LEIDSE GEOLOGISCHE MEDEDELINGEN, Vol. 37, pp. 135—145, published separately 1-6-1969

SEDIMENTOLOGY OF THE NORTHWESTERN SHORES OF THE RÍA DE AROSA (NW SPAIN)

BY

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ABSTRACT

A study of the beaches on the NW shores of the Ría de Arosa was made with respect to shape and structure of the beaches, grain-size distributions, heavy mineral associations, and relations of the heavy minerals to the bedrock of the hinterland.

Most of these numerous small beaches are situated in inlets determined by the occurrence of relatively weak bedrock (mostly schists).

Grain-size generally fall in fractions $> 50\ \mu$, and some beaches even contain important amounts $> 2000\ \mu$. Many grain-size distributions are bimodal owing to the mixing of different beach layers by wave action or, in a few cases, to mixing with fluvial sands.

The heavy mineral compositions of the fluvial and beach deposits approximately reflect the mineral compositions of the bedrock, especially in the deeper inlets of the Ría, whereas most of the beaches on the more exposed parts have a more varied heavy mineral composition.

In some cases the minerals indicate a weak long-shore transport of the sands.

INTRODUCTION

As part of a combined geological, oceanological, and biological survey of the Ría de Arosa (NW Spain), the authors studied, during the summers of 1962 and 1964, the beaches along its NW shore (i.e. the SE coast of the Barbanza Peninsula), with special emphasis on relationships to the petrographical composition of the adjacent bedrock.

Beach samples were generally taken at the mean low tide line (LWL) from the surface layer; in several cases a mean high tide level sample was also obtained (HWL) and dune samples were taken twice. On many of the beaches trenches were dug perpendicular to the tide lines for sampling deeper layers.

Some samples of residual soils in the hinterland and of the sediments of some rivers and small streams discharging into the Ría de Arosa were also studied. The heavy-mineral fractions of all samples, and in a few cases also the light minerals, were separated in the laboratory in Leiden for further microscopical analysis. Grain-size analyses were also carried out on most of the samples.

For full technical details concerning the treatment of the samples for granulometric analysis and the separation of heavy minerals, we refer to Müller (1964), and for the separation of the light minerals to Vogel (1965).

To determine the grain frequencies, the line counting method was applied (Edelman & Doeglas, 1933). In each slide, one hundred non-opaque minerals were identified. The opaque mineral content is expressed as a percentage of the total heavy-mineral fraction. The authors intend to give a description of the beaches (Kluyver) and to relate the heavy mineral associations of beach and river sands (Arps and Kluyver) to the minerals of the rocks in the hinterland (Arps).

The authors are greatly indebted to Dr. P. Hartman for determining the clay minerals, to Dr. J. D. de Jong for his assistance in the field, and to Professor A. J. Pannekoek, Dr. J. D. de Jong, and Dr. P. Floor for critical reading of the manuscript. Thanks are also due to Dr. W. S. Koldijk for the many valuable discussions and to Mr. J. Bult and Mr. B. Lieffering who expertly executed the drawings.

MORPHOLOGY OF THE BEACHES

Field observations on the beaches are collected in a systematic form in Table I (p. 144). The data given for the shapes and dimensions of the beaches and the grainsizes mentioned in the Table are only visual approximations.

The NW shore-line is indented, especially where granites alternate with schists. The coarse-grained granite in the southwestern section is more susceptible to weathering, and therefore to erosion, than the tough andalusite schists, but in the eastern section, to the contrary, inlets frequently occur in the schists, granite bodies and large pegmatites forming the capes. In almost all cases a relation between beach-inclination and grain-size was observed. Shepard (1963) states that the inclination of a beach is primarily dependent on the permeability of the sediment; the greater the permeability, the greater the inclination. The beach-inclinations in the Ría de Arosa are smaller than those

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In backflap:
appendix I: geological map and heavy mineral assemblages
appendix II: figures 10–17
appendix III: tables II–IV

