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Comparison of ESR and Amino Acid Data in Correlating and Dating Quaternary Shorelines Along the Patagonian Coast, Argentina

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ABSTRACT

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Five areas along the Patagonian coast, Argentina, were sampled for ESR age estimates in order to elucidate earlier conclusions on the number, characteristics, geomorphology, correlation and amino acid age estimates of Quaternary shorelines in Patagonia (Rutter *et al.*, 1989). Areas investigated include: San Blas, San Antonio Oeste, Caleta Valdes, Bahia Bustamante and Puerto Deseado. The ESR ages generally confirmed conclusions based on the amino acid data. The "oldest" shorelines are found at elevations between 24 and 41 m above mean sea level and are judged to represent the penultimate or older interglacial. The "intermediate" aged shorelines are present at some locations, represented by beach ridges varying between 20 and 28 m. These ridges were probably formed during the last interglacial (isotope stage 5e). Well defined "young" beach ridges between 8–12 m above mean sea level are found in most locations and have been ^{14}C dated and verified by amino acid and ESR dates as Holocene in age.

ADDITIONAL INDEX WORDS: *Argentina, Patagonia, ESR, amino acid racemization, raised shorelines, Quaternary.*

INTRODUCTION

The coastal area of Patagonia possesses a number of raised shorelines, consisting largely of raised beach ridges and deposits at varying elevations. There has been very little information on the number, age, characterization, geomorphology and development of these features. Recently we completed a preliminary study on the correlation and dating of these littoral zones relying heavily on amino acid dating techniques on various marine mollusca (Rutter *et al.*, 1989). Six areas were investigated from San Blas southward to Tierra del Fuego, a distance of over 1500 km. Although other raised beaches and deposits are present, the areas investigated were judged to display some of the best sequences and were easily accessible. In this paper, we compare ESR (Electron Spin Resonance) age estimates with those based upon amino acid racemization data in five of the original areas—San Blas, San Antonio Oeste, Caleta Valdes, Bahia Bustamante and Puerto Deseado (Figure 1). Rutter *et al.* (1989) should be consulted for background on the geology and sea level development of the Patagonian coast, and amino acid dating techniques and Radtke *et al.* (1985), Radkte (1989) on ESR dating techniques and related regional geomorphological problems.

PREVIOUS WORK

Previous work has centered on the identification, number and age of emerged shorelines (WITTE, 1916; FERUGLIO, 1950; AUER, 1959; CODIGNOTTO, 1983; FASANO *et al.*, 1983; RABASSA *et al.*, 1984; PORTER *et al.*, 1984; and RABASSA, 1987). The work by FERUGLIO (1950) provides a framework of the entire Patagonian coast. On the basis of the topographic position, geographic distribution, and a thor-

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Figure 1. Location map of areas investigated along the Patagonian coast, Argentina.

ough analysis of fossil invertebrates, mainly molluscs, he distinguished six marine terraces:

Terrace I	170–186m (above mean sea-level)
Terrace II	105–140 m
Terrace III	70–80 m
Terrace IV	35–40 m
Terrace V	15–18 m
Terrace VI	8–10 m

Terraces IV, V and VI are composed of modern fauna. Terrace VI is the youngest which he refers to as "recent." Later work by CODIGNOTTO (1983) using radiocarbon dating methods confirms a Holocene age for this terrace that extends along most of the Patagonian coastal plain and correlates with equivalent shorelines in the Pampas area to the north. Terraces IV and V were judged to be Pleistocene age but do not extend beyond the last interglacial (FERUGLIO, 1950). The former is deeply dissected (CIONCHI, 1983) and represents the oldest Pleistocene high-stand. Terraces I, II, and III are assumed to be older than Pleistocene.

Previous work indicates that there is a general agreement that sea levels were higher than the present at least during the last interglacial (oxygen isotope stage 5e) and during the Holocene (early to mid-). Sea levels lower than the present are associated with the most recent glacial maximum during isotope stage 2 (FRAY and EWING, 1963). There is also agreement that elevations of the marine terraces in Patagonia are higher than the equivalent levels in the Pampas area to the north in Buenos Aires Province (FASANO *et al.*, 1983).

Based on relatively high amino acid ratios and extrapolation from non-linear kinetic models, RUTTER *et al.* (1989) suggested that the "oldest" Quaternary marine deposits, found at elevations between 24 and 41 m above mean sea level, are judged to be older than isotope stage 5e. An "intermediate" aged littoral zone may be present at some locations based upon beach ridges or platforms varying in elevation between 16 and 28 m above mean sea level. D/L ratios are generally lower than those for the "oldest" zone but show a greater variation. This zone may represent isotope stage 5e sea-level stand. Well defined "young" beach ridges between 8–12 m above mean sea level are found in most locations and have been ^{14}C dated, and verified by amino acid ratios, as being Holocene. The presence of Quaternary aged emerged littoral zones at roughly the same elevation suggests that the glacio-eustatic contribution is the primary cause of the high sea level stands whereas secondary variations are attributed to other factors.

ESR (ELECTRON SPIN RESONANCE)

ESR spectroscopy allows detection of paramagnetic centers formed by ionizing radiation. With time and successive natural irradiations (α, β, γ, and cosmic rays) electrons are transformed from ground state (valance band) to the higher energy level. After recombination with positive charge deficit sites these paramagnetic centers can be detected by ESR—spectroscopy. The number of trapped electrons and the height of the ESR signal is proportional to the strength of the radioactive field (dose rate) and the time (age) of irradiation (for details see GRÜN, in press). Therefore, the basis for ESR dating is the constant increase of paramagnetic defects with time. An ESR age is determined by the following equation:

$$\text{Age (a)} = \frac{\text{Accumulated Dose (AD) in Grays}}{\text{Annual Dose } (D_o) \text{ in Grays/year}}$$

The accumulated dose (AD) is what the sample has received during its geologic age and is usually determined by the so-called "additive dose" method (see GRÜN, in press). With a zero ESR signal at the time of formation the extrapolation towards zero intensity allows the estimation of the AD. The annual dose (D_o) is produced by the radioactive elements in the sample (internal dose-rate) and its surroundings (external dose-rate). The internal dose-rate is calculated by chemical analysis and/or INAA (Induced Neutron Activation Analysis) of U and Th (K is negligible). The external dose rate is measured indirectly by gamma spectrometry of the embedding matrix (U and Th) and AAS (Atomic Absorption Spectrometry) (K).

In this investigation, mollusc shells were dated. The first published mollusc dates were in 1981, when the ESR method was in its infancy (IKEYA and OMURA, 1981; RADTKE *et al.*, 1981). Unfortunately, the method, especially in mollusc shells, is subjected to various interferences related to the evaluation of the AD. These include such influences as ESR lines, humic acid radicals, stability of traps, recrystallization effects, and logarithms or linear fitting. Other problems related to the determination of the AD are alpha efficiency, zoning effects, isotopic disequilibrium, water effects and uranium accumulation (see GRÜN, in press). Here we will discuss only two of the basic problems—the life time of the traps and the identification of multiple ESR lines, two problems that must be discussed together.

The ESR spectra of aragonitic mollusc shells display at least five different signals in the region of dating interest (RADTKE *et al.*, 1985; GRÜN, in press). The signals at *g = 2.0056 and 2.0031 are often not gamma-sensitive and sometimes are reduced by artificial radiation.When using signal heights for deriving AD, the AD's from the signals g = 2.0018 and g = 1.9976 seem too low and the AD derived from g = 2.0007 too high. However, when performing a plateau test on the integrated spectrum, the region between g = 2.0020 and 1.9976 yields an AD plateau (MOLODKOV, 1988). GRÜN (in press) showed with annealing experiments that the interfering signal at 2.0018 is relatively unstable, but the total signal decays with the same rate as g = 2.0007. Therefore, it appears legitimate to use the total signal height for AD-determination.

Recent experiments by KATZENBERGER *et al.* (1988) and KATZENBERGER (1988) demonstrated the ESR spectrum of a mollusc sample is rather complex, and the definition of a dating signal can be a problem. They stated that the dating signal suggested by RADTKE *et al.* (1985) is composed of two lines (CO_2^-, g = 2.0019 and g = 2.0007) but the composed signal at 2.0019 must not be used as a dating signal. They investigated the signals under different temperatures and found that the nature of 2.0007 is probably a point defect associated with a cation like Mg^{2+}. The signal at g = 2.0019 is a very sensitive radiation line, which is not eliminated by thermal pretreatment. In this respect, this species behaves like CO_2 but must not be confused with it, even it CO_2 has a component value of 2.0016—close to 2.0019. The lifetime of the center at g = 2.0019 is known to be shorter than that of CO_2. KATZENBERGER (1988) draws the pessimistic conclusion that as a result of his basic studies on the origin and behaviour of the various signals, ESR dating of mollusc shells is questionable at the moment and previously published dates should be interpreted with caution.

On the basis of the results presented below, it can be stated that ESR dating of mollusc shells still is of considerable value in Quaternary studies. Of course, one must avoid overinterpretation of the "absolute" ESR ages. In any case, because of the low lifetime of the traps, ESR ages over about 150,000 years should be regarded as minimum ages. In the present study, it was still possible to identify the last interglacial period (80–130,000) as well as an older interglacial (>150,000 years) and the Holocene (<10,000 years) in spite of Katzenberger's objections.

According to GRÜN (in press) there are generally three error sources that influence an ESR age. These are (1) systematic errors, *e.g.* source calibration and applied curve fitting, (2) errors due to detection limits, *e.g.* reproducibility of signal intensity or chemical analyses and (3) interferences of post sedimentary diagenetic processes such as crystallization or U and Th migration. Therefore, the individual error is

*g = spectroscopic splitting factor or g (values) difficult to estimate. GRÜN (in press) suggests carrying out replicate analysis on samples from the same geological unit and comparing these results with independent dating methods. The precision of repeated analyses, which gives evidence on diagenetic processes which cannot be simulated in the laboratory, is in the range of 15% to 20% for mollusc shells. Holocene ESR ages display a higher error, because of the small signal height which is masked by background noise, thus generally representing maximum ages.

The following procedures were used in preparing ESR samples. The samples were crushed and the 100–400 micron fraction was used for measurements. Neither grinding nor light effects were observed. The measurements were carried out by a Bruker 200 tt ESR spectrometer at a microwave frequency of about 9.5 Ghz and a magnetic field strength of about 3400 mT. The microwave power was 2 mW, the modulation amplitude 0.5 G_{pp} and the magnetic field scan was about 1 mT min^{-1}. Table 1 shows the ESR data.

