Wind-blown dusts over the Central Mediterranean

Eolian dusts
Meteorological conditions
Mineralogy
Chemical composition
Sediments of the Mediterranean Sea

Poussières éoliennes
Conditions météorologiques
Minéralogie
Composition chimique
Sédiments de la Mer Méditerranée

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ABSTRACT

Dust samples were collected, as a part of the Eolo Project of the Italian CNR, in order to investigate their contribution to sedimentation in the Mediterranean Sea. Seasonally variable amounts of atmospheric dusts are characterized by different mineralogy and chemical composition. Abundant poorly-organized illite and important amounts of kaolinite (and palygorskite) were recognized in dusts of southern provenance. Abundant better-organized illite and important amounts of chlorite (and serpentine) were found in dusts of northern provenance. Study of the chemical composition of the wind-blown dusts showed that eolian supplies from the N were characterized by 20-30% of organic matter, by a ferromagnesian composition and $Na/K > 1$ ratio, while a mere 2-3% of organic matter, higher Si/Al ratios and Ca contents, and a $K/Na > 1$ ratio, characterize dusts from the S.

Very similar mineralogy and chemical composition confirmed the identity and the continuity of the same Saharan dust-carrying storm.

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RÉSUMÉ

Poussières éoliennes sur la Méditerranée Centrale

Dans le cadre du Projet Eolo du CNR italien, des échantillons de poussières éoliennes ont été prélevés pour étudier l'importance de l'apport éolien dans la sédimentation actuelle de la Méditerranée.

Les résultats obtenus ont montré que les quantités prélevées varient en fonction de la saison d'échantillonnage, et que la minéralogie et la composition chimique des poussières se révélaient des bons indicateurs d'origine. Des teneurs élevées en illite peu cristallisée et la présence de kaolinite (et de palygorskite) caractérisent les poussières en provenance du Sud, tandis qu'une illite mieux cristallisée et des quantités importantes de chlorite (et serpentine) sont les constituants essentiels des apports liés aux vents du Nord.

Les poussières en provenance du Nord contiennent 20 à 30% de matière organique, et sont caractérisées par une composition ferromagnésienne et par des rapports $Na/K > 1$; les poussières en provenance du Sud, au contraire, contiennent seulement 2 à 3% de matière organique, et sont caractérisées par de hautes teneurs en Ca, par rapports SiO_2/Al_2O_3 élevés et par des rapports $K/Na > 1$.

L'identité et la continuité du même épisode de transport de poussières sahariennes sont démontrées par une composition minéralogique et chimique très semblable.

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INTRODUCTION

Research carried out during the past 10 years concerning the sediments of the Mediterranean Sea has shown that a significant contribution is made by wind-blown dust to present sedimentation (Chamley, 1971; Venkatarathnam, Ryan, 1971; Tomadin, 1974; Chester *et al.*, 1977; Tomadin, 1981). Since the Mediterranean basin is located between the European and the African continents, and collects sediments from both sides, its

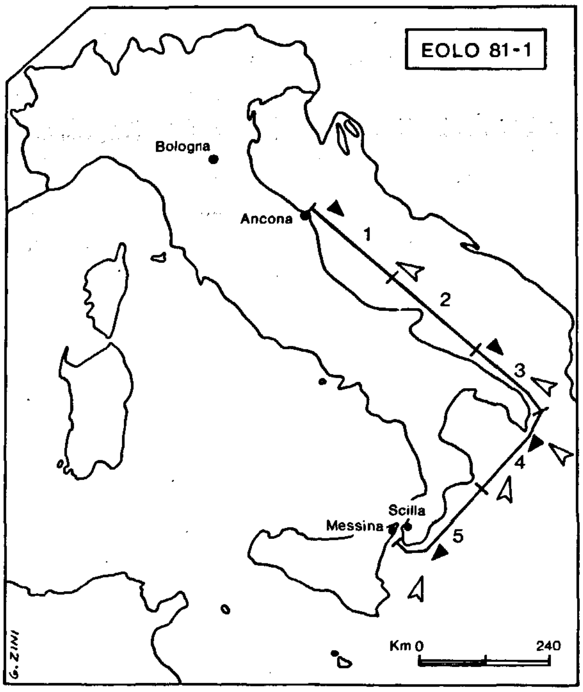


Figure 1 *a*
Eolo 81-1 *sampling tracks* (*Ancona-Messina*).
Routes d'échantillonnage de Ancona à Messina pendant la croisière Eolo 81-1

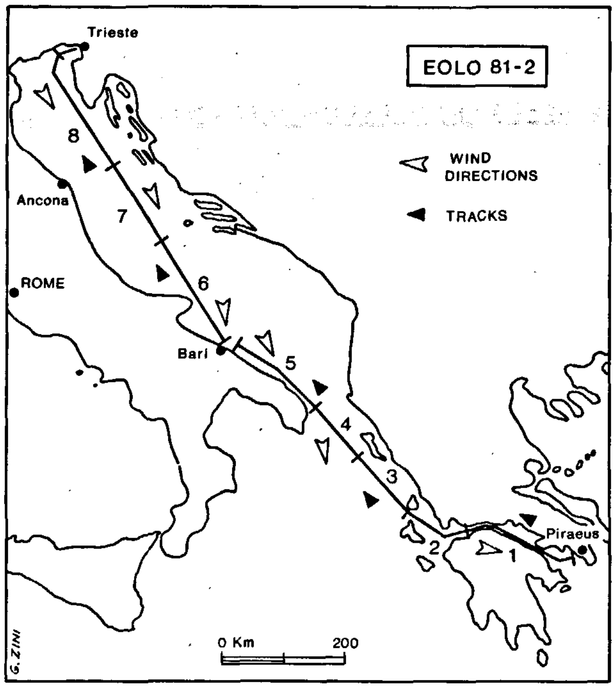


Figure 1 *b*
Eolo 81-2 *sampling tracks* (*Piraeus-Trieste*).
Routes d'échantillonnage du Pirée à Trieste pendant la croisière Eolo 81-2.

proximity to the northern margin of an important climatic area of the world, the Sahara desert, is obviously significant.

The Eolo Project was initiated by the Italian CNR in 1981, in order to investigate the contribution of eolian dust to sedimentation in the Mediterranean Sea. This three-year programme of seasonal sampling involves the collection of atmospheric dusts close to the seawater-air interface. This type of sampling is designed to eliminate as far as possible the influence of pollutants from industrial activity.

