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BLOCKFIELDS AND BLOCKSTREAMS IN THE LIGURIAN ALPS (MOUNT BEIGUA, ITALY)

ABSTRACT: FIRPO M., GUGLIELMIN M. & QUEIROLO C., *Blockfields and Blockstreams in the Ligurian Alps (Mount Beigua, Italy)*. (IT ISSN 1724-4757, 2005).

The landscape around the summit of the Monte Beigua Massif (1.287 m a.s.l.) is characterised by the accumulation of large blocks without any source rock faces at their head and by some relict rocky relief.

The aims of the present paper are to analyse systematically these landforms, to provide an explanation of their genesis, and to reconstruct the paleoclimatic evolution of this area. Eleven block accumulations have been analysed from a morphological, morphometrical and sedimentological point of view. The block accumulations are all characterised by open work texture at least in the upper 1.5 m, their angular or subangular shape, their frequent vertical dipping, the none or little vegetation in contrast to the woodland coverage just outside the landforms. All these morphological characteristics, and above all, the surface flow structures and pattern blocks, suggest that solifluction, gelifluction or frost creep or a combination of these can be considered responsible for the downvalley movement of these accumulations.

To understand whether the periglacial conditions are still present in the area or not, two dataloggers, each one with 4 external thermistors, were installed in January 2003. The subsurface temperature (2 cm) has a range between –13°C and 30°C with very strong diurnal oscillations that, during late winter, can reach 35°C. During the early winter there are very frequent daily freezing-thawing cycles that decrease at the end of the winter and the onset of the spring.

The relatively high frost penetration measured now and the usually low winter snow cover suggest a very effective frost action in the past, especially during the Wurm, when the MAAT reached 10-15°C less than in modern times (Clark, 1972) and in this case could be calculated around –2°-0°C.

The formation of blockstreams is tentatively attributed to cryotic conditions during the Wurm.

KEY WORDS: Blockfields, Blockstream, Pleistocene, Liguria, Italy.

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Il Massiccio del Monte Beigua, costituito da cime che superano l'altitudine dei 1000 metri e raggiungono i 1.287 metri sul livello del mare, è caratterizzato dalla presenza di numerosi depositi formati da grandi blocchi. L'obiettivo di questo lavoro è l'analisi di tali depositi ai fini di individuarne i processi che li hanno formati e di contribuire alla ricostruzione paleoclimatica dell'area.

Nella parte sommitale del massiccio e sul versante settentrionale sono stati rilevati undici depositi, che sono stati distinti in due tipi in base alla forma: a) corpi longitudinali allungati parallelamente alla direzione di massima pendenza del versante con morfologie superficiali di flusso (lobi, rughe e solchi trasversali e longitudinali) talvolta trasversali al pendio identificabili come «blockstreams»; b) forme equidimensionali senza strutture superficiali di flusso o isorientamenti dei blocchi identificabili come «blockfields».

Nei blockstreams i massi tabulari sono spesso verticalizzati, e gli assi maggiori dei blocchi sono quasi sempre immergenti in direzione opposta al flusso e con inclinazione maggiore di 30°. Le dimensioni dei blocchi superficiali, metrica nella parte alta delle forme, diminuiscono scendendo verso il fronte, ma non scendono mai al di sotto dei 60 cm.

Al fine di verificare se persistono in quest'area condizioni periglaciali sono stati posizionati, nel Gennaio 2003, due dataloggers con quattro sensori esterni di temperatura all'interno di un blockstream. La temperatura misurata in superficie (-2 cm) varia tra –13°C e 30°C con un oscillazione minima-massima giornaliera, molto alta, che durante l'inverno può raggiungere anche i 35°C. La relativamente alta penetrazione del fronte di congelamento misurata insieme con la scarsa copertura nevosa suggeriscono una effettiva azione del ghiaccio nel passato specialmente durante il Wurm, quando la MAAT doveva essere 10-15°C più bassa dell'attuale (Clark, 1972). La formazione dei blockstreams potrebbe essere attribuita alle condizioni criotiche verificatesi durante il Wurm.

TERMINI CHIAVE: Blockfields, Blockstream, Pleistocene, Liguria, Italia.

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INTRODUCTION

The upper slopes and summit of the Voltri area in northern Italy, is characterised by the accumulation of large blocks without any rock faces at their head and by relict rocky relief that has attracted much attention in the past (Issel, 1892; Sacco, 1934). Explanations for the genesis of these features have been proposed (Conti, 1940) but systematic analyses of their distribution, geomorphic characteristics, and relationships with surrounding bedrock and deposits have never been carried out. Moreover, the Quaternary history of this area of Liguria is almost unknown, except for information provided for the Holocene by the pollen record found in mires (Braggio Morucchio & *alii*, 1978, Cruise, 1990). The existing paleoclimate reconstruction is uncertain and, speculative. One reconstruction suggest the area could have been covered by spruce forest since the Eemian Interglacial (Ravazzi, 2002). According to Büdel (1951), the area was in a Loess-tundra zone during the Weichselian while others (e.g. Velichko, 1982, Poser, 1948) exclude the occurrence of permafrost south of the Alps, and hence also in this area. However, Kaiser (1960) hypothesised that permafrost aggradation occurred during on earlier glacial period.

The aims of this paper are to describe these landforms, to discuss their genesis, and to contribute to reconstructing the paleoclimatic evolution of this area.

FIG. 1 - Study area: location map (squares for climatic stations).

STUDY AREA

The study area, located along the watershed between the Po and Ligurian river basins, is not far from Genova and the Ligurian Sea. It contains the Beigua massif, comprising several summits over 1000 m a.s.l. with the highest at 1287 m a.s.l. The area is limited by the Orba river to the North; by the Stura and Cerusa Valley to the East, by the marine terraces of Piani d'Invrea to the South, and by the Teiro and Erro valleys to the West (fig. 1).

From a geomorphological point of view, the area can be divided into three main landscape units: 1) the southern slope: a very steep slope dipping towards the Ligurian Sea; 2) the northern slope: a gentle slope dipping to the Po river basin, characterised by several valleys rich in terraces; 3) the summit areas: areas above 1000-1200 m a.s.l. on the northern side of the watershed, characterised by gentle slopes and flat areas. The first two landscape units were mainly fashioned by gravitational and fluvial processes, while the third appears almost unaffected by these processes (fig. 2).

Geologically, the Beigua massif is in the middle of the meta-ophiolitic Voltri Group composed of serpentinites, metabasites and metasediments that form the basement of the Ternary Piedmont Basin. In the study area, we surveyed three main metamorphic lithotypes: serpentine schists, metabasalts (Prasinite *Auct*.), and eclogites. The first two are weakly to pervasively affected by schistosity, while eclogites are massive or fractured rocks (Desmons & *alii*, 1999).

