Proposal of a littoral cell on the coast of Chile, ~34-37° S

*Keller, B.[1], Martín, A.[1]

[1]ORBE Ambiental, Vitacura 2955, Las Condes, Santiago, Chile

*corresponding author: keller.barry@gmail.com

andres.martin@orbeconsultores.com

Abstract

A littoral cell is potentially recognized along the Chilean margin, extending between the Biobío and Maipo rivers. This identification is based on published information, without additional oceanographic investigations. Northward sediment transport is driven by oceanic swell from the southwest and confined by submarine canyons that act as sediment sinks. Major Andean rivers supply most of the sand, inferred by others from composition and color. The proposed model highlights a long, tectonically stable littoral system sustaining coastal morphology and surf dynamics, analogous to Californian littoral cells. The south to north extent of the proposed cell, approximately 390 km, is relatively long compared to littoral cells at similar north latitudes in California and elsewhere.

Keywords: littoral cell, sediment transport, Chilean margin, coastal geomorphology, Andean rivers

Una posible celda litoral en las costas de Chile, ~34-37° S. En esta contribución se identifica una celda litoral a lo largo del margen chileno que se extiende entre los ríos Biobío y Maipo. Este reconocimiento se basa en información publicada, sin investigaciones oceanográficas adicionales. El transporte de sedimentos hacia el norte se encuentra controlado por el oleaje desde el suroeste y limitado por cañones submarinos que actúan como sumideros de sedimentos. Los principales ríos andinos aportan la mayor parte de la arena, la que se infiere por medio de su composición y color.

El modelo propuesto destaca un sistema litoral extenso y tectónicamente estable que sostiene la morfología costera y la dinámica del oleaje, análogo a las celdas litorales californianas. Su extensión de sur a norte es de unos 390 km, relativamente larga comparada con celdas litorales en California y otras zonas del mundo.

Palabras clave: celda litoral, transporte de sedimentos, margen chileno, geomorfología costera, ríos andinos

1. Introduction

As a geology professor, Francisco “Pancho” Hervé has guided many groups of students to the coast of Chile at the latitudes 34-37° S, including trips to show and evaluate outcrops of metamorphic and oceanic rocks exposed at the beaches of Pichilemu (~34.5° S) and Tanumé (~34.2° S) (Fig. 1; see Palape et al., 2014). The direction of the normal oceanic swell in this area means that waves consistently come from the southwest. Here we describe a littoral transport system of unconsolidated sediment, with transport from south to north, carried by littoral currents that are driven by the energy of breaking waves. As such, the sand bottom offshore of the coast, and the beaches themselves, receive sediment not only from the local coast, but from more distant geologic sources.

2. Concept of littoral cell

In coastal sedimentary transport systems, the balance of sediment may be defined as the equilibrium between sediment stored in the system and the sum of the volumes of sediment that enter and leave the system. The reach of coast that includes Tanumé and Pichilemu is an open coast with littoral transport of sand-sized sediment carried from the south by currents forced by breaking waves.

A littoral cell is an internationally accepted oceanographic model of a geographic compartment of coastal sediment transport and storage. It provides a useful framework to consider the impact of human activities that might change sources and transport of sediment. As described by Komar (1998; see figure 2), a littoral cell occupies a section or reach of the coast in which unconsolidated sediment (sand and gravel) is transported, largely isolated from adjacent littoral cells. Within a cell, sediment can enter from local erosion and transport from rivers, and can leave via aeolian transport, human activity, or loss to deeper water via submarine canyons. In the north Pacific Ocean, a regime of littoral cells on the coast of California is well defined (e.g., Patsch and Griggs, 2006). Longshore dimensions of these California littoral cells are typically one to tens or hundreds of kilometers, controlled by the locations of additions and losses of sediment. The impetus for the present study was an environmental review of a proposed coastal development project near 34° S, in which there was concern that the project might impact surfing waves, which break over the offshore sand bottom that is maintained by the littoral transport regime. Finding no documentation of an interpretation of littoral cells in this area, the present study was performed as part of the review, but additional oceanographic investigation was not possible.