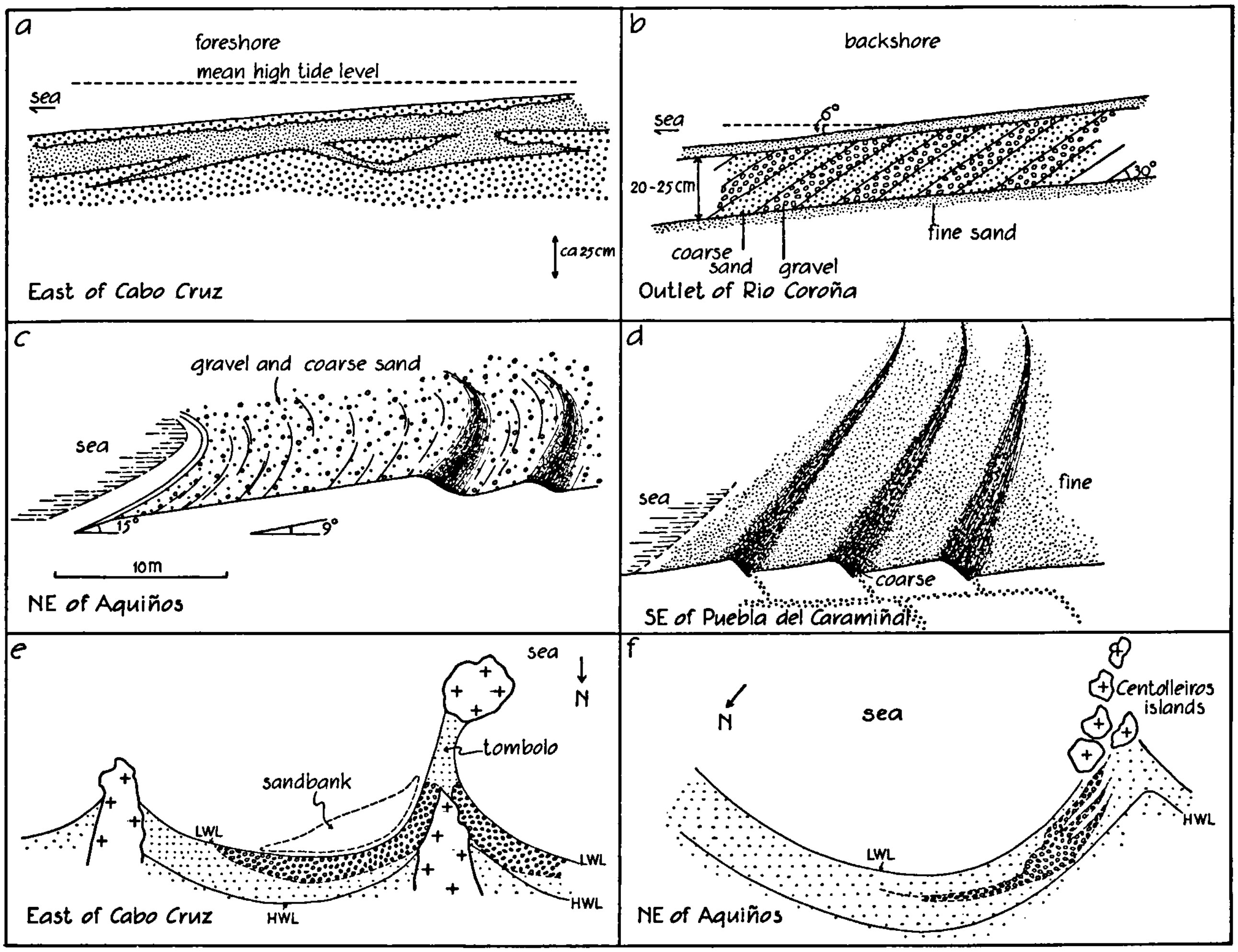

Fig. 1. Some examples of beach structures.

mentioned by Shepard, which fact can be attributed to the rather sheltered position of most of the Ría beaches as compared to the open ocean beaches where Shepard compiled his data.

Most locations showed, beneath the beach surface, wedging-out layers of alternating coarse and fine-grained material. Sometimes these layers have a considerably greater inclination than the actual beach surface (Figs. 1a and 1b). The top layers are almost always fine-grained (Figs. 2a and 2b).

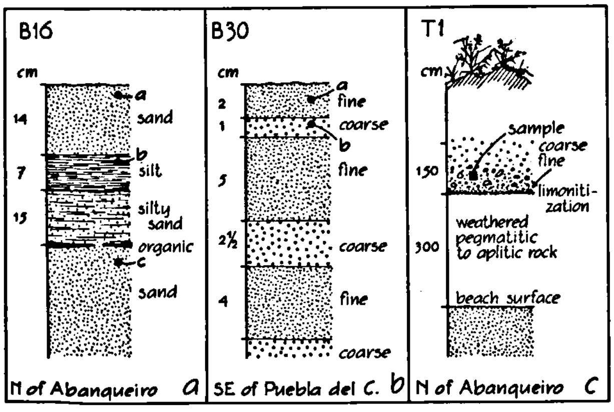

Fig. 2. Two beach-profiles (B16 and B30) and a terrace-profile (T1).

On three of the large crescent-shaped beaches, distinctively coarser material occurs in the middle than on both ends. This may be attributed to the much stronger wave-action in the middle of the beach, where the finer particles tend to be washed out (see also below).

Various coastal features, such as tombolos, mudflats, berms, bars and lagoons, can be observed; some of these are shown in Fig. 1.

GRAIN-SIZE DISTRIBUTION

One of the features shown by most of the beach deposits under study is a low percentage or lack of fractions smaller than 50 μ. This is the result of the winnowing effect of the waves upon the beaches (Fig. 3). Moreover, many of the sands have more than 20 % material with a grain-size of > 2000 μ. This can be explained by the grain-size of the source material — in many cases coarse-grained granitic rocks — directly behind the beaches, and forms an indication that little transport of sediment takes place along the coast. This conclusion is also supported by the heavy-mineral distributions (see p. 140).

Several of the distributions are bimodal; the two examples shown in Fig. 12 are from the same locality but from different levels in a profile, B 30a being taken from the surface layer and B 30b at a depth of 2—3 cm. Other examples can be found in Figs. 15 and 17. The bimodality of B 32 (Fig. 15), a surface sediment at the mouth of the Rio Esteirón, may perhaps be explained by a mixing of marine and fluviatile sediments. The distribution of B 26 (Fig. 14) probably indicates a similar effect. Sample B 36 (Fig. 17) was not taken in the direct vicinity of a stream, and its bimodality is perhaps explained by the mixing of different layers by wave action. Another possibility is the mixing of decomposed rock material of the directly adjacent hinterland, where the post-tectonic coarse-grained granite contains many large, finer-grained granite inclusions.

Samples B 34, B 33, and B 35 in Fig. 16 show the sand distributions in the middle and at both ends of the same beach, respectively. They clearly demonstrate the winnowing effect of the waves upon the central part of the beach. Fractions smaller than 300 μ in B 34 have been washed out; B 33 and B 35, taken on opposite ends of the beach, give roughly the same distribution curves except that about 10 % of the material with sizes < 300 μ, has been retained.

On the whole, the general appearance of the cumulative curves of the beach deposits is more or less identical, displaying a tendency to remain confined to the coarser fractions, i.e. coarser than 210 μ. There is also a tendency of the sediments to become coarser grained and better sorted going from the Rio Ulla toward the Atlantic Ocean; this also holds for the more exposed sediments (Cabo Cruz). Some local decrease in grain-size can be observed near rivers or in the more sheltered positions of the ria. Fig. 3 clearly shows the positions of the sediments in a triangular grain-size diagram (Folk, 1954; Koldijk, 1968) from which the sand and the silt/clay fraction percentages were determined. The river sediments appear to be concentrated in a more restricted part of the diagram, although lying within the field of the beach deposits.

Numerical results concerning sorting, skewness, and median grain-size are shown in Table IV. No measurements of the rounding coefficients were carried out; for this, we refer to Koldijk's paper on the bottom-sediments of the ria. In general, our visual observations of roundness are comparable to those of Saínz-Amor (1960) in the Ría de Vigo. Most beach sands are angular, with a tendency to become sub-angular to sub-rounded in the SW parts of the ria and the more exposed beaches.

