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Harmonising and mapping Patagonian Shelf seabed sediment data

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Abstract. Maps of seabed sediment distribution on global continental shelves are useful for a wide range of applications, including for habitat mapping, predicting sedimentary carbon stocks, and providing insight into past and present oceanographic conditions and the processes influencing sediment transport and deposition. Whilst some continental shelves have relatively well mapped seabed sediments, others lack publicly available, harmonised datasets. The Patagonian Shelf, also known as the Argentine Shelf, is one of the world's largest continental shelves, but there is currently no database that has compiled publicly available seabed sediment data. In this paper we collate and harmonise existing published and open-access seabed grain size data for the Patagonian Shelf. The paper combines both quantitative and qualitative data from published and grey literature and translates these data into two modified Folk sediment classification schemes. Ordinary Kriging is used to map the spatial distribution of different sediment classes across the shelf and allows us to assess uncertainty in the predictions of seabed sediment type. Overall, our sediment maps agree well with previously published maps over the central and northern shelf. Key differences are the classification of shell-rich sediments, and the spatial distribution of coarse sediments, particularly over the southern shelf. The latter would be further resolved with greater sampling of seabed sediments in the region. The data products produced for this study are grain size point data for the shelf and interpolated Geographic Information System (GIS) layers of seabed sediments and associated prediction errors. These are freely available for download via Zenodo (Roseby et al., 2026; https://doi.org/10.5281/zenodo.19111158).

1. Introduction

Maps of seabed sediment distribution on global continental shelves are useful for a variety of purposes. For example, an understanding of surficial sediment type is important for habitat mapping (Robinson et al., 2011), predicting sedimentary carbon stocks (Diesing et al., 2021, 2024; Smeaton et al., 2021) and can provide insights into past and present

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oceanographic conditions and the processes influencing sediment transport and deposition (Ward et al., 2025). Whilst some continental shelves have relatively well mapped seabed sediments, amongst them the Northwest European Shelf (e.g. Kaskela et al., 2019), others lack publicly available, harmonised datasets.

The Patagonian Shelf, also known as the Argentine Shelf, is one of the world's largest continental shelves, covering 9.6 million km^2 (Violante et al., 2014; Fig.1). Extensive research on sediment distribution on the shelf has been conducted over the 20th and 21st Centuries. In the late 1950's and early 1960's the Lamont-Doherty Earth Observatory recovered ~170 piston cores from the shelf via the research vessel *Vema*, providing insight into the shelf lithology (Fray and Ewing, 1963; Guilderson et al., 2000). Other work has published detailed seabed sediment maps for specific sub-regions of the shelf (Parker et al., 1982; Mouzo and Paterlini, 2017) or provided an overview of sediment type for the entire shelf (Parker et al., 1996, 1997; Violante et al., 2014). Publicly available point observations of surficial sediments and grain size data originate from several additional studies (Boosman, 1973; Richards and Dzwilewski, 1974; Roux and Bremex, 1996; Fernandez, 2006; Bernasconi and Cusminsky, 2009; Lantzsch et al., 2014; Moreira et al., 2016; Tuduri et al., 2018; Ronda et al., 2019; Oliva et al., 2020; Doldan et al., 2021; Chaparro et al., 2022; Desiage et al., 2023).

Despite this broad understanding of the large-scale distribution of sediments on the Patagonian Shelf (e.g. Violante et al., 2014), and availability of detailed regional case studies, there is currently no open database that has compiled publicly available seabed sediment data from across the shelf. Furthermore, existing maps do not appear in a format which can be easily incorporated into Geographic Information System (GIS) software. This paper outlines the steps taken to collate and harmonise existing open-access seabed grain size data for the shelf. These steps include the collation of both quantitative and qualitative sediment data from published and grey literature, and the translation of these data into two modified Folk schemes (Folk, 1954; Kaskela et al., 2019; Smeaton et al., 2021). The data products produced for this study are grain size point data for the shelf and interpolated Geographic Information System (GIS) layers of seabed sediments and associated prediction errors.

2. Regional Setting

The Patagonian Shelf is ~2,400 km long and oriented approximately north-east to south-west. It has an average width of 400 km, varying between 170 and 850 km (Fig. 1a; Violante et al., 2014 and references therein). With water depths typically less than 150 m (average depth is 115 m), much of the continental shelf was exposed during Pleistocene sea-level lowstands (Guilderson et al., 2000; Violante and Parker, 2004). Past cycles of shelf exposure and flooding have greatly influenced the shelf lithology and bathymetry. The Patagonian Shelf is generally smooth but features four terraces, oriented north

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north-east to south south-west, separated by high-gradient steps (Groeber, 1948; Parker et al., 1997; Violante et al., 2014). These terraces may be associated with interruptions in sea-level rise during past marine transgressions, that led to cliff-like erosional features to form at the palaeo-shoreline (Perillo et al., 2005; Violante, 2005; Ponce et al., 2011).

