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There is currently much interest in the effect of bottom currents on sediments in the deep ocean, in the complex interaction of bottom current, turbidity current and pelagic depositional processes, and in distinguishing between their respective deposits (e.g. Richardson *et al.* 1981; Shor *et al.*, this volume). These studies are of particular importance for the understanding of deep-sea sedimentation and for the reconstruction of palaeo-oceans.

Many of the major contourite drifts in the North Atlantic have now been cored and their sediments examined in detail. We have thus been able to construct a general picture of contourite facies, refining the earlier work of Hollister & Heezen (1972). Two main contourite types have been described (Stow & Lovell 1979; Faugères *et al.* 1979; Stow 1982): *muddy contourites* are relatively homogeneous and extensively bioturbated, whereas *sandy contourites* occur as thin, irregular, bioturbated lag deposits or more rarely as clean, cross-laminated beds. Both commonly comprise a mixture of biogenic and terrigenous material. Gradations between these two types as well as coarser-grained gravel lag deposits (*gravelly contourites*) have also been observed.

However, most of the cores studied to date represent either isolated or very widely-spaced sites on drifts that are many hundreds of kilometres long and tens of kilometres wide. We thus have very little idea of the horizontal distribution or vertical sequences of sediments within such drifts. We also lack detailed information on the small-scale variability of contourite facies in response to the known dynamic variability of bottom currents. We are not yet, therefore, sufficiently confident to unambiguously identify contourites in ancient rock sequences, nor to use facies variability as an accurate indicator of the development and fluctuation of palaeo-bottom currents, although several interesting attempts have been made in these fields (e.g. Pastouret *et al.* 1978; Auffret *et al.* 1981; Lovell & Stow 1981).

For these reasons, a much more detailed study of a contourite drift was clearly necessary, preferably one sufficiently small to allow a close-spacing of core stations and in an area where the physical oceanography was well-known. Several relatively small contourite drifts have been identified on the south Iberian margin (Vanney & Mougenot 1981), and were almost certainly constructed by the deep Mediterranean outflow through the Straits of Gibraltar. One of these, the Faro Drift, was selected for detailed study (Fig. 1).

The French oceanographic vessel, RV Noroit, was taken to the area in November 1982 and completed some 300 km of 3.5 kHz seismic profiling, occupied 24 sites for piston coring (with associated gravity coring) and 5 sites for bottom photography (Fig. 1). Subsequent laboratory analyses included X-radiography of centimetre-thick slabs of core, impregnation and thin-sectioning, grain-size determination by sedigraph and sieving, compositional determination of the sand and clay fractions, and geochemical, palaeomagnetic and biostratigraphical studies. The preliminary results of this work have been reported by Faugères *et al.* (in press). In this paper we describe in detail the nature of contourite facies, typical contourite 'sequences' and their hydrodynamic interpretation.

Oceanography and bathymetry

At the present day there is a deep outflow of warm (> 13°C), saline (> 36.4‰), low-oxygen (4.1 to 4.6 ml/l) Mediterranean Water through the Straits of Gibraltar (Madelain 1970; Zenk 1975; Reid 1978; Ambar & Howe 1979). This water-mass flows north and west along the southern margin of Spain and Portugal at depths of 400–1400 m (Fig. 1). At Cape St Vincent, part