3. Methods and data sources

The primary methodological approach of this study is based on extensive fieldwork conducted over several years, which forms the foundation for many of the observations presented in the Results section. This study was performed using publicly available data sources. These include the nautical chart SHOA N°5000 (Bahía de Valparaíso-Golfo de Arauco), which contains bathymetric features of the offshore area along with other bathymetric charts, the 1:1,000,000-scale Geological Map of Chile (Sernageomin, 2002), and images from Google Earth obtained in 2025. The Google Earth imagery cites as sources: SIO (Scripps Institute of Oceanography), NOAA (National Oceanographic and Atmospheric Administration), U.S. Navy, NGA (National Geospatial-Intelligence Agency), and GEBCO (General Bathymetric Chart of the Oceans). From these publicly available sources, and without additional oceanographic investigations, a possible littoral cell configuration is proposed. Among the Google Earth sources, a GEBCO bathymetric image was particularly helpful in identifying submarine canyons.

4. Results

Ayala Vergara (1983) observed that the swell direction for the coast of Chile near 34° S is from the southwest, so the expected littoral transport caused by the energy of breaking waves would be from south to north, which is in accordance with visual observations. To evaluate the possible configuration of a littoral cell in this area, bathymetric and geographic features were examined to find any similarities to those that limit littoral cells of the coast of California in the northern Pacific. The extent and features of the suggested littoral cell are shown in figure 3.

Based on the observed sediment transportation direction, the southern end of the cell is located north of Punta Lavapié (37°14′ S), a prominent coastal feature forming the south end of the Golfo de Arauco that reaches some 33 km into the ocean. Off the coast is an island and, just to the north, a submarine canyon that appears to possibly be a paleochannel of the Biobío River, which reaches the coast at Concepción (36°46' S). Any sediment transported from further south (e.g., from an adjacent littoral cell) would presumably be diverted to deeper water via the submarine canyon, which may be maintained by modern oceanographic processes.

The northern end of the proposed littoral cell is at a submarine canyon off the coast at San Antonio (33°37' S), possibly a paleochannel of the Maipo River. At this canyon, the transported sediment is inferred to be diverted seaward into deeper water.

Significant features of the proposed cell, including sediment transport credits and debits, are listed in Table 1.

Table 1. Important features of the littoral cell.

Feature	Sediment transport type	Latitude (° S)	Distance from southern boundary (km)	Canyon distance from shore (km)	Canyon head depth (m)	Estimated sediment flux
Biobío River, Canyon	Credit, debit	36.8	0	0	~0	Significant
Itata River	Credit	36.4	54	-	-	Minor
Maule River	Credit	35.3	170	-	-	Significant
Mataquito River	Credit	35.1	216	-	-	Minor
Offshore submarine canyons	Potential debit	~34.6	240	~15	~500	Interpreted not to be debits
Rapel River	Credit	33.9	346	-	-	Minor

Maipo River, Canyon	Debit	33.6	390	0	~0	Significant debit for this cell. Credit to cell to north?

The input sources of sediment to the littoral cell ("credits" in the terminology of Komar, 1998; see figure 2) include rivers that drain the high Andes, and those that drain the Coast Range, and local erosion at the coast. It is inferred, partly due to the consistently gray color of the sand as observed by the authors and noted by Tala (2024), that the characteristic volcanic rocks of the Andes are the dominant source of sediment to the littoral cell. Compared to the Coast Range, the Andes has a higher level of precipitation and glaciers that generate sediment. The annual precipitation of the river drainages within the Andes is in the range 1,000 to 5,000 mm/year, while in the Coast Range it is in the range 500-1,200 mm/year (DGA, 1987). Within the interpreted extent of the littoral cell, from south to north, rivers from the Andes are the Biobío, Itata, Maule, Mataquito, Rapel, and Maipo. The interpretation of an Andean origin for most of the sediment is supported by the study of Tala (2024) of sand at Pelluhue (35.8° S), between the Itata and Maule rivers, who concluded that "the sands of Pelluhue are composed principally of lithic fragments of andesitic and dacitic volcanic rocks", presumably representing Andean sources but not associated with specific areas or formations. When they compared the chemical composition (using a portable XRF analyzer) of the Pelluhue sands with those of Pichilemu, they found them to be virtually identical, which supports the idea of a uniform sand source within the littoral cell.

