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Mass physical, granulometric and mineralogical Characterisation of the glaciomarine sediments of the Bransfield Basin (NW Antarctic Peninsula)

Caracterización física, granulométrica y mineralógica de los sedimentos glaciomarinos de la Cuenca de Bransfield (NO de la Peninsula Antártica)

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ABSTRACT

The textural analysis of two gravity cores reveals that the sediments in the Central and Eastern Bransfield subbasins are mainly clayey silts with some coarser levels of sandy silts. While a turbidity origin can be attributed to the coarser levels, other processes should control the deposition of the fine fractions, e.g. settling of suspended particles, ice-rafting and ash airfall Chlorite, smectite and illite are the dominant clay minerals. While a detritic origin can be attributed to chlorite and illite the diagenetic alteration of volcanic glass origin is the most likely origin for smectite even though a minor detritic contribution cannot be completely enied Higher sand and smectite contents, and more abundant ash laminated facies suggest that the volcanic influence is higher in the Eastern Bransfield core than in the Central Bransfield core.

RESUMEN

Se describen las características físicas, granulométricas y mineralógicas de los sedimentos de dos testigos de gravedad procedentes de las subcuencas Oriental y Central de Bransfield. Los sedimentos están compuestos mayoritariamente por limos arcillosos laminados con algunos niveles de limos arenosos. A los niveles más groseros se les atribuye tentativamente un origen turbidítico. No obstante, la decantación pelágica, el transporte por icebergs, y las lluvias de cenizas han podido jugar un papel significativo en la acumulación de los sedimentos más finos. Los minerales mayoritarios en la fracción arcilla son la clorita, la esmectita y la illita. A la clorita y a la illita se les atribuye un origen detrítico, mientras que la alteración diagenética del vidrio volcánico es la fuente más probable para la esmectita. Los mayores contenidos de arena, cenizas, facies laminadas y esmectita en el testigo de la subcuenca Oriental de Bransfield indicarían una mayor influencia volcánica en este que en el testigo de la subcuenca Central.

Key Words: *Bransfield Basin, marine sedimentology, clay mineralogy, chlorite, smectite, illite.*

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Introduction

The Bransfield Basin is a narrow, elongated, back-arc extensional basin located between the northern tip of the Antarctic Peninsula and South Shetland Islands, between 60-63° S. It is subdivided in three subbasins (Western, Central and Eastern) which are limited by Deception and Bridgeman highs (Fig.1).

Rocks outcropping in the northern tip of the Antarctic Peninsula and South Shetland Islands can be grouped as belonging to six tectonic environments (Pallàs, 1996). (1) The basement, formed by plutonic and metamorphic rocks of Devonian and Permo-Carboniferous age; (2) the acretionary prism of metamorphic rocks cropping out in Smith and Elephant Group Islands; (3) the fore arc sedimentary units (Trinity Peninsula Group and Graywacke Shale, Myers Bluff and Byers Formations) cropping out extensively in Antarctic Peninsula and more locally in Livingston Island; (4) the magmatic arc represented by igneous (Antarctic Peninsula batholit) and volcanic rocks (Antarctic Peninsula Volcanic Group) that form most of South Shetland Islands; (5)the back arc sedimentary units (Nordenskjold Formation and Botany Bay, Gustav, Marambio and Seymour Island Groups) cropping out in the Eastern side of Antarctic Peninsula; and (6) intra-arc extensive zones represented by volcanic rocks cropping out dispersely in South Shetland Islands and more extensively in James Ross Island. In addition, more than one hundred of aligned submarine and subaerial volcanic edifices, some of them active in subrecent and present times, have been identified in the Bransfield Basin area (Canals *et al.*, 1994; Gracia *et al.*, 1996). These edifices have contributed to the supply of material to the basin, either as basalt flows or piroclastic ejecta.

Jeffers and Anderson (1991) identified and mapped five modern lithofacies and sedimentary environments in Bransfield Basin: coarse gravel found in shallow banks (<250 m), muddy sands and sandy muds characteristic of slopes, terrigenous muds with occasional sandy horizons found in bays and canyons and associated fanlike lobes, graded volcanic ash units interbedded with diatomaceous muds and oozes accumulating in basin floor.