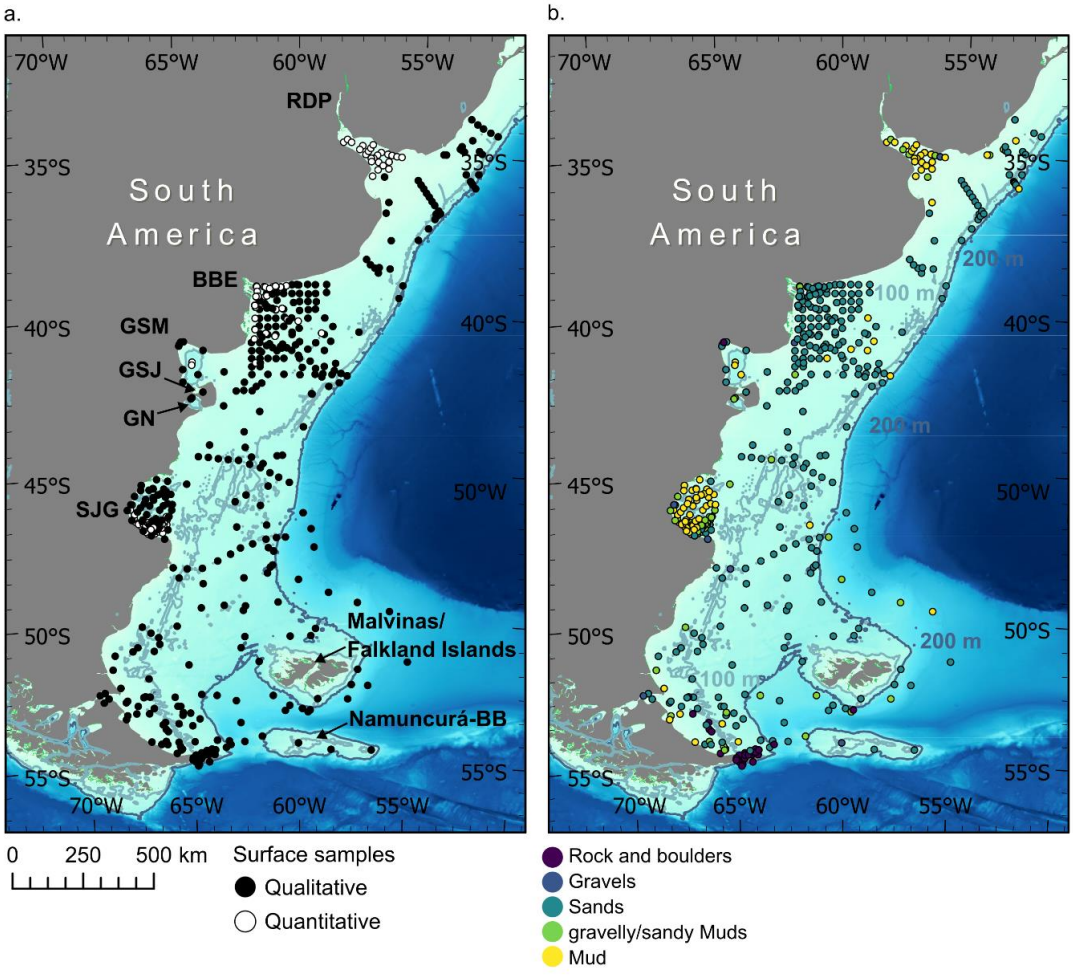

Figure 1: Map of the Patagonian Shelf with graduated colour and contours indicating shelf bathymetry. Bathymetry is from GEBCO Compilation Group (2024). Compiled sediment samples are shown, with colour indicating (a) whether the sediment data at that site are quantitative or qualitative and (b) seabed sediment type based on a five class modified Folk scheme (Folk-5; Fig. 2). Locations noted in the text are indicated: Río de la Plata estuary (RDP), Bahia Blanca Estuary (BBE), Golfo San Matías (GSM), Golfo San José (GSJ), Golfo Neuvo (GN) San Jorge Gulf (SJG), and Namuncurá-Burdwood Bank (Namuncurá-BB).

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Dominant sources of sediment to the shelf are the Andean region and the Brazilian Shield (Depetris and Griffin, 1968; Potter, 1994; de Mahiques et al., 2008; Violante et al., 2014), introduced through coastal erosion, and fluvial and aeolian transport (Violante et al., 2014). Sediments are predominantly terrigenous, eroded from the land, and composed of silicate minerals. The shelf seabed is dominated by sands (fine to medium grained quartz), with accumulations of mud within sheltered coastal regions including within Río de la Plata estuary, the Bahia Blanca estuary, Golfo San Matías, Golfo San José, Golfo Neuvo, Golfo San Jorge and the inner Patagonian Shelf south of Golfo San Jorge (Fray and Ewing, 1963; Parker et al., 1997; Violante et al., 2014). The extensive sand cover represents relict transgressive littoral barrier systems, formed during sea-level rise following the Last Glacial Maximum (26-21 ka BP; Violante and Parker, 2004; Clark et al., 2009). Gravels are found in patches, predominantly located along the southern Patagonian Shelf, with areas of shell hash towards the northern extent, seawards of Rio de la Plata (Violante et al., 2014).

