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GENESIS OF THE ALTO VEZ GLACIAL VALLEY PLEISTOCENE MORAINES, PENEDA MOUNTAINS, NORTHWEST PORTUGAL

CARACTERIZAÇÃO E GÉNESE DAS MOREIAS PLISTOCÉNICAS DO VALE GLACIÁRIO DO ALTO VEZ, SERRA DA PENEDA, NOROESTE DE PORTUGAL

Santos, João, *CEGOT (Univ. Coimbra), Coimbra, Portugal, jsantos@kent.edu*
Cunha, Lúcio, *CEGOT (Univ. Coimbra), Coimbra, Portugal, luciogeo@ci.uc.pt*
Vieira, António, *CEGOT (Univ. Minho), Guimarães, vieira@geografia.uminho.pt*
Bento-Gonçalves, António, *CEGOT (Univ. Minho), Guimarães, bento@geografia.uminho.pt*

ABSTRACT

Glacial landforms and sediments that are the product of past glaciations can provide geomorphologists with meaningful information on the nature of processes that are occurring in modern glaciers. This paper investigates the genesis of Pleistocene moraines present in the Alto Vez Glacial Valley of northwestern Portugal using till fabric and grain size analysis. The present-day moraine morphology and sedimentology in this valley reveals the presence of two types of till. The clast-rich medium sandy diamicton present in unit 1 of moraine 1 is interpreted to be a lodgment till deposited during a stage of glacial advance into the lower glacial valley. The clast-rich coarse sandy diamictons present in unit 2 of moraine 1 and unit 1 of moraine 2 are interpreted to be supraglacial melt-out tills (ablation tills) deposited during stages of glacial stability and moraine building fallowed by recession from the lower glacial valley.

RESUMO

As formas e depósitos glaciários, testemunhos de antigas glaciações, podem fornecer aos geomorfólogos importantes dados sobre a natureza dos processos que ocorrem em glaciares atuais. Com este artigo pretende-se caraterizar e apontar alguns elementos para a génese das moreias de idade plistocénica presentes no Vale Glaciário do Alto Vez no noroeste de Portugal, através da análise do *till fabric* e do estudo granulométrico das frações arenosa e fina. A análise morfossedimentar das moreias presentes neste vale revelou a presença de dois tipos de *till* glaciário. O *diamiction* rico em clastos embalados por areias médias presente na unidade 1 da moreia 1 é interpretado como correspondendo a um *till* de alojamento depositado durante uma fase de avanço glaciário. Os *diamictions* ricos em clastos compostos por areias grosseiras presentes nas unidades 2 da moreia 1 e 1 da moreia 2 são interpretados como sendo *tills* de fusão supraglaciários depositados durante fases de estabilidade e recuo glaciário.

1. INTRODUCTION

Landforms and sediments that are the product of past glaciations can explain processes that are occurring in actual glaciers (Benn and Evans, 1998). Sediments carried in, under, and on a glacier are deposited in a variety of ways at the ice margin (Benn and Evans, 1998; Easterbrook, 1999). In addition to direct deposition by the glacier itself (till deposition), glacial sediments can also be deposited by an array of other processes such as fluvial, lacustrine, marine, eolian, and mass wasting. Although several depositional processes may be involved, much of the sediment deposited is usually very poorly sorted, containing a wide range of particle sizes (diamictons). The constitution of these diamictons can be analysed and interpreted using several glacial sedimentological techniques.

Till fabric and grain size analysis are among the techniques used to examine the sedimentological history and internal composition of various moraine types through a study of the dip and orientation of enclosed pebbles (Andrews, 1971) and through a calculation of the degree of sediment sorting (Nichols, 1999). In this paper we try to characterize the Pleistocene moraines currently present in the Alto Vez Glacial Valley, in northwestern Portugal, and investigate their genesis, using till fabric and grain size analysis.

2. SETTING AND PREVIOUS WORK

The Alto Vez Glacial Valley located in the Peneda Mountains of northwest Portugal is the study area for this research (Fig 1). The valley has a south-north orientation and in certain locations reaches latitudes superior to 42° N making it the northernmost valley in mainland Portugal that suffered the effects of Pleistocene glaciations. During the peak of the last glacial stage the valley was the home of a valley glacier approximately 8 km long with ice thickness reaching more than 100 meters in several locations (Coudé-Gaussen, 1981). Identification of glacial landforms and the first reconstruction of the ice margin positions in this valley was primarily the work of Coudé-Gaussen (1981) and Brum Ferreira *et al*. (1999). These first studies revealed the location of the valley's major glacial landforms via geomorphologic maps and integrated this valley in the context of the Northwestern Pleistocene glaciations, but they lacked a detailed sedimentological approach.