Table 1. *ESR sample locations, analytical data and ages.*

Area	Location Number	Sample Number	Genus
San Blas	A-5a	D-1194-a	Mytilus sp.
San Blas	A-5a	D-1194-b	Mytilus sp.
San Blas	A-5b	D-1125-a	Pitar sp.
San Blas	A-5b	D-1125-b	unidentified
San Blas	A-5b	D-1125-c	unidentified
San Antonio Oeste	A-8	D-1126-a	unidentified
San Antonio Oeste	A-8	D-1126-b	unidentified
San Antonio Oeste	A-8	D-1196-a	Macrocallista sp.
San Antonio Oeste	A-8	D-1196-b	Macrocallista sp.
San Antonio Oeste	A-10	D-1198-a	unidentified
San Antonio Oeste	A-10	D-1198-b	venerid sp.
San Antonio Oeste	A-13	D-1127-a	unidentified
San Antonio Oeste	A-13	D-1127-b	unidentified
San Antonio Oeste	A-13	D-1127-c	Mytilus sp.
San Antonio Oeste	A-14	D-1201-a	Glycymeris sp.
San Antonio Oeste	A-14	D-1201-b	Glycymeris sp.
San Antonio Oeste	A-15	D-1202-a	Macrocallista sp.
San Antonio Oeste	A-15	D-1202-b	Macrocallista sp.
San Antonio Oeste	A-16	D-1203-a	Voluta sp.
San Antonio Oeste	A-16	D-1203-b	Macrocallista sp.
San Antonio Oeste	A-16	D-1128-a	Macrocallista sp.
Caleta Valdes	A-17	D-1129-a	unidentified
Caleta Valdes	A-17	D-1129-b	Mytilus sp.
Caleta Valdes	A-17	D-1129-c	unidentified
Caleta Valdes	A-19	D-1205-a	Pelecypoda
Caleta Valdes	A-19	D-1205-b	Pelecypoda
Bahia Bustamante	A-21	D-1206-a	Protothaca sp.
Bahia Bustamante	A-21	D-1206-b	unidentified
Bahia Bustamante	A-23	D-1208-a	Protothaca sp.
Bahia Bustamante	A-24	D-1130-a	Protothaca sp.
Bahia Bustamante	A-24	D-1130-b	Protothaca sp.
Bahia Bustamante	A-24	D-1209	unidentified
Bahia Bustamante	A-24	D-1210-b	Protothaca sp.
Bahia Bustamante	A-24	D-1211-b	unidentified
Bahia Bustamante	A-24	D-1211-c	Protothaca sp.
Bahia Bustamante	A-25	D-1212-a	unidentified
Bahia Bustamante	A-25	D-1212-b	venerid sp.
Bahia Bustamante	A-26	D-1131-a	Eurhomalea sp.
Bahia Bustamante	A-28	D-1214-a	unidentified
Bahia Bustamante	A-28	D-1214-b	unidentified
Bahia Bustamante	A-31	D-1218-b	unidentified
Puerto Deseado	A-32	D-1219-d	unidentified
Puerto Deseado	A-33	D-1220-a	Mytilus sp.
Puerto Deseado	A-33	D-1220-b	unidentified
Puerto Deseado	A-34	D-1221	Mytilus sp.

AMINO ACID RACEMIZATION

As a first approximation of the number and the distribution of equivalent shorelines along the Patagonian coast, D/L ratios of aspartic acid and leucine of molluscs were utilized, in conjunction with traditional geomorphic and stratigraphic methods. In order to avoid erroneous interpretation from reworked specimens, whole shells believed to be in living position were used in most cases. D/L ratios of other amino acids, such as valine, alanine, proline, glutamic acid and phenylalanine were also determined. The D/L ratios of a variety of species from the same sampling site were evaluated because the same variety of molluscs was not always found at all sampling sites of varying age. In other words, relative ages were determined from a number of species, not from just one form.

Variation in D/L ratios of amino acids of different genera of the same age have long been recognized (WEHMILLER, 1980). In addition, variations of D/L ratios in different parts of a single specimen can be found. In our study we compare and utilize a variety of species of several genera of bivalves and gastropods. We recognize and expect that there will be variations of D/L ratios of amino acids for different species and within species of the same age. For a more complete discussion of this problem, see RUTTER *et al.* (1989). However, it was anticipated that the variation would not be enough to mask trends or groupings of D/L ratios between species of considerable age differences. It would be desirable to compare the different rates of racemization of each species when analyzing D/

Table 1. *Continued.*

Thickness (mm)	Uranium Content Sample (ppm)	U-Content (ppm)	Th-Content (ppm)	K-Content (%)	Accumulated Dose (Gy)	(mGy/a)	Annual Dose (mGy/a)	(mGy/a)	ESR age (Yrs. BP)
0.95	1.70	3.00	7.00	1.45	234.00	0.3480	0.7591	1.0605	108.000
1.30	1.54	3.00	7.00	1.45	203.20	0.3190	0.6031	1.0605	102.000
3.90	1.89	3.00	7.00	1.45	152.30	0.4302	0.1225	1.0605	94.500
2.00	1.46	3.00	7.00	1.45	136.30	0.2918	0.3602	1.0605	79.600
3.20	2.95	3.00	7.00	1.45	135.20	0.5943	0.2060	1.0605	72.700
4.40	0.29	2.00	5.00	0.94	72.70	0.0654	0.0586	0.7170	86.500
3.90	0.36	2.00	5.00	0.94	78.10	0.0798	0.0861	0.7170	88.500
3.10	0.90	2.00	5.00	2.08	130.20	0.1918	0.1959	1.1781	83.200
4.10	0.58	2.00	5.00	2.08	140.00	0.1337	0.1285	1.1781	97.300
3.80	2.13	2.00	6.00	2.00	280.60	0.5987	0.1079	0.9502	≥ 169.000
5.40	1.72	2.00	6.00	2.00	335.40	0.5359	0.0529	0.9502	≥ 218.000
4.50	2.39	3.00	6.00	1.62	410.50	0.7235	0.1211	1.1326	≥ 208.000
3.20	2.11	3.00	6.00	1.64	437.00	0.6485	0.1940	1.0575	≥ 230.000
0.60	1.56	3.00	6.00	1.62	567.80	0.3949	1.0579	1.1326	≥ 220.000
3.70	1.16	3.00	7.00	3.10	139.90	0.2284	0.3216	1.5474	66.800
3.90	1.13	3.00	7.00	3.10	144.70	0.2277	0.2829	1.5474	70.300
3.60	0.92	2.00	6.00	2.30	149.10	0.2032	0.2328	1.2022	91.000
3.40	1.00	2.00	6.00	2.30	180.10	0.2339	0.2477	1.2022	107.000
2.20	0.82	2.00	7.00	2.32	225.00	0.2247	0.4290	1.3669	111.000
3.60	0.70	2.00	7.00	2.32	170.70	0.1585	0.2070	1.3669	96.000
0.45	0.84	2.00	7.00	1.98	246.40	0.1473	1.3006	1.2831	90.200
4.30	1.28	2.00	7.50	1.98	255.60	0.3459	0.1539	1.1880	151.000
1.40	0.80	2.00	7.50	1.98	88.50	0.1241	0.6229	1.1880	45.800
2.40	1.45	2.00	7.50	1.98	157.90	0.3050	0.3136	1.1880	87.400
5.00	2.16	4.00	11.00	2.53	202.30	0.4669	0.2308	1.7641	82.200
6.70	2.26	4.00	11.00	2.53	193.80	0.4960	0.1237	1.7641	81.400
3.20	0.39	2.00	11.00	2.55	12.20	0.0457	0.2351	1.5928	6.510
2.70	3.00	2.00	11.00	2.66	11.70	0.0339	0.3560	1.6200	5.820
5.50	0.28	3.00	9.00	3.10	17.20	0.0357	0.1095	1.7770	8.950
4.50	1.20	3.00	3.00	1.36	210.20	0.3206	0.1264	0.9891	146.000
3.50	1.28	3.00	3.00	1.36	202.40	0.3333	0.1478	0.9891	138.000
4.30	1.06	2.00	2.00	0.66	208.10	0.3126	0.0751	0.6786	≥ 195.000
5.60	1.18	3.00	4.00	1.80	215.80	0.3151	0.0834	1.1574	139.000
2.20	0.40	3.00	7.00	2.32	230.10	0.0929	0.4631	1.4250	116.000
5.70	1.50	3.00	7.00	2.32	266.20	0.3973	0.1162	1.4250	137.000
2.80	1.30	2.00	5.00	1.33	474.90	0.4315	0.1373	0.9932	≥ 305.000
3.70	1.49	2.00	5.00	1.33	357.60	0.4652	0.0918	0.9932	≥ 231.000
4.40	0.77	2.00	5.00	1.07	462.40	0.2685	0.1029	0.9291	≥ 356.000
3.20	1.68	2.00	8.00	3.15	517.80	0.5071	0.3003	1.5614	≥ 219.000
4.30	2.29	2.00	8.00	3.15	543.20	0.7057	0.1947	1.5614	≥ 221.000
0.70	3.00	2.00	7.00	0.14	624.00	0.8725	0.2966	0.7393	≥ 328.000
1.10	0.10	2.00	6.00	1.91	462.00	0.0280	0.7271	1.1560	≥ 242.000
1.10	1.00	0.50	2.00	0.03	291.60	0.3254	0.0592	0.2668	≥449.000
3.70	1.00	0.50	2.00	0.03	265.40	0.3592	0.0149	0.2668	≥415.000
1.10	0.50	2.00	2.00	1.00	8.800	0.0496	0.4255	0.7924	6.940

L ratio data, but this information is available for only three of the 15 species used.

An estimation of absolute ages of littoral zones were made by comparing the D/L ratios from this study with D/L ratios of known ages from other investigations and by adopting non-linear kinetic models developed by others (WEHMILLER and BELKNAP, 1982). D/L ratios were compared with radiocarbon dates on Holocene beaches where they were judged to be accurate, and then extrapolated to undated Holocene beaches. Radiocarbon dates available for older beaches are suspect for the following reasons: (1) Most samples were determined on a liquid scintillation counter at the University of Buenos Aires. A high pressure counter would have probably extended the dates beyond the limit of radiocarbon dating; (2) the oldest dates do not consistently date what are believed by other criteria, such as position above sea level, to be the oldest deposits in the area; (3) the high amino acid ratios are judged to indicate much older ages than those of the older finite ^{14}C dates, and (4) dates on what are believed to be Quaternary deposits associated with the highest sea level rise so far identified in the area, isotope stage 5e or older, are much too young.

