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WEATHERING IN PLEISTOCENE BADLANDS FROM IONIAN CALABRIA, SOUTHERN ITALY

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ABSTRACT: Pulice I. *et al., Weathering in Pleistocene badlands from Ionian calabria, southern* Italy.
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This work investigates the main factors and processes that control geochemistry and mineralogy of clay lithotypes affected by calanchi landforms in the area of Caulonia (RC), in southern Calabria. In the present study are shown the results obtained from a multidisciplinary study that integrates geomorphologic, chemical and mineralogical data by means of a multivariate statistic analysis using the Principal Component Analysis (PCA) method to extract factors.

RIASSUNTO: Pulice I. *et al.,* Studio dell'alterazione sui calanchi pleistocenici della Calabria ionica, Italia meridionale.
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Il presente lavoro è finalizzato a dare un contributo su alcuni fattori e processi che controllano la geochimica e la mineralogia dei litotipi argillosi affetti da morfologie calanchive nell'area di Caulonia (RC), in Calabria meridionale. Vengono presentati i risultati di uno studio multidisciplinare a carattere geomorfologico, chimico e mineralogico, elaborati attraverso l'ausilio dell'analisi statistica multivariata mediante il metodo dei componenti principali (PCA).

Key words: badlands, weathering, mineralogy-geochemistry

Parole chiave: calanchi; alterazione, mineralogia- geochimica

1. INTRODUCTION

Badland landforms are very common in Plio-Pleistocene marine clays of southern Italy. Associated morphologies are typical of arid or semi -arid climates, but were also found in different conditions (e.g. Berael *et al.*, 1993; Bryan & Yair, 1982; Imeson, 1993). Badlands can be distinguished in "calanchi" (morphological units with steep slopes and sharp ridges, according to Alexander, 1982), "biancane" (dome-shaped small hills affected by rills and salt efflorescence), and transitional forms between calanchi and biancane (Alexander, 1982; Sdao *et al.*, 1984)

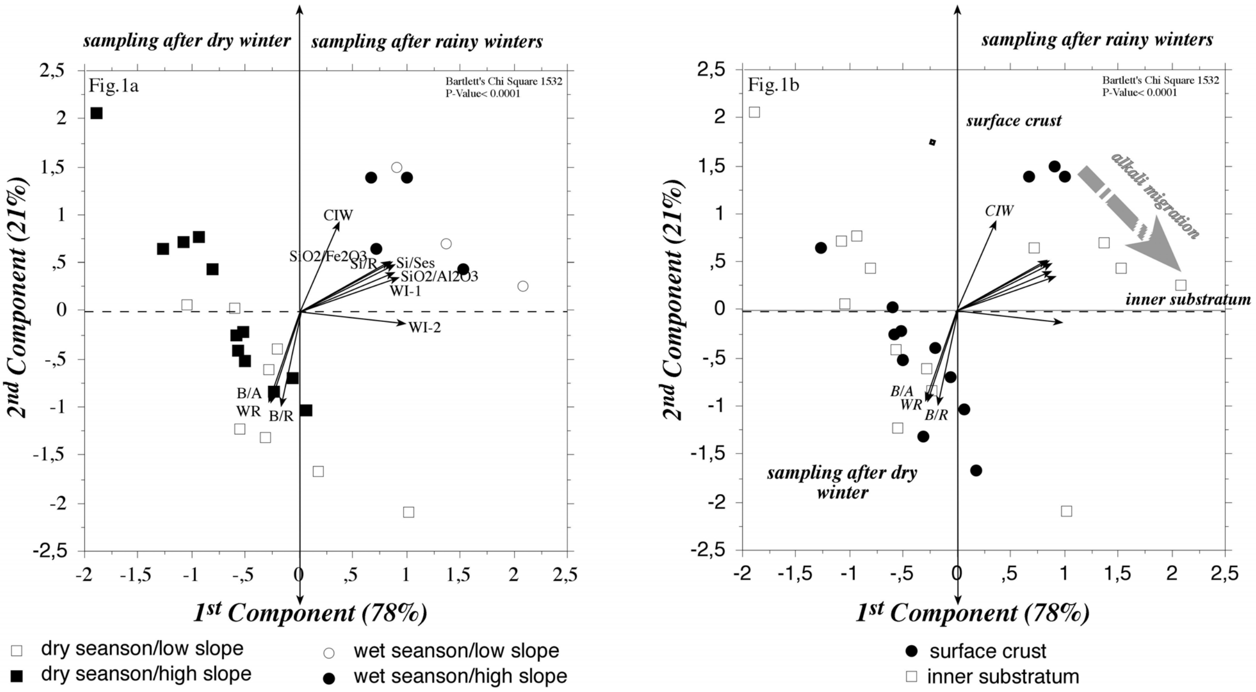

Fig.1, Orthogonal plot of the PCA using as variables in the input matrix the calculated weathering indices.
Diagramma ortogonale della PCA utilizzando come variabili nella matrice di input gli indici di alterazione.

