

For Joern Thiede

LATE QUATERNARY SEDIMENTATION OFF THE WESTERN SAHARA

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ABSTRACT

Late Quaternary sediments on the West African continental margin between 24° N and 15° N were studied with R. V. «Meteor» (1971) and «Valdivia» (1975). Cores on the shelf were taken with a 6 m-vibrocorer, in deeper water mainly with a 12 m Kastenlot corer.

During Holocene, and up to the present time, more or less arid climatic conditions north of the Senegal River area reduced terrigenous supply. Therefore, the biogenic-carbonate content exceeds about 50%, Wüstenquartz numbers $\frac{\text{red} + \text{yellow quartz}}{\text{white quartz}} \times 100$ are high (20 to more than 200), indicating eolian input. The Senegal River supplied fine grained, green colored, terrigenous material with some plant debris.

During Würm, the Mediterranean climatic zone with winter rains was shifted more than 5° to the south and was reaching Banc d'Arguin (at about 20° N). Therefore, the terrigenous supply was increased in this northern part and consequently the carbonate content and the Wüstenquartz numbers dropped below 50% and 10, respectively. The arid zone was also shifted to the south; as a consequence, the Senegal River did not reach the sea, eolian supply diluted the biogenic carbonates, and increased Wüstenquartz numbers to more than 200. Eolian dunes covered parts of the shelf. Ratios of radiolarians/planktonic foraminifera and planktonic/benthonic

organisms and sedimentation rates of organic carbon indicate stronger upwelling in the northern region. Turbidity currents were more frequent, eroding as much as a third of the material supplied by pelagic sedimentation.

INTRODUCTION

Recent sedimentation conditions differ markedly off NW Africa and off Brasil. On the western side of the Atlantic warm surface waters and trade winds from the sea with high coastal ranges favour precipitation and river supply of terrigenous material. Also reefs built up by different organisms and mangrove formations influence sedimentation there.

NW Africa on the contrary generally has a flat topography and at present, in the southern part, only the Senegal River and some smaller ones supply fluvial sediments. Trade winds with eolian material are coming from the Sahara Desert. With the cold Canary current system they cause upwelling with cool surface waters and reefs are therefore absent.

Since 1967 the marine geology group of Kiel University and geophysicists of the Geological Survey (Bundesanstalt für Geowissenschaften und Rohstoffe, Hannover) tried to take standard profiles off NW Africa with different echosounders, airgun, surface sediment samplers and corers from the shelf to the deep sea operating from RVs «Meteor» and «Valdivia» (Fig. 1, Closs et al., 1969, Seibold, 1972). In

deeper waters mainly 12 m box corers (15 x 15 or 30 x 30 cm, Kögler, 1963) were used for sampling.

In the following, our main concern will be a comparison between Holocene and Late Pleistocene sedimentation conditions as derived from continental slope and rise sediments in about 800 — 3000 m of water depth. The shelf deposits and sedimentation conditions are described in «Meteor» Publications, e.g.

Kudras, (1973, Siedler and Seibold, 1974; Portugal, Morocco);

Newton, Seibold and Werner, (1973: Northern Sahara)

Lange, (1975: Sahara-Senegal);

Sarnthein and Walger, (1974: South of Cap Blanc);

Einsele *et al.*, (1974: Mauretania).

In general, terrigenous input is influenced by the climatic zonation illustrated in Fig. 1. Many climatic factors shift seasonally in their intensity to the North or South. There is a core of eolian input, for example, in winter, centered around Cap Blanc — Cap Verde Islands (dashed lines in Fig. 1). The 20°C surface isotherm in August off southern Portugal shifts to southern Senegal in February and then back again to the North. Upwelling was observed around Cap Blanc during the entire year and only during 5-6 months off the Senegal River mouth (Schemainda and Nehring, 1975).

HOLOCENE SEDIMENTATION

One of our sedimentological methods is a quantitative analysis of different grain fractions. As an example, standard profile A off C. Bojador, 26°N is discussed (Fig. 2).