CLIMATIC CONSTRAINTS

The only two weather stations, located close to the study area with a long climate record available, are at Melogno at 1000 m a.s.l. and Alpicella at 405 m a.s.l. (fig. 1). These two stations show a pluviometric regime with two maxima, one in spring (April-May) and one in Autumn (October-November) for the period 1934-1983. The mean annual precipitation is around 1200 mm. The air temperature shows a minimum in January and a maximum in July-August with a mean annual air temperature (MAAT) of 9.9 °C at Melogno and 14 °C at Alpicella. Since November 2001 a new weather station at Pianpaludo (865 m a.s.l.) provides local climate information. There, the MAAT for 2002 was 9.1 °C, while the total precipitation was high (2818 mm) because heavy rainfall occurred in November causing flooding in the Piedmont area (almost 700 mm in 17 days). The hourly air temperature ranged from 27 °C in July to –10.9 °C in January with an amplitude of 37.9 °C. Systematic snow cover data are not available for the area, but from our own periodic measurements, the winter snow cover is usually thin (< 30 cm) and persists for fewer than 15 days. The winter of 2003/2004 was exceptional because snow cover continued for more than two months.

METHODS

A preliminary interpretation of aerial photographs at a scale of 1:10,000 was carried out to define the main scree slope and block accumulations. Second, a detailed geomorphologic field survey was made to map the various landforms. All identified landforms were digitised and in-

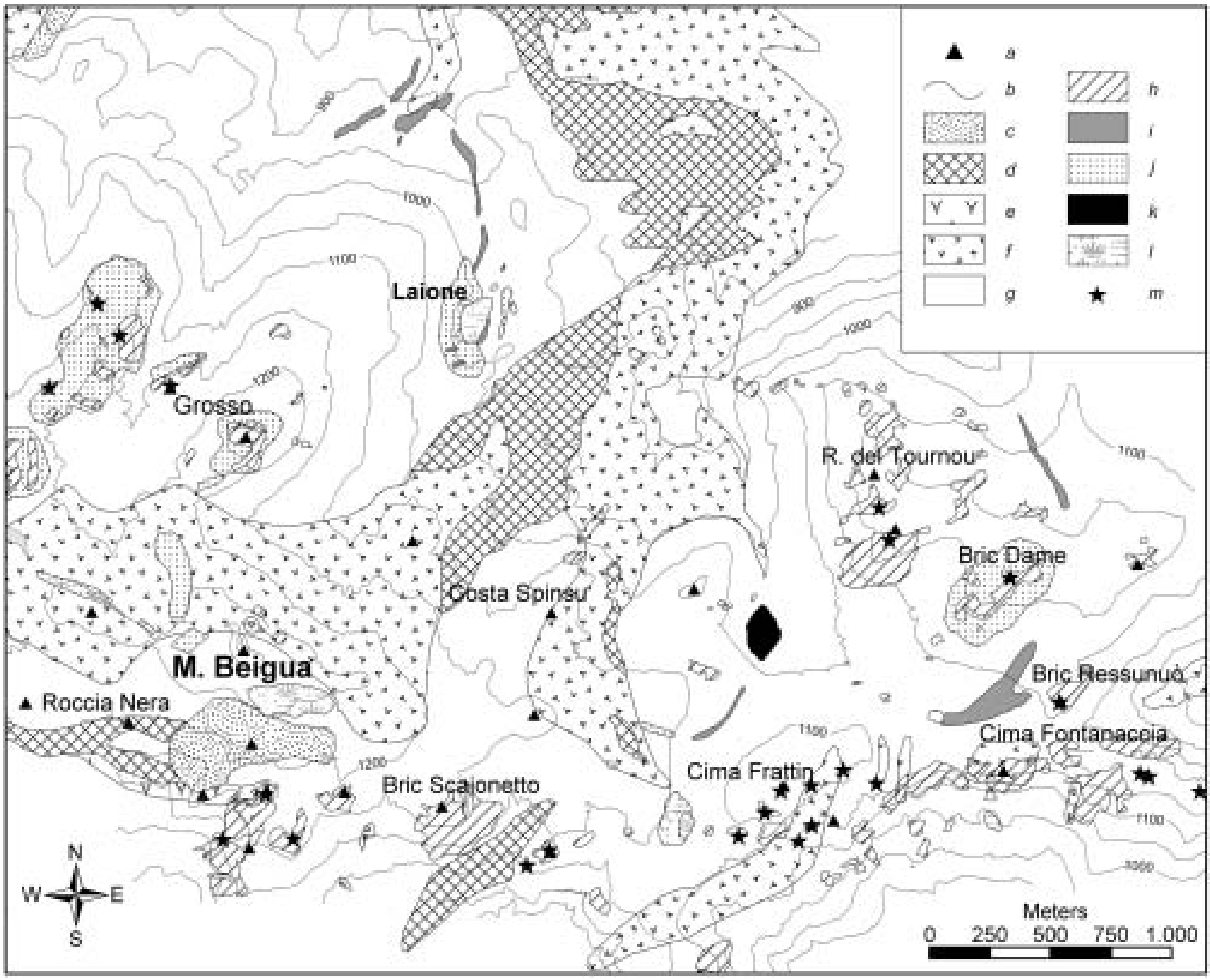


FIG. 2 - Geomorphological map of the examined area: *Forms and deposits:* a) mountain summits; b) contour lines (e = 50 m); c) colluvium; d) metasediment; e) metabasalts; f) eclogitic metabasalts; g) serpentine schists; h) wedging rock; i) relict blockstream; j) gravitative block deposits; k) relict blockfield; l) peat; m) tor-like feature.

cluded in a GIS system of the Mount Beigua Regional Park at 1:25,000 scale.

The main morphological characteristics (tab. 1) of the deposits were recorded along several transects parallel to the flow direction. On several block accumulations, a topographical survey using a laser theodolite was carried out. That involved a total of 305 measurement points (with a density of 1 point/10 m^2) located randomly over the whole feature, always located on the highest vpoint of the chosen block. In addition, two transversal sections, with points spaced 1.5 m apart, were carried out in order to obtain detailed sections along which the characteristics of all the blocks (e.g. size, long axis orientation, dip, shape, roundness, lithology, lichen coverage, presence of weathering features) were measured.

The processing of the topographical data allowed us to achieve an accurate TIN (triangulated irregular network surface) and, afterwards, a digital elevation model (1 m of pixel) using ArcGis 8.3. Lacking any natural exposures, a 2.5-m-deep trench was dug in the frontal part of the block accumulation «Lajone 2» to describe the internal structure.