In the present paper, we compare the concentrations, mineralogy, chemical composition and grain-size of dusts collected as a part of the Project, during two sampling cruises: Eolo 81-1 and Eolo 81-2 (Fig. 1 *a* and 1 *b*), under different meteorological conditions.

SAMPLING AND LABORATORY PROCEDURE

Dust samples were collected on four mesh panels of 1 m^2, according to the technique described by Prospero and Bonatti (1969). Even if the collection efficiency of the meshes is low in comparison with that of filter samplers (Parkin *et al.*, 1970; Chester, Johnson, 1971; Chester, 1972; Glaccum, Prospero, 1980) and does not provide volumetric data, this method has been adopted for sedimentological research in different areas of the world (Prospero, Bonatti, 1969; Parkin *et al.*, 1970; Chester *et al.*, 1972; Aston *et al.*, 1973; Chester *et al.*, 1977).

The main factors in favour of mesh panels sampling include: the representativity of large air volumes for sedimentological work (Prospero, Bonatti, 1969; Parkin *et al.*, 1970); the pedogenetic significance of collected fractions in the identification of source areas (Chester, 1972); the acceptable quality of the mineralogical data hitherto available (Glaccum, Prospero, 1980; Prospero, 1981); and the lack of most of the anthropic pollutants present in the < 1 µm fraction (Prospero, 1981).

Suitable analytical procedures were developed, with due reference to the amounts of dusts normally collected. The routine operations performed on the dusts may be summarized as follows:

— dust particle collection: the mesh panels are rinsed in an ultrasonic vessel of deionized water (about 20 l for sample);

— weight determination of the dry bulk sample;

— X-ray diffraction analysis on powders and on oriented-particle mounts;

— particle size analysis by photo-extinction sedimentometer;

— chemical analysis by instrumental techniques. Owing to the relatively small amounts of the samples, major, minor and trace elements were determined by colorimetric analysis and atomic absorption spectroscopy (flame and flameless AAS) after a single solution method (Mazzucotelli, Barbangelo-Sangiorgi, 1978), and an ion-exchange procedure (Mazzucotelli *et al.*, 1976; Frache *et al.*, 1978). Loss of ignition (1 000°C) was determined only when larger samples were available.

METEOROLOGICAL CONDITIONS

Investigations on wind trajectories over the Mediterranean Sea have identified several episodes of dust-carrying storms from the Sahara (Prodi, Fea, 1978, 1979; Yaalon, Ganor, 1979).

During the sampling cruises Eolo 81-1 and Eolo 81-2, meteorological phenomena were consequently taken into account to compare flow patterns at the sea surface with those at the 500 mb level (Fig. 2, 3).

This comparison makes it possible:

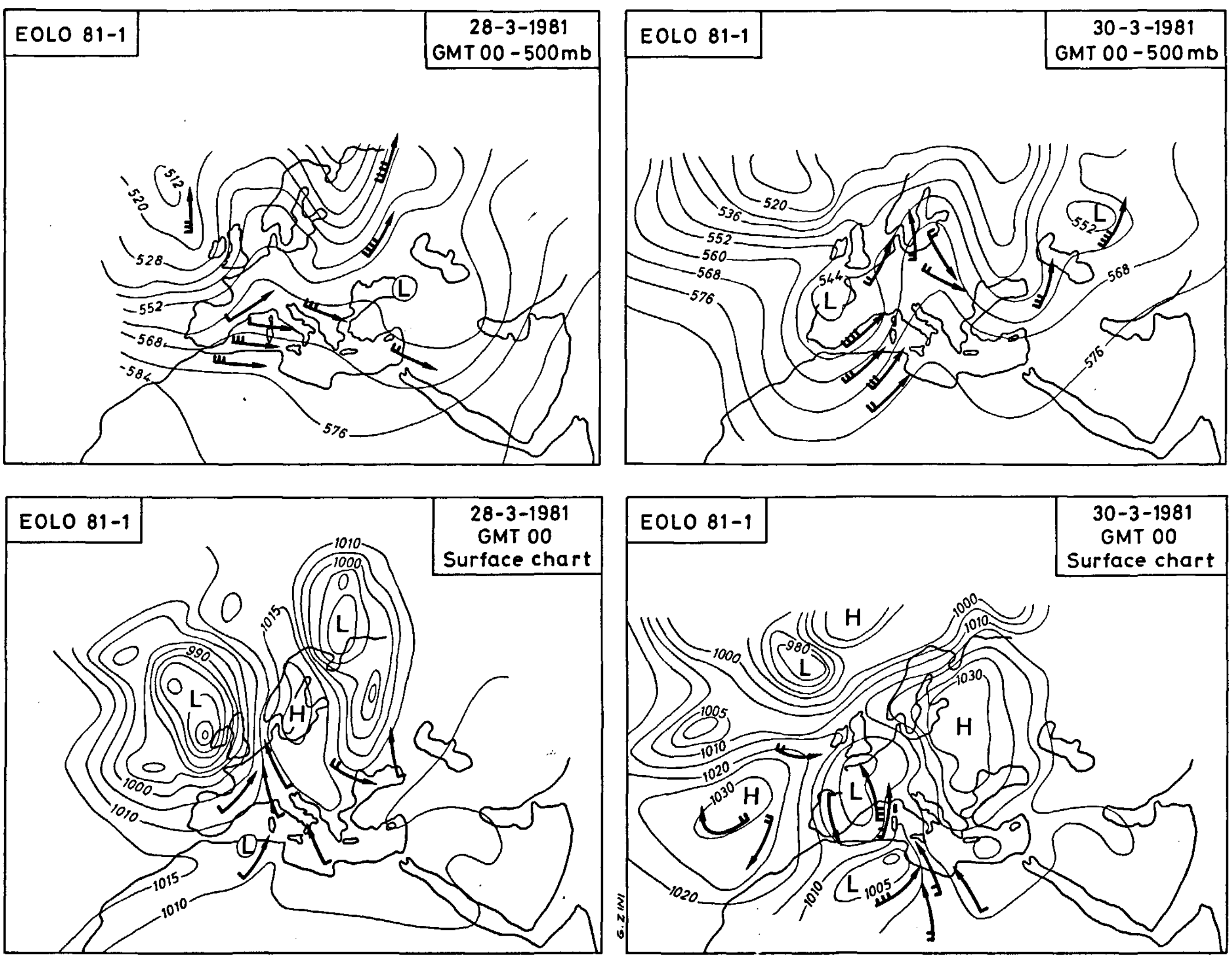
a) to determine the transport close to the seawater-atmosphere interface, where the probability of finding low atmospheric dust contributing to sedimentation is higher (Prospero, Bonatti, 1969);

b) to distinguish between the direct or indirect transport (Prodi, Fea, 1978) and diffusion by local winds (Borghi, 1980) of dusts already present in the atmosphere.