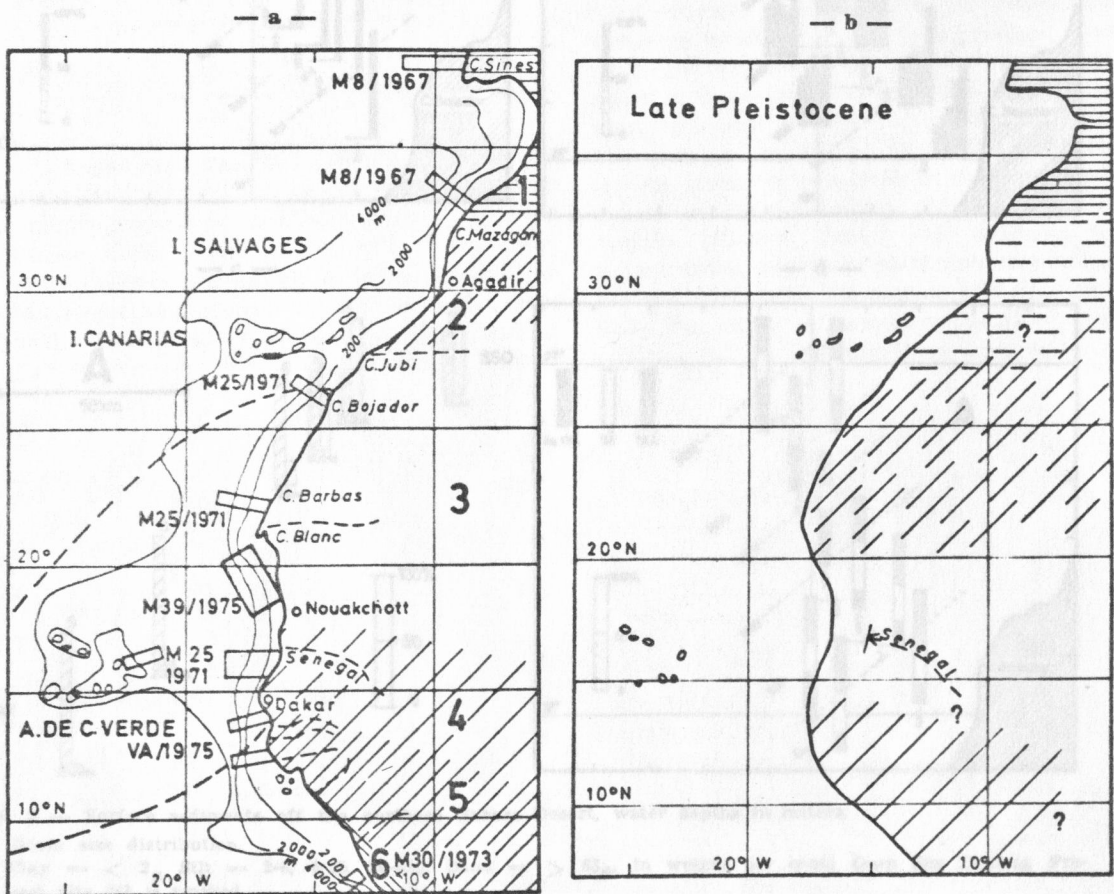


Fig. 1 — Climatic zonation of NW Africa and main study areas. a) Recent conditions, b) Latest Pleistocene. 1 — Mediterranean; 2 — Steppe climates with winter rains; 3 — Desert climate; 4 — Steppe; 5 — Savannah climates with summer rains; 6 — hot, humid tropical climate. «Meteor» (M) and «Valdivia» (Va) cruises 1967-1975. Dashed boundaries around C. Verde Islands — center of dust falls during winter.

There the sand fraction decreases sharply at water depths below about 700 m because finer particles are winnowed out in shallower depths and concentrated in deeper parts. Therefore lower slope and upper rise sediments are mainly composed of silt and clay (2a). Up to present only a few near-bottom current velocity measurements on the upper slope are published (Mittelstaedt, 1972; Seibold, 1974). They seem to confirm winnowing action. The carbonates (2b)

are biogenic, aragonite and magnesium calcite was only found in shallow water, dolomite nowhere. More than 70% of the sand fraction consists of calcium carbonate, mostly from planktonic foraminifera on the slope, from molluscs on the shelf. A second carbonate maximum in the silt fractions is influenced by coccoliths; there they may contribute up to 40 weight percent. Noncarbonate sand/silt and clay particles (2c) illustrate this same trend around 700

