RADIOCHRONOLOGY IN A MARINE SEQUENCE OF NORTHERN CHILE, FOR HIGH RESOLUTION PALEOSISMOLOGICAL AND PALEOCLIMATIC RECONSTRUCTIONS

Gabriel VARGAS(1,2,3), Luc ORTLIEB(2), Jorge VALDES(4)

1: Departamento de Geología, Universidad de Chile, Plaza Ercilla 803, Santiago, Chile. gvargas@cec.uchile.cl
2: IRD, 32 Avenue Henri Varagnat, 93143, Bondy Cédex. Luc.Ortlieb@bondy.ird.fr
3: D.G.O., Université Bordeaux I, Avenue des Facultés, 33405 Talence Cédex.
4: Facultad de Recursos del Mar, Universidad de Antofagasta, Casilla 170, Antofagasta. jvaldes@uantof.cl

KEY WORDS: Radiochronology, ^{210}Pb, ^{14}C, laminated sediments, paleoclimate, paleoceanography

THE BAHIA MEJILLONES SEDIMENTARY SYSTEM

A particular depositional environment. Mejillones bay (23°S) is a particular sedimentary system along the coast off central-northern Chile. Its geographical situation, protected from the prevalent southwestern winds, together with the presence in the vicinity of an important upwelling cell (Rodríguez et al., 1991; Marín et al., 1993), that drives primary productivity processes specially intensified during the spring, favour vertical deposition of biogenic debris, organic matter and some eolian lithogenic particles. The result is the prevalence, generally at depths greater than 70 m, of hemipelagic sedimentation within the bay. The exceptionally good preservation of the sediments, which is related to the prevalence of waters with depleted concentrations of O_2 (generally <0.1 ml/l below 50 m depth) (Escribano, 1998), gives to this sedimentary record the potential for paleoclimatic and paleosismological studies at a high resolution time scale.

Constraints for radiocarbon geochronology. The determination of a precise chronology from radiocarbon data for recent coastal marine sedimentary sequences, presents some problems. In addition to the methodological constraints due to variations in the production rate of ^{14}C in the atmosphere trough time, the "Suess Effect", the "Bomb Effect" and the difference between the ^{14}C stock in the atmospheric and oceanic reservoirs (Global Oceanic Reservoir Effect, *"R"*) (Stuiver et al., 1998), local variations of the *R* factor trough time (ΔR) must be considered. In eastern boundary coastal areas, these variations result from variations of the input, during strong upwelling events, of CO_2 with depleted activity of ^{14}C, from deeper waters to the surface of the sea (*e.g.* Brown et al., 1993). This type of processes hampers the determination of a precise chronology from high resolution sedimentary records. In this communication, we show some results and geochronological interpretations from ^{210}Pb and ^{14}C data, and we discuss the significance of anomalous structural and textural features within the sedimentary sequence of Mejillones bay.

^{210}Pb AND RADIOCARBON GEOCHRONOLOGY FROM CORE F981A

The core F981A was retrieved from the zone of maximal biogenic accumulation. After corresponding assumptions, the application of the CF-CS (Constant Flux-Constant Sedimentation) model from ^{210}Pb results, the net mass accumulation rate calculated for the upper 10 cm of the core F981A is W=

3.24 ±0.18 g/cm^2/100 years (➔ Mean sedimentation rate ~R= 13.1 ±0.7 cm/100 years). The application of the CRS (Constant Rate of Supply) model gives a mean mass accumulation rate of W= 3.78 ±0.03 g/cm^2/100 years (➔ Mean sedimentation rate ~R= 15.57 ±0.03 cm/100 years), for the same segment.

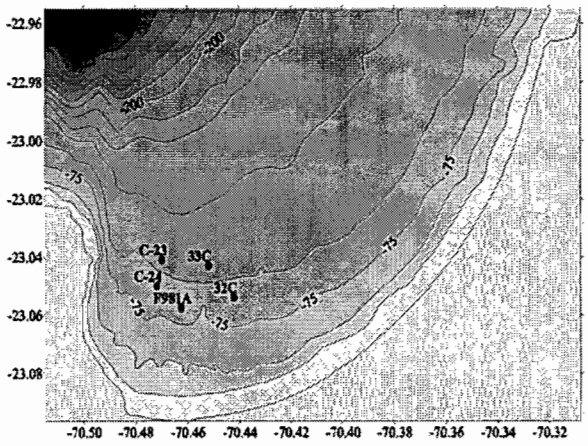

Fig. 1. Situation of cores retrieved from the Mejillones bay, northern Chile. Bathymetric curves every 25 m.

