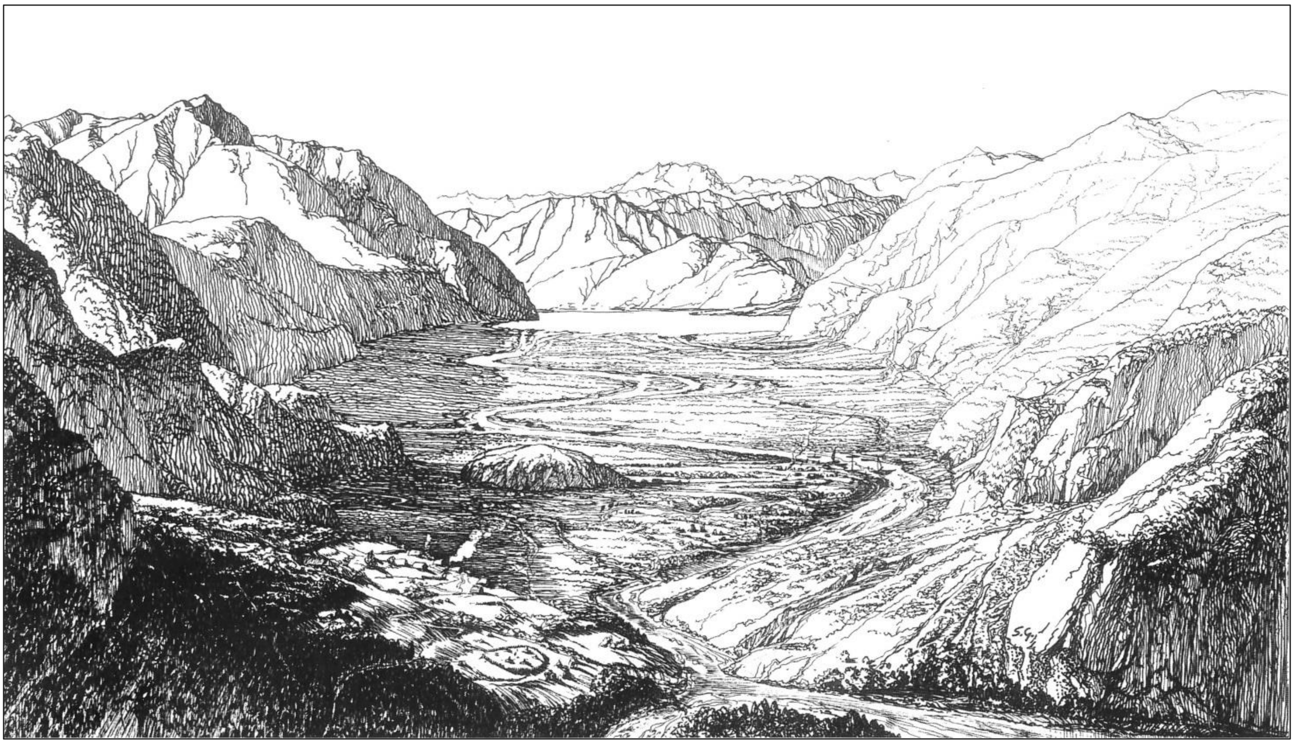
(Page 18) Palaeogeography of the Ticino Valley at three moments of the Holocene.

Modified from SCAPOZZA *et al*. (2012). 1/ Hydrography, 2/ Fluvio-deltaic deposit, 3/ Alluvial fan.

Source: SCAPOZZA (2016).


Palaeogeography of the Ticino Valley during the Oldest Dryas (ca. 20.0 - 14.5 cal. ka BP)
Fluvio-deltaic deposits
Dépôts fluvio-deltaïques
Rivers and lakes
Cours d'eau et lacs
N
0 1 2 3 4 5 km
Equidistance of the contour lines: 100 m
Equidistance des courbes de niveau: 100 m
Biasca
Iragna
Osogna
Lodrino
250
Prosito
Cresciano
Moleno
Preonzo
Claro
Gnosca
245
Gorduno
Arbedo
218 - 220
Bellinzona
Monte Carasso
Sementina
Giubiasco
Camorino
Gordola
Tenero
Riazzino
Cugnasco
Gudo
Lake Maggiore
210 - 212
S. Antonino
Quartino
Contone
Cadenazzo
Magadino
1500
1000
500