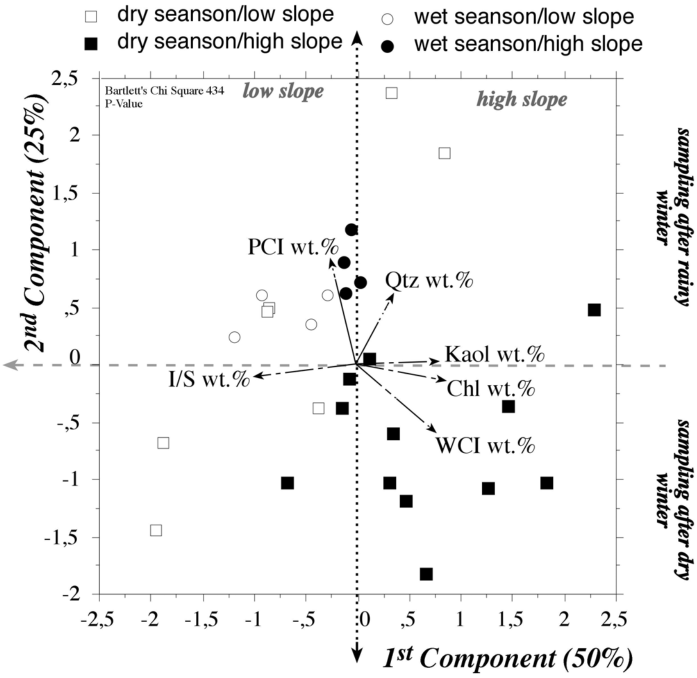

Fig.2, Orthogonal plot of the PCA using as variables in the input matrix the distributions of clay minerals (wt %).
Diagramma ortogonale della PCA utilizzando come variabili nella matrice di input le distribuzioni dei minerali argillosi.

Several authors described badlands in details and attempt to interpret the main factors and causes of their triggering and development, particularly in the Mediterranean climate. The role of tectonics, human impact, vegetation and land-use changes, physical, chemical and mineralogical properties of the lithology - among which dispersivity (deflocculation) and expandability of clays (BATTAGLIA *et al.*, 2002; GERITS *et al.*, 1997) - as well as the development of the surface crust and pipes (FAULKNER *et al.*, 2000; HARVEY AM. 1982) were investigated.

The aim of the present work is to asses the main factors controlling the development of weathering in Pleistocene badlands affecting shallow-marine and transitional clays of Late Pliocene–Quaternary age in SE Calabria (southern Italy). To do this chemical and physical characteristics of 30 samples from a small calanchi catchment, located in the area of Caulonia (Reggio Calabria, southern Italy), have been compared to mineralogy. Besides, a large suite of weathering indices have been also calculated for each sample. Their variation has been analyzed taking into account that samples were collected at different time in the year (wet season *vs* dry season), on the opposite flanks of the catchment exhibiting different slopes, and from the first centimeters (surface crust) toward the internal portion (inner substratum).

2. METHODS

Following interpretation of aerial photos at 1:33,000 scale and a geomorphological survey, clay lithotypes were sampled in a selected calanchi catchment near Caulonia, for subsequent laboratory analyses, which included the measurement of specific properties. Sampling was performed with special rules designed to characterize specific microforms, such as the outer crust and the inner massive portion of the substratum (PULICE *et al.*, 2009).

On the bulk sample (< 2 mm) and the clay fraction (< 2 μm) a qualitative mineralogical analysis was performed by X-ray diffraction (XRD) on powder and oriented specimens, respectively. It was carried out with a Rigaku D/MAX-2200/PC (Cu-Kα radiation, graphite secondary monochromator and sample spinner). XRD analyses on oriented clays were made on air-dried, glycolated, and heated at 375°C specimens. A software (McDiff4.2) using the JCPDS (Joint Committee on Powder Diffraction Standards) mineralogical database was applied for the identification of mineral phases.

Chemical analyses were performed using XRF spectrometry and on the basis of metal oxides several weathering indices, commonly used in comparing the extent of chemical alteration, were calculated (i.e. CIW = Chemical Index of Weathering, and other indices based on ratios between silica or bases vs other oxides, e.g. Al_2O_3, Fe_2O_3, TiO_2, etc.).

3. RESULTS AND DISCUSSION

Among the main mineral phases identified, clay minerals dominate, followed by quartz, calcite, K-feldspar and plagioclase. Illite, illite/smectite (I/Sm) mixed layers, kaolinite and chlorite are the main clay minerals identified. XRF data exhibit higher values of silica, alumina and calcium.

In order to asses the main factors controlling the development of weathering in the studied Pleistocene badland a multivariate statistical approach, using the Principal Component Analysis (PCA) method to extract factors, have been carried out.

In Fig. 1a are shown the results from the multivariate statistical analysis carried out using in the input matrix the calculated weathering indices.