$\delta^{13}C$ and C/N measurements on the organic fraction of the sediments samples from core F981A, clearly reflect the phytoplanktonic origin of the organic matter deposited in the bay. All the radiocarbon measurements were made on this fraction of the sediment. ^{14}C results from core F981A suggest that the sudden increase of the conventional radiocarbon age is linked to sudden increases of ΔR in the Mejillones system, most probably resulting from the intensification of the upwelling cell (Fig. 2). The anomalously low value of the conventional radiocarbon age of the most superficial sample, suggests an input of ^{14}C due to the Bomb Effect.

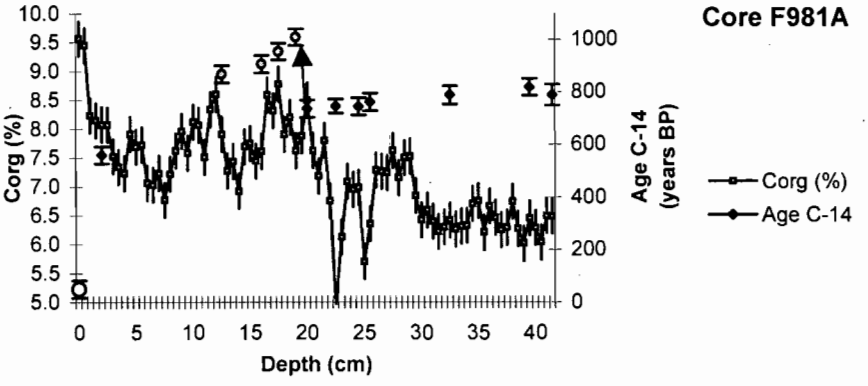

Fig. 2. Conventional radiocarbon ages and organic carbon content from the core F981A. The anomalous increase of the radiocarbon ages at about 18 cm depth (black arrow, grey circles), is correlated with an increase of the organic carbon content, that results from a primary productivity intensification, due to intensified upwelling processes. The white circle shows the superficial sample affected by the Bomb Effect.

These considerations lead to exclude from the geochronological model the ages affected by an increased ΔR and the age affected by the Bomb Effect. Using a linear regression for the remaining data, it is possible to calculate a net mass accumulation rate of W= 3.4 ±0.5 g/cm^2/100 years (➔ Mean sedimentation rate ~R= 16.7 ±2.2 cm/100 years) for the whole core F981A. The accuracy and precision of the ^{210}Pb and ^{14}C chronologies, are confirmed by the close values of W. This high value of W in the zone of the maximal biogenic accumulation within the bay, makes possible high resolution paleoclimatic and paleosismological reconstructions. Based on the extrapolated chronology from ^{210}Pb data, and by using the Marine Calibration

Curve for radiocarbon data (Stuiver et al., 1998), we calculate a mean ΔR= 262±13 years for the period between 1730 AD and 1880 AD.

ON THE OCCURRENCE OF DISCONTINUITIES IN THE SEDIMENTARY SEQUENCE

The occurrence of anomalous features in the sedimentary sequence at Mejillones was reported in previous works and assumed to be linked to a seismic event (Valdés, 1998; Ortlieb et al., 2000). Ortlieb et al. (2000) reported a slump between 46 cm and 57.5 cm depth in the core 23 (Fig. 3), which was correlated with an angular unconformity also observed in several other cores. It was interpreted that such a strong seismic event occurred about 1200 yrs B.P. (uncalibrated). In cores 24 and 32C, the angular discontinuity was observed at about 70 cm and 75 cm depth, respectively (Fig. 3).

