GRAVEL	ISSN 1678-5975	Dezembro - 2008	V. 6 – nº 2	15-21	Porto Alegre

Coarse-Grained Ripples Offshore Atlantic Tierra del Fuego

Isla, F.I.[1]

[1] CONICET-UNMDP, Centro de Geología de Costas y del Cuaternario, Mar del Plata (fisla@mdp.edu.ar).

RESUMEN

Las óndulas de sábulo, o mejor llamadas óndulas de grano grueso han sido reinterpretadas en relación a su formación por flujos oscilatorios de alta energía o combinados. En el este de Tierra del Fuego, a profundidades de 40 m, estas formas de fondo aparecen relacionadas a mantos de arena o campos de ondas de arena. Un *box core* extraído de esta plataforma y submuestreado cada cm hasta una profundidad de 30 cm indicó que el fondo está compuesto por sábulo y arena gruesa, y que el fango aumenta con la profundidad. Estas formas deben considerarse al momento de interpretar el transporte máximo que puede ocurrir a estas profundidades.

ABSTRACT

Granule ripples, or better called coarse grained ripples (CGR), have been reinterpreted in relation to their occurrence caused by high-energy oscillatory or combined flows. In Eastern Tierra del Fuego, at depths of 40 m, these bedforms are associated to sand sheets and sand-wave fields. A box core sampled every cm to a depth of 30 cm indicated that the bottom is covered by sabule and coarse sand, and that silt and clay increased with depth. These bedforms should be considered in order to interpret the maximum bedload transport that can occur at these depths.

Key words: granule ripples, continental shelf, Tierra del Fuego.

INTRODUCTION

Previously called dunes, megaripples or gravel waves (Forbes and Boyd, 1987), coarse grained ripples (CGR) formed under oscillatory flows in depths between 3 and 160 m in the continental shelf or lower shoreface (Leckie, 1988). They have spacings between 0.25 and 3 m and amplitudes of 3 to 35 cm, but are difficult to discern in the geological record. They are thought to be formed by waves ranging from 1-9 m wavelength and periods typical of oceanic waves (6-16 sec: Leckie, 1988).

In the present study, a field of CGR is described offshore northern Tierra del Fuego based on side-scan sonar records (Fig. 1) and grain-size analyses performed every cm along a box core.

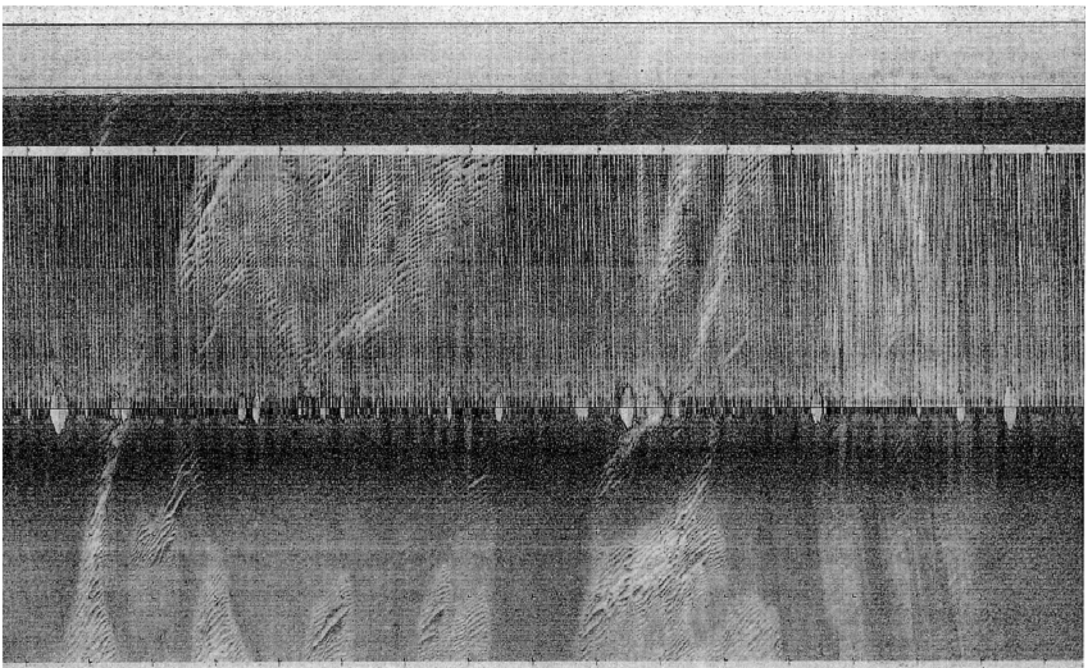

Figure 1. Sonographic record of coarse grained ripples offshore northern Tierra del Fuego.