The objective of the present work is to study the mass-physical (density, water content), textural (granulometry) and mineralogical properties of the seafloor sediments in order to determine modern the sedimentary and postsedimentary active processes in the Bransfield Basin. To this purpose, two gravity cores, GEBRA-1 and GEBRA-2 were obtained at 62°35'36"S/ 58°32'53"W and 1652 m depth in the Central Basin floor, and at 61°56'56"S/ 55°10' 21"W and 1106 m depth in the lower part of the Antarctic continental slope of the Eastern Basin respectively (Fig. 1).

Methodology

After core splitting for visual description, a known volume of sediment was collected each five cm and was analyzed for physical properties, granulometry and X-ray mineralogy.

To find density, water content and porosity, the samples were previously weighed and dried in an oven at 60°C. For grain size analysis, samples were wet sieved with a 63μm mesh and the finer fraction was analyzed with a COULTER-LS apparatus. The granulometric results were then recalculated to percentages of total sample mass. Oriented aggregates were prepared for X-ray analysis using the solution resulting from wet sieving of the coarse fraction and following the procedure described by Carbonne (1990). Two slides of each sample were prepared, the first to be analyzed under normal conditions and the second one to be analyses after ethylene glycol solvation. Analyses were performed with a XR diffractometer SIEMENS D-500 (Cu radiation source -λ=1.5418 Å, velocity of 1°20/min.).

A semiquantitative analysis based on the weighing of peak areas proposed by Biscaye (1965) was performed on all the samples considering chlorite (twice the 7 Å glycolated peak area), smectite (once the 17 Å glycolated peak area) and illite (four times the 10 Å glycolated peak area) as the only constituents of the <5μm fraction. This semi-quantitative mineralogical analysis is prosecutively used to interpret the vertical tendencies in each single core and to establish comparisons between samples of different locations in the same basin. However, it is not used to find the absolute values of mineral composition.

Results

Types of sediment: The 251 cm long core GEBRA-1 is mainly composed of laminated grayish olive clayey silt excepting the six basal cm which are formed by black, ash-rich, sandy silt (Fig.2). The 440 cm long GEBRA-2 is mainly composed of laminated dark olive and olive gray silt and clayey silt excepting a 4.5 cm thick, darker, ash-rich, sandy silt level at 302 cm depth (Fig.3). we have distinguished five different types of sediments according to the degree of lamination and grain size: sandy silt (Ss), massive silt (M), diffusely laminated silt (DL), clearly laminated silt (CL) and black, ash-rich, silt levels (B) the percentages of each type of sediment in the two cores is shown in Table 1.

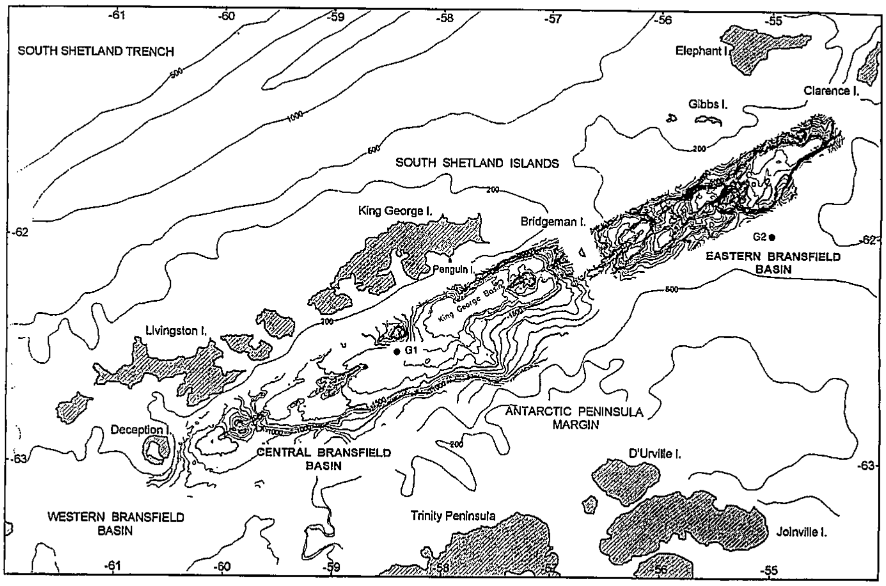

Fig.1. Bathymetric chart of the Bransfield Basin with the location of cores GEBRA-1 (G1) and GEBRA-2 (GO).