Early Holocene (ca. 11.6 - 9.5 cal. ka BP)
Bellinzona
Monte Carasso
Sementina
Gordola
Tenero
Riazzino
Cugnasco
Gudo
Giubiasco
Camorino
Lake Maggiore
204 - 207
S. Antonino
Quartino
Contone
Cadenazzo
Magadino
1500
1000
500
Older Atlantic (ca. 7.0 cal. ka BP)
Bellinzona
Monte Carasso
Sementina
Gordola
Tenero
Riazzino
Cugnasco
Gudo
Giubiasco
Camorino
Lake Maggiore
200
S. Antonino
Quartino
Contone
Cadenazzo
Magadino
Subboreal (ca. 4.0 - 3.5 cal. ka BP)
Bellinzona
Monte Carasso
Sementina
Gordola
Tenero
Riazzino
Cugnasco
Gudo
Giubiasco
Camorino
Lake Maggiore
193 - 197
S. Antonino
Quartino
Contone
Cadenazzo
Magadino
1
2
3
0 1 2 3 4 5 km

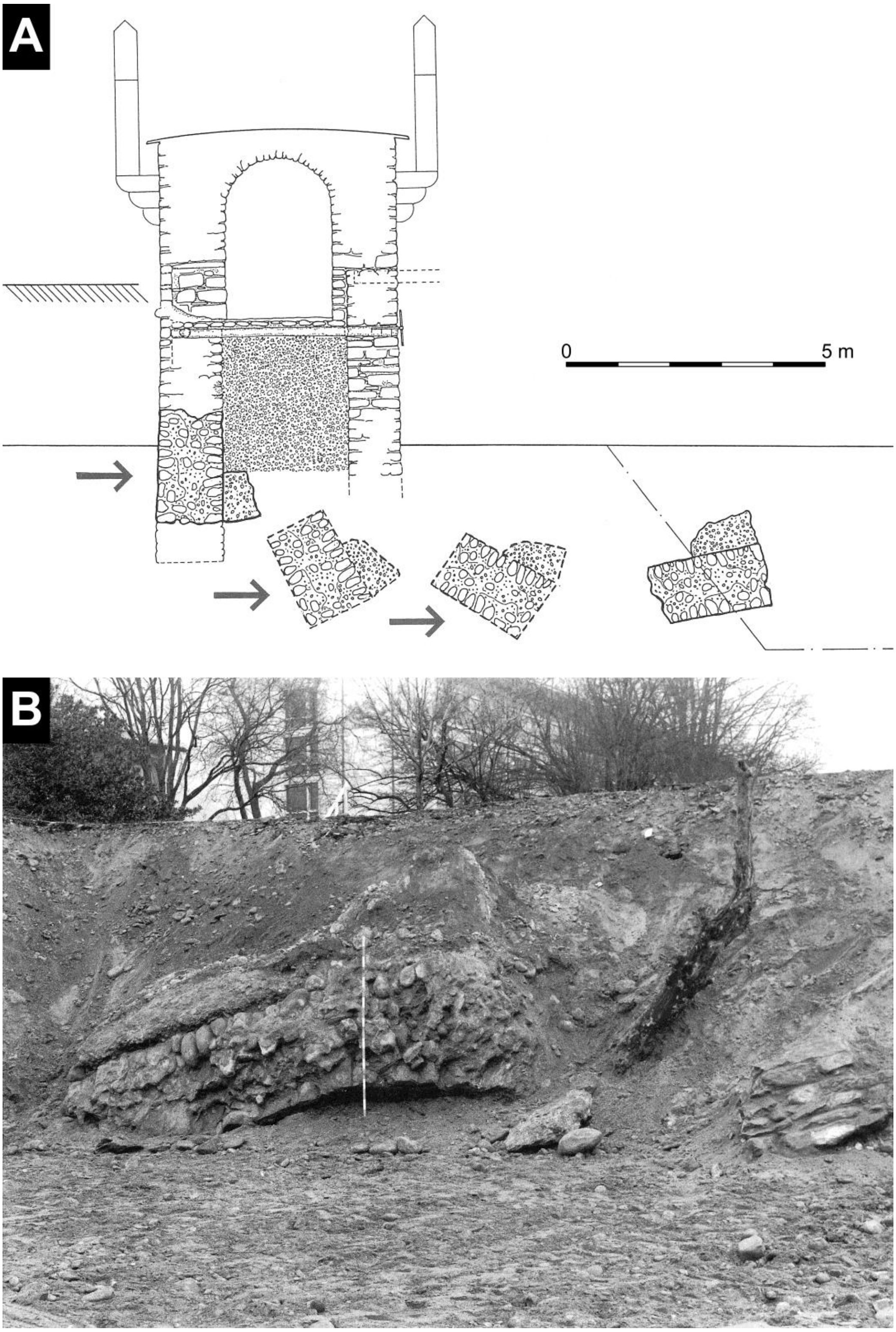


Artistical representation of the Bellinzonese and Piano di Magadino during the first century before Christ

The fluvial morphology of the Ticino river with a single meandering channel – which was longitudinally navigable and the witnesses of a climatic phase of relatively calm hydrosedimentary dynamics, – was documented for the period between the Iron Age and the Middle Ages by Scapozza & Oppizzi (2013).