Five dust samples were collected along a constant course from Ancona to Messina in the spring of 1981 during the Eolo 81-1 cruise (Fig. 1 *a*). At the beginning of the sampling (March 28), meteorological conditions (Fig. 2 *c*) were characterized by a high-pressure wedge over Central Europe, between two low-pressure systems centered on Northwestern and Eastern Europe. This barometric trend favoured a wind circulation from SE to NW, which was in fact registered on board. Because the 500 mb pattern (Fig. 2 *a*), showing a wind circulation from the western to the eastern quadrants, was in contrast with the previous surface situation, dust transport was determined by local winds from the SE.

Two days later (March 30), the meteorological maps showed at both the 500 mb (Fig. 2 *b*) and sea level (Fig. 2 *d*) a very important cyclonic area centered on the Iberian Peninsula. These conditions favoured the direct transport of dusts of African origin by winds blowing from the S and SW. Land-deposited dusts transported by this important event were collected on the same day at points some 800 km apart, in Messina (Sicily) and in Bologna (Northern Italy).

Eight dust samples were collected along constant courses from Piraeus to Trieste in the autumn of 1981, during the Eolo 81-2 cruise (Fig. 1 *b*). On this occasion, the meteorological situation was characterized, througthout the entire sampling period (compare Fig. 3 *a, c* and Fig. 3 *b, d*) by a high-pressure field centered on the Atlantic and affecting the western Mediterranean. The flow pattern at the 500 mb level was consistent with conditions at the sea surface, when the high-pressure field spread over the Central Mediterranean. The general wind conditions were thus favourable to an indirect transport of dusts from the NW to SE, as registered on board.



(from EUROP. WETTERB. DEUTSCH. WETTERDIENSTES)

Figure 2

Meteorological evolution during the Eolo 81-1 sampling at the 500 mb (a-b) and sea levels (c-d).

Évolution météorologique pendant l'échantillonnage Eolo 81-1 au niveau de 500 mb (a-b) et de la mer (c-d).

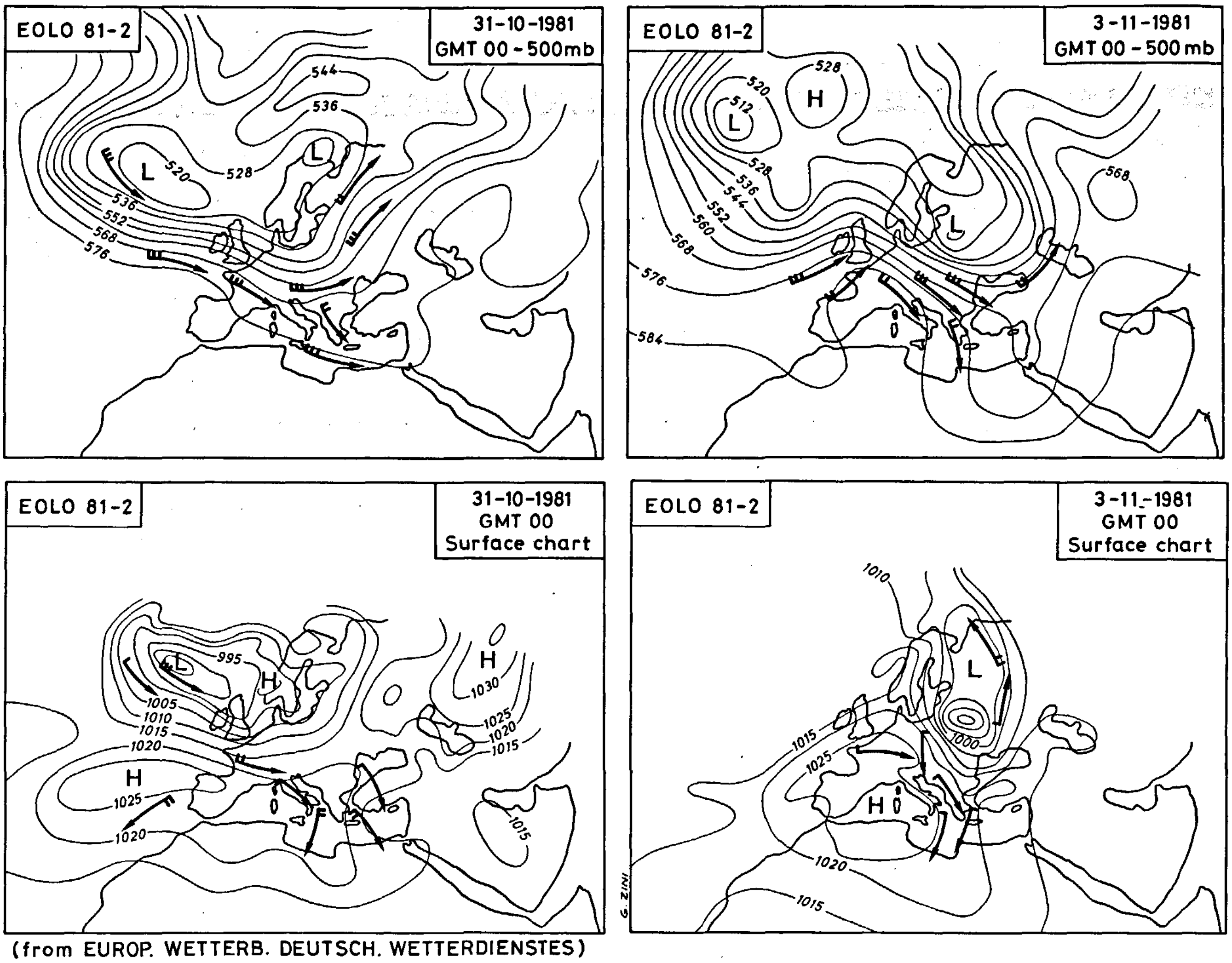


Figure 3

Meteorological evolution during the Eolo 81-2 *sampling at the* 500 *mb (a-b) and sea levels (c-d).*

Évolution météorologique pendant l'échantillonnage Eolo 81-2 au niveau de 500 mb (a-b) et de la mer (c-d).