SUBMERGED GLACIGENIC COARSE DEPOSITS

Caldenius (1932) first envisaged that glacigenic deposits may have covered the Atlantic continental shelf of northern Tierra del Fuego, although he had never recognized them directly. Guided by the knowledge of those days he proposed four major glacial advances, where only the oldest “initioglacial” reached the Atlantic continental shelf, close to the inlet of the Magellan Strait (1932).

More recently, at the Western Magellan Strait, five glacier advances were recognized; the most extended may have culminated during substages of marine isotope stage 5 (Clapperton *et al.*, 1995). Several glacial deposits were described for the Eastern Magellan Strait (Meglioli, 1992; Rabassa *et al.*, 1992; Bujalesky and Isla, 2006). Isla and Schnack (1995) mapped the northern fueguian continental shelf distinguishing two submerged morainic arcs: the modernmost and close to the coast (related to the Cabo Nombre moraines of Caldenius), and the oldermost extending some km offshore (and related to the moraines of Cabo Vírgenes). Vernengo and Zarpellón (2002) mapped the erratic boulders submerged at the inner shelf close to cabo San Sebastián (Fig. 2). Mouzo (2005c) questioned the extension of the outermost morainic arcs, corroborating the intuitive assumptions or some submarine information that lead Caldenius (1932) to propose his submerged morainic arcs. Mouzo (2005a and b) proposed a submerged glacial valley to depths of 80 m, and mapped erratic boulders up to the outer continental shelf (Mouzo, 2005c). It comes clear that it was not a true glacial valley but a lobe produced by the Estrecho de Magallanes piedmont glacier ("Magellan Lobe" as stated by Rabassa *et al.*, 2000; Bahía Posesión, Kimiri Aike and Brunswick lobes stated by Araya-Vergara, 2000). However, these erratics were not assigned to any glaciation, as Mouzo (2005) only recognized as moraines the area that had been already mapped as an erratic boulder field close to Cabo Nombre (Isla and Schnack, 1995; Vernengo and Zarpellón, 2002).

Figure 2. Erratic boulders deposited at the beach of Cabo Nombre.

REGIONAL SETTING

The climate of Tierra del Fuego is dominated by the prevailing westerly winds, with Pacific cyclones moving eastwards, not far from the Antarctic Ice Sheet (Tuhkanen, 1992). The northern fueguian shelf is dominated by strong tidal currents.

At the Atlantic coastline, mean tidal range diminishes toward the southeast: 6.6 m in San Sebastián Bay, 4.16 m in Rio Grande outer estuary. Maximum tidal currents are over 2 knots (either during the flood or ebb) at the inlet of San Sebastián Bay, and of 5 knots within the bay (spring tidal ranges reach 10.4 m). Tides induce reversal currents at the inner shelf. During neap tides, there is more assymetry between tidal currents: stronger towards the south. Higher tidal ranges cause maximum tidal currents of 75 cm/seg (Fig. 3).

Wave climate is relatively benign at the Atlantic coast due to the dominance of the strong westerly winds. Reports from the British Meteorological Office, covering a sea area from the coast to longitude 65° W and between latitudes 50° and 55° S (period 1949-1968), indicates:

(a) the frequency of wave heights higher than 3.5 m is very low;
(b) around 20% of waves were less than 1 m in height on average throughout the year;
(c) long-period waves are relatively uncommon; and wave with periods greater than 10 seconds come from the east and northeast;
(d) gales of 41-47 knots from any direction between N and ESE (with a return period of 50 years) are estimated to generate an extreme wave height of 12 m and a period of 11.5 seconds in a depth of 50 m (spring tide level);
(e) this estimated extreme wave would break in a water depth of 15 m (chart depth + tidal height above chart datum + storm surge), and would be

near the breaking point in 10 m depth even at spring high water.

A record of one year at Estancia Cullen (52°49'19" S, 68°13'52" W, 110 km north of the city of Rio Grande) gave the following results:

(a) a maximum wave height of 5.86 m has been recorded (Compagnie de Recherches et d'Etudes Oceanographiques and Geomatter 1985);
(b) maximum significant wave height was 3.43 m;
(c) average significant wave height was 1.02 m;
(d) maximum wave period recorded was 17.5 seconds;
(e) maximum significant period was 12.9 seconds;
(f) average significant period was 5.5 seconds;
(g) waves higher than 3 m corresponded to periods of 7 to 9 seconds;
(h) the longer periods were associated with wave heights of 1.25 m;
(i) the stronger swell is associated with north and northeast winds;
(j) the estimated extreme wave height would be 5.8 m for NE to E winds and 7 m for winds from the north for a return period of 50 years.