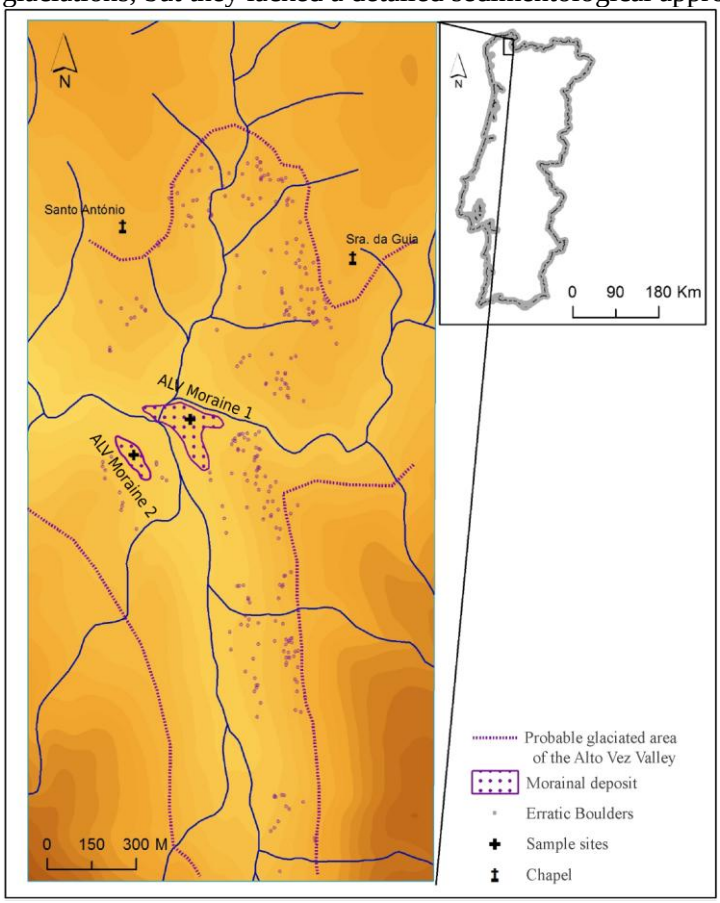

Figure 1 – Alto Vez Glacial Valley Location, Moraines, and Sample Sites

3. METHODOLOGY

Two major lateral moraines in the valley where chosen for this research (Fig 1). Their sedimentology was analysed through the use of till fabric (Andrews, 1971) and grain size analysis techniques (Nichols, 1999). A total of eight pebble-fabric analyses were determined at two sites (at least one site

per moraine) (Fig 1 and Table 1) by measuring the long axis of twenty-five elongated pebbles. For each analysis, pebbles were taken from natural exposures in moraines, and all pebbles were taken from an area of less than 1 m^2. The upper 50 cm of every exposure was not sampled to avoid any degree of disturbance. The data were plotted and contoured on equal-area nets using the program of Kamb (1959). Statistical analysis of the data was performed using the eigenvalue method discussed by Mark (1973). Grain size distributions of eight samples collected from the same two sites used for pebble-fabric analysis (Fig 1 and Table 1) were described using the Wentworth-Udden grain size classification (Wentworth, 1922) and the phi scale (ϕ) of Krumbein (1934).

Table 1 – Alto Vez Glacial Valley Moraines: Sample Locality, Grain Size, and Till Fabric Data

				Grain Size %			Sorting (phi)		Till Fabric Analysis			
Site	Exposure	Unit	Sample	Gravel[a]	Sand[b]	Mud[c]	Graphic Mean	Standard Deviation	Azimuth	Plunge	S_1	S_3
ALV Moraine 1	1	1	1	17,8	74,5	7,7	1,35	2,14	129	24	0,8684	0,0524
ALV Moraine 1	1	1	2	16,5	76,4	7,1	1,33	2,06	140	15	0,9287	0,0114
ALV Moraine 1	1	1	3	15,3	74,6	10,1	1,40	2,10	129	16	0,8901	0,0266
ALV Moraine 1	1	2	1	25,6	67,2	7,2	0,85	2,14	80	31	0,6419	0,0444
ALV Moraine 1	1	2	2	25,8	66,3	7,9	0,83	2,16	105	24	0,5200	0,0775
ALV Moraine 1	1	2	3	29,1	59,0	11,9	0,80	2,31	56	33	0,5255	0,0866
ALV Moraine 2	1	1	1	28,0	64,5	7,5	0,68	2,17	192	38	0,5100	0,1037
ALV Moraine 2	1	1	2	26,2	66,0	7,8	0,60	2,05	185	18	0,6004	0,0682