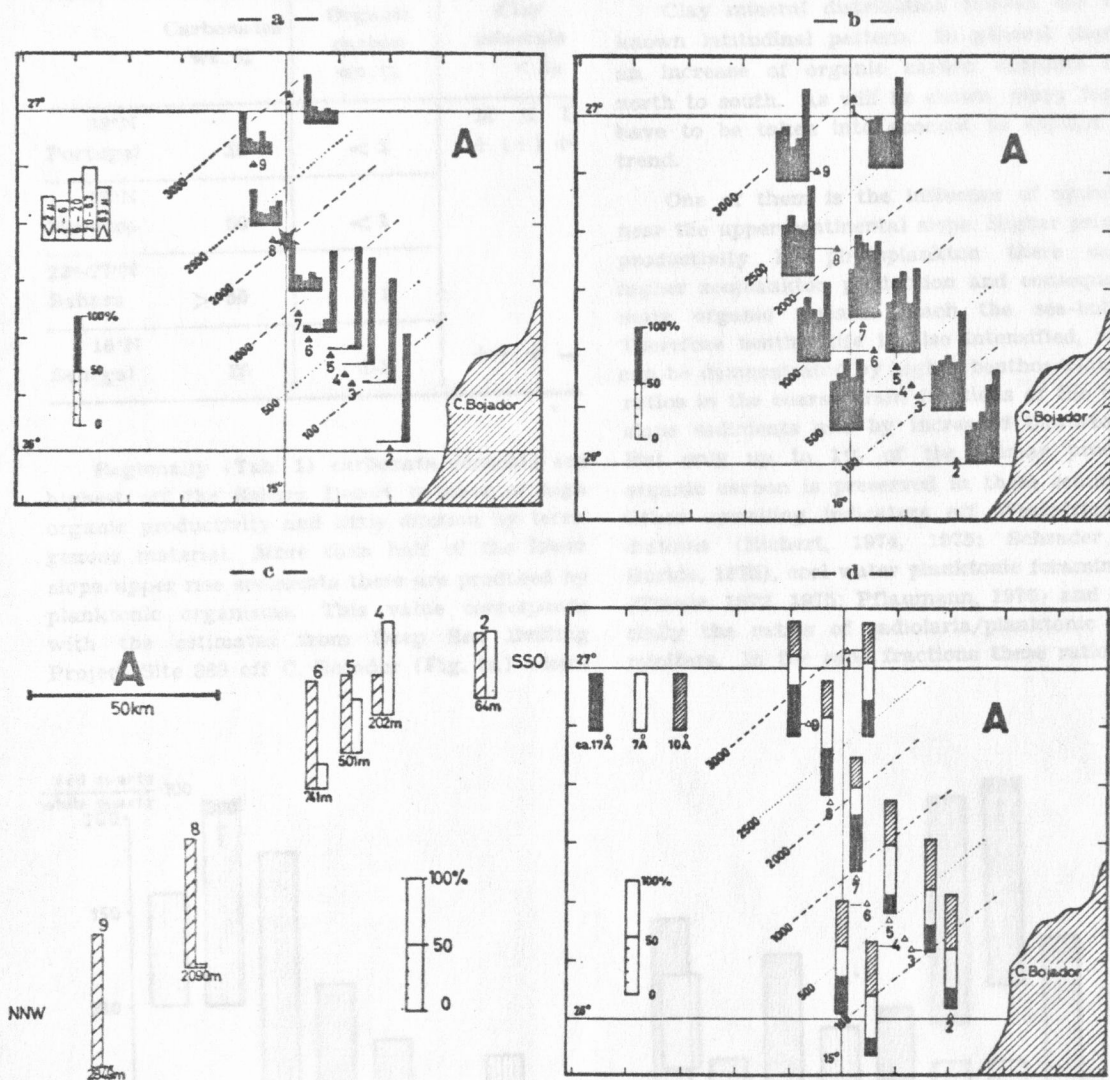


Fig. 2 — Surface sediments off the northern Sahara Desert, water depths in meters.

- Grain size distribution. Clay = $< 2 \mu$, Silt = 2-6, 6-20, 20-63 μ , Sand = $> 63 \mu$, in weight per cent; Deep Sea Drilling Project Site 369 is marked.
- Calcium carbonate contents in weight per cent. Grain size fractions as in Fig. 2a.
- Non-carbonate clay (hatched columns) and Silt + Sand (white columns) in weight per cent.
- Contents of montmorillonite (black), kaolinite (white), and illite (hatched) in the size fraction $< 2 \mu$ (After LANGE, 1975).

m water depth, even more pronounced than the grain size distribution of the total sediment did (Fig. 2a). The montmorillonite content increases towards the deep sea (2d).

TAB. 1 — NW-AFRICA: HOLOCENE MARINE SEDIMENTS (~ 800-3000 m water depth)

	Carbonates wt. %	Organic carbon wt. %	Clay minerals < 2μ
38°N Portugal	30	< 1	M K I + (+) +
33°N Morocco	50	< 1	
22°-27°N Sahara	> 50	< 1	
16°N Senegal	20	1-3	++ + -

Regionally (Tab. 1) carbonate contents are highest off the Sahara Desert because of high organic productivity and little dilution by terrigenous material. More than half of the lower slope/upper rise sediments there are produced by planktonic organisms. This value corresponds with the estimates from Deep Sea Drilling Project Site 369 off C. Bojador (Fig. 2a) where

carbonate (and siliceous) remains contribute more than 2/3 of Tertiary and Upper Cretaceous sediments (Lancelot, Seibold *et al.*, 1975).

Off Portugal higher rainfall and a more pronounced topography and therefore higher river supply dilute carbonates as in the case off the Senegal River mouth; there green silts and muds are typical surface sediments from the shelf region to the deep sea.

Clay mineral distribution follows the well-known latitudinal pattern. In general there is an increase of organic carbon contents from north to south. As will be shown, many factors have to be taken into account to explain this trend.

One of them is the influence of upwelling near the upper continental slope. Higher primary productivity by phytoplankton there causes higher zooplankton production and consequently more organic remains reach the sea-bottom. Therefore benthic life is also intensified, which can be demonstrated by higher benthos/plankton ratios in the coarse grain fractions of the upper slope sediments and by increased bioturbation. But only up to 1% of the primar produced organic carbon is preserved in these sediments. Other upwelling indicators off Westafrica are diatoms (Richert, 1974, 1975; Schrader and Burkle, 1975), cool water planktonic foraminifera (Thiede, 1972, 1975; Pflaumann, 1976) and especially the ratios of radiolaria/planktonic foraminifera. In the sand fractions these ratios are