Fig. 1.- Mapa batimétrico de la cuenca de Bransfield con la situación de los testigos GEBRA-1 (G1) y GEBRA-2 (G2). Modificado de Gràcia et al.,(1996).

Physical properties:

The average Water content (dry weight basis) in GEBRA-1 and GEBRA-2 cores is 191.51% and 155.50%, respectively. The average dry density is 0.48 and 0.54 g/cm^3 respectively. Grain size analysis reveals that GEBRA-1 and GEBRA-2 are composed mainly of clayey silt, with average percentages of 71.8% and 75.2% for silt, 25.6% and 19.8% for clay and 2.5 and 5.1% for sand. There are only a few centimetric levels in which the sand content is higher, reaching 16.45% and 20.14% as maximum in GEBRA-1 and GEBRA-2,respectively. The number of coarse layers (with sand contents higher than the average) is bigger in the Eastern subbasin core, where they are more abundant in the lower and middle parts of the recovered succession. On the Central Bransfield Basin, sand levels increase towards the top of the core GEBRA-1.

The microscopical examination of <63μm particles yields two main kinds of components: ash particles and biosiliceous debris (diatom frustules and radiolarian spicules). The contents of ash particles increases significantly in the coarser levels.

Mineralogy: X-ray analysis has yield three main minerals identified as chlorite, smectite and illite. Other minor constituents are quartz and albite. The presence of kaolinite is discarded due to the imposibility to discern 3.54 Å and 3.58 Å even working at low scanning velocity.

The sequence of chlorite peaks consits of

	Ss	M	DL	CL	B
GEBRA 1	2.6%	6%	62.4%	23.6%	5.4%
GEBRA 2	1.0%	20.5%	28.0%	50.0%	0.5%

Table 1. Abundance of sediment facies types in the GEBRA-1 and GEBRA-2. Ss: sandy silt; M: massive silt; DL: diffusely laminated silt; CL: clearly laminated silt; B.: black, ash rich, silt levels.

Tabla 1. Abundancia relativa de las diferentes facies sedimentarias en los testigos GEBRA-1 y GEBRA-2. Ss: limos arenosos; M:limos masivos; DL: limos difusamente laminados;CLlimos netamente laminados; B:niveles de limos negros ricos en cenizas.

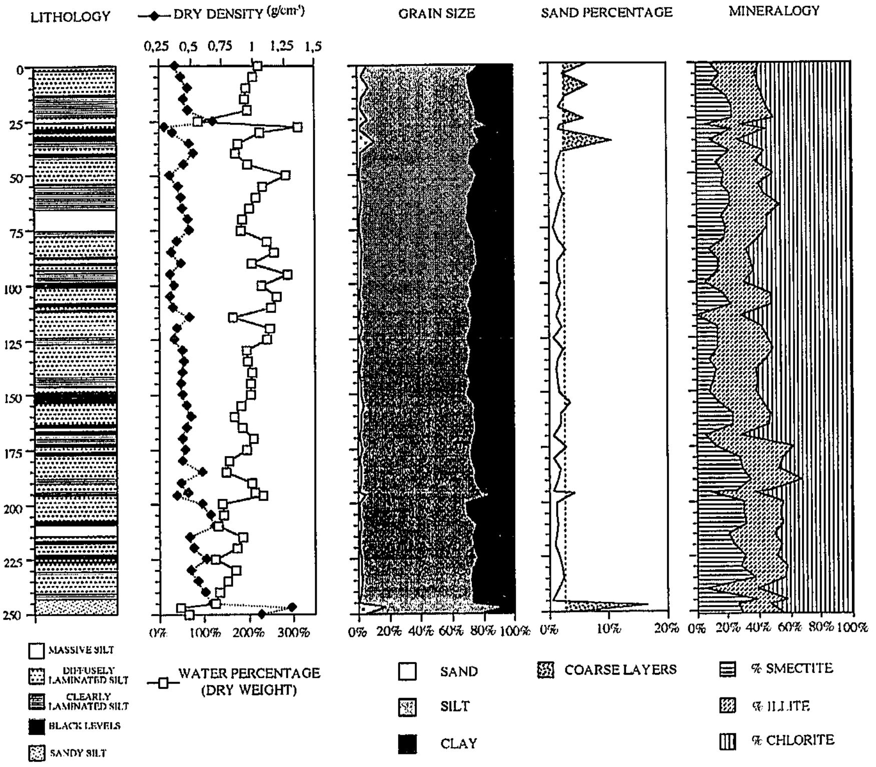

Fig.2. Logs of core GEBRA-1.