More than 200 samples were prepared as outlined in RUTTER *et al* (1979), using acidified ethanol and pentafluoropropionic anhydride to derivatize the purified amino acids obtained from the shell samples. Each sample was prepared only once, unless it was found to be too weak to analyze and then it was prepared a second or third time with greater mass of shell. This was usually a necessary procedure with older samples.

The amino acids were separated by Gas Chromatography using a Chirasil-Val capillary column, with a temperature program that ensured baseline resolution between the aspartic acid D and L peaks on the chromatogram. The standard mixture was analyzed daily, the D/L ratios calculated and, if necessary, the temperature program was adjusted to produce standard ratios between 0.9800 and 1.0500. Accuracy of instrument performance was tested by analyzing an interlaboratory shell standard and our own standards. The ratios were found to be within the expected range.

Each sample preparation was analyzed three times. The D/L ratios for up to seven amino acids were calculated by dividing the computer integrated peak areas and then dividing by the standard ratio to adjust for fluctuations in instrument performance. It was not possible for the integrator to calculate accurate peak areas for all amino acids in each sample. Shells with greater amounts of threonine deterioration showed interference with alanine peaks. Shells with a greater concentration of serine, proline, glycine, isoleucine, threonine and possibly bacterial amino acids such as β-alanine, produced chromatograms with peaks obscuring the D-leucine peak. Valine converts from the L form to the D form very slowly, so the D peak is very small compared to the rest of the chromatogram and is susceptible to baseline disturbances, and crowding by larger peaks. The most suitable amino acid was aspartic acid which eluted in an isolated position on the chromatogram, and often occurred in higher concentration than the other amino acids. Leucine is reported also, although the ratios are not as consistent as aspartic acid because of poorer chromatographic separation. The main use of the leucine ratios is to compare with the results of others, such as WEHMILLER and BELKNAP (1982), in order to utilize their non-linear kinetic models based upon leucine racemization. For each amino acid D/L ratio determined, the mean and standard deviation were calculated for the three runs.

AREAS INVESTIGATED AND RESULTS

San Blas

Setting. The village of San Blas is located about 230 km east of San Antonio Oeste and about 200 km south of Bahia Blanca on Isla del Jabali. The area is characterized by a broad, relatively low relief setting consisting of littoral sands and gravels and wind-blown dune sand, with elevations varying from about 4 to 12 m above mean sea level (Figure 2).

On the basis of morphological expression and elevations, WITTE (1916) defined a five stepped coastline: Stages I, II and III of Pleistocene age and Stages IV and V of Holocene age. The term "stage" was used by WITTE (1916). The deposits consist of sand, gravel and abundant marine fossil remains. Stages I and II represent poorly defined coastlines with altitudes of > 8 m above mean sea level whereas Stages III and IV represent well defined marine terraces at about 2 and 8 meters above mean sea level respectively. Stage V represents modern beaches.

Recently TREBINO (1987) analyzed the principal features of the San Blas area. He recognized three levels of marine terraces. The youngest terrace (Level III) is at about 3 m above mean sea level and yielded radiocarbon ages between 2,170 ± 110 and 3,450 ± 110 years BP. The remaining two, of Pleistocene age, are at about 10–11 m (Level II) and 12–14 m (Level I) above mean sea level. He also mentioned beach ridges at Isla del Jabali, 7 m high, dated at 4100 and 5370 years BP. Towards the west, undifferentiated mollusc remains yielded radi-

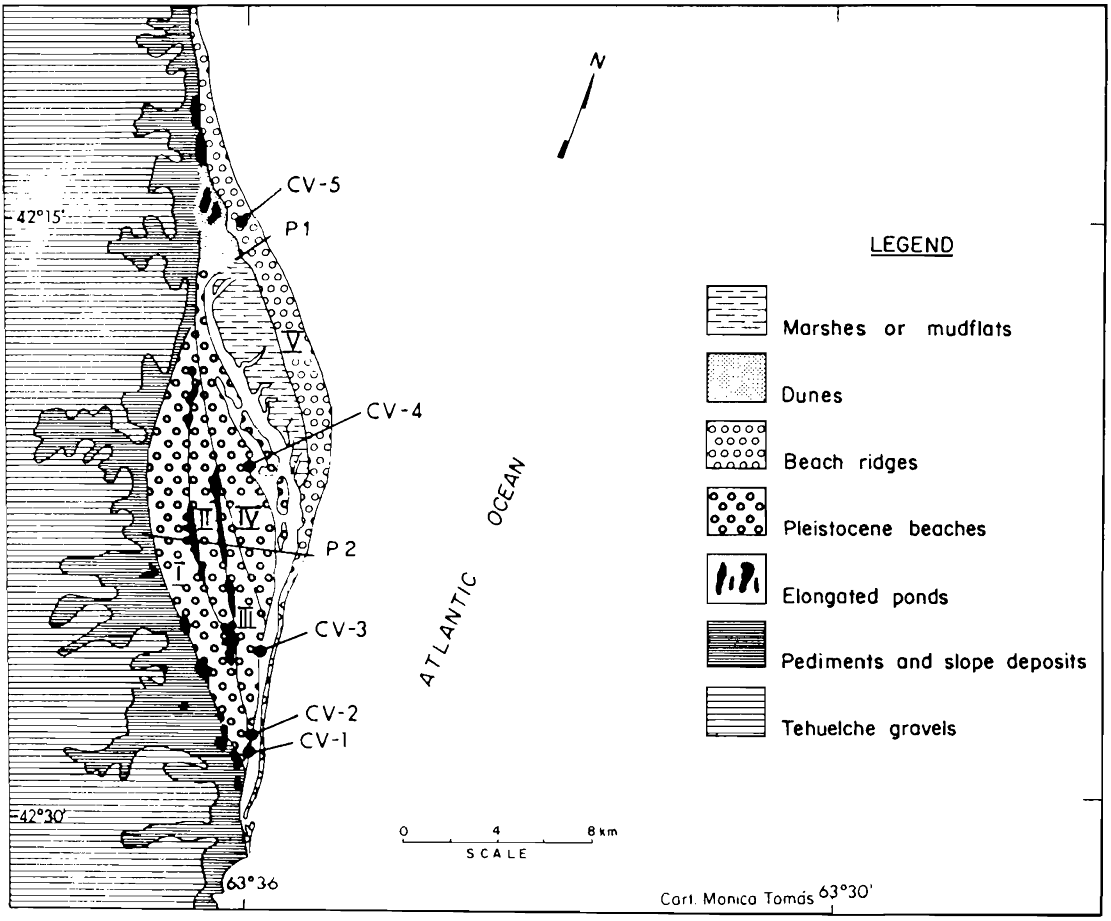


Figure 2. Geological and site location map, San Blas area.

ocarbon ages between 28,400 and 29,120 years BP. These samples were from fossil spits at about 9–10 m above mean sea level.

The ESR sample sites are at Faro Segunda (A-5a and A-5b), 26 km south of the village of San Blas (Figure 2). A wave cut cliff displays about 9 meters of section above the modern beach. The section consists of loess containing a paleosol, and over 6 m of well sorted and bedded beach gravels with some sand, that overlies bedrock. Molluscs are found along distinct beds at several stratigraphic positions within the section. Samples for ESR dating were taken from two horizons in the lower part of the section where whole shells in living positions were embedded in sand. Horizon A-5b is about ½ meter from the base of the section whereas A-5a is located about one meter above A-5b.

Results. ESR ages of 102,000 and 108,000 years BP were derived from A-5a and ages of 72,700, 79,600 and 94,500 years BP from A-5b (Figure 3). It should be noted that the older dates are from the stratigraphically higher position. However, their position leaves little doubt that the samples are from the same stratigraphic unit and should be very close to the same age. The samples from A-5a were derived from *Mytilus sp.* and the 94,500 year BP age at A-5b from *Pitar sp.* whereas the others are from unidentified shells. These dates fall within the "intermediate age" range that were obtained in

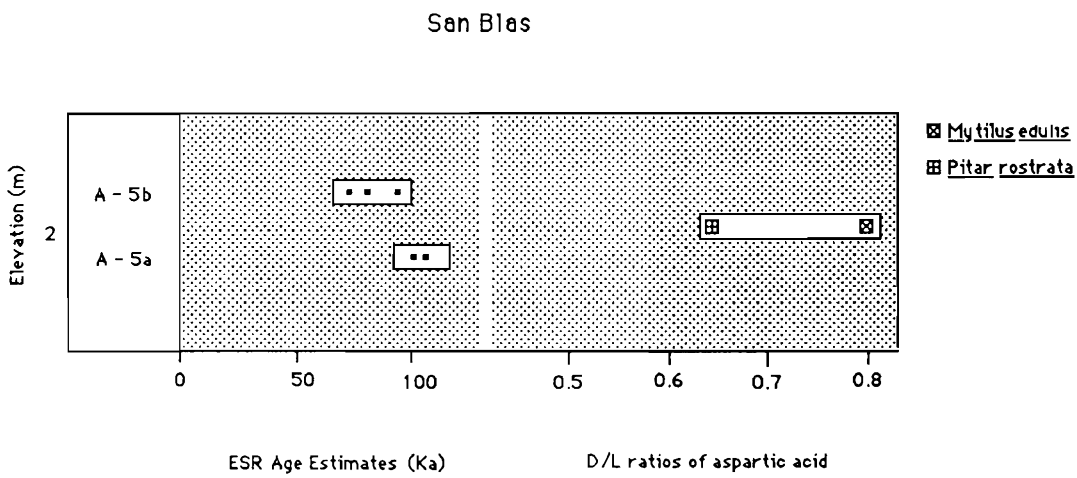


Figure 3. Plot of ESR age estimates and D/L ratios of aspartic acid of each mollusc species according to site location, San Blas area.

other areas in the course of this study. They are interpreted as sediments that were deposited during the last interglacial period, isotope stage 5e, when sea levels were higher.

D/L ratios of aspartic acid were obtained from shells from near the same horizon as A-5a. Ratios of .65, and .80 were derived from *Mytilus edulis* and *Pitar rostrata* respectively (Figure 3). Based upon comparative D/L ratios, geomorphology and stratigraphy in other locations, these ratios were interpreted as some of the oldest deposits along the Patagonian coast and therefore, pre-last interglacial (RUTTER *et al.*, 1989). This interpretation is at variance with the ESR age estimates that suggest a younger age.