BEDROCK OF THE HINTERLAND

In the adjacent hinterland N and NW of the Ría de Arosa (see also Floor, 1968), intrusive and metamorphic rocks are exposed, most of them strongly weathered. Some small areas near the coast are covered with Quaternary marine and/or fluvial

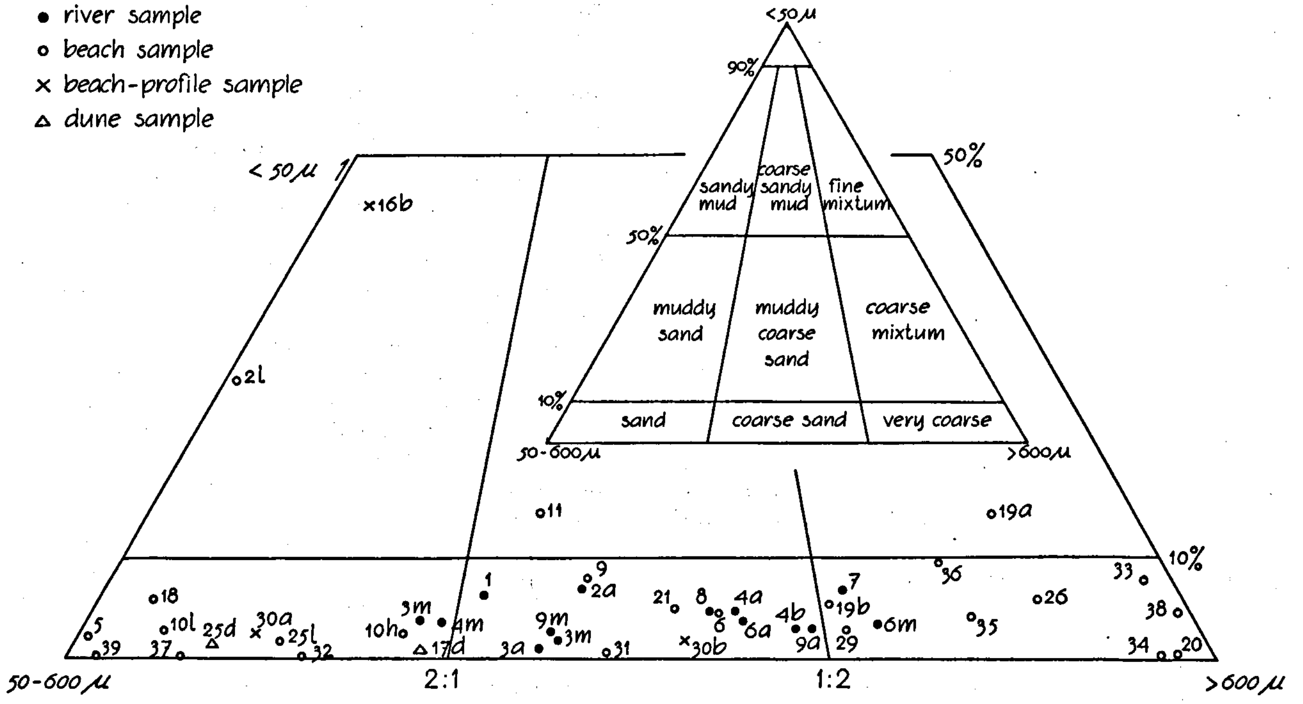

Fig. 3. Grain-size distribution plotted in a triangular diagram, modified after Folk (1954).

deposits (SW of Boiro, Abanqueiro, etc.). Aeolian deposits were also observed; near the ocean (Aquiños) these sediments cover extensive parts of the hinterland.

The bedrock of the hinterland can be divided into three groups:

1. Pre-Hercynian schists, para- and orthogneisses, and amphibolites;
2. Hercynian granites (intrusive and anatectic), migmatites, pegmatites, and aplites;
3. Hercynian post-tectonic granites, porphyries, dolerites, pegmatites, and aplites.

The qualitative composition of some representative samples of the most important rocks of the area are shown in Table II (most data supplied by Mr. J. B. M. ten Bosch, 1964). The Pre-Hercynian metasediments and amphibolites show great variety; among the orthogneisses, plano-linear and glandular types can be distinguished. During the Hercynian orogeny, several granites were produced, viz. an intrusive megacrystal biotite granite and some anatectic twomica granites. In the NE part of the area and in the Rio Coroño valley, migmatites occur.

The post-tectonic intrusive granites are a megacrystal two-mica granite and a biotite (hornblende) granite, also called Caldas de Reyes granite; both are coarse-grained.

With the exception of the post-tectonic group, all the rocks are foliated approximately NNW-SSE, making an angle of 70 to 80° with the general direction of the NW ria coast.

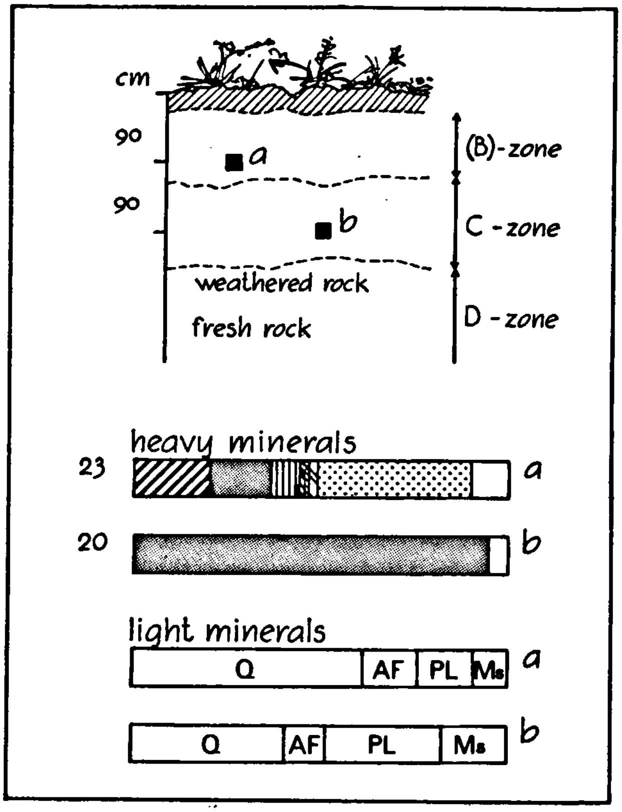

Fig. 4. Soil-profile of the anatectic two-mica granite (S5) in the valley of the Rio Beluso (Q: quartz; AF: alkali feldspar; PL: plagioclase; MS: muscovite; legend for heavy minerals: see appendix I).

SEDIMENTARY PETROLOGY

Heavy minerals of the bedrock

We may first review the more important minerals (see also Floor, 1968) and discuss their occurrence in the bedrock and the river and beach sands.

All metasediments and granitic rocks of the area contain *zircon*, in sizes corresponding to those of the more recent sediments. This mineral is idiomorphic in some granites and gneisses, but rounded in the metasediments as well as in some granites. Therefore, the rounding of most of the zircons in recent deposits must have taken place during a Pre-Hercynian sedimentation.

Tourmaline occurs in many rock-types and is locally abundant in some schists, paragneisses, pegmatites, and aplites. Some of the metasedimentary inclusions in the anatectic two-mica granite of the Barbanza Peninsula were even found to be wholly tourmalinized. The colour of tourmaline in both the bedrock and the sediments is usually dark brown (n_o), but zoned specimens with a bluish core and a brown rim sometimes occur. Blue tourmalines are also present in small quantities.