3. Methods

3.1 Data compilation and classification

This study compiles archival surface sediment grain size data (both quantitative and qualitative) for the Patagonian Shelf from published literature, PhD theses and core repositories. Qualitative data are based on surface sediment descriptions, from a combination of grab, dredge and trawl samples, and the upper units of cores. Quantitative data are primarily based on sediment sieving and/or laser particle analysis. For this study, quantitative grain size data are reported as percentage gravel (> 2mm), sand (2-0.063 mm) and mud (<0.063 mm) based on the Folk classification scheme (Folk, 1954).

Kaskela et al. (2019) described the compilation and harmonisation of seabed sediment data for European seas. They utilised a modified Folk scheme to classify sediments, with three granularities of 16, 7 and 5 classes (Folk, 1954; Kaskela et al., 2019). We utilised a similar scheme here, altering the five-class division so that sediments with a high mud content (>90%) were in an isolated category (Fig. 2; Williams et al., 2019). Mud-rich sediments can act as a major sink for nutrients (including organic carbon) and pollutants (Palanques et al., 1990; Liu et al., 2011; de Mahiques et al., 2015; Atwood et al., 2020; Diesing et al., 2021; Smeaton et al., 2021). Furthermore, they form unique habitats with distinct benthic communities (e.g. JNCC, 2022). We therefore saw value in isolating this grain size category from sediments with a higher sand and gravel content (Fig. 2). We opted to exclude a 16-class scheme from the final dataset, based on the large qualitative component and uncertainty around translating sediment descriptions to such a fine granularity. Quantitative data was classified into a seven (Folk-7) or five (Folk-5) class scheme based on the percentage of gravel, sand and mud, whilst qualitative descriptions were translated using expert judgement (Fig. 2). The classification of qualitative descriptions was carried out by two independent researchers to improve reliability and validity of the categorisation process – any differences

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in classification were discussed and resolved through consensus. In addition to the grain size categories shown in the Folk triangle, both the Folk-7 and Folk-5 schemes include a rock and boulders category (Fig. 2).

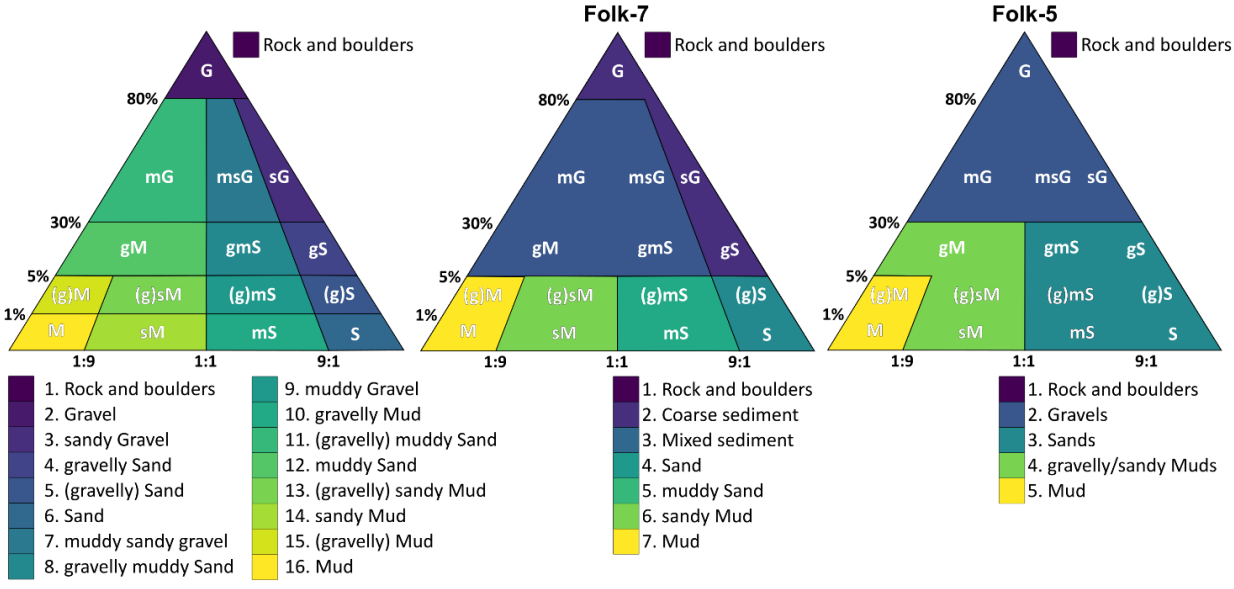

Figure 2: The Folk sediment triangle (left; Folk, 1954) and derived seven (Folk-7) and five class schemes (Folk-5; middle and right, respectively) used in this study.