To understand the climatic conditions within one of the block accumulation, two HOBO Pro dataloggers manufactured by Onset (USA) each one with 4 external thermistors were installed. The thermistors were placed directly in the ground at depths of 2, 30, 60, and 120 cm and fixed between the surface of two blocks to avoid any influence of direct incoming radiation and to record the real temperature within an open work blocky layer. The temperature was recorded every 10 minutes.

RESULTS

Morphology

The fig. 2 shows the location of 11 block bodies that were identified, together with tors and other gravitational features. The small tor that occur along the ridge of Mount Beigua are shown in fig. 3d. Evidence of mechanical disintegration is widespread on the rock outcrops throughout the study area above an altitude of 1100 m a.s.l.

Table 1 summarises data collected during survey of these 11 block bodies. All lie between 900 and 1100 m a.s.l. Four are located near the watershed between the Po and Ligurian river basins between 1050 and 1100 m a.s.l. The others are located on northern exposed slopes above 900 m, with the exception of one deposit that is located in a valley bottom at 680 m a.s.l. The mean slope of all 11 deposits varies between 2°-12°.

The block accumulations vary in extent from about 40,000 m^2 for one (ID1; Pian del Fretto) to 1762 m^2 (ID2 near the Lajone marsh). If the two largest deposits are excluded, the other 9 blockstreams fall within a range of 4000 to 10,000 m^2. Their average length is 275 m.

Almost all the block bodies (10) are located in valley bottoms on gentle slopes (< 10°). They have a lobate or tongue shape with a length/width ratio ranging between 3.8 and 14.6. These blocks are characterized by an open-work texture where block size ranges between 1.5 and 0.6 m in diameter (fig. 3a). Blocks are almost always angular, with metabasalt ones often being tabular. Blocks generally decrease in size from the upper part (average of 1.1 m) to the front (average of 0.8 m). By contrast, roundness of the blocks increases slightly downward. Weathering pits with a diameter of some decimeters and a depth of some centimeters, occur mainly on blocks with subhorizontal faces. Other weathering features, such as grooves, appear along joints or on steep faces along the line of maximum dip. These weathering features seem to be controlled by lithology because they are developed almost exclusively on the serpentine schists. Although lichen coverage is always greater than 70%, it was not possible to undertake any lichenometric analyses due to the concretion of the lichen thalli.

The orientation of the long axis of the blocks is variable, but generally three areas with relatively homogeneous patterns can be noted: (i) apex, (ii) central part, and (iii) front. In the apex, the long axes are randomly oriented with a wide range of inclinations (10-90°). In the central part there is a predominance of blocks with long axes parallel to the direction of the landform. The blocks have a high inclination (> 60°) that increases from the middle of the blockstreams to its border. The front part is characterized by imbrication of blocks with an inclination always greater than 35°. Only one block accumulation is equidimensional with a length/width ratio of ca. 1; it is located on a slope. In this case, the surface is characterized by an open-work texture where the block size ranges between 1.5 m and 0.8 m in diameter (fig. 3b). The blocks are almost always angular and appear to be devoid of preferential orientation.

All 11 examined block accumulations are composed exclusively of the same lithology as the underlying bedrock.

The detailed topographical analysis of the Lajone 2 deposits and the derived DEM were used to show the flow structures. Along 26 transversal and 3 longitudinal profiles, a surface curvature analysis (concavity, convexity, flatness, verticality) was carried out. Based on the results of this statistical analysis and on the geomorphological survey, the surface of the deposit can be divided into five zones from the apex to the front (fig. 4):

A. a gently depressed surface with circular form;
B. a zone with small lobes parallel and transversally oriented to the direction of the deposit;
C. a zone characterized by very gentle surfaces (< 8°) with longitudinal ridges and troughs;
D. a zone with sharp (clear) transversal ridges and troughs;
E. a frontal part, with a flat area behind a steep (30°) scarp (3 m in height).

Along the two transects (AB, CD of fig. 5a) the topographical measurements of the detailed fabric analysis were carried out. The profile CD referring to the central part of the Lajone 2 deposits is shown in fig. 5c and 5f. The vectors reported in fig. 5c and the frequency rose diagram (fig. 5b) show that the mean direction of the a-axis is north-south, parallel to the flow direction of the body. The density polar plot and the stereogram of fig. 6d show also that almost all the blocks are very steeply inclined (>35°) with some of them even being vertical.

The profile AB is located in the frontal part of the landform; fig. 6a and fig. 6b shows the imbrication of the main part of the blocks that dip upslope with an inclination almost greater than 35°. The long axes direction ranges between 100° and 200°, with more than 40% included in a narrower range (180-200°).

Thermal regime of the blocky layer

Figure 7 shows the trend of mean monthly temperature for 2003 recorded in the frontal part of the Lajone 2 deposit, at different depths (2, 30, 60, and 120 cm). The ground surface temperature (GST), defined at –2 cm according to Guglielmin (2004), ranged between 26 °C in July and 1 °C in January with an amplitude of 25 °C and a mean annual surface temperature (MAST) of 11.7 °C. The deepest temperature, recorded at –120 cm, ranged between 15.5 °C in August to –1.5 °C in January with an amplitude of 17 °C.

Figure 8 shows the mean daily temperature pattern for the period between 5 August 2003 to 16 September 2004 at the different depths (2, 30, 60, and 120 cm). The GST ranged between 33 °C in July to –30 °C in January with an amplitude of 43 °C. The temperature at –120 cm, ranged between 21 °C in August to –4 °C in January with an amplitude of 25 °C.

Figures 9a and 9b show two seasonal examples of the temperature recorded at the same depth (60 cm) on the

TABLE 1 - The main morphological and sedimentological data collected during the surveys of the 11 blocks bodies