San Antonio Oeste

Setting. San Antonio Oeste on San Antonio Bay lies at the head of San Matias Gulf about 330 km southeast of Bahia Blanca (Figure 4). The bay represents one of the common Patagonian embayments flooded repeatedly by marine transgressions. During these transgressions beach ridges were constructed, spits developed and wind and wave-induced currents formed littoral barriers. The Holocene drop in sea level left emergent tidal flats, marshes, and large sand banks flanking the main ebb channel.

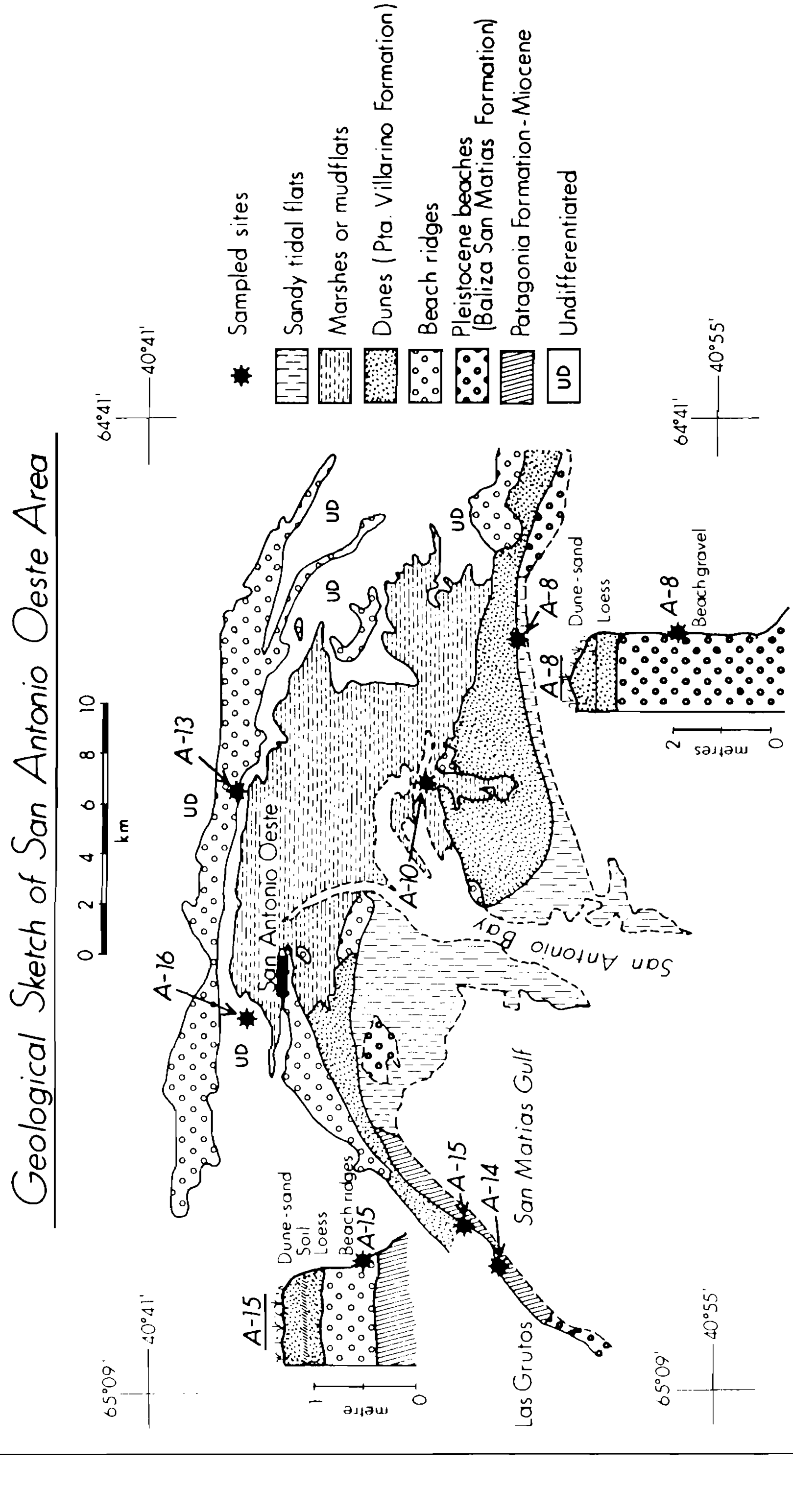
Between 10 and 12 m above mean sea level, FERUGLIO (1950) found sands and gravels with molluscs similar to extant species in the peninsula where the city of San Antonio Oeste is situated, and on the peninsula east of the Bay. Because the molluscs are similar to living ones, the deposits were thought to be post glacial.

ANGULO *et al.* (1979) recognized two different lithostratigraphic units: Baliza San Matias (Pleistocene) and San Antonio (Holocene) Formations. The Pleistocene deposit is typically a conglomerate with shells in a muddy matrix, whereas the Holocene unit forms distinct beach ridges composed of gravels in a sandy matrix. However, the San Antonio Formation yielded radiocarbon ages older than 27,000 years BP (FIDALGO *et al.*, 1980).

During the 1984 IGCP Project-200 field meeting, San Antonio outcrops were visited. Discussion centered upon the reliability of the radiocarbon dates and the degree of $CaCO_3$ cement coating the pebbles in supposedly Holocene sediments. Many thought that too much cementation had taken place for them to be Holocene (PIRAZZOLI and SCHNACK, 1985).

The area provided many sampling sites. Two sites, assumed to be equivalent in age are located on abrasion platforms below mean sea

Figure 4 (*facing page*). Geological and site location map, with selected sections, San Antonio Oeste area. (Modefied, after Angulo *et al.*, 1979.)


Geological Sketch of San Antonio Oeste Area
0 2 4 6 8 10
km
Sampled sites
Sandy tidal flats
Marshes or mudflats
Dunes (Pta. Villarino Formation)
Beach ridges
Pleistocene beaches (Baliza San Matias Formation)
Patagonia Formation-Miocene
Undifferentiated
UD
64°41'
40°41'
40°55'
65°09'
A-16
A-13
A-10
A-8
A-15
A-14
San Antonio Oeste
San Antonio Bay
San Matias Gulf
Las Grutas
Dune-sand
Soil
Loess
Beach ridges
Beach gravel
metre
metres
0
1
2

level, at Caleta Falsa, A-10, and Las Grutas, A-14 (Figure 4). Whole shells were collected from highly indurated sand and beach pebbles.

Most other sites are between 8–12 m above mean sea level. At A-8, Baliza San Matias, the section lies about 11 m above mean sea level and consists of sand dunes with anthropogenic middens that overlie up to 1.5 m of loess over a thick sequence of beach gravels. The beach gravels dip to the northwest, are well to moderately sorted, and consist mostly of pebbles between 2–4 cm diameter with a sand and silt matrix. Archaeological middens, which have been ^{14}C dated at about 2000 years BP, form the upper part of the beach gravels. Another location between 8–12 m above mean sea level is A-15, La Rinconada (on the west side of San Matias Gulf). Here, a 50 cm section of beach gravels overlies a marine platform and underlies a soil developed in silt and fine sand (loess?) under sand dunes. Whole shells were collected from the beach gravels.

Two sites are located away from the coast. A-13, Baliza Camino, is about 24 m above mean sea level. Whole mollusc shells were collected from beach gravels that are overlain by reworked loess. The other site, A-16, is located on beach ridges, at elevations between 8 and 12 m above mean sea level.

Results

Results of ESR ages from various locations in the San Antonio Oeste area indicate three broad age groups (Figure 5). The oldest dates, which are considered minimum, are ≥ 169,000 years BP (unidentified mollusc); ≥ 218,000 years BP (*Venerid sp.*) taken from A-10, Caleta Falsa at sea level; ≥ 208,000 years BP (unidentified mollusc); ≥ 230,000 years BP (unidentified mollusc), and ≥ 220,000 years BP (*Mytilus sp.*) taken at A-13, Baliza Camino at about 24 m elevation. Intermediate aged samples were all derived from units all at about 10 m elevation. At A-16, about 2 km northwest of San Antonio Oeste, dates of 90,200 years BP (*Macrocallista sp.*), 96,000 years BP (*Macrocallista sp.*) and 111,000 years BP (*Voluta sp.*) were obtained. At A-8, Baliza San Matias, molluscs yielded ages of 86,500 years BP (unidentified mollusc); 88,500 years BP (unidentified mollusc); 83,200 years BP (*Macrocallista sp.*), and 97,300 years BP (*Macrocallista sp.*). At A-15, La Rinconada, shells derived from beach gravels yielded dates of 91,000 years BP (*Macrocallista sp.*) and 107,000 years BP (*Macrocallista sp.*). The youngest ages were from A-14, Las Grutas, where beach rock is exposed at mean sea level. *Glycymeris sp.* yielded dates of 66,800 years BP and 70,300 years BP. The oldest dates are interpreted as

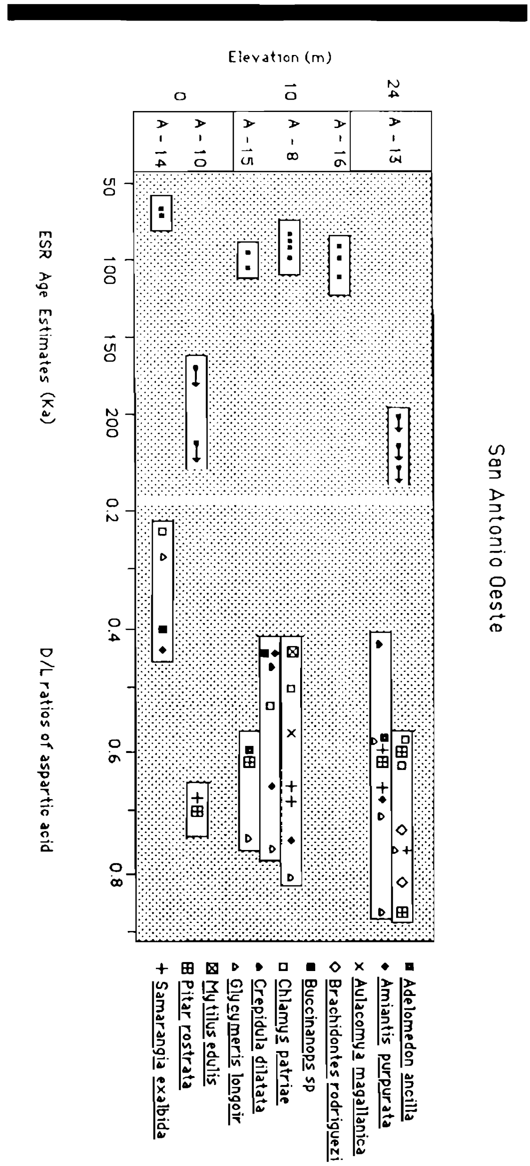


Figure 5. Plot of ESR age estimates and D/L ratios of aspartic acid of each mollusc species according to site location, San Antonio Oeste area.

the penultimate interglacial or older, the intermediate ages the last interglacial (isotope stage 5e), and the youngest as late glacial.