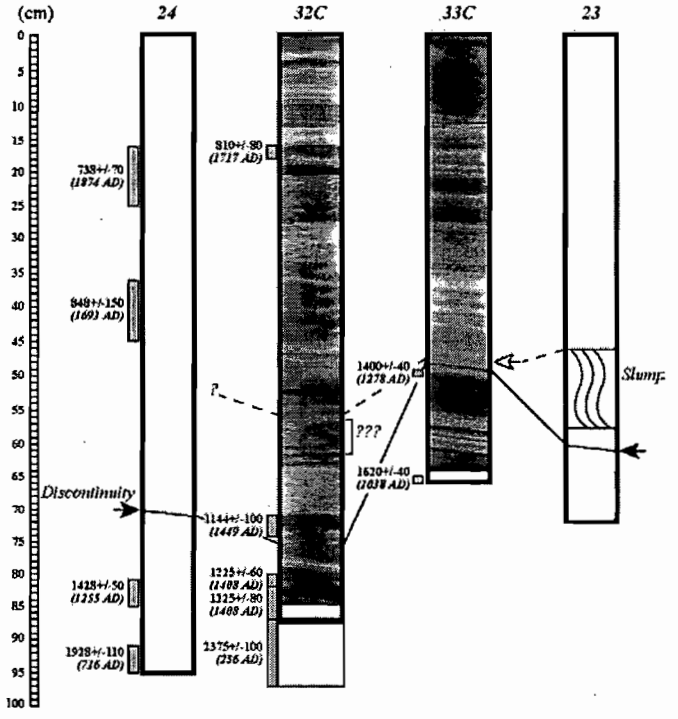

Fig. 3. Anomalous structures and radiocarbon data from cores of Mejillones Bay. A discontinuity level (black arrow and continuous line) observed in all the cores is interpreted as the result of a strong seismic event. A second anomalous feature, which was observed in core 33C (white arrow), is interpreted as a second event, that caused a hiatus estimated to encompass about 30 cm of the sedimentary sequence. This second event is tentatively correlated with the slump observed in the core 23.

In the core 33C, this discontinuity is located at a 47.5 cm depth. It is associated with a slight change in the geometric disposition of the layers, and with a lenticular anomalous deposit enriched in lithogenic debris (visible in thin sections). Another anomalous lenticular deposit was observed several centimeters above the angular discontinuity, suggesting the occurrence of a second event. Taking into account the stratigraphic position of the discontinuity in the core 33C, with respect to the cores 24 and 32C, and the presence of this second anomalous feature in the sequence, we interpret that the occurrence of this second event was responsible for the disparition (erosion) of about 20-30 cm of sequence. As the angular discontinuity was observed at a 60 cm depth in the core 23, we interpret that the slump is more probably associated with this second seismic event than with the first one. Both lenticular deposits should result from reworking of material from shallower areas of the basin. Therefore, after these detailed observations of the

structure, the texture and the mineralogical composition of the sediments, we interpret that structures like angular discontinuities, lenticular deposits enriched in lithogenic debris and slumps, can effectively be associated to the occurrence of strong seismic events or tsunamis in the region.

The radiocarbon data avalaible for cores 24, 32C and 33C, after calibration using Calib.4.3 (Stuiver & Reimer, 1993) and taking into account a ΔR= 262 ±13 years, suggest that the first strong seismic event occurred after 1400 AD, possibly between 1400 AD and 1450 AD, and that the second event occurred at about 1700 AD, or before. For the two last major historical earthquakes in this region, in august 1868 and may 1877, Kausel (1986) inferred magnituds of M_w= 7 and M_w= 5, respectively. The observation from thin sections of sequence in cores F981A and 33C, did not reveal anomalous structural or textural features in the upper sequence, especially in the upper half of the core 33C. This suggests that the two seismic (and/or tsunami) events interpreted from the structural and textural anomalous features in the sedimentary series, were probably more intense, at least in the region of the Mejillones bay, than M_w= 7.

REFERENCES

Escribano R., 1998. Population dynmics of *Calanus chilensis* in the eastern boundary Humboldt current. *Fisheries Oceanography* 7: 245-251.

Kausel E., 1986. Los terremotos de Agosto de 1868 y Mayo de 1877 que afectaron el sur de Perú y el norte de Chile. *Bol. Acad. Ciencias*, 3 (1): 8-13.

Marín V., Rodríguez L., Vallejos L., Fuenteseca J., Oyarce E., 1993. Efectos de la surgencia costera sobre ela productividad primaria primaveral de Bahía Mejillones del Sur (Antofagasta, Chile). *Rev. Chilena de Historia Natural*, 66: 479-491.

Ortlieb L., Goy J.L., Zazo C., Hillaire-Marcel Cl., Vargas G., 1995. Late Quaternary coastal changes in northern Chile. Guidebook for a fieldtrip (Antofagasta-Iquique, 23-25 november). IGCP Project 367, 1995 Meeting, ORSTOM, Univ. de Antofagasta, 175 p.

Ortlieb L., Escribano R., Follegati R., Zuñiga O., Kong I., Rodríguez L., Valdés J., Guzmán N., & Iratchet P., 2000.Recording ocean-climate changes during the last 2,000 years in a hypoxic marine environment off northern Chile (23°S). *Rev. Chilena de Historia Natural*, 73: 221-242.