ID	name	surface morpho	surface structure	deposit location	mean elev. [m]	mean dip [°]	aspect	area [m2]	width [m]	length [m]	lenght /width ratio	vegetation coverage	rock cliff or main scarp	type form	mean size block [cm]	block shape	block round-ness	block lithology	block fabric
1	FRETTO	flat	absent	saddle	1101	6	SW	39578	129	521	4,04	discont. lichen	Y	block stream	100	prism	sub-rounded	serpentineschists	random
2	LAIONE 1	flat	absent	slope	986	2	N NE	1762	22	144	6,55	discont. lichen	N	block stream	100	tabular	sub-angular	serpentineschist	vertical
3	LAIONE 2	undulating	longitudinal ridge	valley bottom	981	5	N	3407	15	200	13,33	discont. lichen	N	block stream	80	tabular	sub-angular	serpentineschist	vertical - imbricate
4	LAIONE 3	undulating	absent	valley bottom	940	8	N	8189	45	390	8,67	discont. lichen	N	block stream	95	tabular	sub-angular	serpentineschist	random
5	RIANUN	undulating	absent	valley bottom	1103	9	N	8875	30	437	14,57	discont. lichen	N	block stream	90	prism	sub-angular	serpentineschist	imbricate
6	TRAVERSA 1	undulating	longitudinal ridge	valley bottom	920	7	NE	6514	34	239	7,03	discont. lichen	N	block stream	130	tabular	sub-angular	metabasit	random
7	TRAVERSA 4	undulating	stone banked lobe	slope	903	7	NE	10866	73	278	3,81	discont. lichen	N	block stream	125	tabular	angular	serpentineschist	imbricate
8	TRAVERSA 5	undulating	traversal ridge	valley bottom	882	10	N-NE	4450	35	223	6,37	discont. lichen	N	block stream	120	tabular	sub-angular	serpentineschist	vertical
9	ZERVAZZO	convex	longitudinal ridge	valley bottom	682	12	N NW	10121	63	253	4,02	discont. lichen	N	block stream	90	tabular	sub-angular	serpentineschist	imbricate
10	RIONDO 1	convex	traversal ridge	valley bottom	1076	9	NE	4594	26	168	6,46	discont. lichen	N	block stream	95	prism	angular	serpentineschist	vertical
11	RIONDO 2	flat	longitudinal ridge	slope	1036	6	NE	20250	155	180	1,16	discont. lichen	N	block field	90	tabular	sub-angular	serpentineschist	vertical

FIG. 3 - a) «Lajone 1» slope blockstream, view from top; b) «Riondo 1» down-valley blockstream, view from top; c) detail of block fabric at front of «Fretto» blockstream; d) little tor-like feature in serpentine schists, near Cima Frattin.

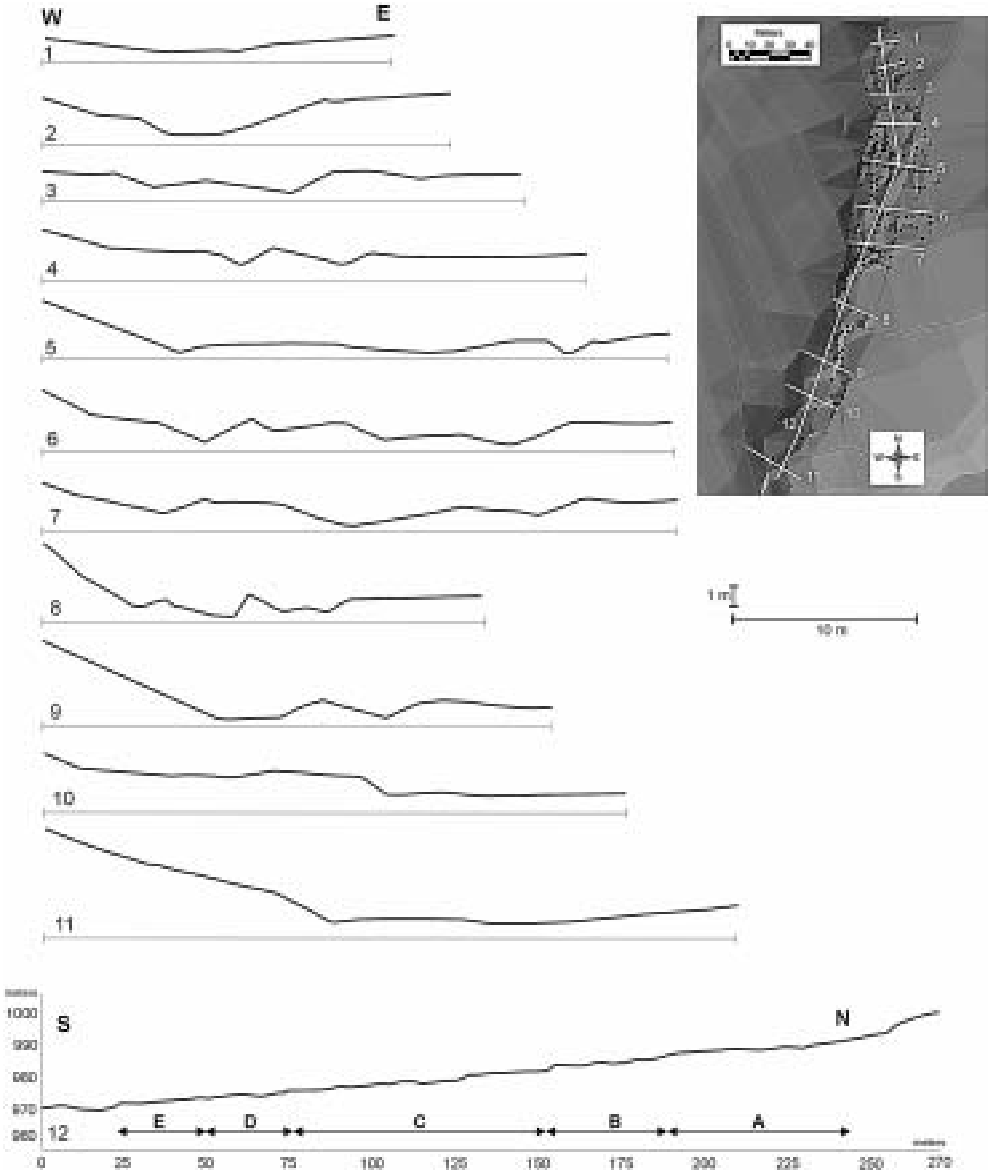
top and on the frontal part of the «Lajone 2» deposit, relative to January and August 2003. In winter, the fluctuations of the temperature were lower than in summer, but there were no clear episodes of zero curtain effect in either part of the landform, nor during the early winter were there very frequent daily thermal freezing-thawing events. The thermal regime was almost similar and simultaneous on the top and at the front in winter and in summer, indicating a negligible chimney effect (Harris & Pedersen, 1998).

The maximum frost penetration was calculated using the linear thermal gradient between the thermistors located at the depths of 60 and 120 cm and exceeded 210 cm.

DISCUSSION AND CONCLUSIONS

As regards the origin of the blocks that occur on the uplands of the Beigua areas, the scree deposits that lie beneath rock scarps can be readily distinguished from

FIG. 4 - Cross profiles and longitudinal profile of the Lajone 2 block stream and sketch of the different morphological zones of the Lajone 2 block stream.



the blocky accumulations described in this paper because the latter occur on slopes or on valley-floors without any bedrock cliff or free face at their head. In addition, scree deposits have a typical gravitational size selection with an increase of size downslope. On the other hand, block accumulations have an opposite trend with the smallest block size in the frontal part of the bodies. This has also been described by Klatka (1962) for the blockslopes and blockstreams of the classical site of Lysa Gora in Poland.