Relatively abundant quantities of *garnet* were found in the NE part of the area deriving mainly from the numerous pegmatites and aplites and to a lesser extent from the metasediments and granites. Most of the garnet is colourless or pink; the yellow variety occasionally found in small quantities in the beach deposits was not encountered in the bedrock.

Authigenic *anatase* and *brookite*, which are important minerals of many soils, are less important in the river sands and only accessorial in the beach deposits.

Andalusite is the main constituent of the numerous andalusite schists occurring together with the Barbanza granite.

The largest amounts of *sillimanite* occur in the migmatites in the NE and in the schist-xenoliths in the NE and NW.

Small quantities of *chloritoid*, *kyanite*, and probably *glaucophane* were found in some river-, beach-, and terrace deposits, but it is peculiar that these minerals have never been found in the bedrock. The same applies to *staurolite*, which was encountered in almost all the sands in accessorial quantities but never in the bedrock.

The zone of paragneisses and schists E and NE of Boiro presents many amphibolite lenses; these form an important source of *amphiboles*, *epidote*, and *titanite*. All amphibolites contain *common hornblende*, and some of them *cummingtonite* as well. The post-tectonic Caldas granite is an important source of *dark-brown hornblende*, *epidote*, and *monazite*, in addition to other minerals.

Titanaugite is abundantly present in the Rio Beluso, probably deriving from a dolerite dike somewhere upstream.

Residual soils (*regoliths*)

In nine places the regoliths of some important rock-types were sampled for investigation of the residual minerals (see also Bisdom, 1967). In most cases two samples were taken, a higher one corresponding with A1, B, or the top level of the C-zone, and a lower one located mostly in the C-zone just above the weathered rock.

Both the heavy and the light mineral composition (50—500 μ) and also the clay minerals were determined (Figs. 4 and 5 and Table III).

The regolith samples did not give the expected results; their mineral compositions are hardly relevant for determining the provenance of the heavy minerals of the river and beach deposits. In all but two cases the deeper samples contained 70 % or more of either zircon or zircon and anatase (and sometimes brookite), the other minerals being present in only small amounts (Fig. 5).

Apparently, weathering was so intense that only the most resistant minerals remained in considerable amounts. The predominance of gibbsite among the clay minerals, with halloysite as second most important component, is also an indication of strong weathering of a humid-subtropical type.

The samples taken in the upper zones of the residual soils mostly show a much wider variety of heavy minerals than those from lower down in the profile. Obviously, this must be due to solifluction and/or blowing-in of sands from elsewhere; the latter process is apparent in the cases where well-rounded particles of staurolite, garnet, and quartz occur. The same difference between a higher and a lower zone in a soil profile was observed by Bisdom (1967) on the opposite shore of the ria.

Heavy minerals of the rivers

Information about the supply of heavy minerals to the beaches is provided by the bed-load of the small rivers discharging into the ria. Their mineral assemblages reflect to a certain degree the mineralogical composition of the rocks over which they flow. Apparently, the rivers, which cut through the thick weathering zone, take their heavy minerals from deeper zones where the rock is less weathered.

Apart from a few samples taken upstream (indicated by addition of *a* and *b* to the sample number), sampling was done near the mouths of the rivers (indicated by *m*) because the compositions at those places were expected to be reflected in nearby beach sands. In general, the 50—500 μ fraction was taken for the counting of the heavy minerals, but in the cases of the Rio Beluso and the Rio Coroño at their outlet in the ria, the 150—300 μ fraction was also considered (see p. 142).

Concerning the individual rivers, the following remarks can be made. Although tourmaline occurs in all the river sands, the Grenla, Té, Beluso, and Brea Rivers are the most important suppliers.

The largest quantities of garnet are supplied by the Rio Grenla and Rio Té, and smaller amounts by the Rial, Beluso, Brea, Coroño, and Lampón Rivers.

The important sources of andalusite are largely restricted to the western parts of the area, and high percentages of this mineral are therefore carried by the Coroño, Lampón, Lerez, and Pedras Rivers. The

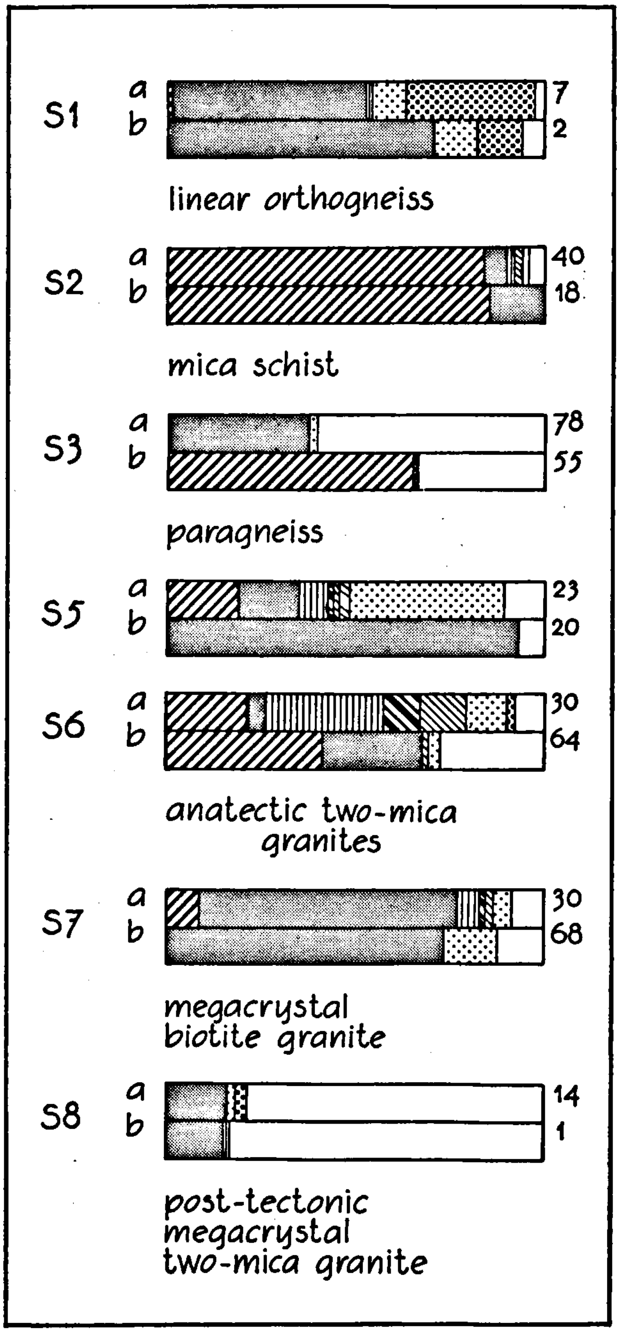

Fig. 5. Heavy mineral assemblages of some regolith samples; a: upper sample and b: lower sample (Legend for heavy minerals: see appendix I).

same can be expected from the Tilleiros and Esteirón Rivers.