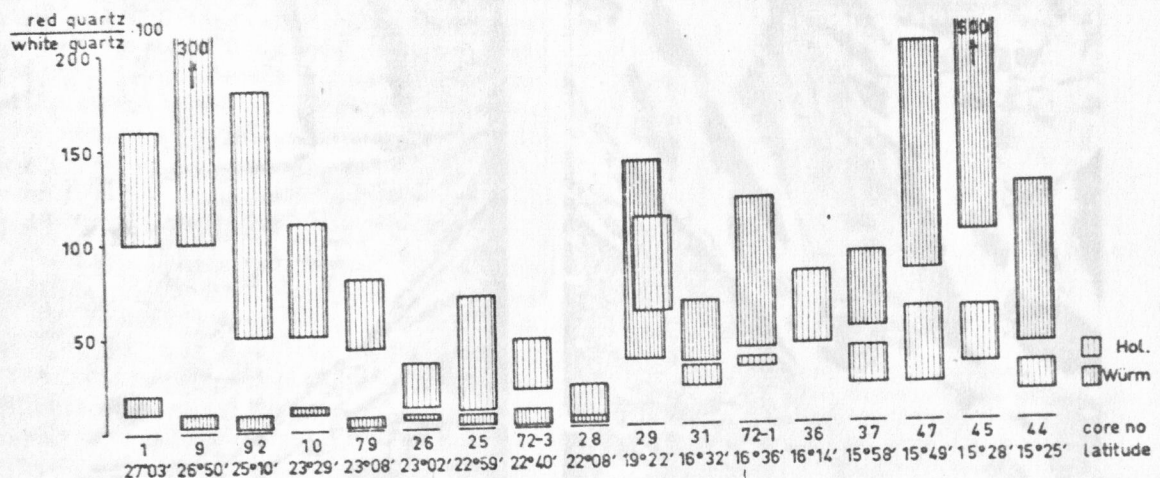


Fig. 3 — Desert quartz numbers in Holocene (widely hatched) and Late Pleistocene (narrow hatched) sediments off NW Africa; lengths of columns show variations of desert quartz numbers; cores are arranged from north to south (After DIESTER-HAASS, in press a).

-- a --



-- b --

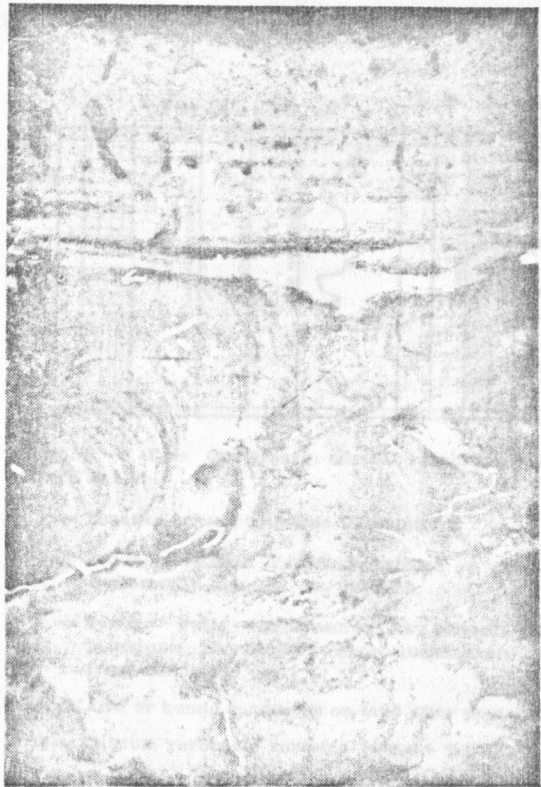


Fig. 4 -- a) Rock fall with rounded blocks and scour effects. "Valdivia" cruise 10-3-1975, station 13316-1; Canyon off Southern Senegal. 1770 m water depth. Width about 1.5 m. b) Turbidite layer above mudflow. "Valdivia" cruise 10-3-1975, station 13203-1, north of Cayar Seamount, 2771 m water depth. Width about 10 cm. X-ray-radiograph. c) and d) Mud flow structures, "Valdivia" cruise 10-3-1975, station 13211-1, off Gambia, 3675 m water depth, width about 15 cm, X-ray radiographs showing plastic flow structures, dragged pyrite filled strings, sharp boundaries etc.

-- c --



-- d --



normally about < 1:99, or radiolaria are completely absent, under upwelling areas near the upper slope they shift to 2 — > 6 : 98 — < 94. The highest ratios are characteristically concentrated around C. Blanc (Diester-Haass, in press, b).

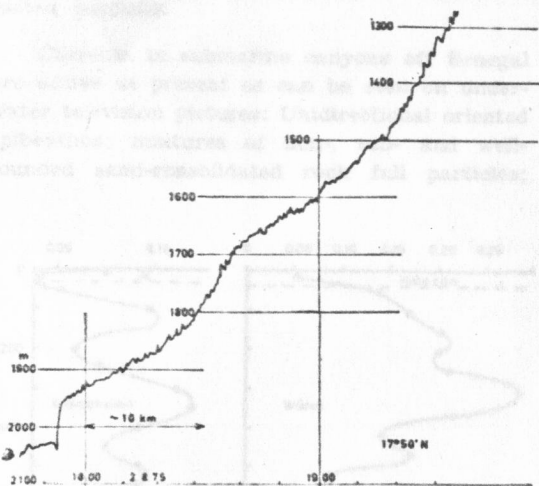


Fig. 5 — Slide-slump morphology on the lower continental slope off Mauretania. Slide units of m- to 10 m-scale, and 100 m-scale, steep sides mostly towards the open sea. Slide scar, near 2000 m of water depth. "Valdivia" cruise 10-3/1975.

Eolian input can best be studied by determining desert-quartz numbers of sand and coarse silt fractions, i.e.:

$$wqn = \left(\frac{\text{red + yellow surface stained quartzes}}{\text{white quartzes}} \right) \times 100$$

As in other above mentioned ratios derived from sediment particles one has to consider diagenetic alterations and losses. In spite of processes possibly influencing the iron oxide coating of desert quartzes in Holocene sediments desert quartz numbers are high north of about 20°N and lower further to the south (Fig. 3) (Diester-Haass, in press, a).