We can exclude a glacial origin hypothesis, as proposed in the past (e.g. Sacco, 1934), because there is no evidence of glacial erosion (such as cirques, roches moutonnées, striae, etc.) nor of diamicton deposits unequivocally attributable to a glacial deposition. In addition, the block accumulations are always composed of the same lithology as the underlying bedrock in the autochthonous blockfields and blockstreams (e.g. Harris, 1994). In a few cases, it cannot be excluded that the blocks originated from large rock avalanches that completely destroyed the original bedrock cliff or ridge. Considering that the shape of the blocks is always angular or subangular, they were probably produced mainly by mechanical weathering. The weathering pits and grooves that occur on the blocks within the blockfields are not present on the surrounding scree slopes with similar steepness, suggesting an older age for the former. These weathering features could be the result of biochemical or biomechanical processes, not exclusive to cryogenic environments, as proposed by Guglielmin & *alii* (2005) for the granites of Northern Victoria Land in Antarctica.

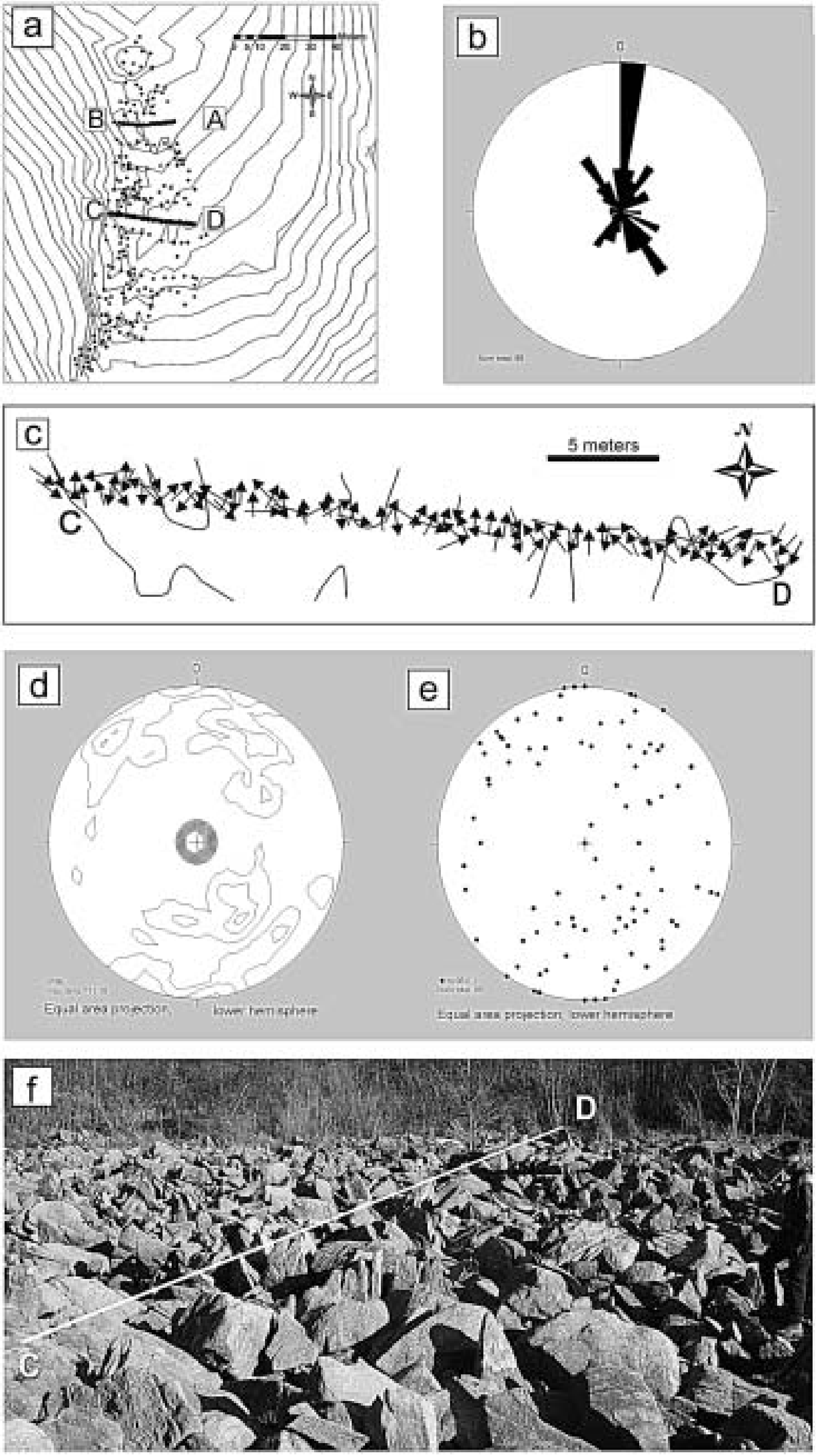
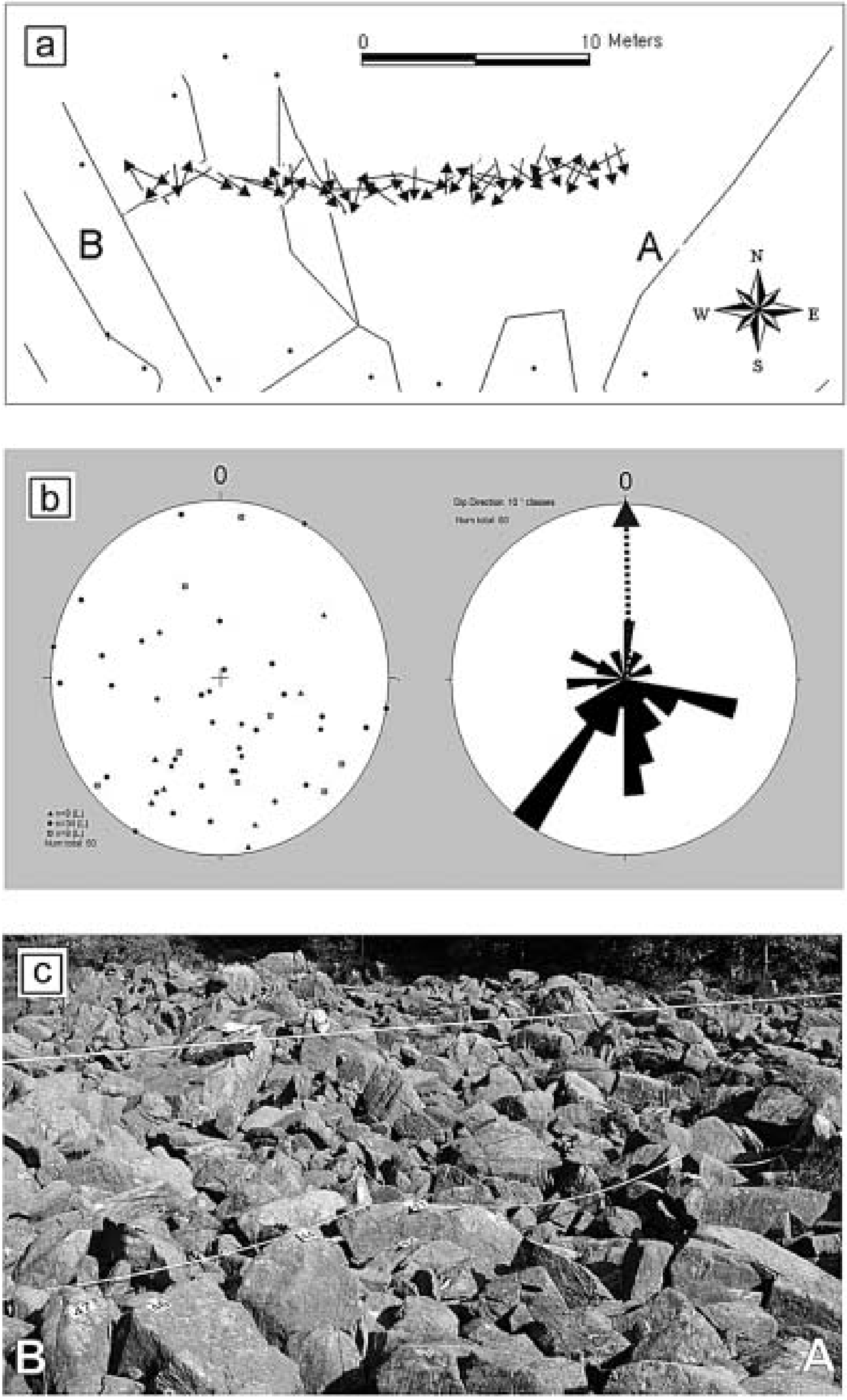