Greater amounts of sillimanite were found in the Arroyo del Rial.

Hornblende, also carried by all the rivers, was found in the greatest amounts in the Rio Brea.

Fluvio-marine terrace deposits

Scattered remnants of fluvio-marine terrace deposits occur at several places along the ria coast. They are located at distinct levels, mainly about 3 (Fig. 2c), 15, 30, and 60 metres above sealevel. SW of Boiro, these deposits are well-layered.

Intensive weathering caused strong limonitization locally; the always rounded to well-rounded pebbles, when not pure quartz, are wholly decomposed.

The area around Abanqueiro also exhibits layered remnants of extremely weathered rocks (colluvium). This colluvium consists of angular to sub-rounded quartz pebbles in a matrix of quartz sand and clay. The rims of the quartz pebbles are always limonitized.

The heavy mineral assemblages of the deposits SW of Boiro (T 2) show a wider variety of minerals than the soils and other sediments. Especially staurolite, glaucophane, and chloritoid, which have not yet been found in the bedrock, occur as important accessories or, in the case of staurolite, as a main constituent in the deposits. Although staurolite, chloritoid and glaucophane have also been found in the Coroño, Lampón, and Pedras Rivers, and kyanite was encountered in the Lerez and Pedras Rivers, it is not yet quite clear whether these metamorphic minerals could have originated from the adjacent bedrock or must have been brought from somewhere upstream.

The mineralogical composition of the deposits N of Abanqueiro (T 1), on the other hand, do not differ much from the beach deposits of this part of the ria, which means that these terrace deposits may have derived from the same bedrock of the hinterland and that the recent beach deposits originated from the adjacent bedrock and/or from the terrace deposits.

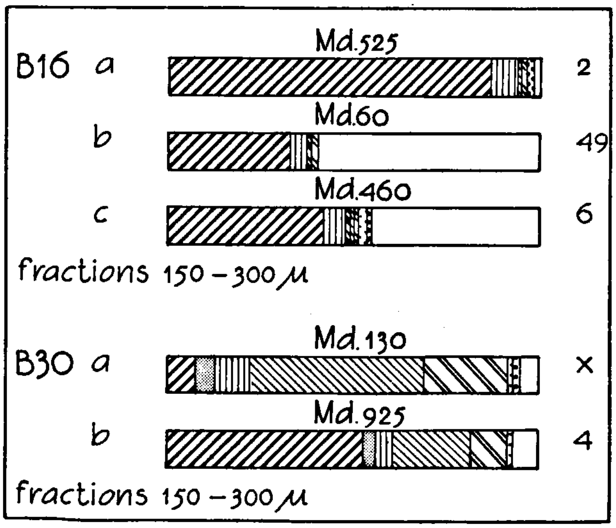

Fig. 6. Heavy mineral assemblages of two beach-profiles (B16 and B30); for position of a, b and c: see Fig. 2 (Legend for heavy minerals: see appendix I).

Heavy-mineral composition as influenced by grain-size and layering

Before discussing the heavy minerals of the beaches, a few remarks should be made on the influence of grain-size and layering on the heavy mineral assemblage.

To demonstrate the variation in heavy mineral percentages of different layers of a beach-profile, the 150—300 µ fractions of B 16, a, b, and c, and B 30, a and b (see also Fig. 2) were investigated; the results are given in Fig. 6. Although the marked differences in grain-size (Fig. 12) were not wholly eliminated by taking the 150—300 µ fraction (which probably accounts for the predominance of tourmaline in the coarse layer), it is clear that the differences in heavy mineral assemblages between the layers are not only determined by differences in grain-size (compare B 16 a and c).

Differences in mineralogical composition related to differences in grain-size are demonstrated by comparison of the LWL and HWL samples of B 1 and B 2 (Fig. 10 and Table IV). The HWL samples are in both cases coarser and better sorted than the LWL samples. Differences are most marked for tourmaline and sillimanite/fibrolite, which show a preference for the coarser HWL deposits, and for epidote and hornblende, which tend to be more concentrated in the finer-grained LWL samples.

Samples B 8 HWL and LWL, to the contrary, show only a minor shift of the mineral percentages (Table IV) and the forms and positions of the cumulative curves of both samples are almost identical (Fig. 10).

Samples B 30 a, B 26, and B 18 were separated into three groups (fractions 50—150 µ, 150—300 µ, and 300—500 µ) to investigate the variation of heavy mineral composition with grain-size (Fig. 7). The rule that zircon is mainly concentrated in the finest fraction was fully confirmed; garnet and epidote appeared to be less restricted to the finer portions. Andalusite and sillimanite tend to concentrate in the coarser fractions, whereas tourmaline, staurolite, and hornblende are more evenly distributed over the fractions.

Heavy minerals of the beach deposits

The results of heavy mineral analyses of the beaches (map and Table IV) confirm that the heavy mineral assemblages are in general directly related to the mineralogical compositions of the bedrock in the adjacent hinterland, although there are exceptions indicating a slight long-shore transport.

The mineralogical composition of the beach sands will be reviewed, starting from the NE, i.e. near the mouth of the Rio Ulla, and going to the SW, near the open ocean.