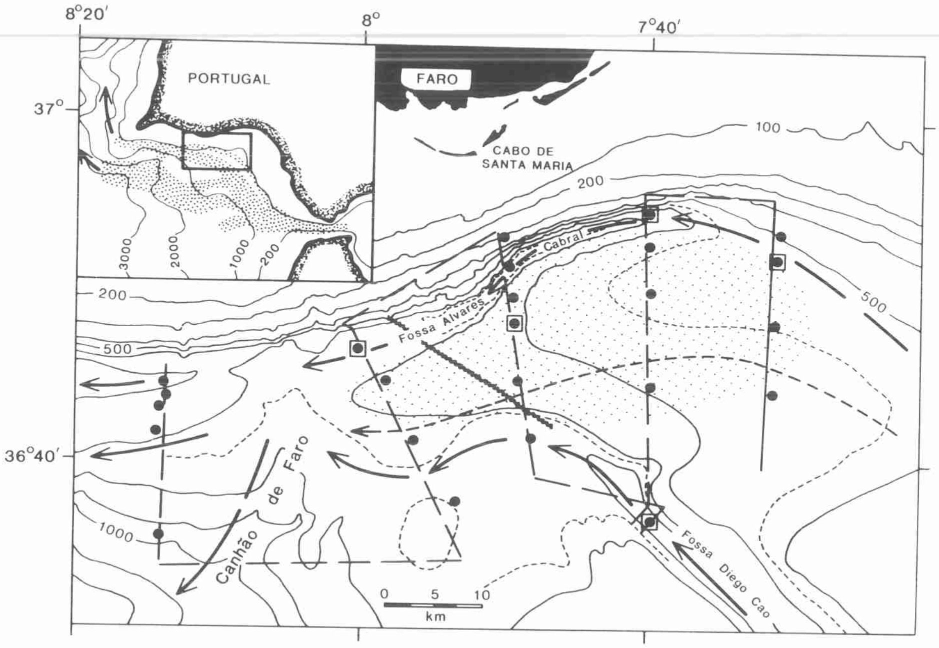


FIG. 1. Study area with Faro Drift in large stipple, showing 3.5 kHZ seismic track (dashed lines), core sites (solid circles), camera stations (open squares), known flow (heavy arrows) and inferred flow (light dashed arrow) of Mediterranean water, and location of seismic profile shown in Fig. 2 (heavy zig-zag). Contours in metre. Inset map shows passage of Mediterranean outflow water over sea floor and location of study area. (From Faugères *et al.*, in press.)

spreads westward into the mid-ocean and part turns north forming part of a larger scale eastern boundary current. In the Gulf of Cadiz there appear to be three main flows, between 1200–1300 m, 700–900 m and 500–700 m, controlled largely by the bottom topography and partly interconnected by down-canyon flow. There is an overall increase in flow depth from west to east.

Flow velocities of up to 300 cm/s have been recorded in the Straits of Gibraltar, decreasing to 180 cm/s just west of the Straits, 30–40 cm/s in the vicinity of the Faro Drift, and 10–20 cm/s at the western end of the Gulf (Melières 1974; Reid 1978). There are local variations due to the influence of bottom topography, some meandering of the flow and counterclockwise gyres, but an overall decrease in velocity concurrent with a westward broadening and deepening of the water mass is observed.

The general effects of the Mediterranean Outflow have been documented by a number of workers (Giesel & Seibold 1968; Heezen & Johnson 1969; Melières *et al.* 1970; Melières 1974; Vanney & Mougenot 1981). Significant erosion takes place in the Straits of Gibraltar as well as in some of the deep channels along the margin, such as the Fossa Alvares Cabral and Fossa Diego Cao to north and south of Faro Drift. Non-deposition is evident in some areas, whereas the accumulation of a series of sediment drifts up to 300 m thick is noted in others. Acoustic and photographic evidence reveals areas of rocky and current-swept bottom and areas of smooth or rolling sediment-covered morphology. Current-controlled bedforms, particularly evident in channelized areas include sediment waves and ripple marks. There has also been a long history of chafing and corrosion of submarine telegraph cables in the Gulf and the Straits of Gibraltar closely related to the Mediterranean Outflow.

The overall constructional aspect of the Gulf of Cadiz with its relatively shallow slope gradient (1 : 300) is probably also, in part, a result of the Mediterranean Outflow, although detailed study reveals a much more complex interplay of controls. A series of papers by Mougenot and coworkers on the south Iberian margin (Baldy *et al.* 1975; Mougenot *et al.* 1979; Mougenot & Vanney 1980, 1982; Vanney & Mougenot 1981) have shown a shelf 15–40 km wide, a narrow and moderately steep slope (1 : 6.5 to 1 : 25 gradient), a series of channels or deeps parallel to the margin interrupted by downslope canyons and four