Table 1

Total amounts of collected dusts and dust-loadings: a) Eolo 81-1 sampling; b) Eolo 81-2 sampling.

Quantités absolues et par unité de volume des poussières éoliennes : *a)* échantillonnage Eolo 81-1 ; *b)* échantillonnage Eolo 81-2.

Dust sample	Hours of sampling	Total weight of dust (g)	Wind direction	Wind average speed (kts)	Average dust-loading ($\mu g/m^3$)
E1-1	12	0.166	SE	20.4	0.10
E1-2	12	0.323	SE	20	0.17
E1-3	8	0.382	SSE	19.75	0.32
E1-4	8	0.296	SSW	36.6	0.19
E1-5	11	0.377	SW	21.3	0.21
Total	51	1,544			
E2-1	5	0.022	WNW	23.4	0.03
E2-2	5.30	0.090	WNW	26	0.09
E2-3	11.30	0.273	NNW	21.5	0.15
E2-4	5	0.671	NNW	15.7	1.15
E2-5	8	0.308	NW	27.7	0.18
E2-6	11.30	0.700	NNW	25	0.31
E2-7	11	0.110	NW	21	0.06
E2-8	11.30	0.182	NW	19.5	0.18
Total	69	2.356			

DUST AMOUNTS

Total amounts and dust-loadings of the two groups of samples are indicated in Table 1 *a* and *b*. The early data represent the amounts of dry bulk sample actually collected on the meshes.

During the Eolo 81-1 sampling (Tab. 1 *a*), and with prevailing winds from the S, yellow dusts (7,5 YR 4/4, Munsell Soil Color Charts) were collected for a total amount of 1.544 μg in 51 hours. During the Eolo 81-2 sampling (Tab. 1*b*) and with prevailing winds from the NW, brown-blackish dusts (10 YR 3/2) were collected for a total amount of 2.356 μg in 69 hours.

To compare these amounts of atmospheric dusts, taking into account the average wind speed recorded on board, a rough estimation was made of the dust-loadings. Average figures of 0.20 μg/m^3 in the spring and 0.27 μg/m^3 in the autumn, for the Eolo 81-1 and Eolo 81-2 samples respectively, were obtained.

These data show a variation of dust concentrations of almost 50%, which makes it possible to differentiate between the two series of collected samples. Since the collection efficiency of the meshes is dependent on particle size, the above dust-loadings do not correspond to volumetric amounts. Since the meshes retain about 10 times less material than filter samplers (Chester, 1972), the figures have to be multiplied by ten to obtain values comparable with those reported for the Mediterranean Sea (Prospero, 1979).

PARTICLE SIZE

The grain-size distribution of the collected eolian dusts appears to be homogeneous. Histograms provided in Figure 4 indicate that the studied samples are clayey silts (f.i. Eolo 81-1, kite 2) or silty clays (f.i. Eolo 81-1, Messina) with a very low sand content, and that the modal class is 4-8 or 2-4 μm.