In San Sebastián Bay, extreme winds higher than 64 knots were estimated from the SW and NW (Compagnie de Recherches et d'Etudes Oceanographiques and Geomatter, 1985) for recurrence periods of 50 years. These conditions would produce maximum significant waves of 2.74 m originated within the bay.

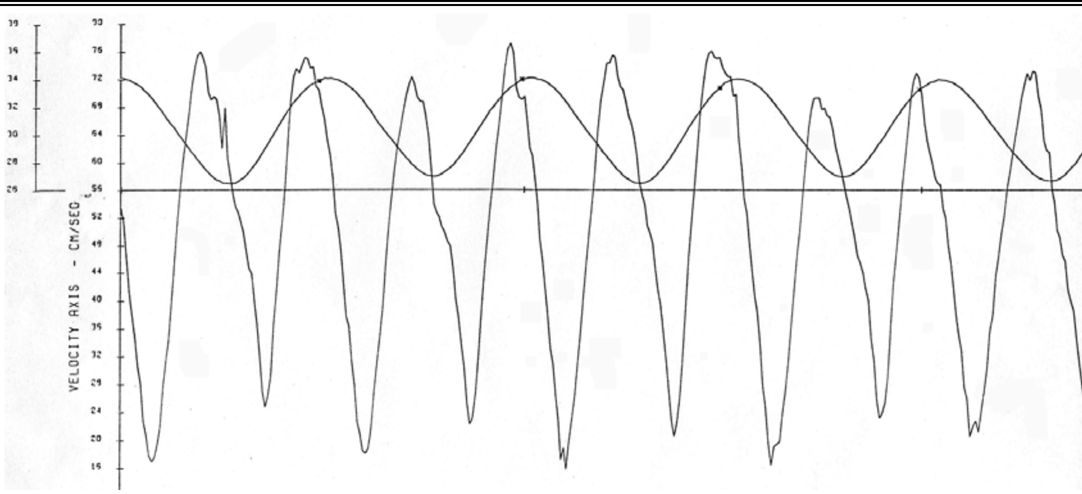

Figure 3. Tidal variations and tidal currents recorded at the Hydra Petroleum platform (provided by Geomatter).

METHODS

Seven bathymetric legs were surveyed normal to the coast in December 1986. A sea-floor mapping system (EG&G SMS 960) and a sub-bottom profiler (EG&G Uniboom 240) operated together.

Box cores and grab samples were collected; on deck, box cores were opened (Fig. 4A) and subsampled into plastic tubes (Fig. 4B). Box cores are the best sampling device to record internal sedimentary structures. At lab, tubes were opened, sampled every centimeter and sieved every 0.5 phi units.

RESULTS

The grain sizes from the sea bottom spanned from sandy gravel to clayey sand (Isla and Schnack, 1995). The longest tube (box core 1) was 0.3 m long and composed dominantly of fine gravel, granules and very coarse sand. It was collected at 40 m depth (Isla and Schnack, 1995). Rounded gravel and sabules were always between 25 and 45%; summed to very coarse sand, they were always more than 50% (Fig. 5A). Mud (silt and clay) increased to the bottom of the core; from less than 1 to 1.6% at the bottom of the core (Fig. 5B). This increase in mud is indicating that at approximately 0.20 m from the bottom there is no winnowing of fine sediments (sieved between granules), and that granule overpassing (in the sense of Isla; pivoting in the sense of Komar and Li, 1988), takes place on granule ripples.

Figure 4. A) Box core device on deck of the *El Austral* vessel. B) Subsampling the box core with plastic tubes.