3.2. Seabed sediment data interpolation

Following Smeaton and Austin (2019) and Smeaton et al. (2021), sediment descriptions were assigned a numerical value, following the seven and five class schemes outlined in Figure 2. Data points were interpolated in ArcGIS Pro 3.0.1, with the Exploratory Interpolation tool used to assess the performance of different interpolation techniques. For both the Folk-5 and Folk-7 datasets, we assessed the accuracy of Universal Kriging (Optimised), Ordinary Kriging (Optimised), Simple Kriging (Optimised) and Empirical Bayesian Kriging (Default). The statistical parameters considered were Mean Error, Root-Mean-Square-Error (RMSE) and the coefficient of determination (R^2), between the observed and predicted values (e.g. Boumpoulis et al., 2023). A model that produces good predictions should have a small RMSE, which considers the difference between the observed and predicted values, and a Mean Error close to 0, which demonstrates a lack of bias in the prediction (Boumpoulis et al., 2023). A high R^2 value indicates a good correlation between observed and predicted values.

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We defined a limit of the interpolated area between the coastline, and the 500 m shelf contour (Fig. 1a; GEBCO Compilation Group, 2024) and included coastal and inshore environments such as gulfs and estuaries. Whilst the shelf is typically shallower than 200 m, by extending the depth of interpolation to 500 m we incorporate Namuncurá-Burdwood Bank (Fig. 1a). This created a shelf area for analysis of 1.21 million km^2.

The reclassify function in ArcGIS was used to 'bin' the interpolated surface, as the interpolation tool allowed for prediction across the 1-7 range when using the Folk-7 scheme, and the 1-5 range when using the Folk-5 scheme (Fig. 2). For example, when using the Folk-7 scheme, a pixel with a predicted value of 3.7 was binned into the 3.5-4.5 (Sand) category. The raster to polygon function was used to convert the reclassified raster layer into a vector format, so that the area of coverage per sediment type could be calculated. To calculate areal measurements in ArcGIS Pro, an Albers equal area conic projection for South America was used following Esri (2025). To assess uncertainty, a standard error of prediction surface was output from the interpolation tool.

4. Results

A total of 486 surface samples were collated (Table 1), 380 (78%) of which were qualitative, and 106 (22%) of which were quantitative (Fig. 1). The mean distance between points (nearest neighbour) is 23 km, with a maximum distance of 163 km. These data mostly come from published literature, PhD theses and from core logs provided by various core/data repositories, including Lamont-Doherty Earth Observatory, Byrd Polar and Climate Research Center and the Antarctic Core Collection at the Oregon State University Marine and Geology Repository. We found seven surface samples that we categorised as shell hash, which were not assigned a Folk code. Most shelly sediments are sands with shell fragments and are therefore categorised as 'Sand' or '(gravelly) Sand' following Smeaton et al. (2021).

The Exploratory Interpolation tool in ArcGIS Pro was used to assess the performance of different interpolation techniques. When considering the outlined statistical parameters across all techniques, we find that Ordinary Kriging (Optimised) demonstrates a relatively low Root Mean Squared Error (RMSE), a Mean Error that indicates a lack of bias and satisfactory R^2 for both the Folk-5 and Folk-7 datasets (Table 2). We therefore use Ordinary Kriging to produce the interpolated sediment maps for this study (Fig. 3 and 4). The cell size of the output raster is 25 km^2.

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Table 1: Data sources for Patagonian Shelf seabed sediment study. Laser Particle Size Analyser (LPSA), Grain Size Analysis (GSA).

Author/Repository	Sampling method	GSA method	No. samples
Bernasconi and Cusminsky (2009)	Piston Core	Description	2
Boosman (1973)	Grab	Description	91
Desiage et al. (2023)	Piston Core	Description	4
Doldan et al. (2021)	Observation	Description	8
Fernandez (2006)	Tube corers, spring corers, dredges, and trawls	Sieving	46
Fernandez (2006), Chaparro et al. (2022)	Tube corers, spring corers, dredges, and trawls	Sieving	39
Lantzsch et al. (2014)	Vibro Core	Description	10
Moreira et al. (2016), Tuduri et al. (2018)	Grab	LPSA	24
Oliva et al. (2020)	Grab	NA	27
Richards and Dzwilewski (1974)	Gravity core	ASTM D422-63	2
Ronda et al. (2019)	Dredge	LPSA	7
Roux and Bremec (1996)	NA	Description	27
Repository: Lamont-Doherty Earth Observatory	Piston core, grab, trawl	Description	167
Repository: Byrd Polar and Climate Research Center	Trawl, dredge, grab	Description	25
Repository: Antarctic Core Collection	Piston core, grab, dredge	Description	7
			Total = 486

Table 2: Performance statistics of different interpolation techniques for the Folk-5 and Folk-7 datasets. For both the Folk-5 and Folk-7 datasets, we assessed the accuracy of Universal Kriging (Optimised), Ordinary Kriging (Optimised, used here), Simple Kriging (Optimised) and Empirical Bayesian (EB) Kriging (Default).