FIG. 5 - Lajone 2 block stream: a) localisation of the detailed sedimentological profiles AB and CD; b) rose frequency diagram of the blocks along CD transect; c) pattern of a-axis vectors; d) stereogram and density plot of the long axis of the CD transect blocks; e) view of the CD transect.

FIG. 6 - Lajone 2 block stream, frontal part: a) pattern of a-axis vectors; b) stereogram of the long axis and rose frequency diagram of the blocks along AB transect; c) view of the AB transect.



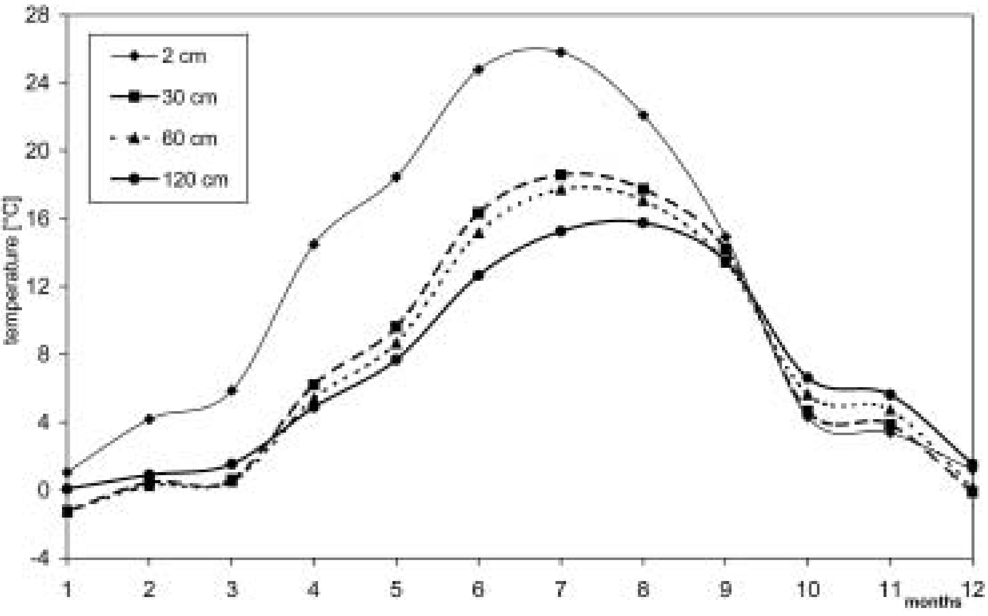


FIG. 7 - Mean monthly ground temperatures recorded in 2003 at the frontal part of Lajone 2 blockstream (980 m a.s.l.) at different depths (2, 30, 60, and 120 cm).

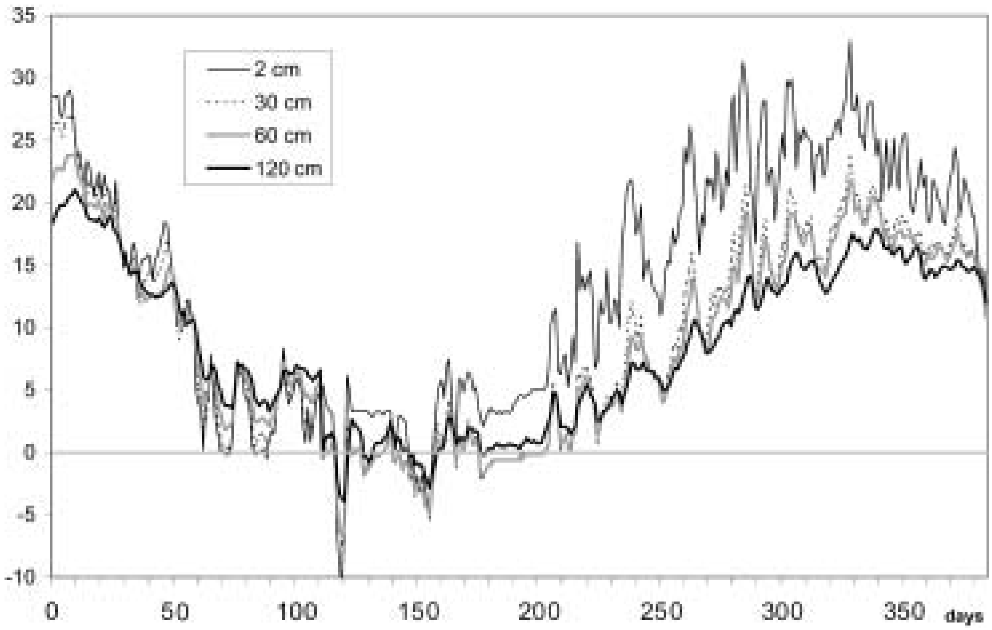


FIG. 8 - Daily mean ground temperatures recorded from 5 Aug. 2003 to 16 Sept. 2004 at the same site and depths as in fig. 7.