Fig. 2.- Perfiles litológicos, de densidad y contenido en agua, del tamaño de grano, del porcentaje de arena y mineralógicos del testigo.

a strong peak at 14.2 Å, a very strong one at 7.12 Å, a weak one at 4.75 Å and again a strong one at 3.54 Å. This sequence is characteristic of iron-rich chlorites (Grim, 1953).

The name of "smectite" has been applied here in a generic way to the expandable material showing a broad peak in the 12,8 Å region, in normal diffraction conditions. That peak shifts to 16.9 Å under ethylene glycol solvation and collapses to 10 Å if the samples are heated to 550°. Any sequence of higher order peaks clearly corresponding to this mineral phase has been identified. This makes really difficult to establish if that peak belongs to a true smectite with an uncommon composition or to an irregular mixed layer mineral involving smectite and illite.

In contrast, illite is easily identified by the rational sequence of peaks at 10, 5, and 3.34 Å.

The maximum, minimum and mean percentages of chlorite, smectite and illite in the sediment samples are shown in Table 2.

Chlorite is the most abundant mineral in both cores whereas smectite is approximately as abundant as illite in GEBRA-2 and less abundant in GEBRA-1 (Fig. 2 and 3). A clear downward increase in smectite content is displayed in GEBRA-1 (Fig. 2). A similar increase in GEBRA-2 is only seen on the top part of the core (Fig.3). Chlorite shows inverse tendencies with respect to smectite, with a downward decrease resulting from the relatively constant content of illite along cores

The comparison betwen the two cores reveals higher smectite contents and lower chlorite contents in the Eastern Basin than in Central Basin. The illite content is similar in both basins.

Discussion and conclusions

Part of the chlorite and illite in Bransfield Basin sediments may result from clastic transport of rock fragments containing these minerals. Such rocks probably belong either to fore-arc sedimentary units Outcropping extensively in the Trinity Peninsula, since they have chlorite and illite as main matrix minerals (Arche, 1992) or to volcanic rocks containing chlorite as an alteration product (Smellie, 1984; Accevedo, 1992; Groeneweg and Beunk, 1992). Chlorite and illite are also formed through physical weathering (mica exfoliation, feldspar sericitization, silicate chloritization) of magmatic and metamorphic rocks (Ehrmann *et al.*, 1992; Charnley, 1989), like those belonging either to the Antarctic Peninsula batholit cropping out locally in the South Shetland Islands and the Trinity Peninsula or to the accretionary prism cropping out in Smith and Elephant Group Islands (Rivano Cortes, 1976). The chlorite and illite deposited in the Bransfield Basin have been considered mainly as detrital clays resulting from relatively complex modes of formation.

The abundance of basaltic substrates in the South Shetland Islands could favour the formation of large quantities of smectite by chemical weathering. Smellie (1984), in a broad petrographic study, indicates the probable existence of smectite in volcanic rocks belonging to the Antarctic Peninsula Volcanic Group and to the Quaternary volcanic rocks of the South Shetland Islands. A second, widely accepted, way of formation of smectite is by early diagenesis in slightly buried volcaniclastic sediments. This process of smectite formation is favoured by the presence of dissolved silica supplied by biosiliceous debris (as diatom frustules) and accesorily by the volcanic glass itself (Charnley, 1989).

In the particular context of the Bransfield

	CHLORITE		SMECTITE		ILLITE	
	range	average	range	average	range	average
GEBRA-1	73.4-32.7%	55.1%	38.4-0.0%	18.8%	49.6-17.3%	26.1%
GEBRA-2	71.9-32.9%	50.2%	46.8-7.5%	25.3%	31.4-14.7%	24.3%

Table 2. Range and average mineralogical compositions of GEBRA-1 and GEBRA-2 cores.

Tabla 2. Rango y composiciones mineralógicas medias de los testigos GERBA-1 y GERBA-2.

Basin, the uncommon composition of its smectites, the abundance of ash particles, the presence of diatom frustules and the general downward increase in smectite content could seem to put in evidence a diagenetic origin for smectite. Nevertheless partial detritic origin cannot be discarded due to the inexistence of a direct correlation between the layers having higher ash contents and the smectite maximums.