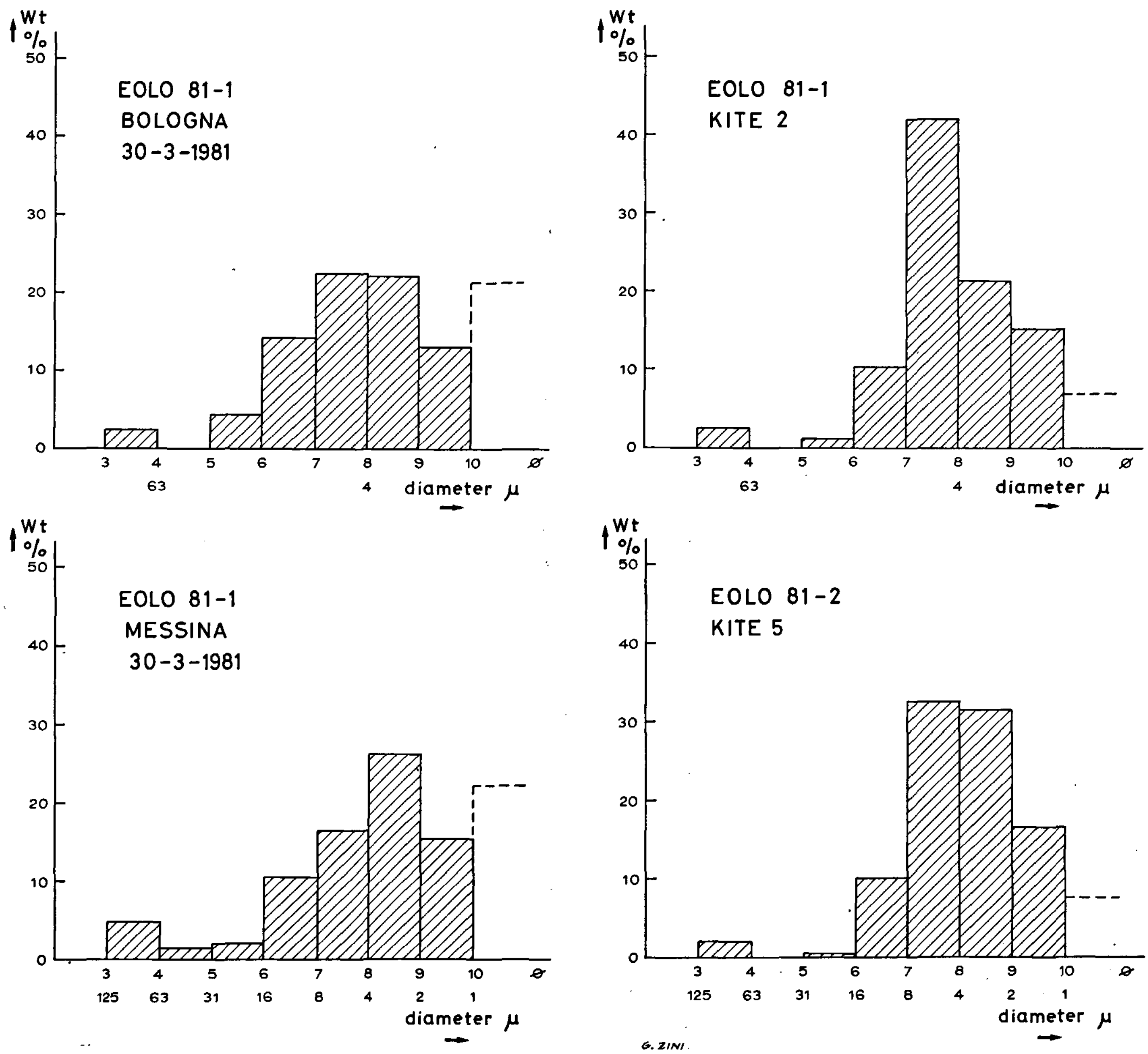


Figure 4

Selected grain-size distributions of sea (Eolo 81-1, kite 2) and land (Messina) collected eolian dusts.

Exemples de distributions granulométriques des poussières éoliennes échantillonnées en mer (Eolo 81-1, kite 2) et à terre (Messina).

Table 2

Mineralogy of the total dust samples: a) sea and land collected dusts (Eolo 81-1); b) sea collected dusts (Eolo 81-2).

Composition minéralogique totale : *a*) poussières éoliennes échantillonnées en mer et à terre (Eolo 81-1); *b*) poussières éoliennes échantillonnées en mer (Eolo 81-2).

Dust	Sample location	Quartz	Plagioclase	K-feldspar	Hematite	Amphiboles	Mica	Kaolinite	Chlorite	Calcite	Dolomite	Analcime	Talc	Halite	Mullite
E1-1	Central Adriatic	••	••	•	—	—	••	—	••	—	•	—	—	—	—
E1-2	Southern Adriatic	••	•	•	••	•	•	—	••	—	tr	—	—	—	—
E1-3	Southern Adriatic	••	•	tr	••	—	•	•	••	—	tr	—	—	—	—
E1-4	Northern Ionian Sea	••	••	••	••	—	•	•	•	—	—	—	—	—	—
E1-5	Strait of Messina	•••	••	••	•	—	••	••	•	—	•	—	—	—	—
SC	Scilla	••	•••	tr	—	•	••	•	••	—	—	—	—	—	—
ME	Messina	•••	••	••	—	—	••	••	—	•••	••	—	—	—	—
BO	Bologna	•••	••	•	—	—	••	••	—	••	••	—	—	—	—
E2-1	Gulf of Saronikos	••	••	•	•	—	•	—	••	•	—	—	•	—	—
E2-2	Gulf of Corinth	••	••	•	••	•	•	•	••	—	—	•	•	•	—
E2-3	Gulf of Patras	••	•	•	••	—	••	—	••	—	—	—	—	—	—
E2-4	North Ionian Sea	•	tr	tr	••	—	•	•	•	—	—	—	•	—	—
E2-5	Southern Adriatic	••	•	•	•	•	••	•	•	—	—	•	—	—	—
E2-6	Southern Adriatic	••	•	•	••	•	••	•	•	—	—	—	•	—	—
E2-7	Central Adriatic	••	•	•	••	•	•	—	•	—	—	•	—	—	—
E2-8	Northern Adriatic	••	•	•	••	•	•	•	••	—	—	•	—	—	•

••• very abundant; •• abundant; • present; tr, trace; ——, absent.

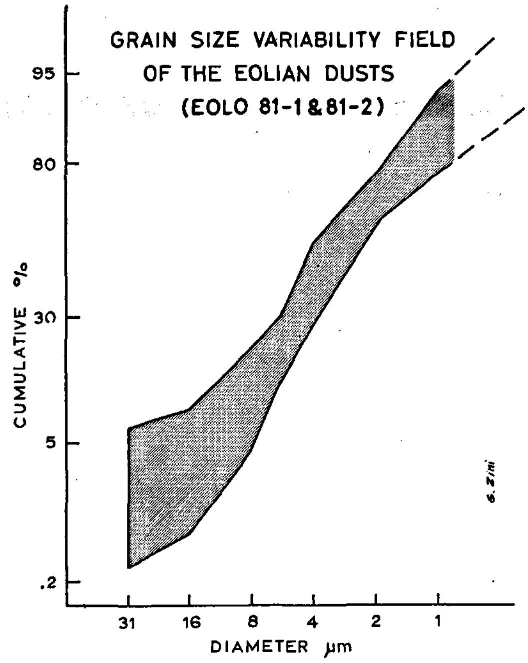


Figure 5

Grain size variability field of the studied dusts.

Enveloppe des variations granulométriques des poussières éoliennes étudiées.

Significant quantities of particles > 16 µm are probably deposited during the first thousand kilometres of transport. The general absence of particles < 1 µm is due to the above-mentioned low collection efficiency of the meshes in the smaller size range. Nevertheless the collected dusts may be considered as sufficiently representative of the soil components of the low atmosphere (Prospero, 1981) to permit sedimentological research.

Only the dusts transported from the S (Messina and Bologna samples) show a moderate increase in the sand fraction, probably in relation to proximity to the main source area.

The grain-size variability field of the wind-blown dusts (Fig. 5) is also narrow, and the cumulative curves reveal a rather constant and homogeneous transport pattern. These parameters are probably again a reflection of collection efficiency. Subsequent dust samplings of the Eolo Project were therefore performed both by mesh panels and by high-volume filter samplers.

MINERALOGY

Mineralogical investigation of the bulk samples (Tab. 2) shows that the most important minerals are quartz, plagioclase and hematite, together with lesser amounts of mica, kaolinite and chlorite. Locally, alkali-feldspars, carbonates, amphiboles and analcime were found.

The clay mineralogy shows that poorly-organized illite constitutes the most important mineral of the < 2 µm fractions (Tab. 3). On average, chlorite increases to the N together with serpentine, while kaolinite, smectite and palygorskite contents are always higher in the southernmost samples.

The mineralogy of the land-deposited dusts (Messina and Bologna samples) is worth mentioning separately. The composition of the samples as a whole and of the

<2 µm fractions each point to a distinction between the land and sea dust samples during the Eolo 81-1 sampling. The former are in fact mainly composed of quartz, calcite, dolomite, kaolinite, plagioclase and mica. In the <2 µm fraction, the most important minerals are illite (55-60 %) and kaolinite (25-30 %), with minor chlorite (5-10 %), smectite (5 %) and little palygorskite *(see* Tables 2 and 3).