These indices are based on the principle that the ratio between concentrations of mobile (such as SiO_2, CaO, MgO, and Na_2O) and immobile elements (Al_2O_3, Fe_2O_3, TiO_2) should decrease over time as leaching progresses. Indeed, the concentrations of the most immobile elements should increase during weathering if surface erosion is negligible. Given the formulations of most weathering indices, decreasing values signify greater weathering. The opposite, however, is true for CIW.

The 1st component (78% of explained variance), grouping together the weathering indices based mainly on silica vs alluminia and TiO_2 relationships, has the highest statistical load in distinguishing the first sampling after a relatively dry winter season from the second one after repeated heavy rainy winters. The amount of SiO_2 usually decreases in weathered materials because it is somewhat soluble, though less than CaO, MgO, K_2O, and Na_2O. Alumina has a low solubility under normal weathering pH, so its relative proportion generally increases in weathered materials. Titania generally increases in relative proportion, as it is essentially insoluble in most weathering environments. The remaining major elements (K, Na, Mg and Ca) decrease as weathering proceeds. Some of these cations are temporarily bound in clay minerals, but as the clay minerals themselves weather, the remaining alkali and alkaline earths are progressively released. Only when the winter was relatively heavy rainy, it can be distinguished between surface crust and inner substratum (Fig.1b). In this conditions, in fact, the rate of runoff is high. This presumably caused migration of alkalis (mobile elements) from the crust toward the substratum, which therefore appears enriched in these elements (higher CIW values in the crust than in the inner portion). On the other hand, there is no evidence of differences in weathering indices between crusts and substratum in samples collected after relatively dry winters (Fig 1b).

The analysis of clay mineral distributions is crucial in evidencing the control of topography on weathering of badlands from Caulonia. In Fig. 2 are shown the results from a second PCA, carried out using in the input matrix the distributions of clay minerals (wt.%). The 1st component (50% of explained variance) well discriminates samples collected from opposite flanks of the catchment that exhibit different slopes. This suggests that topography (mainly slope and aspect, that affect rates of water runoff) likely controls the weathering of the original mineral assemblages of Caulonia badlands. In fact, I/Sm and poorly crystalline illite (PCI) prevail in samples along gentler slope, whereas the original mineral assemblage - mainly made of well crystalline illite (WCI), chlorite, kaolinite and quartz - dominates along steep slope. The control exerted by topography is more evident in samples collected after a relatively dry winter.

REFERENCES

ALEXANDER D. (1980) - *Difference between 'calanchi' and 'biancane' badlands in Italy.* In Badland Geomorphology and Piping, Bryan R, YairA (eds). Geobooks: Norwich, 71–88.

BATTAGLIA S., LEONI L. & SARTORI F. (2002) - *Mineralogical and grain size composition of clays developing calanchi and biancane erosional landforms.* Geomorphology **49**, 153–170.

BERAEL C., POESEN J. & VAN WESEMAEL B. (1993) - *Rill and gully erosion in relation to rock fragment cover and surface slope along a hillslope in south eastern Spain.* In Desertification in a European Context: Physical and Socio-Economic Aspects, Fantechi R, Peter D, Balabanis P,Rubio JL (eds). Proceedings of the European School of Climatology and Natural Hazards Course, Alicante, Spain, from 6 to 13 October, 371–375.

BRYAN R. & YAIR A (1982) (Eds) - *Badland Geomorphology and Piping.* Geobooks, Norwich.

FAULKNER H., SPIVEY D. & ALEXANDER R. (2000) - *The role of some site geochemical processes in the development and stabilisation of three badland sites in Almerìa, Southern Spain.* Geomorphology, **35**, 87–99.

GERITS J., IMESON A.C., VERSTRATEN J.M. & BRYAN R.B. (1997) - *Rill development and badland regolith properties.* In Rill Erosion: Processes and Significance, Bryan RB (Eds.), Catena Supplement., **8**, 141–160.

HARVEY A.M. (1982) - *The role of piping in the development of badlands and gully systems in south-east Spain. In* Badland Geomorphology and Piping, Bryan R, Yair A (eds). Geobooks: Norwich, 317–335.

IMESON A.C. (1993) - *The physical, chemical and biological degradation of soil.* In Desertification in a European Context: Physical and Socio-Economic Aspects, Fantechi R, Peter D, Balabanis P, Rubio JL (Eds). Proceedings of the European School of Climatology and Natural

SDAO G., SIMONE A. & VITTORINI S. (1984) - *Osservazioni geomorfologiche su calanchi e biancane in Calabria.* Geografia Fisica e Dinamica del Quaternario, **7**, 10–16.Hazards Course: Alicante, Spain; 6–13 October: 153–168

PULICE I., SCARCIGLIA F., LEONARDI L., ROBUSTELLI G., CONFORTI M., CUSCINO M., LUPIANO V. & CRITELLI S. 2009 - *Studio multidisciplinare di forme e processi denudazionali nell'area di Vrica (Calabria orientale).* In Memorie Società Geografica Italiana, Roma: Società Geografica Italiana, **87** (I –II), 403-417.

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