All the block accumulations described here are characterised by (i) an open-work texture in the upper 1.5 m of thickness, (ii) angular or subangular blocks, (iii) frequent vertical dipping, or imbrication of the boulders, (iv) and an absence or paucity of vegetation (except for the epilithic lichens). The accumulations are composed of the same underlying lithology. Moreover, all the 11 examined block bodies have a gentle slope (< 12°), lower than the repose angle of the material, and almost none have any rock cliff or free face. In many ways they are similar to the famous «stone streams» of the Falkland Islands (Anderson, 1906; Clapperton, 1975).

With regard to their morphologies, 10 of the 11 block accumulations examined have a tongue shape and are developed within valley-floors. These are considered autochthonous blockstreams. These blockstreams differ from blockfields, because the former exibit flow structures such as transversal and longitudinal ridges and stone-banked lobes. The fabric pattern, with imbrication well pronounced in the frontal part of the blockstreams and

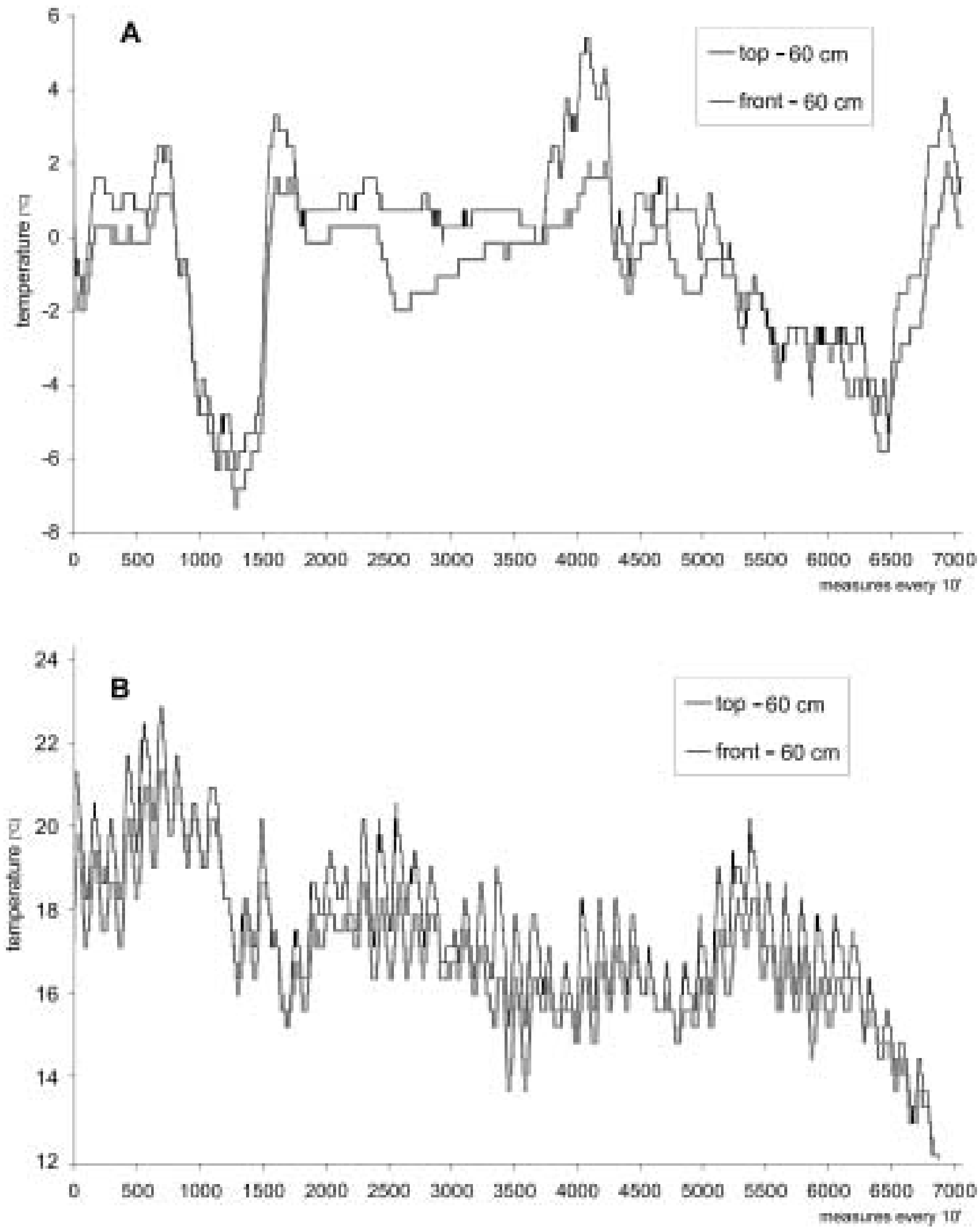


FIG. 9 - Comparison between the thermal regime of the apex and the front of the Lajone 2 blockstream: a) ground temperature recorded every 10 min at 60 cm depth in January 2003; b) August 2003.

with the orientation of the long axis of individual blocks transverse to the gradient, is similar to that which is described in literature from elsewhere (e.g. Caine, 1972, in Tasmania). In our cases, we did not find that the inclination of the long axis of the blocks was less steep than the gradient, as shown by many authors (e.g. Caine, 1972; Klatka, 1962); on the contrary, the blocks are always steeper than the gradient.

The clast fabric, the gentle slope of the blockstreams, and the flow structures on their surface indicate mass transport. Considering the evidence of the tors and of frost wedging of some rock outcrops and, above all, the relatively high frost penetration now measured and the usually low winter snow cover, it can be argued that solifluction under non-periglacial conditions is unlikely.

It cannot be said whether the debris supply was contemporaneous with, or whether it preceded the gelifluction and/or frost creep mobilisation of the blockstream. If one accepts the model proposed by Czudek & Demek (1972) and by Romanovskii & Tyurin (1983), in which movement (usually with a rate of some centimetres per year) may be due to creep of thawed blocks over an icy base with a high ice content (>50%), one has to accept that the mobilisation occurred under periglacial conditions with deep seasonal frost or under permafrost conditions.