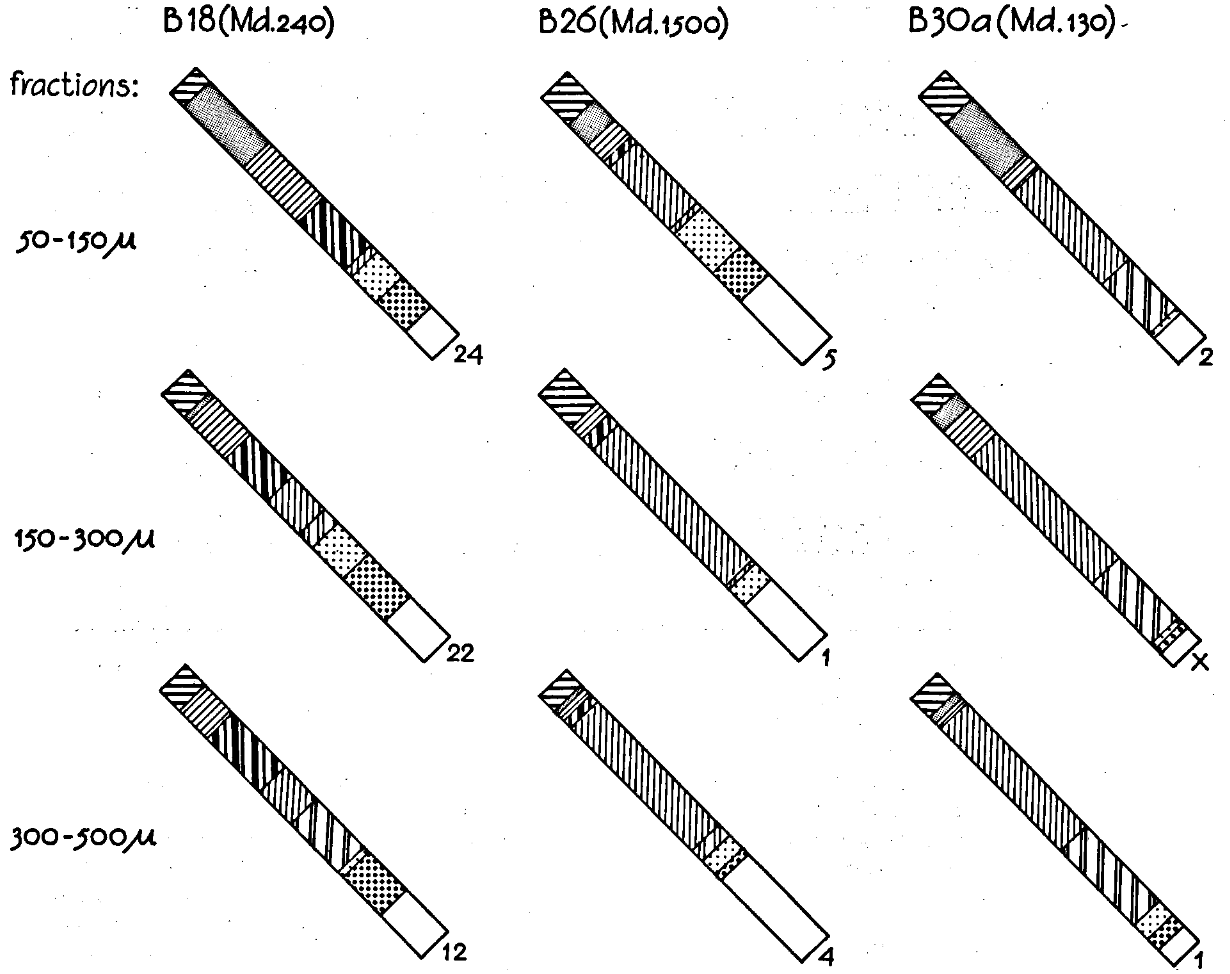

Fig. 7. Heavy mineral assemblages in three sub-fractions of three beach-samples (B18, B26 and B30a) (Legend for heavy minerals: see appendix I).

High percentages of garnet, tourmaline, and sillimanite/fibrolite are found in the northeastern migmatic sector (B 1—B 8). Within this sector, the highest percentages of sillimanite/fibrolite occur in the Ensenada del Rial (B 1 HWL) and of tourmaline more to the SW, in the Rianjo area (B 7—9); garnet is more irregularly distributed. The relatively high percentages of hornblende, epidote, and staurolite (B 1 LWL, B 2 LWL, and B 5) must be regarded as an influence of the Rio Ulla.

The beaches around the Ria de Abanqueiro show the association of tourmaline, garnet, and occasionally common hornblende (B 9—B 17). Most amphibolites occur in the paragneisses W and SW of Puente Beluso, as is clearly reflected in the high hornblende percentage of B 11—15, with the exception of B 13 (large granitoid/pegmatoid bodies directly behind). Important quantities of andalusite are found on the N and E shores of the Ria de Abanqueiro (B 10—12). The large quantity of titanaugite in the Rio Beluso hardly affects the mineral association of the beach deposits (max. 6 % only in B 11) or of the bottom sediments (Koldijk, pers. comm.) (Fig. 8a and 9).

The mineralogical compositions of samples B 18—B 23, taken in the area of the Caldas granite, do not directly correspond with the expected picture. Three factors must be considered to account for the observed differences.

Firstly, the Caldas granite contains very many, sometimes large inclusions of all kinds of rock. Secondly, scattered remnants of Quaternary deposits occur on the peninsula of Cabo Cruz. Thirdly, there is the

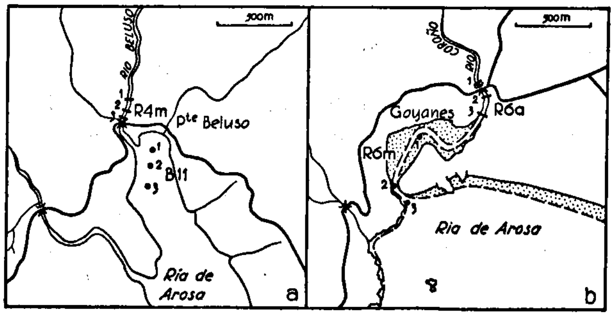

Fig. 8. Detail maps of the outlets of the rivers Beluso and Coroño.