LATE PLEISTOCENE SEDIMENTATION

For this purpose we compare sedimentation conditions during the Holocene period (i.e. zone Z; Ericson and Wollin, 1968) in a simplified manner with those during the latest cold period of the Pleistocene (i.e. zone Y, about 11000-73000 years before present; Broecker and Van Donk, 1970). In many cores, however, it was further possible to subdivide the Holocene period and even more so the latest Pleistocene, i.e. zone Y. Examples are given in Figs. 6, 7, and 8.

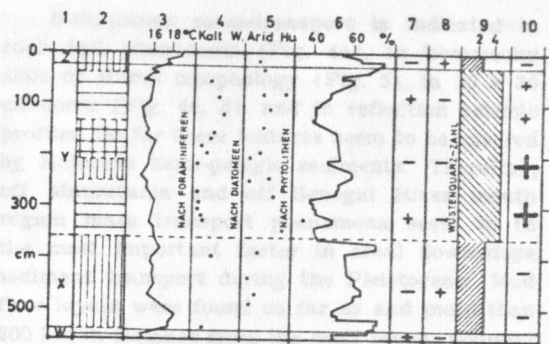


Fig. 6 — Late Quaternary climatic evolution, northern Sahara.

- 1 = Zonation after planktonic foraminifera.
- 2 = Sediment colours. Vertically hatched = greyish, horizontally hatched = greenish.
- 3 = Surface water temperatures as derived from planktonic foraminifera and, qualitatively (4), from diatoms.
- 5 = Arid or humid conditions on land after phytoliths.
- 6 = Calcium carbonate contents (weight %).
- 7 = Relative input of terrigenous material.
- 8 = Desert quartz numbers.
- 9 = Accumulation rates of total wet sediments in cm/1000 years.
- 10 = Relative importance of upwelling phenomena. Note the interruption of zone Y by a phase resembling Holocene conditions.

Core 12310-4, "Meteor" cruise 25/1971, 3080 m water depth, 300 km off C. Barbas (Fig. 1a). Simplified after DIESTER-HAASS *et al.*, 1973

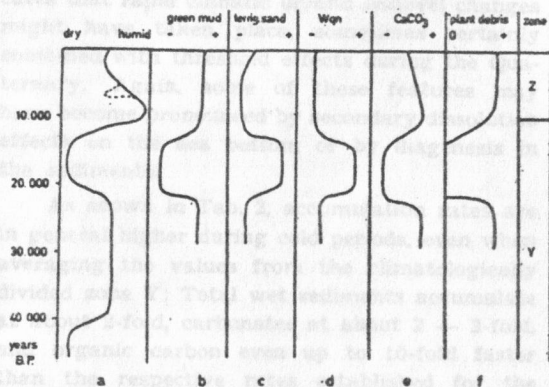


Fig. 7 — Late Quaternary climatic evolution, Mauretania/North Senegal. a = Summary curve (MICHEL, 1973), b = Content of green mud from Senegal river, c = Amount of terrigenous sand and coarse silt, d = Desert quartz numbers, e = Calcium carbonate contents, f = Amount of plant debris. Stratigraphic zonation as in Fig. 5. Schematic diagram after DIESTER-HAASS, 1975.

Ice rafted material was found in Late Pleistocene sediment cores off Portugal and Morocco (Fig. 1a, M 8/1967; Kudrass, 1973). The coarse grain size fractions clearly were derived from the North Atlantic area. Evidence is based on statistical treatment of the petrology of ice rafted particles.

Currents in submarine canyons off Senegal are active at present as can be seen on underwater television pictures: Unidirectional oriented epibenthos; mixtures of non-, sub- and well-rounded semi-consolidated rock fall particles;

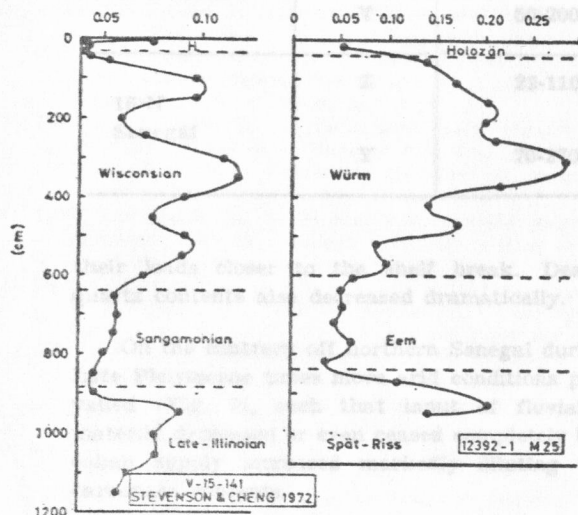


Fig. 8 — Organic nitrogen in two sediment cores off Argentina (STEVENSON & CHENG, 1972, and off NW Africa (MÜLLER, Ph. D.-Dissertation, Kiel University, 1975). Water depths 5670 and 2575 m, distance from the coast 1300 and 220 km, respectively. Note remarkably similar nitrogen distribution with sediment depths.

scour marks around blocks, often filled with white biotritus (Fig. 4a). However, canyon bottoms off Senegal studied so far mostly are covered by a few centimeters of mud and canyon walls by a few decimeters to meters. Therefore turbidity current activity appears to be at present a restricted phenomenon. This is in marked contrast to the turbidites found in some Late Pleistocene cores and in continuous seismic reflection profiles off NW Africa.