Apart from the origin of clay minerals in the Bransfield sediments, its mode of sedimentation deserves also a discussion. One of the processes contributing sediments to the basin floor is the downward settling of biogenic and lithogenic particles. Pelagic settling may be one of the modes of transportation for biogenic and detritic clays, but cannot explain the presence of sand-size ash particles. Those ash particles may reach the sea bottom either through ash airfall related to the Quaternary volcanic explosive activity, or through deep- sea currents, or as ice-rafted debris. The presence of diatom frustules mixed with the ash particles in the coarse fraction of the thicker sandy silt layers implies that they may form by probably deposition of sediment transported by deep-sea currents. The origin of laminations and black levels in the sedimentary columns is still a matter of speculation.

The high number of laminas and the high sedimentation rates measured, e.g. 80 to 340 cm/Ky (De Master *et al.*, 1987; Venkatessan y Kaplan, 1987), would favour the hypothesis of turbiditic origin. However, further research needs to be done to fully confirm this point.

The apparent dissimilarities between the two cores regarding, first, the sand, the laminated facies and, second, the proportion of coarse layers, suggest that the sedimentary processes in the Eastern and Central Bransfield Basins should be somewhat different. The coarser and more laminated sediments from Eastern Basin are ash richer, which implies a higher volcanic influence on this basin. The higher smectite content in the Eastern Basin reinforces the former interpretation on the volcanic influence.

Future research is going to be focused on biogenic silica and Fe- Mn oxides content in order to investigate the origin of smectite e.g. diagenetic vs. detritic. The study of the morphoscopy of grains will help to precise the sedimentary processes governing the coarse fraction accumulation and the formation of laminas. Thermoluminiscence dating will allow to better constrain the time frame of the two cores and hence the accumulation rates. And, finally, the organic geochemistry of the sediments will be useful to know the prevailing environmental conditions on the basin floor during the time of deposition.

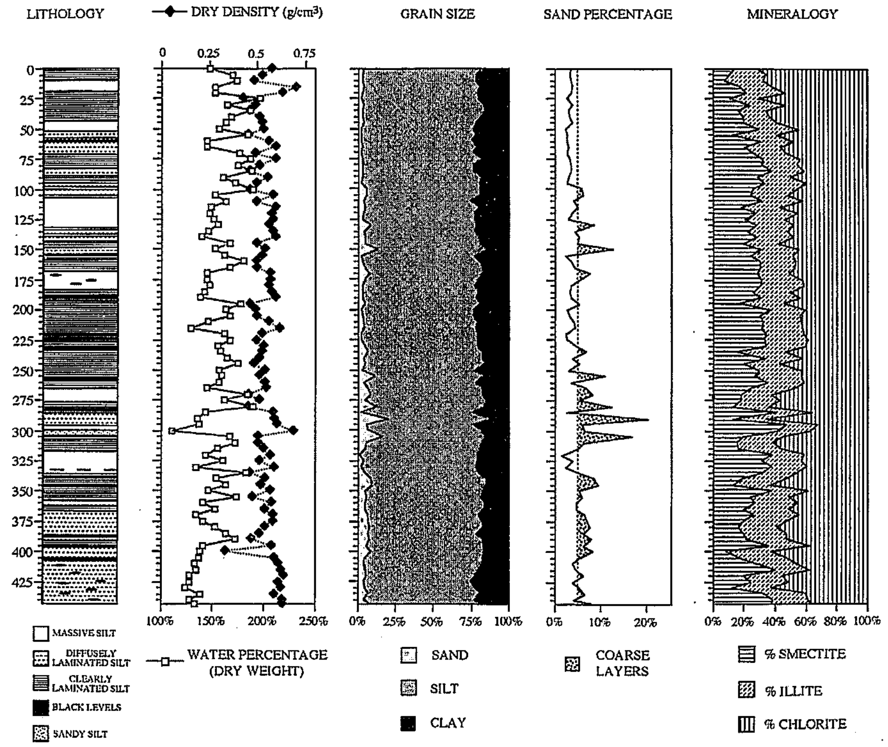

Fig. 3.- Logs of core GEBRA-2.

Fig. 3.- Perfiles litológicos, de densidad y contenido en agua, del tamaño de grano, del porcentaje de arena y mineralógicos del testigo GEBRA-2.

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