Gravel[a] = Pebbles + Granules (-2.0 phi to -1.0 phi)
Sand[b] (-0.5 phi to 4 phi)
Mud[c] = Silt + Clay (>4.0 phi)
S1 and S3 eigenvalues measure fabric strength (degree of clustering)

4. GEOMORPHOLOGY AND SEDIMENTOLOGY

4.1. Alto Vez Lateral Moraine 1 (ALV Moraine 1)

This lateral/end moraine is located in the lower eastern portion of the valley and it is approximately 80 meters high (Fig 1). Generally speaking it has a southeast-northwest orientation, which is parallel to the paleo-ice flow direction in this location of the valley. A natural exposure in this feature of approximately 2.10 meters revealed that it is composed of two sedimentary units (Fig 2A).

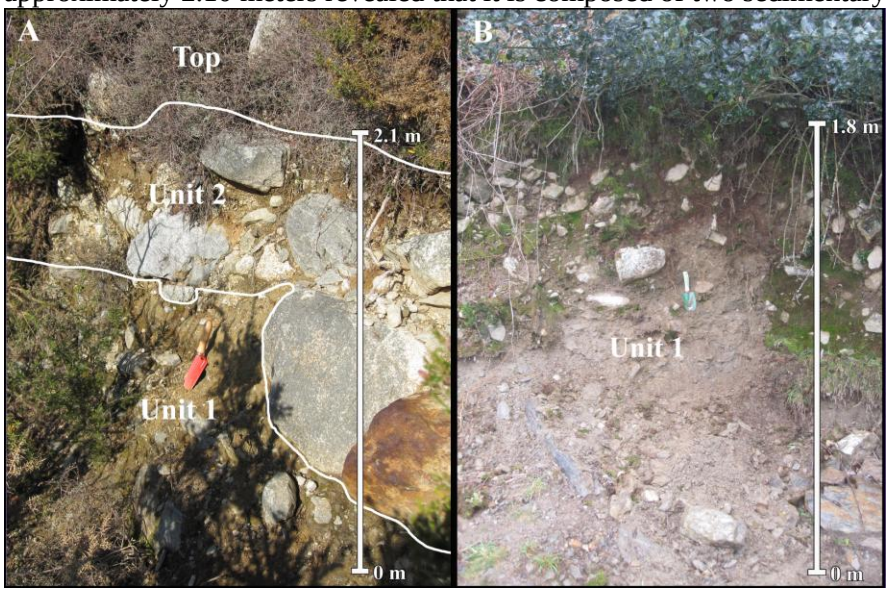

Figure 2 (A) – Alto Vez Lateral Moraine 1 Exposure. (B) Alto Vez Lateral Moraine 2 Exposure

Unit one is approximately 1.2 meters thick and is composed of a massive very poorly sorted (standard deviation values ranging from 2.06ϕ to 2.14ϕ; Table 1) light brown clast-rich medium sandy diamicton. Clasts are moderately to well oriented to the paleo-ice flow direction in this location of the

valley (average azimuth values ranging from 129° to 140°; Table 1). Clasts present a moderate range in dip/plunge values (15° to 24°; Table 1). S_1 eigenvalues ranging from 0.86 to 0.92 express moderate to strong fabric strength (clustering) (Table 1) in this unit. Clasts in the samples are also striated and are sub-angular to sub-rounded.
Unit two is approximately 0.9 meters thick and is composed of a massive very poorly sorted (standard deviation values ranging from 2.14ϕ to 2.31ϕ; Table 1) light brown clast-rich coarse sandy diamicton. Clasts are poorly oriented to the paleo-ice flow direction in this location of the valley (average azimuth values ranging from 56° to 105°; Table 1). Clasts present a moderate range in dip/plunge values (24° to 33°; Table 1). S_1 eigenvalues ranging from 0.52 to 0.64 express weak fabric strength (Table 1) in this unit. Clasts in the samples are not striated and sub-angular to angular.