	Folk-5				Folk-7			
	Universal	**Ordinary**	Simple	EB	Universal	**Ordinary**	Simple	EB
RMSE	0.643	**0.636**	0.634	0.652	1.075	**1.066**	1.072	1.083
Mean Error	-0.002	**0.000**	0.015	-0.009	-0.005	**0.001**	-0.034	-0.016
R^2	0.603	**0.612**	0.614	0.597	0.565	**0.572**	0.568	0.563

4.1. Spatial variability in sediment classification

The general pattern of sediment distribution modelled for the Patagonian Shelf (Fig. 3a and 4a), largely reflects previously published maps (Violante et al, 2014; modified after Parker et al., 1996). The shelf is dominated by sands, with lower proportions of gravel, muds and rock/boulders (Fig. 5). Results of the Folk-7 interpolation indicate that 53% of the shelf is

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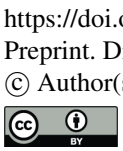

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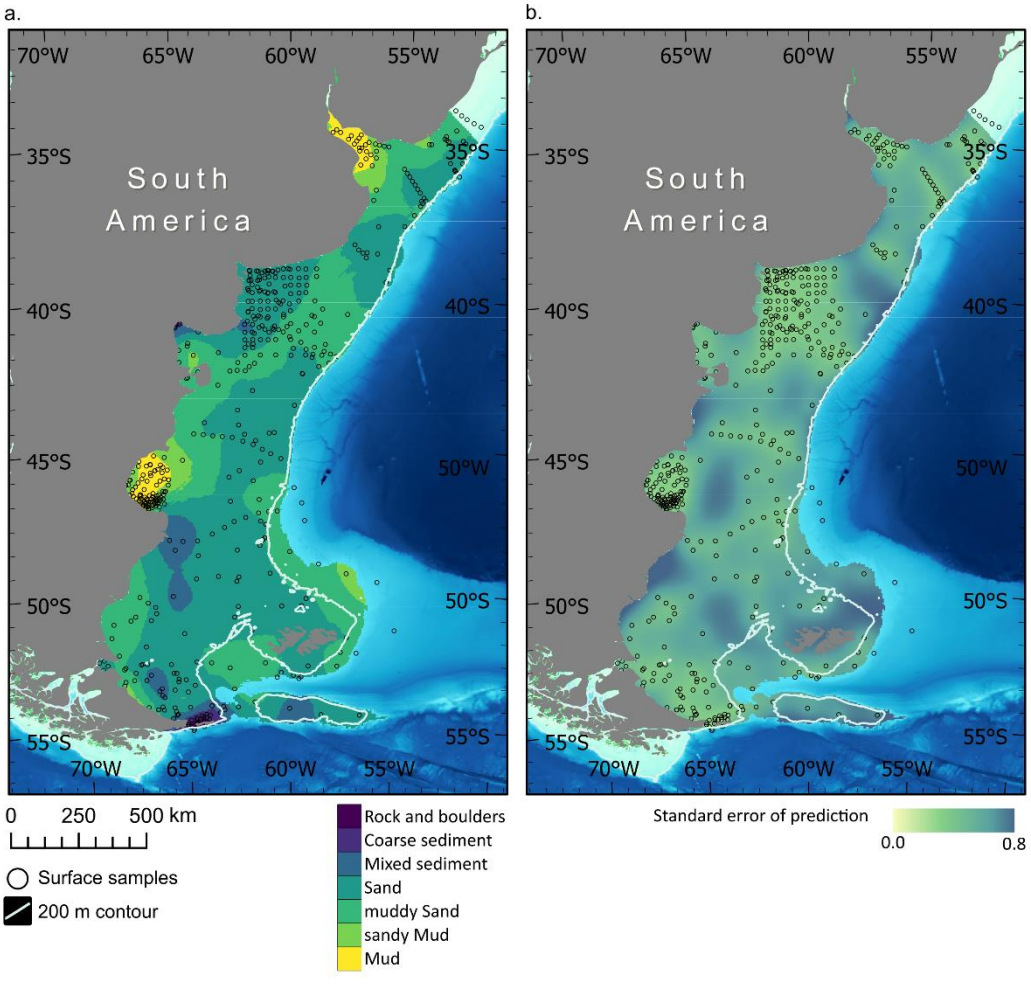
166 comprised of Sand, 34% is muddy Sand, with only 4% and 3% of the shelf comprised of sandy Mud and Mud, respectively.
167 Based on this scheme, 5% of the shelf sediments are Mixed and only 1% Coarse. For the Folk-5 scheme, where Sand and
168 muddy Sand are combined, 83% of the area of the shelf falls into this category. 12% of sediments are gravelly/sandy Muds,
169 with 3% of the shelf comprised of Mud. Only 1% of sediments are considered Gravel under the Folk-5 scheme.
170