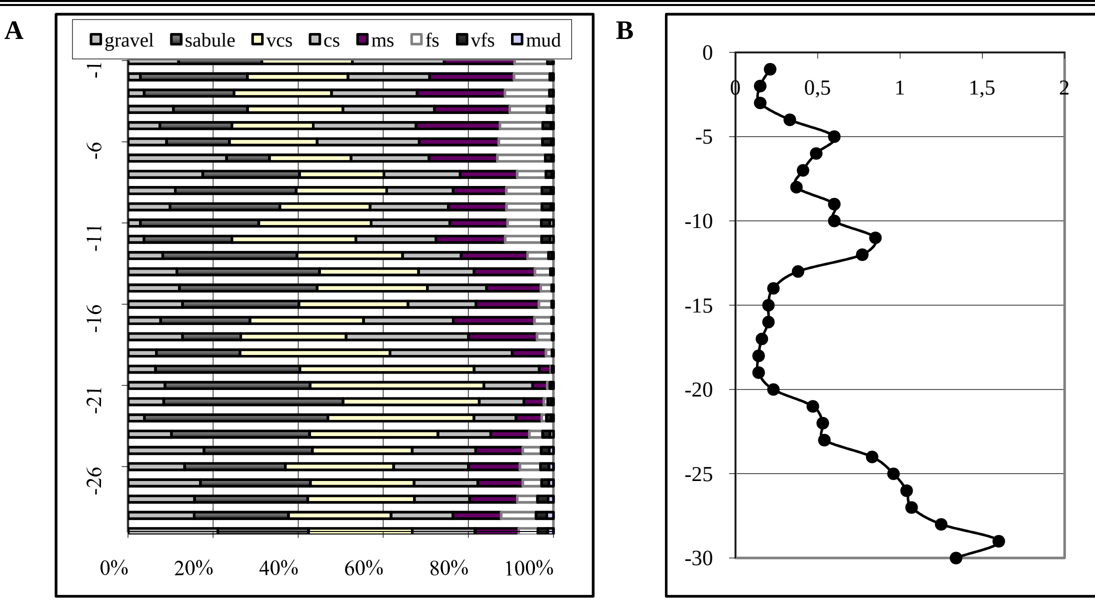

Figure 5. A) Grain-size composition along box core 1. B) Variations of the mud fraction (<62 microns), depths in cm.

DISCUSSION

Leckie (1988) stressed the lateral or vertical relations between CGR and hummocky cross stratification (HCS). While CGR occur in grain sizes between gravel and coarse sand, HCS occurs in fine to very fine sand. In plan view, CGR occur in patches or linear stripes (ribbons)

2-25 m wide dominated by fine gravel or granules. When they are associated to sand wave fields the granule stripes are 1 m below the oceanic bottom. In Nova Scotia shelf gravel patches are at depths greater than 30 m and more than 5 km distant from shore (Forbes and Boyd, 1987). In the Middle Atlantic Bight (Eastern USA inner shelf) they were assigned to the bedload transport induced by high-intensity storm events (Swift and Freeland, 1978). As they are associated to high energy events they do not move frequently; critical threshold velocity necessary to initiate their transport occur only between 0.5 and 12% of a year (Leckie, 1988). CGR are formed by oscillatory or combined flows similar to the hummocky cross stratification. They are not relict features, they moved in the upper regime and during some portion of the year (Leckie, 1988). However, minimum threshold velocities are thought to be reached in occasion of combined flows (Amos *et al.*, 1988). For the case of Tierra del Fuego, they are assigned to the combined action of waves higher than 3 m and the strong tidal currents sweeping the inner shelf.

CONCLUSIONS

1. A coarse-grained ripple field is reported offshore northern Tierra del Fuego.
2. A stratification of fine gravel, sabules and coarse-grained sand was recognized in the box core.
3. Silt and clay occur in percentages of less than 1% in the upper 0.2 m but increased to more than 1% towards the bottom of the box core (0,3 m).
4. These bedforms are particularly useful to recognize in order to interpret the maximum transport that can occur at these depths.

ACKNOWLEDGEMENTS

The crew of the *El Austral* vessel helped during the sampling cruise. Particularly, R. Zibechi conducted the side scan operations, while D. Galfon dealt with the subbottom profiler performance. A. Robbiano provided useful geological and meteorological information. Grain-size analyses were performed by S. Serra and A. López de Armentia.

REFERENCES

AMOS, C.L.; BOWEN, A.J.; HUNTLEY, D.A. and LEWIS, C.F.M. 1988. Ripple generation under the combined influences of waves and currents on the Canadian continental shelf. **Continental Shelf Research 8**, 10, 1129-1153.

ARAYA-VERGARA, J.F. 2000. Perfiles submarinos por los piedmonts del Estrecho de Magallanes y Bahía Nassau, Chile Austral. **Anales del Instituto Patagonico, Serie Ciencias Naturales 28**, 23-40.