Silvano Gilardi, *Al tempo degli elvezi: Porto nella valle*, indian ink on carta, 36 x 50 cm, 1992, ©Ufficio dei beni culturali, Bellinzona.

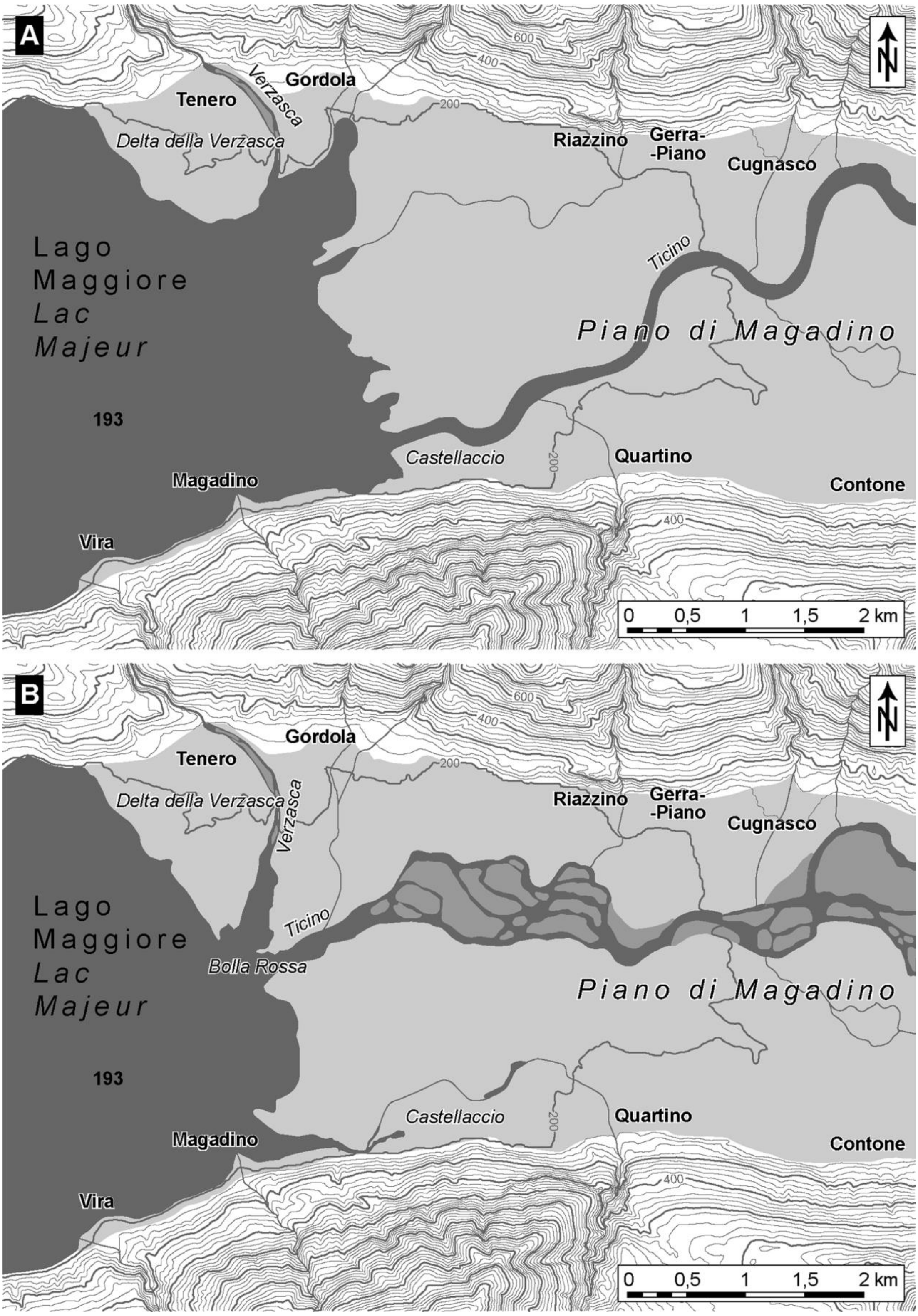
Source: Scapozza & Czerski (2019)



Impact of the *Buzza di Biasca* of 20th May 1515 on the Murata in Bellinzona.

(A) Section of the Murata and dynamics of the fragments overwhelmed by the *Buzza di Biasca*. (B) Fragments of the Murata overwhelmed by the *Buzza di Biasca*, visible in 1993 in the visible in the building site of the Archivio di Stato (Cantonal archive).

Source: SCAPOZZA *et al*. (2015).



Representation of the Ticino river delta at two moments of its recent history.

(A) During the Late Middle Ages (around AD 1300–1400). (B) After the *Buzza di Biasca* of 20th May 1515 (around AD 1600).

Source: Scapozza & Oppizzi (2013).