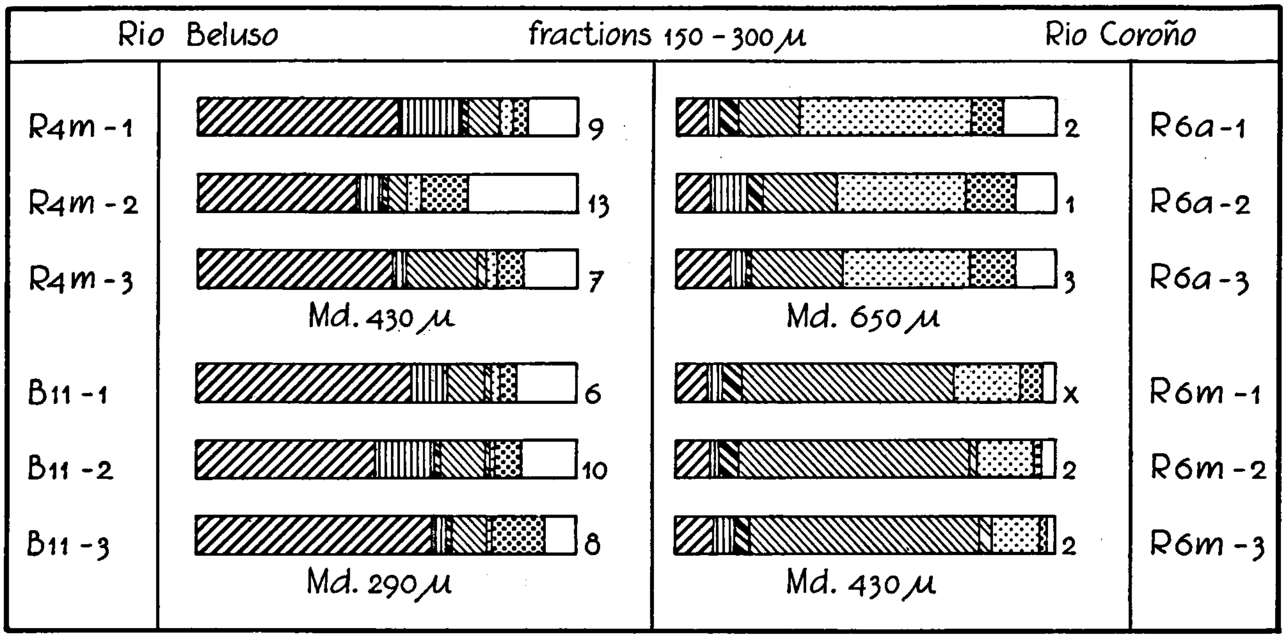

Fig. 9. Heavy mineral assemblages of the rivers Beluso and Coroño at their outlets in the Ria de Arosa. For the locations: see Fig. 8 (Legend for heavy minerals: see appendix I).

effect of the reworking of the older, now submerged, Rio Ulla sediments by the action of the waves as the sea level rose. Probably, this last factor also accounts for the rather wide variation in sample B 5.

The sands of the beaches around the Ensenada de la Merced (B 24—30) are very rich in andalusite, especially in the central part (B 28: 76 %). To the NE (Playa Barraña area) the sands also contain important quantities of epidote and alterite. When these results are compared with those obtained from the Rio Coroño (150—300 μ), we find that the heavy-mineral distribution of the river is very well reflected by the beach sands (B 25 and 26).

The sands of the Rio Coroño (Figs. 8b and 9) show, towards the river mouth, steadily increasing percentages of andalusite, whereas the amounts of epidote, and less clearly those of hornblende and alterite, decrease while those of tourmaline, garnet, and staurolite remain nearly the same. The large amount of andalusite in the Rio Coroño reflects the fact that the river cuts through andalusite schists at the mouth near Puente Goyanes. Other minerals are derived from the wide variety of bedrock upstream.

The greater variety of minerals in the NE part of the Ensenada, which is exemplified by the HWL sample of B 24, might also be explained by the occurrence of the terrace deposits S and SW of Boiro (T 2), which are reworked by the waves.

The large amounts of andalusite in the sands of Playa Barraña (B 24) and N of Cabo Cruz (B 23) and moderate amounts even E of Cabo Cruz, indicate a local sediment transport due to long-shore drifting during the winter storms from the SW.

The mineral sillimanite (fibrolite) becomes increasingly important towards the SW part of the Ensenada (B 29 and B 30).

The beach deposits S and SW of Puebla del Caramiñal (B 29—30) still contain much andalusite, but toward the ocean the amounts decrease. Sillimanite and tourmaline are rather important in this part of the ria and hornblende (mainly basaltic hornblende), some epidote, and alterite are also present in variable amounts. The mineralogical composition of sample B 38 differs greatly from that of the beach sands nearby; this could be a local variation depending on the source-rock. The SW region of the ria, on the whole, does not seem to express a relation between sands and source-rocks. Disturbing factors that can be expected are the reworking of the older Rio Ulla sediments (the old course of this river is now submerged, Pannekoek 1966) and the influence of the terrace sediments of the Aquiños area.

According to Parga-Pondal (1935), small quantities of monazite occur in the beach deposits E of Palmeira (B 31, B 32). This mineral is probably derived from the Caldas de Reyes granite, although its presence has also been established in most of the other rock-types of the area (Arps).

CONCLUSIONS

1. The relation between the heavy mineral assemblages of the beach deposits and bedrock of the adjacent hinterland is in general clearly shown by the inner parts of the ria, although exceptions to this rule are present. The more exposed parts of the Ria (in the SW, the beaches E of Cabo Cruz, Ensenada de la Conchas in the NE) generally have the widest

mineralogical variation. Weak local long-shore sediment transport and reworking of the now submerged Rio Ulla sediments may also be mentioned as causes for a more varied composition.

2. The source of the metamorphic minerals staurolite, glaucophane, kyanite, and chloritoid occurring in accessorial quantities in several samples is still not entirely clear, since these minerals were not encountered in the bedrock.

3. The metasediments and migmatites contribute to the Ria sediments mainly the minerals tourmaline, andalusite, sillimanite, and sometimes also garnet. From the amphibolites are derived hornblende, epidote, and titanite. The granitic rocks are responsible for supplying zircon, monazite, basaltic hornblende (Caldas granite), epidote, and garnet. The many pegmatites and aplites very often contain large amounts of garnet and tourmaline.

4. The heavy mineral distributions are strongly dependent on grain-size, and therefore selective sampling of the beaches with respect to structures and layering is required to ensure reliable and comparable results.

5. The influence of contributing rivers is small. The Rio Ulla seems to be the only important exception to this, but its influence is probably restricted to the NE part of the Ria.

6. Most beach-sands have little or no material finer than 50 μ, and in many cases more than 20 % of the material is coarser than 2000 μ. It was found that the sands in the centre of some beaches were coarser than on both ends, obviously due to stronger wave action in the centre.

7. There are great differences in grain-size between the different layers of the beach profiles.

8. Most grain-size distribution curves are bimodal; in some cases this suggests some kind of mixing of different layers of a profile or of sands of different provenances.

RESUMEN

LA SEDIMENTOLOGÍA DE LAS PLAYAS DE LA PARTE N.O. DE LA RÍA DE AROSA (GALICIA, ESPAÑA)

Este estudio se basa en observaciones hechas sobre la forma de las playas, su estratificación, composición granulométrica, minerales pesados y sus relaciones con las rocas adyacentes.
La mayor parte de las ensenadas, generalmente de corta extension, se encuentran en zonas rocosas de poca resistencia (especialmente esquistos).
Las arenas estan constituidas principalmente de granos cuyo tamaño es superior a los 50 micrones; en algunas el tamaño sobrepasa, en porcentaje importante, los 2000 micrones.
Algunas curvas granulométricas presentan dos maximas, probablemente como resultado de una mezcla de varias capas por efecto de la resaca o de una mezcla con arenas fluviales.
La composición de sedimentos fluviales y costeros refleja una analogía con el contenido mineralógico de las rocas adyacentes, especialmente en las partes interiores de la ria; mientras que la composición de los minerales pesados de las arenas costeras de las partes exteriores, es más heterogénea.
Hay indicios de la existencia de un transporte débil de material detrítico que se efectua paralelo de la costa.