As mentioned, the southern and northern limits of the suggested littoral cell are submarine canyons. The south-north extent of the cell is approximately 390 km, notably larger than most California cells (typically 10-100 km; Patsch and Griggs, 2006), but comparable to major systems worldwide. For comparison:

- Santa Barbara cell (California): ~100 km.
- Silver Strand cell (California): ~25 km.
- Southeast Australian littoral cells: 50-200 km.
- Portuguese coastal cells: 30-150 km.

Other submarine canyons were identified offshore of the Maule and Mataquito rivers, but these are located farther offshore (5-10 km) and at greater depth, approximately 100 m or more, beyond the typical depth and extent of littoral sediment transport and thus are not considered to be sediment exit routes for the suggested littoral cell (“debits” in the in the terminology of Komar, 1998; see figure 2).

5. Future research

Identification of littoral cells on the coast of Chile may be relevant in the context of sediment budgets in central Chile. In recent decades, several beaches along the central coast of Chile have exhibited a measurable reduction in sediment volume, often manifested as persistent sand loss, although spatial and temporal variability remains significant (Martínez et al., 2022). This phenomenon of coastal erosion has become increasingly relevant within the context of climate variability and anthropogenic pressures on coastal systems. A comprehensive understanding of the hydrodynamic processes governing nearshore current systems is essential, as these play a key role in modulating sediment transport, deposition, and erosion. Moreover, the sustained decline in regional precipitation patterns and the associated decrease in terrigenous-clastic sediment input from river systems could have exacerbated the sediment deficit along the shoreline. These interacting marine and fluvial processes highlight the need for integrated, process-based research to better assess sediment budgets and the long-term morphodynamic evolution of sandy coasts in central Chile.

6. Concluding remarks

This study applies the concept of a littoral cell, as developed for the coast of California, to a section of the coast of Chile at similar latitude south as the California cases are north. Based on inputs (credits) and outputs (debits) of sediment identified in published information, a suggested littoral cell with northward transport of sediment is proposed, extending from Biobío River in the south to Maipo River in the north, with ultimate transport of sediment to deeper water via a submarine canyon located offshore of San Antonio. With a coastal extent of approximately 390 km, this is relatively long compared to littoral cells in California and elsewhere. In view of the long-term tectonic stability of this subduction-related coast, a similar coastal sediment transport mechanism may have been active for millions of years, although the configuration of the coast and orientation with respect to the oceanic trench may have varied considerably (Hervé et al., 2000). Future studies of this regime could concentrate on aspects of the sediment itself and of the bathymetric configuration. The sediment could be studied from the point of view of detailed grain type evaluation, a relatively low-cost effort that could be performed by graduate students. Detailed studies of the bathymetry would probably require studies at sea, perhaps including multi-beam sonar, that would be relatively costly and require an established oceanographic investigator.

Acknowledgements

Albatros Oceanografía y Ambiente, an environmental consulting company, helped with understanding of the wave climate of the coast of central Chile. Camilo Palape and an anonymous reviewer helped revise this manuscript.

References

Araya Vergara, J. F. 1983. Influencias morfogenéticas de los desalineamientos y líneas de costa contrapuestas en el litoral de Chile central. Investigaciones Geográficas: Una Mirada Desde El Sur, 30: 3-23.

DGA. 1987. Balance Hídrico de Chile. Ministerio de Obras Públicas.

Hervé, F., Demant, A., Ramos, V., Pankhurst, R.J. & Suárez, M. (2000). The Southern Andes. In Cordani, U.G., Milani, E.J., Thomas Felho, A. & Campos, D.A. (eds) Tectonic Evolution of South America. 31st International Geological Congress, In-Folio Produção Editorial, Gráfica e Programação Visual, Rio de Janeiro, Brazil, 605-634.

Komar, P. 1998. Beach Processes and Sedimentation. Second Edition. Prentice Hall. 544 pp.