Rodríguez L., Marín V., Farías M., Oyarce E., 1991. Identification of an upwelling zone by remote sensing and *in situ* measurement, Mejillones del Sur Bay (Antofagasta-Chile). *Sci. Mar.*, 55 (3): 467-473.

Ruegg J.C., Campos J., Armijo R., Barrientos S., Briole P., Thiele R., Arancibia M., Cañuta J., Duquesnoy T., Chang M., Lazo D., Lyon-Caen H., Ortlieb L., Rossignol J.C., Serrurier L., 1996. The M_W= 8.1 Antofagasta (North Chile) Earthquake of July 30, 1995: First results from teleseismic and geodetic data. *Geophys. Res.Letters*, 23 (9): 917-920.

Stuiver M., Reimer P., Bard E., Beck W., Burr G.S., Hughen K., Kromer B., McCormac G., Van Der Plicht J. & Spurk M., 1998. Intcal98 radiocarbon age calibration, 24,000-0 cal BP. *Radiocarbon*, 40 (3): 1041-1083.

Valdés J., 1998. Evolución oceanográfica reciente de la Bahía Mejillones del Sur (23°S). Evidencia geoquímica en sedimentos marinos. Ph.D Thesis, Centro EULA-Chile, Universidad de Concepción, 114 p.

Géodynamique andine
Andean Geodynamics
Geodinámica Andina

Résumés étendus
Extended abstracts
Resúmenes expandidos

Organisateurs **Organizers** **Organizadores**

Institut de recherche pour le développement
Paris

Université Paul Sabatier
Toulouse
France

2002

IRD
Institut de recherche pour le développement

UNIVERSITE PAUL SABATIER
TOULOUSE III

GÉODYNAMIQUE ANDINE
ANDEAN GEODYNAMICS
GEODINAMICA ANDINA

5th International Symposium on Andean Geodynamics

Université Paul Sabatier, Toulouse, France,
16-18 Septembre 2002

Résumés étendus
Extended abstracts
Resúmenes ampliados

Organisateurs / Organizers / Organizadores
Institut de recherche pour le développement
Université Paul Sabatier

IRD
INSTITUT DE RECHERCHE POUR LE DÉVELOPPEMENT
Paris, 2002

COMITÉ D'ORGANISATION
COMITE ORGANIZADOR
ORGANIZING COMITTEE

P. Baby (IRD-Toulouse), J. Darrozes (Univ. Paul Sabatier-Toulouse), J. Deramond (Univ. Paul Sabatier-Toulouse), B. Dupré (CNRS-Toulouse), J.-L. Guyot (IRD-Toulouse), G. Hérail (IRD-Toulouse), E. Jaillard (IRD-Quito), A. Lavenu (IRD-Toulouse), H. Miller (Univ. München), T. Monfret (IRD-Géoscience Azur), G. Wörner (Univ. Göttingen)

Comité scientifique et représentants nationaux
Comité Científico y Representantes Nacionales
Scientific Advisory Board and National Representatives

R. Armijo (IPG, Paris), J.-P. Avouac (CEA, Paris), R. Charrier (Univ. Chile, Santiago), J.-Y. Collot (IRD, Géoscience Azur), L. Dorbath (IRD, Strasbourg), S. Flint (Univ. Liverpool), B. France-Lanord (CNRS, Nancy), L. Fontboté (Univ. Genève), Y. Gaudemer (Univ. Paris VII), R. Gaupp (Univ. Jena), F. Hervé (Univ. Chile, Santiago), T.E. Jordan (INSTOC, Cornell), J. Mojica (Univ. Bogotá), O. Oncken (Univ. Potsdam), L. Ortlieb (IRD, Bondy), R.J. Pankhurst (Brit. Antartic Surv.), V. Ramos (Univ. Buenos Aires), P. Ribstein (IRD, Paris), C. Robin (Univ. Clermont-Ferrand), S. Rosas (Univ. Lima), F. Sàbat (Univ. Barcelona), M. Schmitz (FUNVISIS, Caracas), R. Suárez Soruco (YPBF, La Paz), M. Rivadeneira (Petroproducción), W. Winkler (ETH, Zürich).

APPUIS FINANCIERS
FUNDINGS
APPOYO FINANCIERO

L'organisation de l'ISAG 2002 et les bourses accordées à un certain nombre de collègues latino-américains ont été possibles grâce au soutien financier de l'IRD (notamment de la Délégation à l'Information et à la Communication), de la région Midi-Pyrénées, de l'Université Paul Sabatier et de l'Andean Comittee de l'ILP.