There is a reasonable relationship between the ESR dates and those estimated by the D/L ratios of aspartic acid derived from various molluscs in the same unit and commonly in the same horizon (Figure 5). The amino acid results show relatively old groupings with high ratios at A-13 and A-10, the same as the ESR ages. Although not as convincing, the same can be interpreted for the samples dated at A-8 and A-15 if the mean of the D/L ratios are considered or when D/L ratios of certain individual species are compared. Here, the ratios are lower and are considered last interglacial. The D/L ratios and ESR ages compare well at location A-14 where both are convincingly lower than the other age estimates. Prior to the present study, however, the amino acid ratios were judged to be Holocene in age even though the mean ratios were somewhat higher than those considered Holocene in other areas along the coast (RUTTER *et al.*, 1989).

Caleta Valdes

Setting. Caleta Valdes is located on the east coast of Peninsula Valdes about 230 km southeast of San Antonio Oeste. The area consists of a series of northwest-southeast trending beach ridges flanked on the west by a pediment below the Patagonian plateau (Figure 6). The beach deposits are typically pebbly, with the younger ridges truncating the older and displaying a well developed set of ridges.

The first reference on the littoral environments of Caleta Valdes was made by ROVERETO (1920). He described two beach ridges with difference in elevation of 5 m, one due to old tidal action and the other related to present tidal conditions. He believed the difference in altitude was due to eustatic sea level change, or to a lesser extent, variation in wave energy caused by less frequent winds from the south and southeast during the late Pleistocene. FERUGLIO (1950) published a list of bivalves and gastropods from the lowest raised beach ridge at Punta Norte.

Five beach ridges have been more recently identified, although identification is tenuous because the four highest are roughly at the same elevation, varying between about 26 and 28 m above mean sea level (FASANO *et al.*, 1983). They are separated on freshness of morphology and minor elevation differences. The highest beach, locally called System I, reaches over 35 m, dropping to about 26 m on the seaward edge, which is about the same elevation as Systems II, III and IV. The youngest raised beach, System V, is between 8 and 14 m above mean sea level.

Samples for ESR age estimates were taken from Systems III and IV. At A-17, shells in living position as well as bits and pieces of shell were collected from within three meters of System III surface. Further to the north, at A-19, a variety of molluscs, both broken and whole, were collected from well developed and "fresh" looking beach ridges of System IV. Although elevations of System IV ridges are similar to the older systems, the ridges are less subdued, and display higher amplitudes than the others.

Results

Ages of 45,800 years BP (*Mytilus sp.*), 87,400 BP (unidentified mollusc) and 151,000 years BP (unidentified mollusc) were determined from System III beach gravels at A-17 (Figure 7). The ages are suspect because of the wide range of ages and diverse material dated. However, the older ages are favored because of the geological setting and comparison with the amino acid ratio data. Therefore, A-17 samples are considered to date from the penultimate interglaciation. The ages derived from A-19, on System IV beach ridges, are 81,400 years BP (Pelecypoda) and 82,200 years BP (Pelecypoda). The ages suggest that System IV beach ridges were formed during the last interglacial.

The relatively high D/L aspartic acid ratios determined for various mollusc shells from System III beach gravels, were interpreted to represent relatively old deposits—the penultimate or older interglacial (Figure 7). Although the ESR dates don't fully support this interpretation, geological and amino acid data are judged to be more reliable. The D/L ratios support the ESR ages for the molluscs collected at A-19, or System IV beach ridges. These are interpreted to represent the last interglacial.

Bahia Bustamante

Setting. Bahia Bustamante is located in east central Patagonia, about 100 km northeast

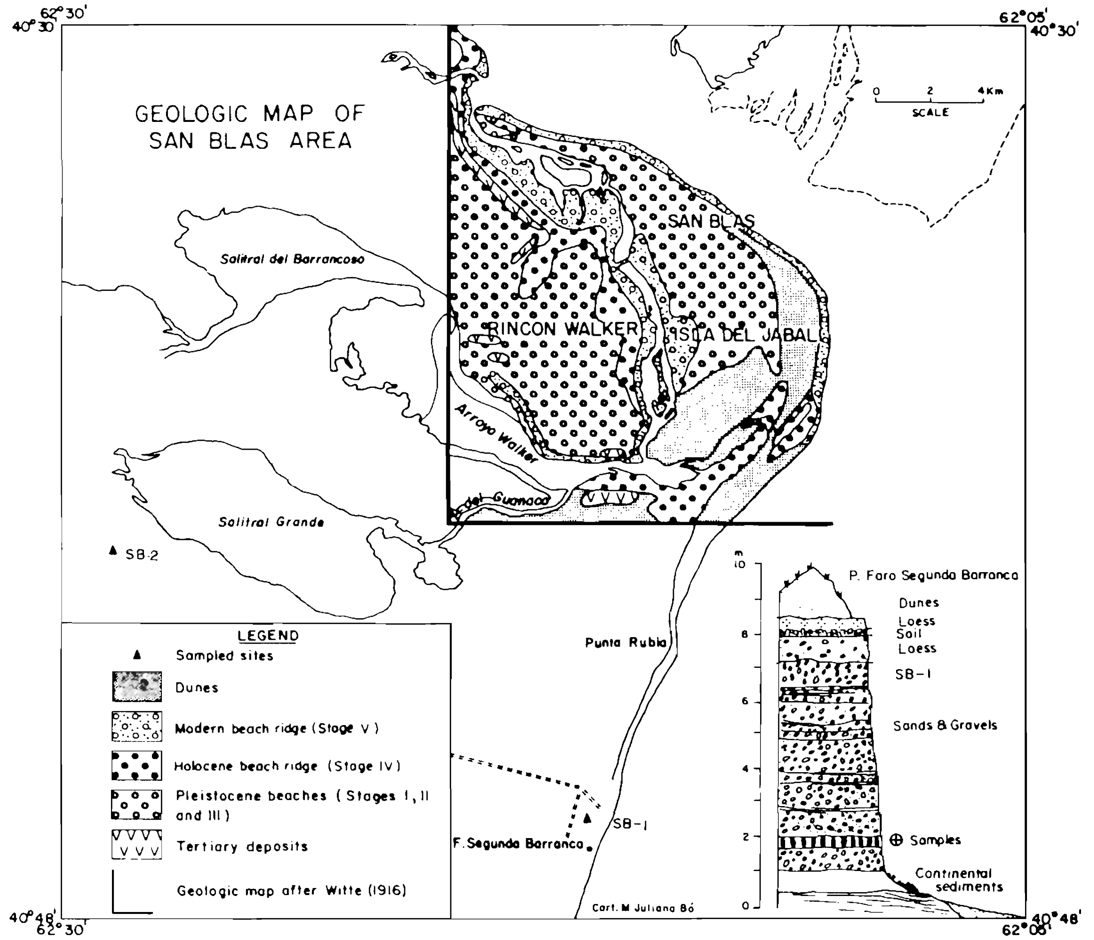


Figure 6. Geological and site location map, Caleta Valdes area, (after Fasano *et al.*, 1983)

of Comodoro Rivadavia (Figure 8). The area consists of an irregular shoreline with many peninsulas and bays. Coastal features include gravel beach ridges, dunes, marshes, and abrasion platforms.

Three systems of Quaternary beach ridges have been distinguished by morphological characteristics, degree of consolidation of sediments, development of drainage networks and elevations (FERUGLIO, 1950). CIONCHI (1983) named them as Systems I, II and III respectively, each related to a transgressive event. In the most landward system (I), between 50 to 1000 m from the coast, there is a series of littoral ridges forming a band with a maximum width of 2,500–3,500 m and reaching a height of 34–41 m above mean sea level. They display a high degree of erosion, are masked by younger detrital material, and consist of sediments with a fairly high degree of consolidation.

The second system (II), below and seaward to System I, consists of a series of ridges, 25–29 m above mean sea level, displaying more pronounced relief and less consolidated material than System I. These ridges are at variable distances from the coast: 2,000 to 3,000 m in the north and next to the coast at Caleta Malaspina. The pattern of this system parallels the present coastline.

The lowermost system (III) is attached to present beach gravels. Their ridges usually reach heights of 8–10 m above present mean

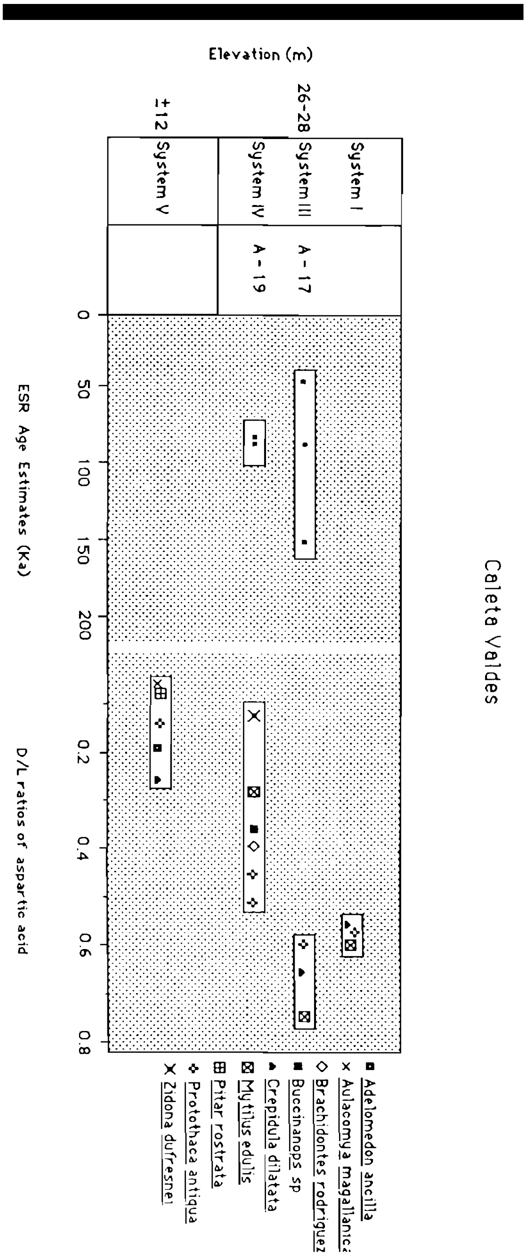


Figure 7. Plot of ESR age estimates and D/L ratios of aspartic acid of each mollusc species according to site location, Caleta Valdes area.

sea level and are composed of loose sediments, and features typical of modern beaches.