Martínez, C., Grez, P.W., Martin, R.A., Acuña, C.E, Torres, I, Contreras-López, M. 2022. Coastal erosion in sandy beaches along a tectonically active coast: The Chile study case. Progress in Physical Geography, 46(2): 250-271.

Palape, C., Hervé F., Heredia N., Martín-González, F. 2014. Deformation of the Paleozoic metamorphic basement in Tanumé-Pichilemu (34°30’ S), Coastal Range, Central Chile. AGU Poster.

Patsch, K., Griggs, G. 2006. Littoral cells, sand budgets, and beaches: understanding California’s shoreline. Institute of Marine Sciences. University of California, Santa Cruz. California Department of Boating and Waterways. California Coastal Sediment Management WorkGroup.

Sernageomin. 2002. Mapa Geológico de Chile. Escala 1:1.000.000.

Tala, F. 2024.Caracterización de las Arenas Negras en la Playa Mariscadero, Pelluhe, Región de Maule. Memoria para Título de Geólogo. Universidad de Desarrollo.

Fig. 1. Prof. Hervé examining the Paleozoic metamorphic rocks at Tanumé, while standing on beach sand that is interpreted to be part of the littoral transport regime.

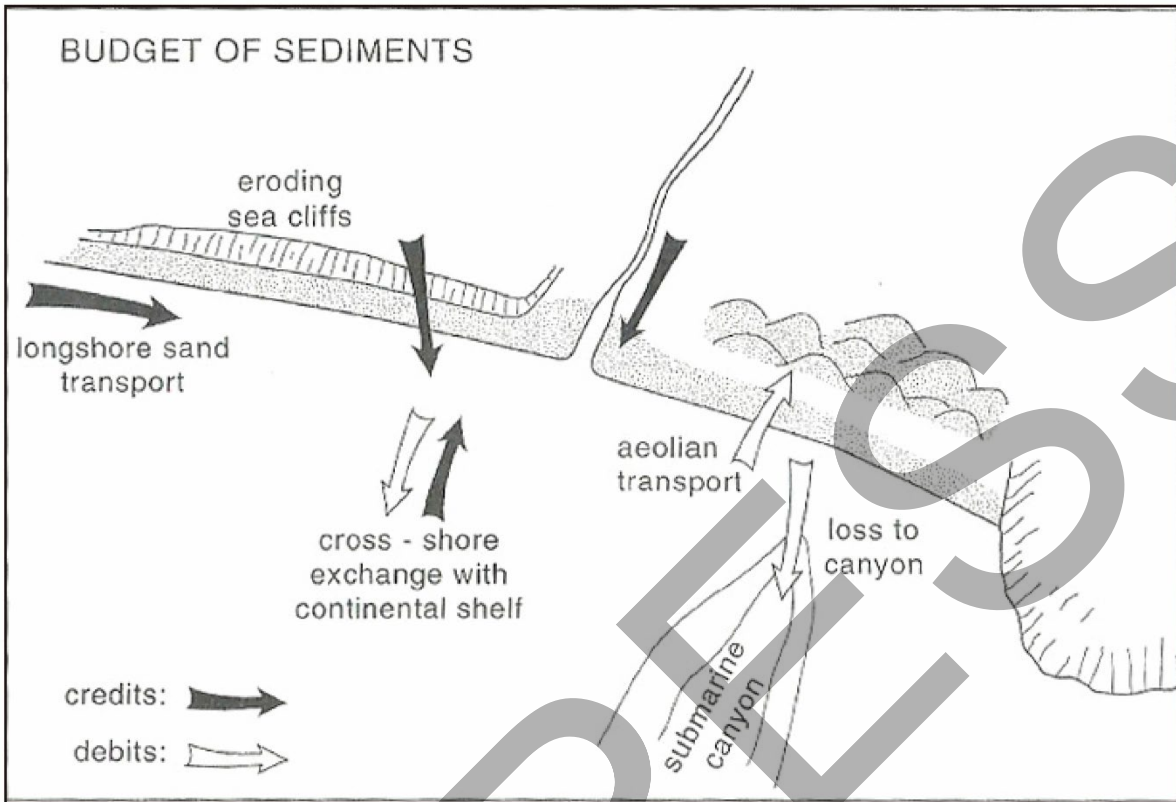

Figure 3

Fig. 2. Schematic diagram of the concept of a littoral cell and its main components. After Komar (1998). No higher resolution available.