BELDERSON, R.H.; WILSON, J.B. and HOLME, N.A. 1988. Direct observation of longitudinal furrows in gravel and their transition with sand ribbons of strongly seas. In: De BOER, P.L. (ed.). **Tide-influenced sedimentary environments and facies**. Reidel Publ. Co., 79-90.

BRAMBATI, A.; FONTOLAN, G. and SIMEONI, U. 1991. **Carta sedimentologica dello Stretto di Magellano**. Programma Nazionale di Ricerche in Antartide, Universitá degli Studi di Trieste, Trieste, 1991.

BUJALESKY, G.G. and ISLA, F.I. 2006. Depósitos Cuaternarios de la costa atlántica fueguina entre los cabos Peñas y Ewan, Argentina. **Revista de la Asociación Geológica Argentina, 61**, 1, 81-92.

CALDENIUS, C.C. 1932. Las glaciaciones cuaternarias en la Patagonia y Tierra del Fuego. **Geografiska Annaler 14**:1-164. Stockholm.

CLAPPERTON, C.H.M.; SUGDEN, D.E.; KAUFFMAN, D.S. and McCULLOCH, R.D. 1995. The Last Glaciation in Central Magellan Strait, southernmost Chile. **Quaternary Research 44**, 2, 133-148.

FORBES, D.L. and BOYD, R. 1987. Gravel ripples on the inner Scotia Shelf. **Journal of Sedimentary Petrology 57**, 46-54.

ISLA, F.I. 1992. Overpassing and armouring phenomena on gravel beaches. Marine Geology, 110, 369-376.

ISLA, F.I. and SCHNACK, E.J. 1995. Submerged moraines offshore Tierra del Fuego, Argentina. **Quater. S. America and Antarctic Pen., 9**, 205-22.

LANGHORNE, D.N. 1980. **A preliminary study of the Haisborough Sand sandwave field and its relevance to submarine**

pipelines. Report 100, Institute of Oceanographic Sciences, Taunton, Somerset, 33 pp.

LECKIE, D. 1988. Wave-formed, coarse grained ripples and their relationship to hummocky cross-stratification. **Journal Sedimentary Research 58**, 4, 607-622.

MEGLIOLI, A. 1992. **Glacial geology and chronology of Southernmost Patagonia and Tierra del Fuego, Argentina and Chile**. Ph.D. Dissertation, Lehigh University, Bethlehem, U.S.A., 216 pp. Unpublished.

MOUZO, F. 2005a. Batimetría y morfología submarina al noreste de la Tierra del Fuego. **Actas XVI Congreso Geológico Argentino**, La Plata, III, 771-778.

MOUZO, F. 2005b. Estructura somera y cubierta sedimentaria Plio-Pleistocena en la plataforma continental al noreste de la Tierra del Fuego. **Actas XVI Congreso Geológico Argentino**, La Plata, III, 779-786.

MOUZO, F. 2005c. Límites de las glaciaciones Plio-Pleistocenas en la plataforma continental al noreste de la Tierra del Fuego. **Actas XVI Congreso Geológico Argentino**, La Plata, III, 787-792.

RABASSA, J., BUJALESKY, G., MEGLIOLI, A., CORONATO, A., GORDILLO, S., ROIG, C. and SALEMME, M. 1992. The Quaternary of Tierra del Fuego, Argentina: the status of our knowledge. **Sveriges Geologiska Undersökning**, Ser. Ca 81: 241-256. Sweden.

RABASSA, J.; CORONATO, A.; BUJALESKY, G.; SALEMME, M.; ROIG, C.; MEGLIOLI, A.; HEUSSER, C.; GORDILLO, S.; ROIG, F.; BORROMEI, A. and QUATROCCHIO, M. 2000. Quaternary of Tierra del Fuego, southernmost South America: an updated review. **Quaternary International** 68-71, 217-240.

SWIFT, D.J.P. and FREELAND, G.L. 1978. Current lineations and sand waves on the inner shelf, middle Atlantic Bight of North America. **Journal Sedimentary Petrolology 48**, 1257-1266.

TUHKANEN, S. 1992. The climate of Tierra del Fuego from a vegetation geographical point of view and its ecoclimatic counterparts elsewhere. **Acta Botanica Fennica**, **145**, 1-64.

VERNENGO, L.A. and ZARPELLÓN, C.J. 2002. Tierra del Fuego-San Sebastián: Adquisición de sísmica 3D marina en agua somera. **V Congreso de Exploración y Desarrollo de Hidrocarburos**. IAPG, Mar del Plata, 12 pp en CD.