Although there are no radiocarbon dates reported from the immediate area, there are dates available for shells from beaches thought to be equivalent from other areas. Samples collected by CODIGNOTTO (1983, 1984) yielded dates of 36,900 ± 2,000 years BP and 37,300 ± 2,400 years BP for the oldest beaches; 30,900 ± 1,100 and 31,800 ± 1,400 years BP for the intermediate beaches and 2,030 ± 85 and 2,880 ± 90 years BP for the youngest.

In the Bahia Bustamate area, four areas were sampled. The sediments consist, in general, of poorly to well sorted beach gravels. Most pebbles are between 2 and 4 cm in length. Shells are abundant in all locations, both broken and whole. Some were collected from near the surface in beach ridges whereas others were collected from sections well below the surface.

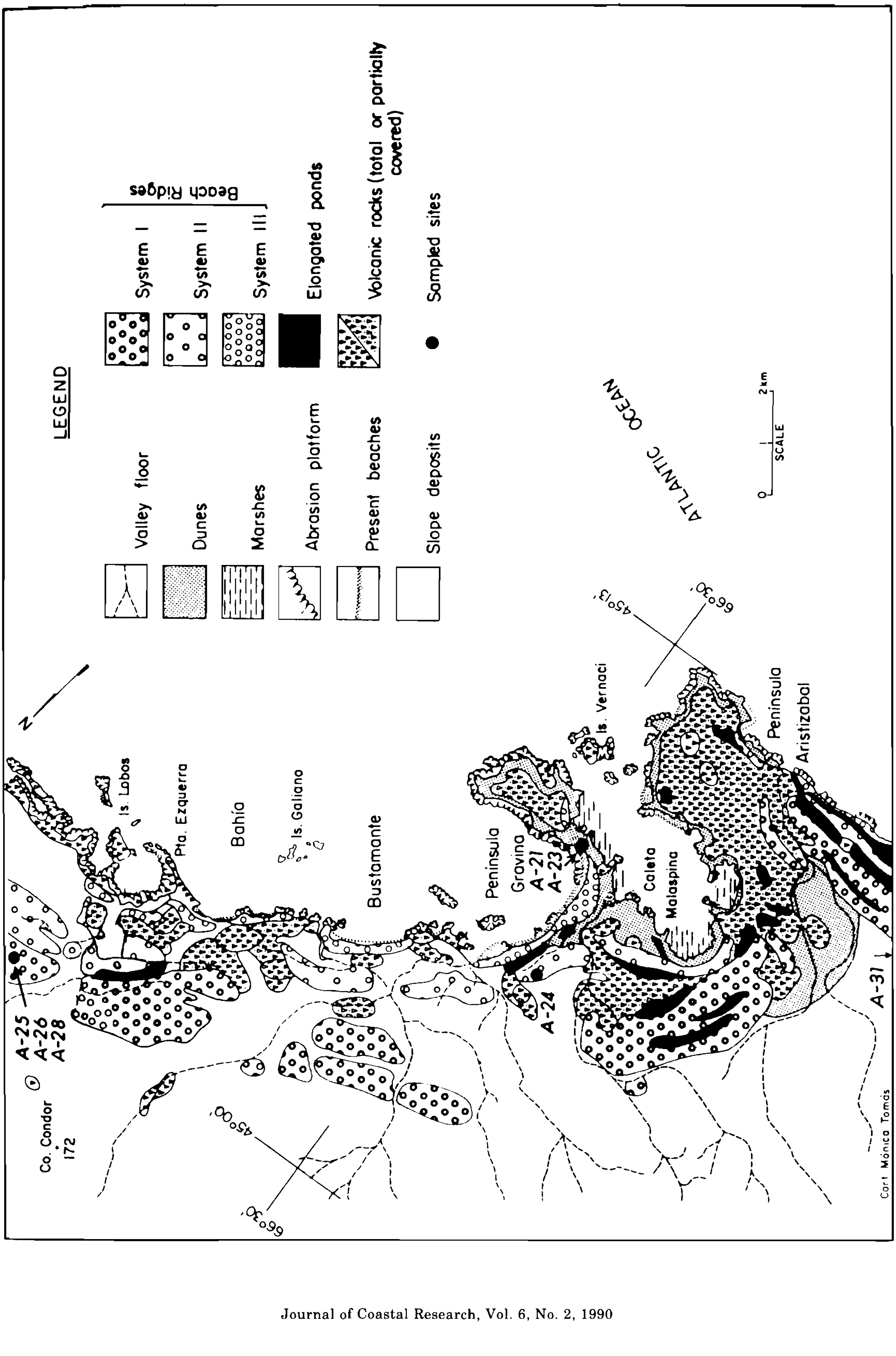
At localities A-25, 26, and 28, a quantity of molluscs were collected from System I beach surfaces between 34 and 41 m above mean sea level. A-31 is located in System I beach gravels beyond the immediate area about 1 km southeast of the arrow at the base of the map (Figure 8). At A-24, several molluscs in living position were collected from a 2 m section of beach gravels from the intermediate, 25–29 m, elevation level (System II) (Figure 9). At A-21, and A-23, on System III beach gravels, 8–10 m above mean sea level, molluscs were collected from the surface or one or two meters below the surface.

Results

ESR age estimates from System I beach ridges (A-25, 26, 28) in the northern part of the area of interest are ⩾ 219,000 years BP (unidentified mollusc), ⩾ 221,000 years BP (unidentified mollusc), ⩾ 231,000 years BP (*Venerid sp.*), > 305,000 years BP (unidentified mollusc) and ⩾ 356,000 years BP (*Eurhomalea sp.*) (Figure 10). At A-31, located at similar elevation and considered to be part of System I, beach ridges in the southern part of the area yielded an age of ⩾ 328,000 years BP (unidentified mollusc). These ages are relatively consistent and indicate that System I beach ridges represent the oldest deposits in the area, from the penultimate interglacial or older.

At location A-24, a series of age estimates were derived from several molluscs from beach gravels that are considered from elevation, geomorphology and stratigraphy to be part of the

Figure 8 (*next page*). Geological and site location map, Bahia Bustamante area, (after Cionchi, 1983).


LEGEND
Valley floor
Dunes
Marshes
Abrasion platform
Present beaches
Slope deposits
System I
System II
System III
Beach Ridges
Elongated ponds
Volcanic rocks (total or partially covered)
Sampled sites
ATLANTIC OCEAN
0
SCALE
2 km
N
Co. Condor
172
A-25
A-26
A-28
Is. Lobos
Pta. Ezquerra
Bahía
Is. Galiano
Bustamante
Peninsula
Gravina
A-21
A-23
A-24
Is. Vernaci
Caleta
Malaspina
Peninsula
Aristizabal
A-31
45°13'
66°30'
45°00'
66°30'
Cart. Mónica Tomás

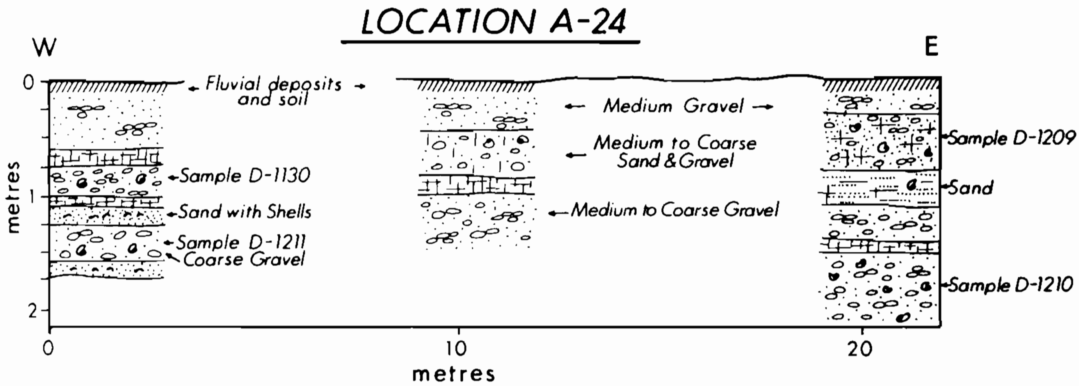


Figure 9. Cross sections of location A-24, Bahia Bustamante area.

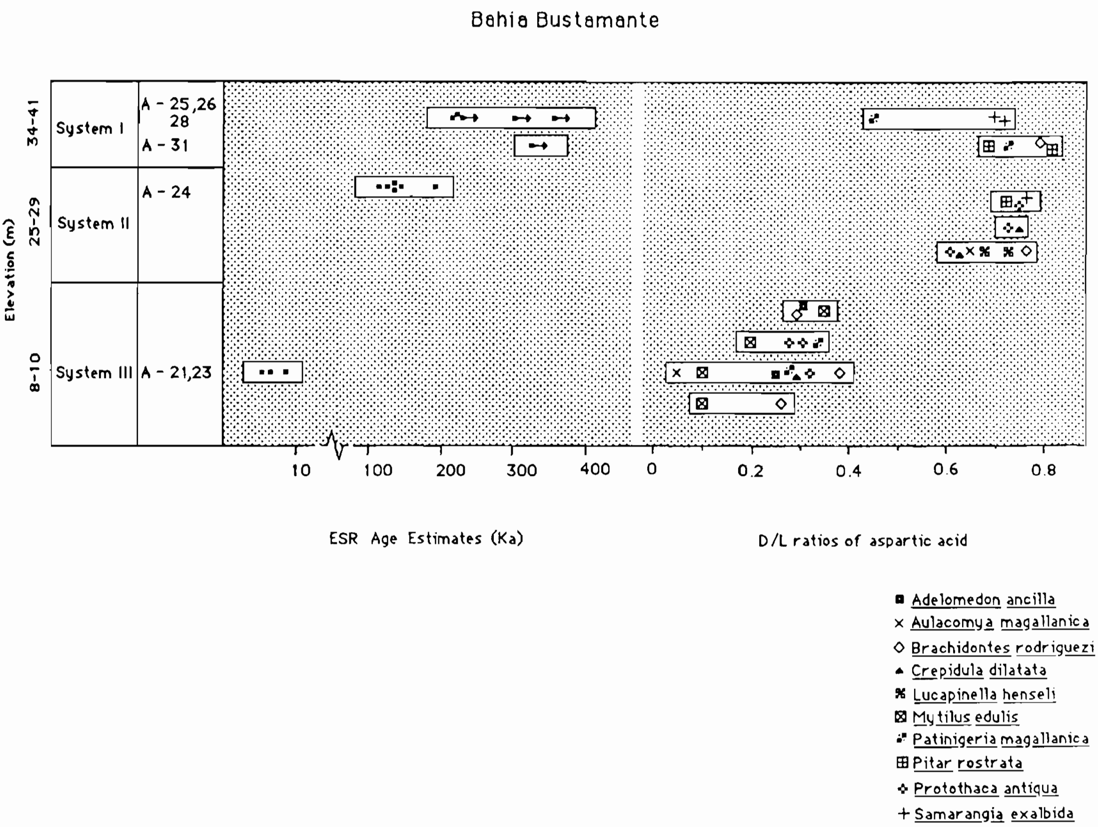


Figure 10. Plot of ESR age estimates and D/L ratios of aspartic acid of each mollusc species according to site location, Bahia Bustamante area.