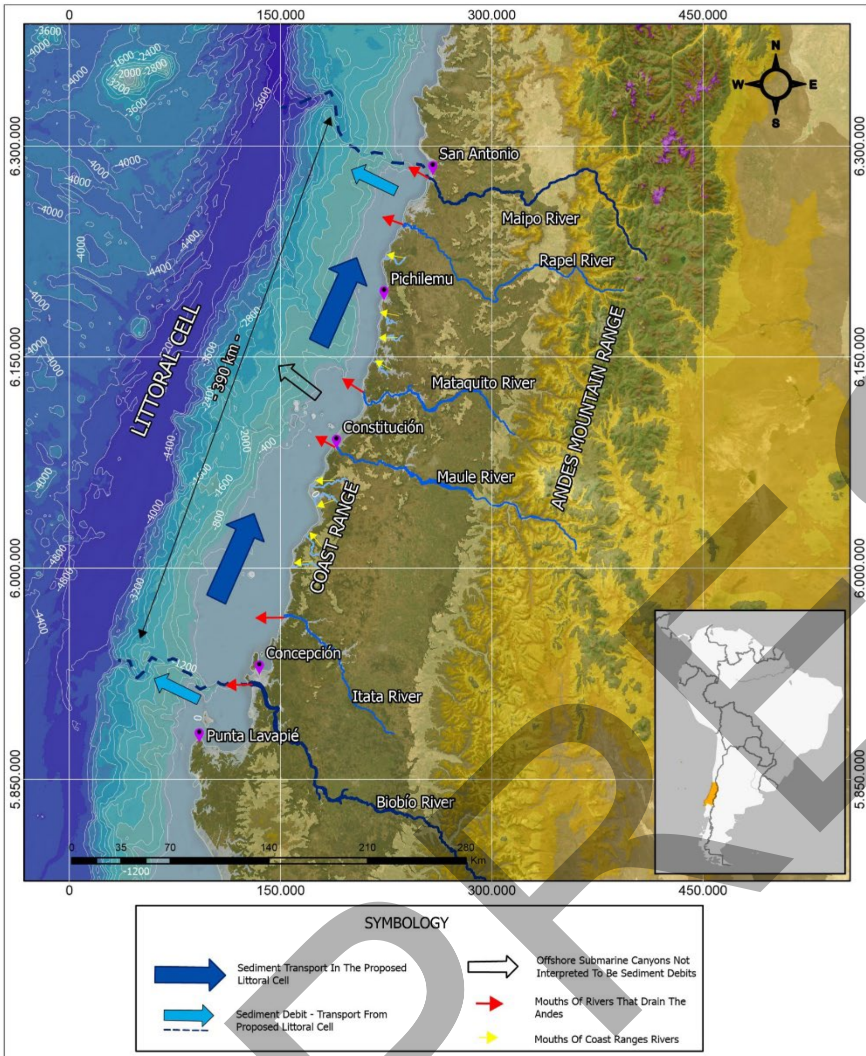

Fig. 3. Identified littoral cell of longshore sand transport between 34-37° S. Large, dark blue arrows indicate the direction of sand transport. Input "credits" of sediment include discharge from rivers draining the Andes (red arrows, blue river courses) and those draining the Coast Range (yellow arrows), as well as local coastal erosion. The main outflow "debit" (light blue arrow) is a submarine canyon offshore from San Antonio (at the mouth of the Maipo River). The southern end of the littoral cell is marked by a submarine canyon offshore from Concepción (light blue arrow at the mouth of the Biobío River). Additional submarine canyons (blank arrows) occur offshore from the Mataquito and Maule rivers, but these are located farther offshore and are not interpreted to function as debits for the littoral cell. Source: GEBCO Raster Image, 2025; bathymetric curves plotted by authors. Projection UTM 19S.