Useful information may be obtained by comparing the clay mineralogy of the dusts with that of marine sediments (Tomadin, 1981) from corresponding underlying areas. The observed illite amounts of the dusts were higher than those of the sediments; on the other hand, little wind-blown smectite was recognized. In the Adriatic Sea, both sediments and dusts suggest the same kaolinite/chlorite ratio, with an increase to the N of chlorite (and serpentine)—typical minerals of Alpine origin, which are mainly transported into the Adriatic Basin by the Po River (Tomadin, 1969). Similarly, the content of kaolinite and palygorskite, typical minerals of peridesertic environments (Chamley, 1971), increases gradually to the S.

The presence of palygorskite in the Mediterranean dusts (as evidenced in samples E1-5 and ME and BO) was appreciable during the severe episodic conditions of direct transport from the S. Moreover, palygorskite was also found in the atmospheric dusts over the northernmost areas of the basin, as a consequence of meteorological conditions favourable to indirect transport (evidenced in several Eolo 81-2 samples). In the marine sediments of the Mediterranean, palygorskite was found only in southern part of the basin, where the eolian supply prevails. On the other hand, in the sediments of the northern part of the basin, where the fluvial supply prevails, palygorskite is diluted and masked by other more abundant clay minerals (Tomadin, 1981).

The mineralogy of the collected dusts emphasizes the changes related to the previously mentioned flow patterns.

The mineralogy of the Eolo 81-1 dusts (E1-1, 2, 3) must be related to transport by local winds carrying abundant chlorite from the surrounding Albanian ophiolitic soils (Tomadin *et al.*, 1982). After a few days, the meteorological conditions changed and became favourable to a direct transport of dusts (E1-4, 5) from the S, characterized by higher quartz, feldspars, kaolinite and mica contents and by smaller but nevertheless appreciable amounts of smectite and palygorskite.

When, at the end of the sampling period (March 30, 1981), direct transport across the Mediterranean to the N become aerodynamically important, the ME and BO samples showed similar compositions. Large amounts of quartz, feldspars, kaolinite, poorly-organized illite and also calcite and dolomite characterize these atmospheric dusts. This mineralogy is comparable to that of the eolian contribution of Saharan origin along the eastern margins of the Atlantic Ocean (Chester *et al.*, 1977; Windom, 1975; Prospero, 1981).

The mineralogy of the Eolo 81-2 collected dusts shows, on the contrary, an irregular mineral distribution, which must be related to the different circulation patterns. Because of the indirect eolian transport of dusts suspended in the lower atmosphere, minerals of southern origin (palygorskite, kaolinite, poorly-organized illite) mix together with minerals from northern source (chlorite, serpentine and better-organized illite).

CHEMICAL COMPOSITION

• Geochemical investigations make it possible to define the elemental composition of the collected grain-size fractions and to evaluate the chemical elements

Table 3

Clay mineralogy of the < 2 µm fractions: a) sea and land collected dusts (Eolo 81-1); b) sea collected dusts (Eolo 81-2).

Composition minéralogique de la fraction <2 µm : *a)* poussières éoliennes échantillonnées en mer et à terre (Eolo 81-1); *b)* poussières éoliennes échantillonnées en mer (Eolo 81-2).

Dust	Sample location	Smectite	Illite	Kaolinite	Chlorite	Serpentine	Plagygorskite	Mix.-Lay.
E1-1	Central Adriatic	—	67	8	25	—	—	— —
E1-2	Southern Adriatic	—	67	11	15	7	—	— —
E1-3	Southern Adriatic	—	55	13	27	5	—	— —
E1-4	Northern Ionian Sea	—	67	14	12	6	—	— —
E1-5	Strait of Messina	8	62	20	10	—	X	— —
SC	Scilla	4	72	6	18	TR	—	— —
ME	Messina	5	61	24	10	—	X	— —
BO	Bologna	8	55	32	5	—	X	— —
E2-1	Gulf of Saronikos	6	60	9	20	5	—	— —
E2-2	Gulf of Corinth	4	66	10	20	—	X	I-CHL
E2-3	Gulf of Patras	10	58	9	23	—	X	— —
E2-4	North Ionian Sea	TR	78	5	10	7	—	— —
E2-5	Southern Adriatic	5	64	12	15	4	X	— —
E2-6	Southern Adriatic	—	70	10	10	10	X	— —
E2-7	Central Adriatic	—	69	9	12	10	X	— —
E2-8	Northern Adriatic	—	72	9	15	4	—	— —

X, present; TR, trace.

contributing to the present sedimentation via eolian transport. The elemental data (Tab. 4 and 5) show a clear distinction between Eolo 81-1 and Eolo 81-2 dusts and, furthermore, between the Eolo 81-1 sea collected samples and those collected over land. The latter (Bologna and Messina samples), both collected during a significant event of direct transport from the S, show a very similar composition and are characterized by higher Ca and Mg contents, corresponding to the large amounts of calcite and dolomite found in the dusts. It may be noted, moreover, that these dusts show very similar major element composition and Co, Cr, Cu contents to those of Saharan dusts sampled over the Atlantic Ocean (Glaccum, 1978).

The Eolo 81-1 sea collected dusts show higher SiO_2, Al_2O_3 and Fe_2O_3 average contents and lower (excluding Ba and V) trace elements amounts. All the Eolo 81-1 samples are characterized by very low organic matter contents (2-3%).

The Eolo 81-2 samples reveal, on the other hand, high organic matter contents (20-30%), lower SiO_2/Al_2O_3 ratios, an increase of Na and Ti and a stronger ferromagnesian character on an organic fraction free basis (Tab. 5). The trace elements contents of the whole sample (values on an organic fraction free basis are not given, the trace elements bounded with the organic matter being unknown) range between those of the Eolo 81-1 sea and those of the Eolo 81-1 land collected samples. The significant increase of Cr may be related to the serpentine and chlorite presence, or considered as pollutant.