These Pleistocene turbidites are intimately linked with mass flow sediments below about 2000 m of water depth, as illustrated in Fig. 4b. Reflection seismic profiles indicate that this combination exists in Neogene series as well.

Subaqueous mass-transport is indicated in rock fall phenomena (Fig. 4a), in hommocky slide or slump morphology (Fig. 5), in 30 x 30 cm-cores (Fig. 4c, d), and in reflection seismic profiles. So far these features seem to be covered by Holocene hemi-pelagic sediments. Therefore, off Mauretania and off Senegal River mouth region mass transport phenomena seem to be the most important factor in areal down-slope sediment transport during the Pleistocene. Mud flow layers were found as far as and more than 200 km in distance from the shelf break. Younger examples, however, are also reported by Embley (1975) north of Cap Blanc.

These more dramatic sedimentation processes are mentioned briefly in order to concentrate more on «normal», hemi-pelagic sediments. One of the typical features encountered with these are the sharp boundaries between different stratigraphic units even within cores with grain-to-grain sedimentation. Generally, sediment colours change rapidly and especially the Holocene/Pleistocene boundary is reflected in drastic changes of many other sediment parameters as well, such as the contents of quartzes, desert quartzes, micas, calcium carbonates, organic carbon and nitrogen, in contents of biogenic particles and in various characteristic ratios. The Holocene/Pleistocene boundary is additionally marked by a layer rich in pteropods from Morocco in the north to Senegal in the south.

Surprisingly the sharp boundaries are well preserved, even in heavily bioturbated sediments. Therefore, even hemi-pelagic sedimentation indicates that rapid climatic or/and sealevel changes might have taken place, sometimes certainly combined with threshold effects during the Quaternary. Again, some of these features may have become pronounced by secondary dissolution effects on the sea bottom or by diagenesis in the sediments.

As shown in Tab. 2, accumulation rates are in general higher during cold periods, even when averaging the values from the climatologically divided zone Y: Total wet sediments accumulate at about 2-fold, carbonates at about 2 — 3-fold, and organic carbon even up to 10-fold faster than the respective rates established for the Holocene warm period. This, however, is caused by different factors in different regions.

Off the northern Sahara as off C. Bojador and C. Barbas (Fig. 6) prevailing humid conditions during Late Pleistocene times increased terrigenous input from land; this was additionally favoured by rivers or active wadis discharging

TAB. 2 — NW-AFRICA: ACCUMULATION RATES (~ 800 to ~ 3000 m water depth, cores without turbidites and mass transport sediments)

		Wet Sediment mm/1000 y	Carbonates mg CaCO ₃ /cm ² 1000 y	Organic carbon mg C _{org} /cm ² 1000 y
26°N C Bojador	Z	40	1540	10
	Y	90	3200	88
22°N C. Barbas	Z	25-60	1160-2750	4-44
	Y	50-200	1860-6810	21-390
16°N Senegal	Z	22-110	640-870	6-158
	Y	70-270	2370	286

their loads closer to the shelf break. Desert quartz contents also decreased dramatically.

On the contrary off northern Senegal during Late Pleistocene times more arid conditions prevailed (Fig. 7), such that input of fluvial material decreased or even ceased completely but eolian supply increased markedly diluting the carbonate contents.

If we restrict our discussion to the desert quartz contents, as in Fig. 3, drastic changes occur around 20°N: North of Cap Blanc high desert quartz numbers during Holocene and low numbers during Late Pleistocene, south of Cap Blanc low values during Holocene and high ones during Late Pleistocene. Therefore, we assume that Mediterranean type winter rains reached as far south as Cap Blanc during Late Pleistocene times and that the center of arid climatic conditions had shifted more than 5° to the south (Fig. 1b). The Senegal river did not reach the Atlantic during the latest period of zone Y (Fig. 1b and 7).

This is in good agreement with earlier results from land geology (Michel 1973, Elouard *et al.* 1969, 1967, Hebrard 1968, Tricart 1963 and others). Further it fits the more general distribution pattern of Fairbridge (1964, 1965, 1972) for the climatic evolution of Africa and is also of interest for more detailed investigations off Brazil (Damuth and Fairbridge, 1970).

Up to now the problem of upwelling during Late Pleistocene off West Africa has not been solved.

Increased bioproduction during Late Pleistocene times may be a general, perhaps worldwide, feature caused by a more pronounced exchange of oceanic water masses. At least Fig. 8 shows a remarkable coincidence between sediment cores off Argentina (Stevenson and Cheng, 1972) and off NW Africa. Similar trends were observed off Southwest India (MARCHIG, 1972).

Additionally, we have some indications of increased upwelling off NW Africa from planktonic foraminifera (Pflaumann, 1976), diatoms (Schrader and Burckle, 1975) and sediment parameters as the radiolaria/planktonic foraminifera ratios and planktonic/benthonic foraminifera ratios (Diester-Haass, 1975). This may be attributed to (a) an intensified Canary Current as demonstrated by results from the CLIMAP-program (McIntyre *et al.*, 1975); (b) intensified trade wind activity as shown by Sarthein and Walger, (1974); and (c) to the fact that the area between coast and upper slope was narrowed by lower sea level stand.