We can also estimate the time necessary for the blockstreams to form, assuming that the length of the blockstream represents the maximum total movement of the individual blocks and that the movement rate was constant in time. Although these assumptions are speculative, applying a minimum rate of 0.6 cm yr^{-1} and a maximum of 6 cm yr^{-1} (French, 1996), one blockstream moved between 33 and 3 ka. If the model proposed by Harris (1994) is correct, blockstreams should be constrained in very arid and cold conditions with a MAAT ranging between –5 and –20 °C and mean annual precipitation lower than 500 mm yr^{-1}. However, the paleoclimatic data available for the area are limited in time. They refer only to the Holocene and are based on the pollen record found in the mires of Lajone, Agoraie and Casanova (Braggio Morucchio & *alii*, 1978, Cruise, 1990). They indicate no periglacial conditions in that period. Given the current state of knowledge, the time needed for their formation cannot be estimated.

According to the climate model proposed by Clark, (1972), during the Weichselian the MAAT was 10-15 °C less than in modern times, and therefore in this area it could have ranged from –1 °C to –6 °C. It is also reasonable to think that with such cold temperatures the precipitation was much lower, meaning that in the Beigua region, cryotic conditions prevailed and the blockstreams would confirm the climatic model proposed by Harris (1994).

Further investigations are required to establish whether or not these features are related to older cold phases during the Pleistocene and to understand when the movement of the blockstreams occurred.

REFERENCES

ANDERSSON J.C. (1906) - *«Solifluction», a component of sub-aerial denudation*. The Journal of Geology, 14, 91-112.

BOELHOUWERS J.C. & SUMNER P.D. (2003) - *The paleoenvironmental significance of southern African blockfields and blockstreams*. Proceedings of the 8th International Conference on Permafrost, Phillips M, Springman S.M, Arenson L. (eds). Balkema Publishers, Lisse, 1, 73-78.

BRAGGIO MORUCCHIO G., GUIDO M.A. & MONTANARI C. (1978) - *Studio palinologico e vegetazione della torbiera del Lajone presso Piampaludo (Gruppo del M. Beigua, Appennino Ligure Occidentale)*. Archivio Botanico Biogeografico Italiano, 54, 115-137.

BÜDEL J. (1951) - *Die Klimazonen des Eiszeitalters*. Eiszeitalter und Gegenwart, 1, 16-26 (English translation: International Geology Review, 1(9), 72-79, 1959).

CAINE N. (1968) - *The blockfields of northeastern Tasmania*. Australian National University, Dep. of Geography Publ. G/6, 127 pp.

CAINE N. (1972) - *Air photo analysis of blockfield fabrics in Talus Valley, Tasmania*. Journal of Sedimentology and Petrology, 42, 33-48.

CLAPPERTON C.M. (1975) - *Further observation on the stone runs of the Falkland Islands*. Biuletyn Peryglacjalny, 24, 211-217.

CLARK, R. (1972) - *Periglacial landforms and landscape in the Falkland Islands.* Biuletyn Peryglacjalny, 21, 33-50.

CONTI S. (1940) - *La nivazione e la morfologia periglaciale dell'Appennino ligure occidentale (Gruppo di Voltri).* Bollettino della Società Geologica Italiana, 59, 69-94.

CRUISE G.M. (1990) - *Pollen stratigraphy of two Holocene peat sites in the Ligurian Apennines, Northern Italy*. Review of Paleobotany and Palinology, 63, 173-182.

CZUDEK T. & DEMEK J. (1972) - *Present day cryogenic processes in the mountains of eastern Siberia*. Geographia Polonica, 23, 5-20.

DESMONS J., APRAHAMIAN J., COMPAGNONI R., CORTESOGNO L., FREY M., with the collaboration of GAGGERO L., DALLAGIOVANNA G. & SENO S. (1999) - *Alpine metamorphism of the Western Alps: I. Middle to high-P/T metamorphism*. Schweizerische Mineralogische und Petrographische Mitteilungen, 79, 89-110.

FRENCH H.M. (1996) - *The periglacial Environment.* Longman, London, 309 pp.

GUGLIELMIN M. (2004) - *Observations on permafrost ground thermal regimes from Antarctica and the Italian Alps, and their relevance to global climate change*. Global and Planetary Change, 40, 159-167.

GUGLIELMIN M., CANNONE N., STRINI N. & LEWKOWICZ A.G. (2005) - *Biotic and abiotic processes of the granite weathering landforms in a cryotic environment in Northern Victoria Land, Antarctica*. Permafrost and Periglacial Processes, 16, 69-85.

HARRIS S.A. (1994) - *Climatic zonality of Periglacial Landforms in Mountain Areas.* Arctic, 47(2), 184-192.

HARRIS S.A. & PEDERSEN D.E. (1998) - *Thermal regimes beneath coarse blocky material*. Permafrost and Periglacial Processes, 9, 107-120.

KAISER K. (1960) - *Klimazeugungen des periglazialen Dauerfrostbodens in Mittel und West Europa*. Eiszeitalter und Gegenwart, 11, 121-141.

KLATKA T. (1962) - *Geneza i wiek globorzy Lysogorskich*. Acta Geographica Lodziendzia, 12, 129 pp.

ISSEL A. (1892) - *Brevi note di geologia locale*: *I, tracce di fenomeni glaciali nel Genovesato*. Atti della Società Ligustica di Scienze Naturali, 3, 19-33.

PAPPALARDO M. & PUTZOLU P.P. (1994) - *Le "Sassaie" dei Monti Pisani: "Colate di pietre" tipiche dell'ambiente periglaciale*. Atti della Società Toscana di Scienze Naturali, Memorie, serie A, 101, 323-342.

POSER NN. (1948) - *Boden und Klimaverhältnisse in Mittel und West Europa während der Würmeiszeit.* Erdkunde, 2, 53-68.

RAVAZZI C. (2002) - *Late Quaternary history of Spruge in southern Europe.* Review of Paleobotany and Palinology, 120, 131-177.

ROMANOVSKII N.N. & TYURIN A.I. (1983) - *Rock stream deserption*. In Proceedings 4th Int. Permafrost Conference, Washington D.C. National Academy Press, 1078-1082.

SACCO F. (1934) - *Il glacialismo nel Gruppo di Voltri*. Atti della Reale Accademia delle Scienze di Torino, 70, 96-105.

VELICHKO A.A. (1982) - *Paleogeography of Europe during the last one hundred thousand years*. Nauka, Moscow, 156 pp.

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