• The chemical composition generally shows a good agreement with the mineralogy. Most K_2O is connected with the clay minerals, and higher SiO_2 and CaO contents correspond, respectively, to the quartz and calcite presence. Increasing iron amounts are due to the Fe-rich phases (mainly oxides) prevailing on the ferromagnesian ones. It is, however, worth mentioning that not all Fe_2O_3-rich dusts (E2-3, 4, 5 and E1-2, 3, 4 samples) correspond to high hematite contents. It is therefore possible that part of the iron is in metallic form linked with organic matter or related to coal burning products (David, 1981).

• The chemical composition makes it possible to differentiate between the dusts according to provenance transport patterns. To this end, well-known petrochemical diagrams (Fig. 6 and 7) were applied.

In the dusts of direct southern provenance (Eolo 81-1 land samples), quartz and the carbonate fraction prevail, whereas the dust transported by local winds from the south (Eolo 81-1 sea samples) are shifted towards the mica compositions. All the Eolo 81-1 samples, characterized by higher mica and K-feldspar amounts, show K/Na > 1 ratios.

The dusts of northern provenance (Eolo 81-2) exhibit a more evident ferromagnesian character and significative influence of chlorite. The decrease of mica and K-feldspar amounts results in K/Na < 1 ratios.

Table 4

Chemical composition of the Eolo 81-1 dusts.

Composition chimique des poussières éoliennes (croisière Eolo 81-1).

	E1-1 (1)	E1-2	E1-3	E1-4	E1-5	$\bar{x}_{sea}$	σ_{sea}	Scilla (1)	BO	ME	$\bar{x}_{land}$	σ_{land}
SiO_2	31.77	63.81	60.89	60.24	60.37	61.33	1.68	55.89	51.12	52.45	51.79	.94
Al_2O_3	21.84	14.35	14.82	15.99	16.92	15.52	1.16	19.72	14.40	11.16	12.79	2.29
Fe_2O_3	9.14	8.45	8.89	8.42	6.48	8.06	1.08	7.37	5.90	4.73	5.32	.83
CaO	12.43	2.82	3.89	3.81	3.35	3.47	.49	2.33	10.54	13.84	12.19	2.33
MgO	7.34	2.21	2.55	3.48	3.10	2.84	.57	3.27	4.43	3.28	3.86	.81
Na_2O	5.55	.92	1.09	—	1.23	.81	.55	3.06	1.06	1.26	1.16	.14
K_2O	6.55	2.92	3.31	2.91	3.91	3.26	.47	4.66	3.79	2.72	3.26	.76
P_2O_5	.21	.20	.21	.13	.19	.18	.04	.16	.38	.46	.42	.06
TiO_2	.68	.68	.66	.75	.84	.74	.08	1.07	.96	1.05	1.01	.06
Ba	1 450	1 380	1 510	1 500	1 500	1 473	62	1 150	1 200	1 050	1 125	106
Co	10	10	10	12	10	11	1	20	28	35	32	5
Cu	60	60	75	55	65	64	9	110	105	135	120	21
Cr	180	160	180	165	175	170	9	150	200	195	198	4
Mn	780	705	755	695	730	721	27	1 050	810	960	885	106
Ni	105	150	130	125	100	126	21	250	210	190	200	14
Sr	1 600	1 450	1 480	1 500	1 500	1 483	24	1 250	2 000	1 750	1 875	177
V	25	45	26	32	38	35	8	30	22	18	20	3
	●	●	●	●	●	*		◧	■	■	□	

L.O.I. = the value in all the sea collected samples range from 2 to 3%. Part of L.O.I. value is imputable to organic matter.
Fe_2O_3 = total iron as Fe_2O_3.

(1) Anomalous values rejected in the average calculation.

Table 5

Chemical composition of the Eolo 81-2 dusts (whole sample and on an organic fraction free basis).
Composition chimique totale et recalculée à 100% sans la fraction organique (croisière Eolo 81-2).

	E2-3	E2-4	E2-5	E2-6	E2-7	E2-8	$\bar{x}$	σ
SiO_2	36.73	39.67	36.11	43.95	41.31	44.87	40.44	3.63
Al_2O_3	11.23	11.16	11.92	12.34	11.98	11.05	11.61	.53
Fe_2O_3	16.98	14.46	14.08	6.34	6.30	6.01	10.70	5.01
CaO	3.56	2.68	2.50	1.38	1.36	1.19	2.11	.95
MgO	4.54	5.17	2.98	2.66	3.83	2.70	3.65	1.05
Na_2O	1.88	1.33	1.53	1.17	2.63	2.46	1.83	.60
K_2O	1.42	1.07	1.22	.69	1.32	.80	1.09	.29
P_2O_5	.20	.18	.16	.26	.30	.12	.20	.07
TiO_2	1.10	.96	1.25	.68	.86	1.15	1.00	.21
L.O.I.	21.05	20.39	26.64	29.59	n. d.	n. d.		
Ba	1 200	950	980	1 050	900	1 150	1 038	118
Co	30	25	26	18	28	25	25	4
Cu	80	66	82	75	76	70	75	6
Cr	210	225	190	260	205	200	215	25
Mn	655	810	1 000	800	710	680	776	127
Ni	215	105	180	160	220	95	163	53
Sr	1 650	2 050	1 800	1 200	1 600	1 850	1 692	289
V	20	40	40	25	30	40	33	9
	▲	▲	▲	▲	▲	▲	◆	

Fe_2O_3 = total iron as Fe_2O_3.
3 *a*... 8 *a*, $\bar{x}a$ and σ_a = chemical data on an organic fraction free basis.

E2-3 *a*	E2-4 *a*	E2-5 *a*	E2-6 *a*	E2-7 *a*	E2-8 *a*	$\bar{x}a$	σa	
SiO_2	47.31	51.73	50.33	63.26	59.11	63.78	55.92	7.05
Al_2O_3	14.45	14.55	16.61	17.76	17.14	15.71	16.04	1.36
Fe_2O_3	21.87	18.86	19.62	9.13	9.01	8.54	14.50	6.23
CaO	4.58	3.50	3.48	1.99	1.95	1.69	2.87	1.10
MgO	5.85	6.74	4.15	3.83	5.48	3.84	4.98	1.22
Na_2O	2.42	1.73	2.13	1.68	3.76	3.50	2.54	.89
K_2O	1.83	1.40	1.70	.99	1.89	1.14	1.49	.37
P_2O_5	.26	.23	.22	.37	.43	.17	.28	.10
TiO_2	1.42	1.25	1.74	.98	1.23	1.63	1.38	.28
	△	△	△	△	△	◇		

CONCLUSIONS

1) Air borne dusts were collected in the Central Mediterranean, close to the seawater-atmosphere interface, with the aim of investigating, as part of the Eolo Project, their contribution to present sedimentation. During the spring 1981 meteorological conditions were favourable to the transport, by southerly winds, of yellow dusts (Eolo 81-1 sampling). In the autumn of 1981 on the other hand, northerly winds favoured the input, by indirect transport, of brown-blackish dusts (Eolo 81-2 sampling).