4.2. Alto Vez Lateral Moraine 2 (ALV Moraine 2)

This lateral moraine is present in the lower western portion of the valley and it is approximately 30 meters high (Fig 1). It has a southeast-northwest orientation, which is parallel to the paleo-ice flow direction in this location of the valley. A natural exposure in this feature approximately 1.80 meters revealed that it is composed of one sedimentary unit (Fig 2B). This unit is composed of a massive very poorly sorted (standard deviation values ranging from 2.05ϕ to 2.17ϕ; Table 1) light brown clast-rich coarse sandy diamicton. Clasts are moderately to poorly oriented to the paleo-ice flow direction (average azimuth values ranging from 185° to 192°; Table 1). Clasts present a moderate range in dip/plunge values (18° to 38°; Table 1). S_1eigenvalues ranging from 0.51 to 0.60 express weak fabric strength (Table 1) in this unit. Clasts in the samples are not striated and sub-angular to angular.

5. INTREPRETATION AND CONCLUSION

The sedimentology of the two Alto Vez Glacial Valley lateral moraines reveals the presence of two till types. The clast-rich medium sandy diamicton present in unit 1 of moraine 1 is interpreted to be a lodgment till. This assumption is supported by the presence of moderately to well-oriented striated clasts with a moderate to small range in dip/plunge values and S_1 eigenvalues expressing moderate to strong fabric strength. According to Benn and Evans (1998) pebble a-axis fabrics in lodgement tills have consistent strong preferred orientations parallel to ice flow, and a-b planes tend to have gentle upglacier imbrications with small ranges in dip values. Grain size results from this unit demonstrate that it is composed of very poorly sorted clast-rich medium sand with striated clasts (Fig 3). These characteristics are all common in lodgment tills where coarser sediment is crushed and striated under moving/advancing ice and become finer with time (Benn and Evans, 1998).

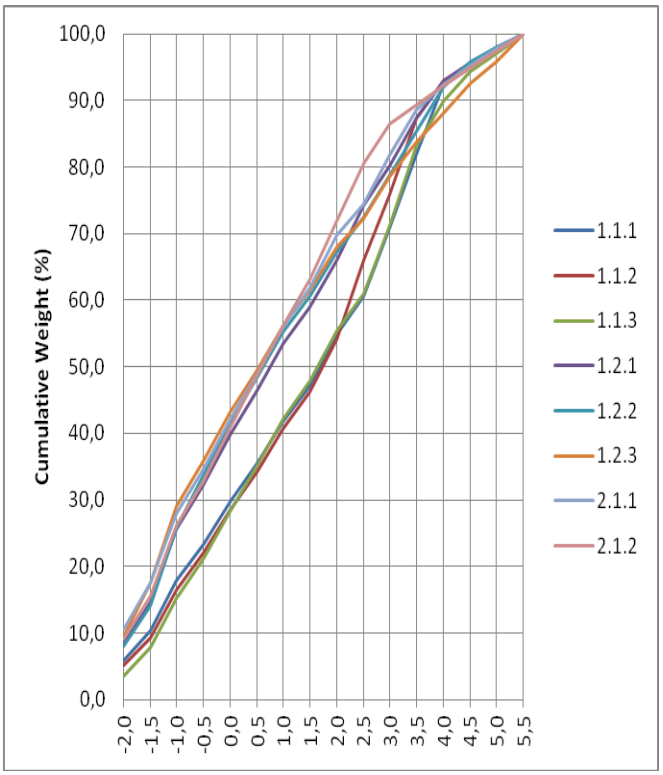

Fig 3 – Granulometric Curves of the Alto Vez Glacial Valley Moraines' Samples

The clast-rich coarse sandy diamictons present in unit 2 of moraine 1 and unit 1 of moraine 2 are interpreted to be supraglacial melt-out tills (or ablation tills). This assumption is supported by the presence of moderately to poorly oriented clasts with a moderate range in dip/plunge values and S_1 eigenvalues expressing weak fabric strength. Pebble a-axis fabrics in supraglacial melt-out tills often have moderate to strong preferred orientations parallel to the ice flow direction (reflecting the original englacial fabrics) but dewatering, sediment reworking by water, and debris slumping all common on supraglacial active or stagnant/receding ice may overprint or change the original fabric (Benn and Evans, 1998). Grain size results from these units also support that they are composed of very poorly sorted clast-rich coarse sand with angular clasts (Fig 3). These characteristics are all common in supraglacial melt-out tills where sediment is coarser and contains more angular clasts due to weathered debris falling on the ice from nearby active mountain slopes (Benn and Evans, 1998).

In conclusion, moraine 1 had, at least, two constructional events. On a first stage ice advance into the lower valley and deposited the lodgment till present in unit 1. On a second stage glacial stability fallowed by recession from the lower valley deposited the supraglacial melt-out till present in unit 2. On moraine 2 the supraglacial melt-out till present in unit 1 only records a stage of glacial stability and moraine building fallowed by recession from the lower valley.

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