RÉSUMÉ

SÉDIMENTOLOGIE DES PLAGES DU RIVAGE N.O. DE LA RÍA DE AROSA (GALICE, ESPAGNE NORD-OCCIDENTALE)

Cette étude contient des observations sur la forme et la stratification des plages, leur composition granulométrique, les minéraux lourds et les relations de ceux-ci avec les roches de l'arrière-pays.
La plupart des plages, généralement de dimensions modestes, se trouvent dans de petites baies qui se situent dans des zones de roches peu résistantes (surtout des schistes).
Du point de vue granulométrique, les sables sont surtout composés de grains de plus de 50 microns; quelques plages contiennent même une importante fraction supérieure à 2000 microns. Plusieurs courbes granulométriques ont deux maxima, probablement par suite du mélange de plusieurs couches par les vagues, ou d'un mélange avec des sables fluviaux.
Le spectre des minéraux lourds des dépôts de plage et des rivières reflète à peu près la composition minéralogique des roches de l'arrière-pays, surtout dans les embranchements intérieurs de la ria, tandis que dans les parties plus exposées la composition est plus variée. Localement on observe l'effet d'un faible courant parallèle à la côte.

sample	shape and other characteristics	dimensions in m		inclination	facing	grain-sizes
		length	width			
B 1 B 2	small bay in river outlet	200	—	< 5°	S	fine sand and silt; organic matter; mudflat
B 3	very small bay	50	25	10°	S	HWL: sand; LWL: fine sand
B 4	small river outlet	—	—	< 5°	S	fine sand and silt; LWL: mudflat
B 5	crescent	150	40 + mudflat 100	5°	S	fine sand and mudflat at LWL; many shells, even forming layers
B 6	straight	60	30	5°	SW	sand and gravel
B 7	irregular, small islands	—	30	5°	SW	sand
B 8	crescent with two capes	250	50	5°	SW	fine sand to gravel; cobbles
B 9	irregular coastline	—	—	—	NW	fine sand to gravel
B10	large open crescent; outlet of important river; small covered dunes	1000	200–100	5°	WSW	sand and gravel
B11 B12	deep bay with two important river outlets	—	—	—	S	silt to gravel; mudflats
B13	irregular coastline; outlet of small river	—	—	< 5°	E	fine to medium-grained sand
B14 B15	crescent and irregular coastline	800	200	< 5°	ENE	HWL: sand and gravel LWL: sand and mudflat
B16	small crescent	200	—	5°	NNE	sand and gravel
B17	broad crescent with dunes	1000	200	9°	SSE	sand and gravel
B18	crescent (E part of Fig. 1e)	400	50	7°	S	coarse sand and gravel
B19	tombolo (Fig. 1e)	—	—	—	—	
B20 B21	large crescent (W part of Fig. 1e)	1000	50	8°	SSW	fine to coarse sand with shell fragments
B22	small crescent	200	50	8°	S	sand
B23	irregular coastline; islands	—	—	—	W	sand
B24	large crescent; on W side: bar and important river outlet	3000	W:30	8°	S	coarse sand and gravel
B25			C:100	5°	SW	sand
B26			E:150	< 5°	WNW	fine sand and silt
B27	irregular coastline	—	—	—	SE	sand and gravel
B28	small crescent	200	50	—	E	sand and gravel
B29	large crescent; important river-outlet in the E and small outlets in the centre and S	2000	S:200	< 5°	S: NE	S: coarse sand
B30	small crescent	150	50	< 5°	NNE	sand and shell-fragments
B31	crescent	400	30	10°	S	coarse sand
B32	crescent with small river outlet	1000	40	10°	S	sand and gravel
B33 B34 B35	large crescent with small river outlet	2000	60	6°	SE	sand, in centre coarser than on both ends
B36	small crescent	60	40	6°	SE	coarse sand to fine gravel
B37	large crescent	1000	30	5°	SSE	fine sand to fine gravel with shell fragments
B38	Centolleiros-Islands	—	—	—	—	sand and gravel
B39	small crescent on irregular coastline, rather sheltered by islands	30	25	8°	SW	coarse sand with many shell fragments

Table I: Field observations on the beaches of the northwestern shores of the Ría de Arosa.

bedrock of the hinterland	samples from	sample
mediumgrained granite; glandular	surface	B 1
ortho-gneiss; migmatites	surface	B 2
two-mica schists	surface	B 3
medium-grained granite with schist	surface	B 4
inclusions		
pegmatitic material with many schist	surface	B 5
inclusions		
medium-grained granite with schist	surface	B 6
inclusions		
schists with pegmatites	surface	B 7
schists with pegmatites	surface	B 8
schists with pegmatites	surface	B 9
medium-grained granite, schists and	surface	B10
pegmatites		
metasediments with amphibolites and	surface	B11
pegmatites/aplites	surface	B12
paragneiss, amphibolites, granites and	surface	B13
pegmatites/aplites		
paragneiss, amphibolites,	surface	B14
pegm./aplites,		
megacrystal biotite granite	surface	B15
paragneiss, amphibolites,	layers	B16
pegm./aplites		
paragneiss, pegm./aplites and	surface	B17
terrace deposits	and dune	B18
	surface	B19
coarse-grained biotite-(hornblende-)		B20
granite with many inclusions	surface	B21
(schists, amphibolites, different types		B22
of granites etc.)		B23
granites and gneisses; terrace deposits	dune	B24
dunes		
	and	B25
medium-grained granite	surface	B26
coarse-grained biotite-(hornblende-)	surface	B27
granite and andalusite schists	surface	B28
filled lagoon	surface	B29
coarse-grained biotite (hornblende-)	layers	B30
granite; B31: covered dunes	subsurface	B31
bar; filled lagoon; coarse-grained	surface	B32
granite	layer	
coarse-grained biotite-(hornblende-)		B33
granite, schists; small dunes and	surface	B34
filled lagoon		B35
coarse-grained granite with inclusions	surface	B36
extensive dune landscape,	surface	B37
granite capes	layer	
coarse-grained biotite-hornblende-	surface	B38
granite with many finer-grained	surface	B39
granite inclusions	layer	

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