Roughly estimated dust-loadings permit a distinction between seasonally variable amounts of atmospheric dusts, characterized by different mineral and chemical composition.

2) The mineralogy of the dusts reflects their origin. High quartz, plagioclase and K-feldspar contents were recognized in the total sample of the dusts blown from the S.

The <2 µm clay mineralogy showed:

a) abundant poorly-organized illite and important amounts of kaolinite (and palygorskite), associated with winds from a southerly direction;

b) abundant better-organized illite and important amounts of chlorite (and serpentine) associated with winds from a northerly direction.

The clay mineralogy of the dusts was compared to that of the sea sediments and several concordant trends were determined.

3) Investigation of the chemical composition permitted differentiation between the dusts on the basis of their provenance, according to the mineralogy. Eolian supplies from the N are characterized by higher organic matter contents (20-30%), whereas only small amounts (2-3%) are present in the dusts of southern provenance. The dust samples from the N show a ferromagnesian composition and Na/K>1 ratios; samples from the S are characterized by higher Si/Al ratios and Ca contents and exhibit K/Na>1 ratios.

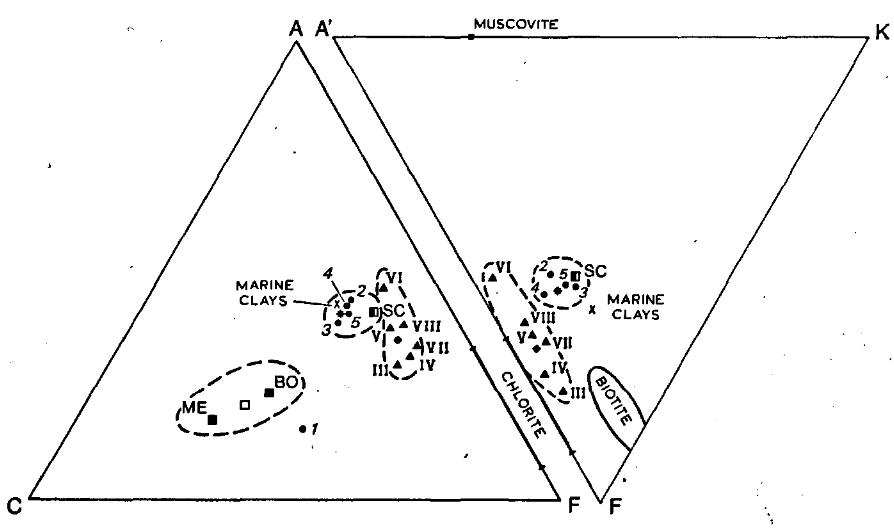


Figure 6
Eolian dusts composition on the ACF and A'KF diagrams (Winkler, 1967). Symbols as in Tables 4 and 5.
Composition chimique des poussières éoliennes sur les diagrammes ACF et A'KF (Winkler, 1967). Symboles d'après les tableaux 4 et 5.

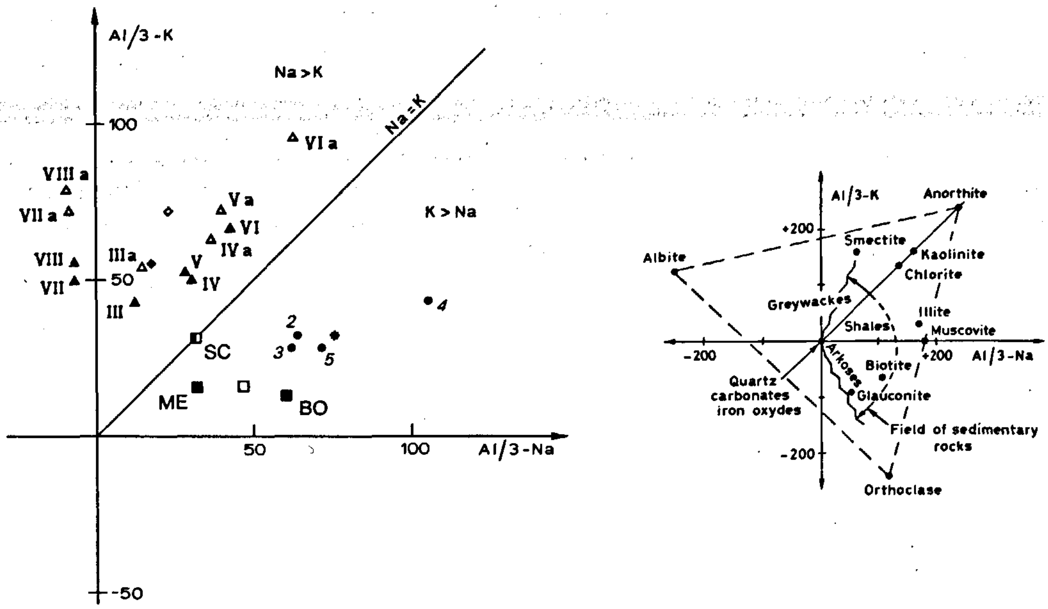


Figure 7
Chemical composition on the (Al/3-K) ƒ (Al/3-Na) diagram (de la Roche, 1968). Symbols as in Tables 4 and 5.
Diagramme (Al/3-K) ƒ (Al/3-Na) (de la Roche, 1968). Symboles d'après les tableaux 4 et 5.

4) A significant event involving the direct transport of Saharan dusts was studied from the meteorological and sedimentological points of view. Atmospheric dusts collected contemporaneously either in Messina or in Bologna, on 30 March 1981, proved the identity and the continuity of the same dust-carrying storm. Despite the distance of 800 km separating the sampling localities, these dusts were characterized:

a) by the same mineralogy: abundant quartz, feldspars and kaolinite, smectite and remarkable amounts of calcite and dolomite;

b) by a chemical composition with a large enrichment of Ca and Mg related to presence of carbonate, and with higher trace element contents.

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