More details are and will be given in several publications in «Meteor-Forschungsergebnisse» as listed in the bibliography. Our main future efforts shall be directed to better stratigraphically subdivide zones Z and Y, to study the more dramatic sedimentation processes like turbidity currents and mass-transport phenomena, and to place more emphasis on investigating the southern region off the Late Pleistocene arid Sahara.

REFERENCES

- BROECKER, W. S. and VAN DONK, J. — 1970 — Insolation changes, ice volumes and the 0/18 record in deep sea cores. — *Rev. Geophys. Space Phys.* v. 8, pp. 169-198.
- CLOSS, H., DIETRICH, G., HEMPEL, G., SCHOTT, W. and SEIBOLD, E. — 1969 — "Atlantische Kuppenfahrten 1967" mit dem Forschungsschiff "Meteor" — Reisebericht. — "Meteor" Forsch. Erg. A, v. 5, pp. 1-71.
- DIESTER-HAASS, L. — 1975 — Sedimentation and climate in the Late Quaternary between Senegal and the Cape Verde Islands. — "Meteor"-Forsch. Ergebn., C, v. 20, 1-32.
- DIESTER-HAASS, L., SCHRADER, H. J. and THIEDE, J. — 1973 — Sedimentological and paleoclimatological investigations of two pelagic ooze cores off Cape Barbas, North-West Africa. — "Meteor" Forsch.-Ergebn., C, v. 16, pp. 19-66.
- DIESTER-HAASS, L. — Late Quaternary climatic variations in NW Africa deduced from East Atlantic sediment cores. — *Quaternary Research* (in press (a)).
- DIESTER-HAASS, L. — Radiolarian/planktonic foraminiferan ratio in a coastal upwelling region. — *J. of Foram. Res.* (in press (b)).
- DIESTER-HAASS, L. — 1975 — Sediments as indicators of upwelling. — *Third Symposium on Upwelling Ecosystems*, Kiel 1975, Proceedings (in press (c)).
- DAMUTH, J. E. and FAIRBRIDGE, R. W. — 1970 — Equatorial Atlantic deep-sea arkosic sands and ice-age aridity in tropical South America. *Geol. Soc. Amer. Bull.* v. 81, pp. 189-206.
- EINSELE, G., HERM, D. and SCHWARZ, H. U. — 1973 — Holocene eustatic (?) sea level fluctuation at the coast of Mauritania. — "Meteor" Forsch. Erg., C, v. 18, pp. 43-62.
- ELOUARD, P. and FAURE, H. — 1967 — Quaternaire de l'Inchiri, du Taffols et des environs de Nouakchott. — *Rapp. Lab. Géol. Fac. Sci. Univ. Dakar*, v. 19, pp. 70 s., Dakar.
- ELOUARD, P., FAURE, H. and HEBRARD, L. — 1969 — Quaternaire du littoral Maurétanien entre Nouakchott et Port Etienne (18°-21° latitude nord). *Bull. Ass. Sénégal et Quatern. Ouest Afr.* v. 23, pp. 15-24, Dakar.
- EMBLEY, R. W. — 1975 — Studies of deep sea sedimentation processes using high frequency seismic data. — Ph. D. Dissertation Lamont Doherty Ob., Columbia Univ., New York.
- ERICSON, D. B. and WOLLIN, G. — 1968 — Pleistocene climates and chronology in deep sea sediments. — *Science*, v. 162, pp. 1227-1234.
- FAIRBRIDGE, R. W. — 1964 — African Ice-Age Aridity. — In: Nairn, A. E. M. (Ed.): *Problems in Palaeoclimatology*, pp. 356-360.
- FAIRBRIDGE, R. W. — 1965 — Eiszeitklima in Nordafrika. — *Geol. Rdsch.* v. 54, n. 1, pp. 399-414.
- FAIRBRIDGE, R. W. — 1972 — Climatology of a glacial cycle. — *Quat. Res.* v. 2, pp. 283-302.
- FÜTTERER, D. — 1974 — Plankton organisms as sediment contributors in the fine grained fraction of surface sediments off West Africa. — *Symp. Marine Plankton Sediments*, Abstr. Vol., Kiel.
- HARTMANN, M., MÜLLER, P. J., SUESS, E. and van der WEIJDEN, C. H. — 1976 — Chemistry of Late Quaternary sediments in their interstitial waters from the NW African continental margin. "Meteor" Forsch.-Ergebn., C. (in press).
- HEBRARD, L. — 1968 — Contribution à l'étude géologique des formations quaternaires de l'Afaut du Es Sahéli et de la partie Nord-Ouest du delta du Sénégal (Mauretania). — *Lab. Géol. Fac. Sci. Univ. Dakar*, Rapp. v. 25, 21 pp.
- KÖGLER, F. C. — 1963 — Das Kastenlot. — *Meyniana*, n. 13, pp. 1-7, Kiel.
- KUDRASS, H. R. — 1973 — Sedimentation am Kontinentalhang vor Portugal und Marokko im Spätpleistozän und Holozän. — "Meteor"-Forsch. Ergebn. C, v. 13, pp. 1-63.
- LANCELOT, Y. and SEIBOLD, E., and shipboard scientific party — 1975 — The eastern North Atlantic. — *Geotimes*, July 1975, pp. 18-21.
- LANGE, H. — 1975 — Herkunft und Verteilung von Oberflächensedimenten des westafrikanischen Schelfs und Kontinentalhangs. — "Meteor" Forsch. Ergebn. C, v. 22, pp. 61-84.
- MARCHIG, V. — 1972 — Zur Geochemie rezenter Sedimente des Indischen Ozeans. — "Meteor" Forsch.-Ergebn. C, v. 11, pp. 1-104.
- MCINTYRE, A., KIPP, N. G., BE, A. W. H., CROWLEY, T. Y., KELLOGG, T., GARDNER, J. V., PRELL, W. and RUDDIMAN, W. F. — 1975 — The glacial North Atlantic 18 000 years ago — a CLIMAP reconstruction. — In: CLINE and HAYS (Eds.) *Geol. Soc. Memoir* 145.
- MICHEL, P. — 1973 — Les bassins des fleuves Sénégal et Gambie. *Étude géomorphologique*. — *Mém. ORSTOM*, N° 63, 752 pp., Paris.
- MITTELSTAEDT, E. — 1972 — Der hydrographische Aufbau und die zeitliche Variabilität der Schichtung und Strömung im nordwestafrikanischen Auftriebsgebiet im Frühjahr 1968. — "Meteor" Forsch.-Ergebn. A, v. 11, pp. 1-57.
- MÜLLER, P. J. — 1975 — Zur Diagenese stickstoffhaltiger Substanzen in marinen Sedimenten unter oxydierenden und reduzierenden Bedingungen. — Ph. D.-Dissertation, 179 pp., Universität Kiel.
- MÜLLER, P. J. — 1975 — Diagenese stickstoffhaltiger organischer Substanzen in oxischen und anoxischen marinen Sedimenten. — "Meteor" Forsch.-Ergebn. C, v. 22, pp. 1-60.
- NEWTON, R. S., SEIBOLD, E. and WERNER, F. — 1973 — Facies distribution pattern on the Spanish Sahara continental shelf mapped with side-scan sonar. — "Meteor" Forsch.-Ergebn. C, v. 15, pp. 55-77.
- PFLAUMANN, U. — 1976 — Late Quaternary stratigraphy based on planktonic foraminifera off Senegal. — "Meteor" Forsch.-Ergebn. C, (in press).
- RICHERT, P. — 1974 — Marine recent planktonic diatom assemblages off North-West Africa and their relation to hydrographic parameters. (Abstract) *Symp. "Marine Plankton and Sediments"* Kiel
- RICHERT, P. — 1975 — Die räumliche Verteilung und zeitliche Entwicklung des Phytoplanktons, mit besonderer Berücksichtigung der Diatomeen im nordwest-afrikanischen Auftriebswassergebiet. — Ph. D.-Dissertation Univ. Kiel, 260 pp.
- SARNTHEIN, M. and WALGER, E. — 1974 — Der äolische Sandstrom aus der W-Sahara zur Atlantikküste. — *Geol. Rdsch.* v. 63, pp. 1065-1087.