System II beach ridges. Age estimates are 116,000 years BP (unidentified mollusc), 137,000 years BP (*Protothaca sp.*), 138,000 years BP (*Protothaca sp.*), 139,000 years BP (*Protothaca sp.*), 146,000 years BP (*Protothaca sp.*), and ≥ 195,000 years BP (unidentified mollusc). These are remarkably consistent and demonstrate conclusively that System II beach ridges are younger than those of System I and most likely represent the last interglacial.

Age estimates for System III beach ridges were made from molluscs collected at locations A-21 and A-23. Ages are 5,820 years BP (unidentified mollusc), 6,510 years BP (*Protothaca sp.*), and 8,950 years BP (*Protothaca sp.*). These are consistent with System III beach ridges which are considered Holocene in age based upon numerous ^{14}C dates (see RUTTER *et al.*, 1989).

The ESR ages are old and the D/L ratios are high for System I, and the ESR ages are young and the D/L ratios low for System II (Figure 10). However, the data for System II beach ridges reveals inconsistencies between the two methods. The locations of the amino acid samples of System II beach ridges are different than those where ESR samples were collected. The amino acid samples were collected near those of A-25, A-26 and A-28, System I samples, but closer to the shore (see RUTTER *et al.*, 1989), on ridges that were mapped as System II beach ridges. Our original conclusion, therefore, was that System II beach ridges were very close to the same age as System I beach ridges and that there was no evidence for "intermediate age" beach ridges. In view of the new ESR data from location A-24, we conclude that System II beach ridges do represent an "intermediate age" of beach ridge formation and that the amino acid samples collected from supposedly System II beach ridges are actually for deposits associated with System I.

Puerto Deseado

Setting. The city of Puerto Deseado is located at the mouth of Rio Deseado, about 250 km southeast of Comodoro Rivadavia (Figure 11). The north-south coastline forms a boundary with the open ocean and then swings westward along Rio Deseado.

Raised beaches and platforms are present within the adjacent area of dissected bedrock resulting in local relief of over 100 m. Five systems of beaches and marine platforms have been recognized (FERUGLIO, 1950). The oldest three, locally called Systems I (Cerro Laciar Terrace), II (Cabo Tres Puntas Terrace) and III (Cerro Alonso Terrace) form platforms observed well beyond the coastline. System I is approximately 170–186 m above mean sea level; System II is 50–70 m below System I but above System III, which is approximately 75 m above mean sea level. Their ages are unknown but it has been suggested that the two highest are Pliocene or early Pleistocene. Neither one conforms to the present coastline configuration. System III may reflect an older Interglacial. The three lower beaches, locally called Systems IV, V and VI are at approximate elevations of 38–40 m, 20–25 m and 8–10 m respectively. These three beaches have been informally correlated with the three levels at similar elevations at Bahia Bustamante.

No radiocarbon dates have been reported from Puerto Deseado. CODIGNOTTO (1983, 1984) collected samples from Puerto Mazarredo near the boundary between the provinces of Santa Cruz and Chubut, 100 km northward from Puerto Deseado. For the 38–45 m high beach (System IV) radiocarbon dates range from 25,000 to 35,000 years BP. Gravel ridges equivalent to the 20–25 m beach ridge level (System V) yielded dates of 31,000 to 34,000 years BP, and for the lower ridges, 8–10 m above mean sea level (System VI), 1,550 to 6,630 years BP.

At Punta Cavendish, sampling site A-32 (System IV), about 4 m of beach gravels and sand are exposed at about 38 meters above mean sea level. They are poorly to moderately well sorted and consist of medium to coarse gravels. Very few mollusc shells were present. Location A-33 (System V) consists of over 4 meters of well rounded, southwesterly dipping beach gravels with pebbles mostly between 2 and 4 cm in diameter. Whole mollusc shells were collected from the top 3 meters of the outcrop. The lower beach, location A-34 (System VI), about 10 meters above mean sea level, consists of well rounded, well sorted gravels, with pebbles mostly between 4 and 8 cm in diameter. Pebbles from this location were more rounded than those at A-32 and A-33, suggesting recycling of older sediments. Mollusc shells, some in living

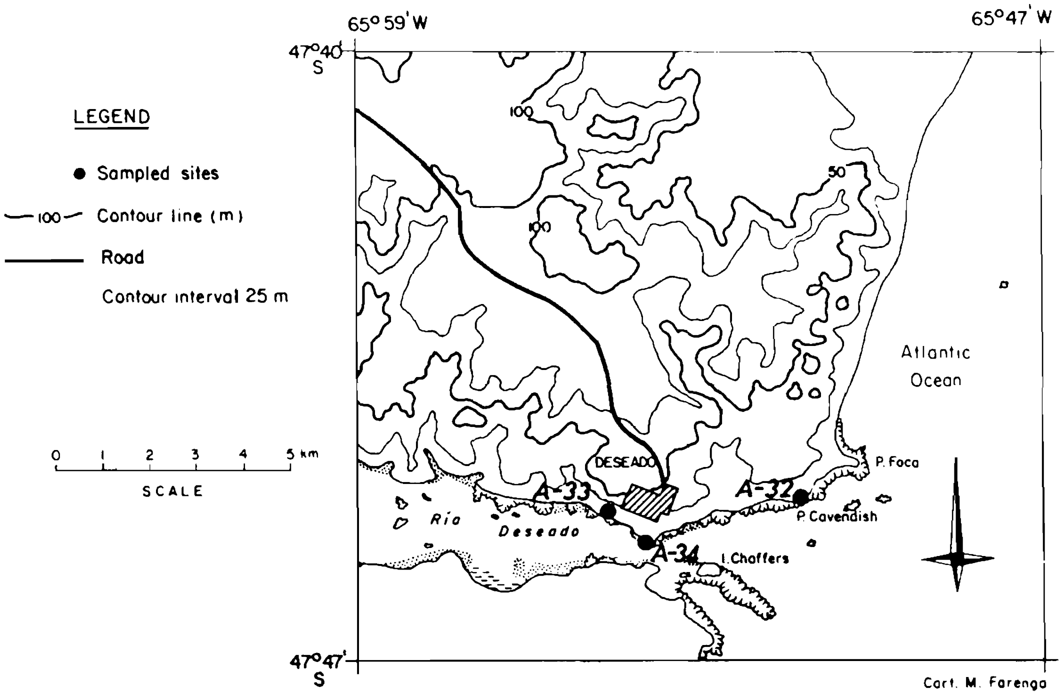


Figure 11. Topographic and site location map, Puerto Deseado area.

position, were collected from the upper meter of the two meter exposure.

Results

Samples for ESR age estimates were collected from the three lower beaches—Systems IV, V and VI (Figure 12). Samples from location A-32, the oldest of the three, (System IV) yielded an age of ≥ 242,000 years BP (unidentified mollusc). This is considered more reliable than others analyzed at this site. They all showed some recrystallization with the one reported the oldest, although still considered a minimum age. Therefore, System IV beaches are considered to be penultimate interglacial or older in age.

The ages derived from location A-33, collected from supposedly System V beach ridges, at a lower elevation than System IV yielded ages of ≥ 450,000 years BP (*Mytilus sp.*) and ≥ 415,000 years BP (unidentified mollusc) from unreworked samples. It was assumed that these beach deposits were part of System V, based upon elevation, geomorphology and stratigraphy and therefore, younger than System IV, and probably last interglacial in age. This anomaly cannot be explained at the present time.

At location 34, System VI beach ridges, an unidentified mollusc yielded an ESR age estimate of 6,940 years BP. This Holocene age is consistent with other beach ridges at elevations of 8–10 m above mean sea level along the Patagonian coast.

The amino acid data supports the ESR age estimates at A-32 and A-34 (Figure 12). The highest ratio corresponds to relatively old ages and the lowest ratios compare favorably to the youngest ages. The aspartic acid ratios derived from A-33, System V, are generally lower than for those derived from A-32. These were originally (see RUTTER *et al.,* 1989) interpreted to represent material deposited during the last interglacial, although this interpretation was never totally convincing. The ESR dates now cast doubt on this interpretation.

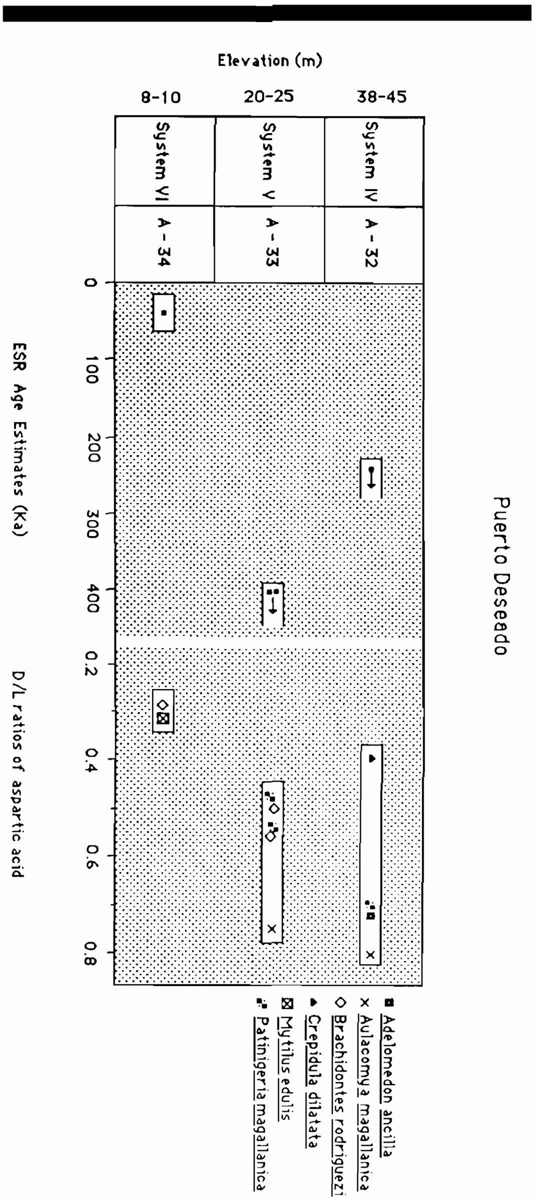


Figure 12. Plot of ESR age estimates and D/L ratios of aspartic acid of each mollusc species according to site location, Puerto Deseado area.