171
172 **Figure 3: (a) Sediment map of the Patagonian Shelf classified using the 7-class Folk scheme, modelled with the Ordinary Kriging**
173 **tool in ArcGIS Pro from archived surface sediment data (Table 1). (b) Map of standard error of prediction from Ordinary**
174 **Kriging.**
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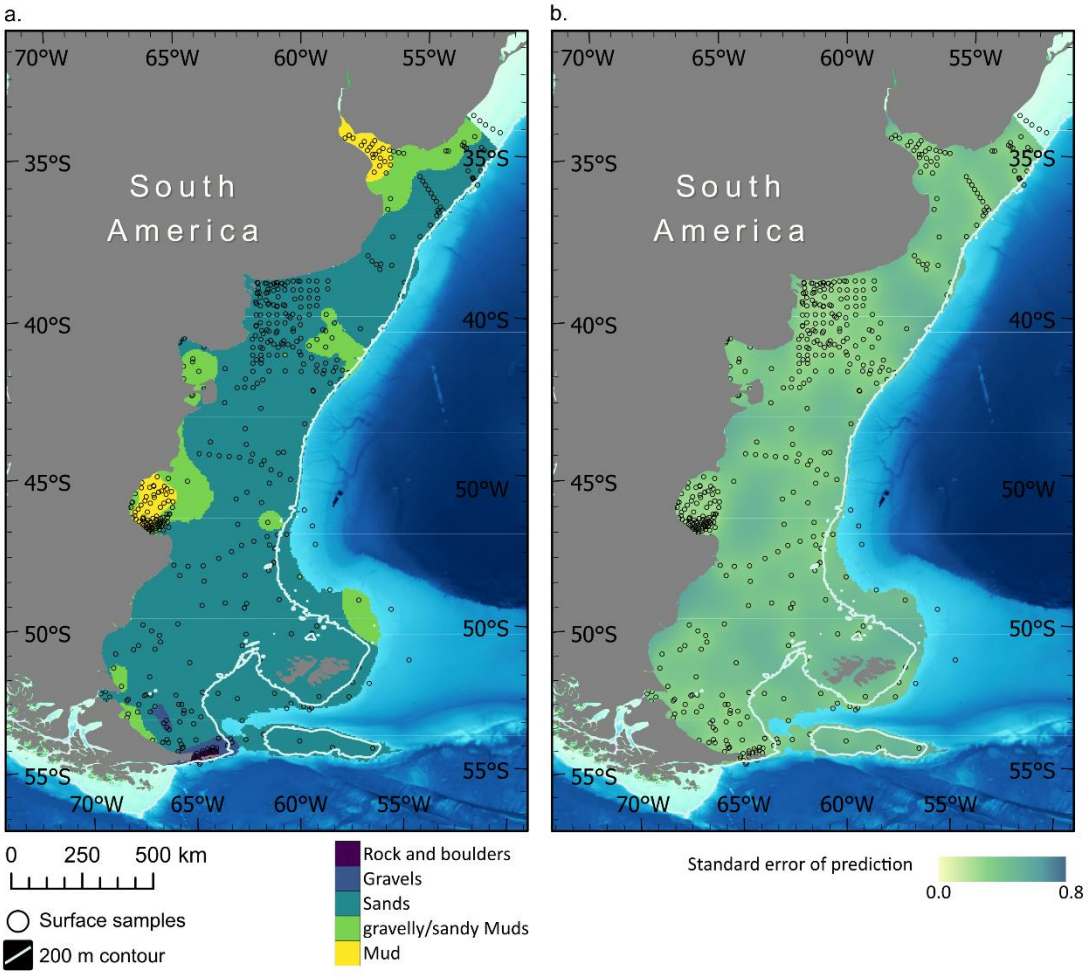

Figure 4: (a) Sediment map of the Patagonian Shelf classified using the 5-class Folk scheme, modelled with the Ordinary Kriging tool in ArcGIS Pro from archived surface sediment data (Table 1). (b) Map of standard error of prediction from Ordinary Kriging.