- SCHEMAINDA, R. and NEHRING, D. — 1975 — The annual cycle of the space temporal dislocation of the north-west African upwelling region. 3. Intern. Symp. Upwelling Ecosystems, Kiel 1975.
- SCHRADER, H. J. and BURCKLE, L. H. — 1975 — Quantative analysis of Late Pleistocene and Recent diatom assemblages from the north Atlantic. *Geol. Soc. Amer., Abstracts* 1975.
- SEIBOLD, E. — 1972 — Cruise 25/1971 of R. V. "Meteor": Continental margin of West Africa. General report and preliminary results. — "Meteor" *Forsch.-Ergebn. C*, v. 10, pp. 17-38.
- SEIBOLD, E. — 1976 — Mechanical processes influencing the distribution of pelagic sediments. — In: Riedel & Saito (Eds). *Marine Plankton and Sediments. Proc. Sympos. Kiel 1974. Micropaleontol. Press, New York* (in press)
- SIEDLER, G. and SEIBOLD, E. — 1974 — Currents related to sediment transport on the Ibero-Moroccan continental shelf. — "Meteor" *Forsch.-Ergebn. A*, v. 14, pp. 1-12.
- STEVENSON, F. J. and CHENG, C. N. — 1972 — Organic geochemistry of the Argentine Basin sediments: Carbon-nitrogen relationships and Quaternary Correlations. — *Geochim. Cosmochim. Acta* v. 36, pp. 653-671.
- THIEDE, J. — 1972 — Dominance and diversity of planktonic foraminiferal faunas in Atlantic Iberomoroccan continental slope sediments. *J. Foramin. Res.* v. 2, n. 2, pp. 93-102.
- THIEDE, J. — 1975a — Shell- and skeletonproducing plankton and nekton in the eastern North Atlantic Ocean. — "Meteor" *Forsch.-Ergebn. C*, v. 20, pp. 33-79.
- THIEDE, J. — 1975b — Distribution of foraminifera in surface waters of a coastal upwelling area. — *Nature* v. 253, pp. 712-714, London.
- TRICART, J. — 1963 — Oscillations et modifications des caractères de la zone aride en Afrique et en Amérique Latine lors des périodes glaciaires des hautes latitudes. — UNESCO: *Change of climate. Proc. Rome Sypos.*, pp. 415-420, Paris.