DISCUSSION AND CONCLUSIONS

The ESR age estimates give us further understanding and control of the correlation and absolute ages of raised shorelines along the Patagonian coast. Although problems are encountered in ESR dating, the method is helpful especially if utilized in conjunction with other criteria and dating methods—in this case amino acid data.

In general, ESR results supported the conclusions reached in the earlier study (RUTTER *et al.*, 1989). Figure 13 shows an age correlation of shorelines along the Patagonian coast based upon aspartic acid ratios (RUTTER *et al.*, 1989), modified here to include ESR age estimates. At San Blas, although data are limited, the ESR age estimates indicated that the oldest deposits are last interglacial whereas the D/L ratios suggested an older age, probably the penultimate interglaciation. In the San Antonio Oeste area, the ESR and amino acid data pretty well correspond except for the youngest deposits. The ESR results suggest that the beach rock at sea level (A-14) formed sometime after the last interglacial. Even though the aspartic acid ratios are relatively high, the authors originally judged (RUTTER *et al.*, 1989) these deposits to be Holocene. At Caleta Valdes there is a discrepancy between the ESR ages and the aspartic acid ratios for samples derived from the oldest shorelines (A-17). The wide variation in ESR ages from the same horizon suggests that the age estimates are inaccurate. Therefore, the original interpretation remains. The ESR and amino acid ages for the Bahia Bustamante area correspond very well, with no interpretation in need of alteration. At Puerto Deseado, the oldest and youngest littoral zones are in agreement with the two data sets, but there are problems with what were considered intermediate aged sediments (A-33). The ESR data show great antiquity whereas the amino acid data correspond with intermediate values obtained in other areas, suggesting that age corresponds to the last interglacial.

The discrepancies pointed out above will remain unsolved until more research is completed. In spite of this, the data sets generally show a reasonable relationship considering the incipient state of development of the two methods. Probably the most important result of the ESR data is the confirmation of absolute age estimates derived from the amino acid data using non-linear kinetics (WEHMILLER and BELKNAP, 1982). The evidence is more and more convincing that the highest level shorelines identified are older than the last interglacial, probably representing the penultimate interglacial or older. The intermediate or mid-

Relative Age	SAN BLAS Location	Elev. (m)	ESR Age Estimates	D/L Ratio
OLDEST (pre or penultimate interglacial)	*A-5b *A-5a	2	72,700 to 101,000	.73
INTERMEDIATE (last interglacial)		12		.54
YOUNG (Holocene)				

Relative Age	SAN ANTONIO OESTE Location	Elev. (m)	ESR Age Estimates	D/L Ratio
OLDEST (pre or penultimate interglacial)	A-13	24	≥ 208,000 to ≥ 230,000	.72 .64
		24		
	A-10	0	≥169,000 to ≥218,000	.69
INTERMEDIATE (last interglacial)	A-16	10	90,200 to 111,000	
	A-8	10	83,200 to 97,300	.62
		10		.55
	A-15	10	91,000 to 107,000	.65
YOUNG (Holocene)	*A-14	0	66,800 to 70,300	.34

Relative Age	CALETA VALDES Location	Elevation (m)	ESR Age Estimates	D/L Ratio
OLDEST (pre or penultimate interglacial)		26-28		.65
	*A-17	26-28	45,800 to 151,000	.69
INTERMEDIATE (last interglacial)	A-19	26-28	81,400 to 82,200	.43
YOUNG (Holocene)		12		.15

Relative Age	BAHIA BUSTAMANTE Location	Elevation (m)	ESR Age Estimates	D/L Ratio
OLDEST (pre or penultimate interglacial)	A-25,26, 28	34-41	≥ 220,000 to ≥ 356,000	.73
	A-31	34-41	≥ 328,000	.81
	A-24	25-29	116,000 to ≥195,000	
		25-29		.74
		25-29		.74
		25-29		.68
INTERMEDIATE (last interglacial)				
YOUNG (Holocene)		8-10		.29
		8-10		.28
	A-21,23	8-10	5,820 to 8,950	.22
		8-10		.21

Relative Age	PUERTO DESEADO Location	Elevation (m)	ESR Age Estimates	D/L Ratio
OLDEST (pre or penultimate interglacial)	A-32	38-45	≥ 242,000	.66
INTERMEDIATE (last interglacial)	*A-33	20-25	≥ 415,000 to ≥ 450,000	.57
YOUNG (Holocene)	A-34	8-10	9,520	.30

*Locations where there are discrepancies between the ESR and Amino acid data.

Figure 13. Correlation and relative ages of littoral deposits at various locations along the Patagonian coast, Argentina. D/L ratios of aspartic acid are mean values for all species analysed at a particular site.

dle elevation beach ridges represent the last interglacial (isotope stage 5e) and the beach ridges at elevations between 8–10 m are Holocene in age.

Future work will center on more detailed investigation of the depositional facies of the littoral zones, more accurate dating by amino acid, radiocarbon, electron spin resonance and U/Th methods, and elucidation of the cause and mechanics of sea level changes.

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□ RESUMEN □

Se ha muestreado cinco áreas a lo largo de la costa de la Patagonia para realizar dataciones estimadas mediante el método ESR con el fin de sacar una serie de conclusiones previas en torno al número, caracteristicas, geomorfologia, correlación y en torno a la datación mediante aminoácidos de las costas cuaternarias en la Patagonia (Rutter et al., 1989). Las áreas investigadas incluyen: San Blas, San Antonio Oeste, Caleta Valdés, Bahia Bustamante y Puerto Deseado. Las edades obtenidas mediante el ESR confirman generalmente las conclusiones basadas en los datos de los aminoácidos. La linea de costa más "antigua" se ha encontrado entre los 24 y 41 m por encima del nivel medio del mar y se considera que representa al penúltimo más antiguo periodo interglacial. Las lineas de costa de épocas "intermedias" se presentan en pocas localizaciones y se caracterizan por depósitos de playa que varian entre los 20 y 28 m. Estas barras se formaron probablemente durante el último periodo interglacial (isótopo 5e). Los depósitos de playa "jóvenes" mejor definidos han sido encontrados entre los 8 y 12 m por encima del nivel medio del mar en gran cantidad de localizaciones. Estos has sido datados mediante la prueba del ^{14}C y verificados mediante dataciones con aminoácidos y método ESR siendo englobados dentro del Holoceno.—*Department of Water Sciences, University of Cantabria, Santander, Spain.*

□ RÉSUMÉ □

On a pris 5 zones de la côte de Patagonie pour élucider par ESR les premières conclusions obtenues par Rutter et al. (1989) sur le nombre de rivages quaternaires, leurs caractéristiques, leur géomorphologie et la corrélation avec les âges estimés par les amino-acides. Ces zones sont: San Blas, San Antonio Oeste, Caleta Valdes, Bahia Bustamente et Puerto Deseado. Les âges estimés par ESR confirment les conclusions des amino-acides. Le plus ancien rivage se trouve entre 21 et 24 m au dessus du niveau moyen de la mer, et semble correspondre au pénulième ou au plus vieil interglaciaire. Le rivage intermédiaire se retrouve en plusieurs points sous forme de beach ridges à 20–28 m. Ces ridges se sont probablement formés au cours du dernier interglaciaire (isotope 5e). Les jeunes beach ridges se trouvent en de nombreux endroits, à 8–12 m au dessus du niveau moyen de la mer. Ils ont été datés au 14C et leur âge vérifié par les amino acides et l'ESR est donné comme Holocène.—*Catherine Bressolier, Géomorphologie E.P.H.E., Montrouge, France.*

□ ZUSAMMENFASSUNG □

An der patagonischen Küste Argentiniens wurden in fünf Gebieten die marinen Terrassen mit dem Ziel untersucht, ältere Forschungen hinsichtlich Anzahl der Stufen, ihrer Geomorphologie und ihrer Chronostratigraphie zu überprüfen bzw. weiterzuentwickeln. Bei den geochronologischen Analysen der fossilen Mollusken konnte gezeigt werden, daß frühere Aminosäure-Razemisierungs-Alter (AAR) von Rutter et al. (im Druck) durch Elektronen-Spin-Resonanz-Datierungen (ESR) grundsätzlich bestätigt wurden. In den Untersuchungsgebieten San Blas, San Antonio Oeste, Caleta Valdes, Bahia Bustamante und Puerto Deseado konnten i.w. drei quartäre marine Küstenlinien ausgegliedert werden. Die "älteste" fossile Küstenlinie befindet sich in Höhen zwischen ca. 24 und 41 m ü.M. und ist mindestens im vorletzten, wahrscheinlicher sogar in einem älteren mittelpleistozänen Interglazial entstanden. Die "mittlere" fossile Terrassenstufe wird in einigen Lokalitäten durch Strandwälle in ca. 20–28 m ü.M. repräsentiert und wurde wahrscheinlich im letzten Interglazial gebildet (Isotopenstufe 5e). Deutlich ausgebildete "junge" Strandwälle wurden in 8–12 m ü.M. in fast allen Gebieten gefunden. Sie repräsentieren aber durchweg Sturmflutstrände, so daß die Höhenlage wenig über den Paläomeeresspiegel und neotektonische Bewegungen auszusagen vermag. C-14-, AAR- und ESR-Datierungen belegen eindeutig ein holozänes, wahrscheinlich mittelholozänes, Alter um ca. 6.000 B.P.—*Ulrich Radtke, Geographisches Institut, Universität Düsseldorf, F.R.G.*