Violante et al. (2014; after Parker et al., 1997) show the areal coverage of sands on the shelf to be 65% and shells to be 12.5%. As described above, here we categorise most shelly sediments as 'Sand' or '(gravelly) Sand' (following Smeaton et al., 2021). This explains the greater proportion of the Patagonian Shelf substrates described as 'Sandy' (Folk-5: 83%) in this study, when compared to the earlier results (Parker 1997; Violante et al., 2014). We find that the spatial distribution of sands align with previous maps, present along the entire length of the shelf and dominant over the middle and outer shelf, particularly in the central and northern regions (Parker et al., 1996; Violante et al. 2014).

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In this study, only 1-5% of sediments are described as Mixed or Coarse (which includes all sediment with a gravel component >5% under the Folk-7 scheme; Fig. 2) or Gravel (which includes Gravel, muddy Gravel, muddy sandy Gravel and sandy Gravel under the Folk-5 scheme; Fig.2), compared to 12.5% reported in earlier studies (Parker et al., 1997; Violante et al., 2014). Gravel is found in greater concentrations south of 46°S, associated with ancient fluvial and glacial-fluvial deposits (Violante et al., 2014). Whilst we also find that Mixed, Coarse and Gravelly sediments are predominantly found south of 46°S, we find that they cover a considerably smaller area. This may be due to the classifications used in this study, where some gravelly sediments are grouped into other categories. For example, under the Folk-5 scheme, where we see the smallest areal distribution of gravelly sediments (1%), gravelly muddy Sands and gravelly Sands are grouped into the 'Sands' category. Gravels have additionally been observed at the southern entrance of the San Matías Gulf (Mouzo and Paterlini, 2017; Alonso, 2025), forming submerged dunes. We do not pick up these features, due to the spatial resolution of data available from the region.

Considering that the data mining exercise carried out in this study is largely based on re-classified sediment descriptions, the discrepancies observed may be due to the subjective nature of both the original descriptions and their reclassification. We also note that the availability of seabed sediment data over the southern shelf is limited in places, with the error in prediction being relatively high around and to the west of Islas Malvinas/Falkland Islands; a sub-section of the shelf that is shown to be largely Gravel in previously published maps (Parker et al., 1996; Violante et al., 2014). Further sampling of surface sediments in this region, or further open-access publication of pre-existing substrate data/observations, would likely help refine the areal distribution of coarse sediments.

Muddy sediments are primarily found within inner shelf gulfs and estuaries of the Patagonian Shelf (Fig. 4 and 5; Violante et al., 2014). Following the Folk-7 scheme, 4% and 3% of the shelf is comprised of sandy Mud and Mud, respectively. We also find that 3% of shelf surface sediments are Mud (>90% Mud; Fig. 2), when using the Folk-5 scheme. Violante et al. (2014; after Parker et al., 1997) classify 8% of shelf sediments as 'Muds'. As noted previously, the difference in areal extent (%) is likely due to the classification of sediment based on original descriptions and their reclassification, which are subjective in nature. However, the distribution of muddy sediments found in this study largely resembles previous maps (Parker et al., 1996; Violante et al., 2014). The largest bodies of muddy sediments on the shelf are found seawards of the Río de la Plata estuary and within San Jorge Gulf. The Río de la Plata estuary (Fig. 1a) is formed at the confluence of the Paraná and Uruguay Rivers. The Paraná River is the second longest river in South America, and carries a large, suspended load of fine sediments - clays and silts - into the estuary at a rate of $160\text{-}200\times10^{6}$ t yr^{-1} (Fossati et al., 2014; Colombo et al.,

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2021). Further fine sediments are supplied by the Uruguay River, which can reach a suspended load of ~100 mg L^{-1} during high discharge events (Colombo et al., 2021). The San Jorge Gulf is not fed by any major rivers but receives sediment from the local coastline (40%) as well as through aeolian (10% dust) and oceanic transport (Desiage et al., 2018). Lower energy hydrodynamic conditions within the central basin promote deposition of oceanic and aeolian-sourced fine sediment, relative to the coastal areas that receive a greater proportion of sediment through coastal erosion (Desiage et al., 2018). Fine sediments (sandy Muds) are also found within Golfo San Matías, Golfo San José and Golfo Neuvo, and along the inner Patagonian Shelf south of Golfo San Jorge (Fray and Erwing, 1963; Violante et al., 2014).

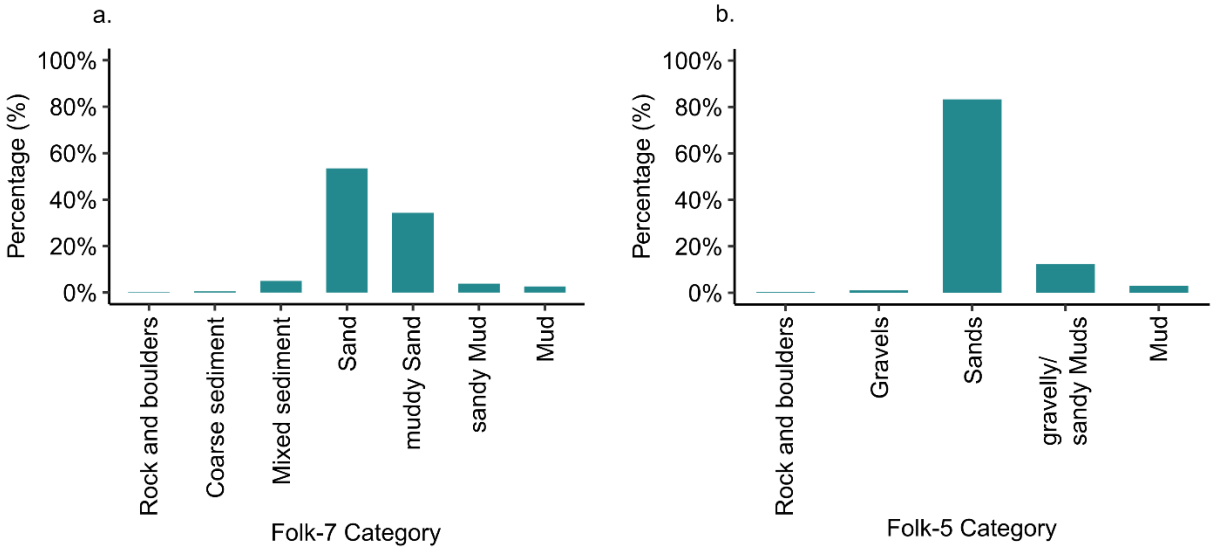

Figure 5: Areal coverage (%) of different sediment classes under the (a) Folk-7 and (b) Folk-5 schemes (Fig. 2).

Overall, the seabed sediment maps produced in this study, based on the harmonisation and interpolation of open-access data, agree well with previously published maps over the central and northern shelf. Key differences are the classification of shell-rich sediments, and the spatial distribution of coarse sediments particularly over the southern shelf. As noted, the areal extent of gravels could be resolved with greater availability of surficial sediment grain size data around and to the west of Islas Malvinas/Falkland Islands. More generally, our standard error of prediction maps highlight regions with sparse sample coverage (Fig. 3b and 4b) or high variability in sediment type. These areas would be of priority for further seabed sampling and would improve the coverage of open-access seabed grain size data for the Patagonian Shelf.

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5. Data availability

All data compiled for this study are openly available via (Roseby et al., 2026; https://doi.org/10.5281/zenodo.19111158) and include:

- A polygon shapefile delimiting the area of interest
- The harmonised seabed sediment data set including information on: Site, Ship/Cruise, Year (of collection), Sampling method, Latitude, Longitude, Depth (metres below sea level), Grain size analysis methodology, Folk-7 classification, Folk-5 classification, Surface sediment type (Folk description), Gravel (%), Sand (%), Mud (%), Author, DOI/source, Repository, Sediment description (from original core log), Notes, Quantitative (Yes/No). If metadata are unavailable cells show 'NA'.
- Georeferenced Tiff-file of the predicted sediment classes (Folk-5)
- Georeferenced Tiff-file of the standard error of prediction (Folk-5)
- Georeferenced Tiff-file of the predicted sediment classes (Folk-7)
- Georeferenced Tiff-file of the standard error of prediction (Folk-7)

6. Conclusions

Seabed sediment maps are of importance to several stakeholders, including those working in marine management and academic researchers. Whilst previous studies have produced surficial sediment maps for the Patagonian Shelf (Parker et al., 1996; Violante et al., 2014), no data source existed for compiled and harmonised open-access data. Furthermore, existing maps do not appear in a format which can be easily incorporated into Geographic Information System (GIS) software. In this study we collated both quantitative and qualitative data from published and grey literature, and harmonised these under two modified Folk schemes (Kaskela et al., 2014; Smeaton et al., 2021). Ordinary Kriging was deemed the most appropriate method for producing continuous seabed sediment maps of the shelf. These maps allowed us to assess the areal coverage of different sediment types and estimate uncertainty in our predictions. The collated and harmonised dataset, and GIS layers of seabed sediment type and associated prediction errors, are openly available via Roseby et al. (2026). Future work could incorporate bathymetric and backscatter data, whilst further sampling of data poor regions and/or further open-access publication of pre-existing seabed sediment data would likely help refine our understanding of the distribution of different seabed sediment types across the Patagonian Shelf.

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Author contribution

ZR: Conceptualisation, data curation, formal analysis, investigation, methodology and writing (original draft preparation). SW: Conceptualisation, writing (review and editing). JS: Conceptualisation, writing (review and editing). TS: Formal analysis, writing (review and editing). CR: Funding acquisition, writing (review and editing).

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Competing interests

The authors declare that they have no conflict of interest.

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