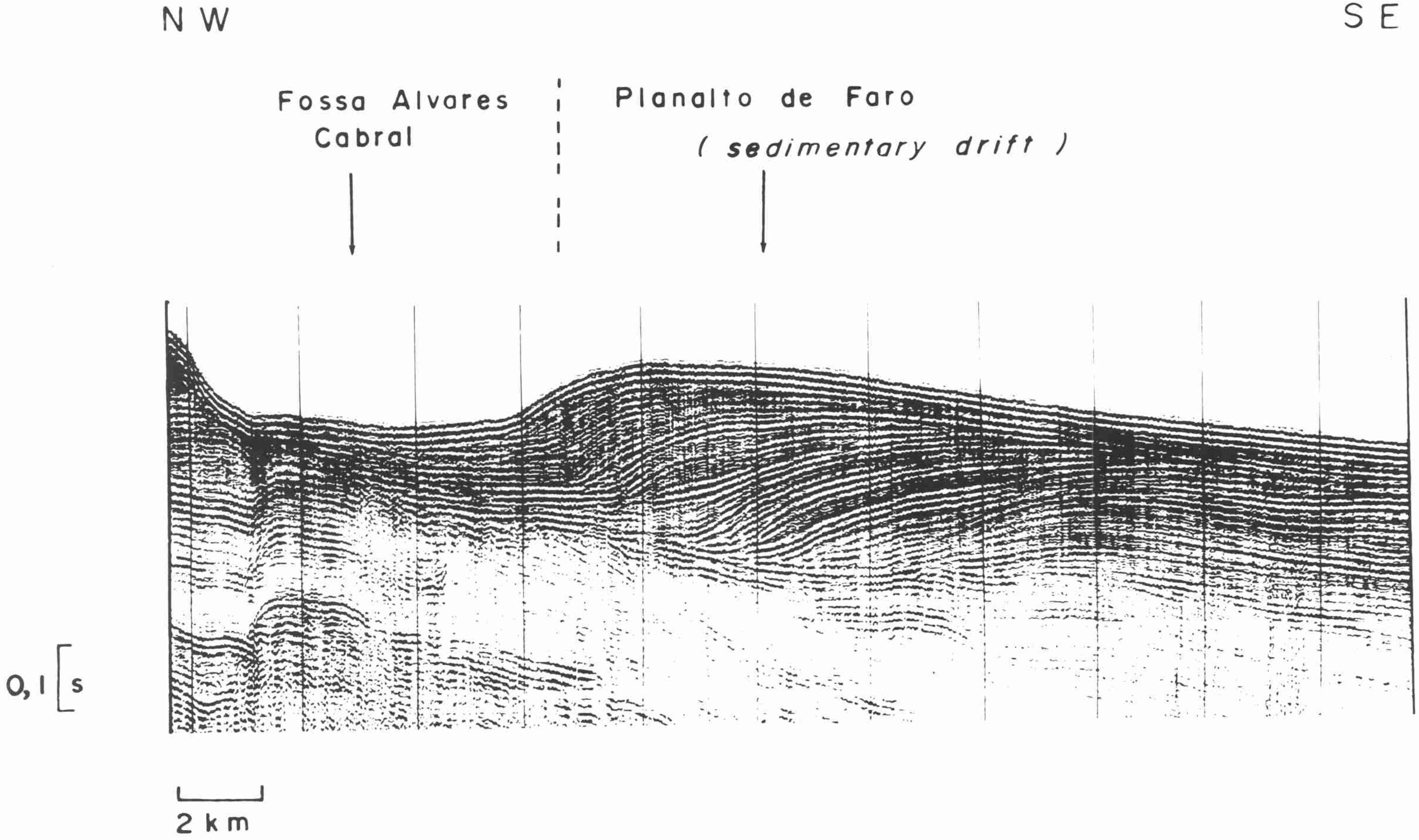


FIG. 2. Seismic reflection profile across the Faro Drift (Planalto de Faro) from Mougenot & Vanney (1982). Location shown in Fig. 1. This 300 m thick contourite drift has been built over a late Miocene-early Pliocene erosion surface by the northward progradation of sigmoidal sedimentary units. Vertical scale in two-way travel time.

constructional mounds or drifts along the length of the margin near the foot of the slope (Fig. 1).

The Faro Drift itself is 40–50 km long, 10–20 km wide, and up to about 300 m in thickness with a maximum present day relief of 160 m (Fig. 2). It appears to have been constructed over a late Miocene–early Pliocene erosional surface and to have prograded steadily to the north or north-west over a distance of about 10 km during the past 5–6 million years (Mougenot & Vanney 1982). The mode of growth appears closely analogous with lateral accretion in a meandering fluvial system or with constructional levee development in a deep-sea fan.

Sediment facies

There is little doubt that over 90% of the sediments cored are true contourites, including virtually all of the Faro Drift cores, as borne out by the microphysiographic and bottom photographic evidence (Faugères *et al.*, in press). Whereas some 5–7% of the material in the canyon to the west, or on the channel floors and steep eroded channel slopes, occurs in distinct turbidite beds and slumped units or is an older more consolidated sediment of unknown origin. In the following sections we describe only the contourites, for which we recognize three main facies: sands and silts, mottled silts and muds, and homogeneous muds.

Sands and silts

The sands and silts form about 5% of sediment and occur in irregular beds from a few centimetres to 20 cm in thickness (Fig. 3). They are almost always surrounded by the mottled silt and mud facies.

Primary sedimentary structures

The top and bottom contacts of the sand and silt beds are mostly irregular and may be sharp but relatively flat, clearly erosive or completely gradational. Erosional contacts appear to be slightly more common at the base of beds. It is often difficult to distinguish contacts that are of primary dynamic nature from those caused by bioturbation, and many of the contacts that change from sharp to gradational across the width of the core have probably been affected by secondary bioturbation (Fig. 4).

There is almost no lamination remaining in any

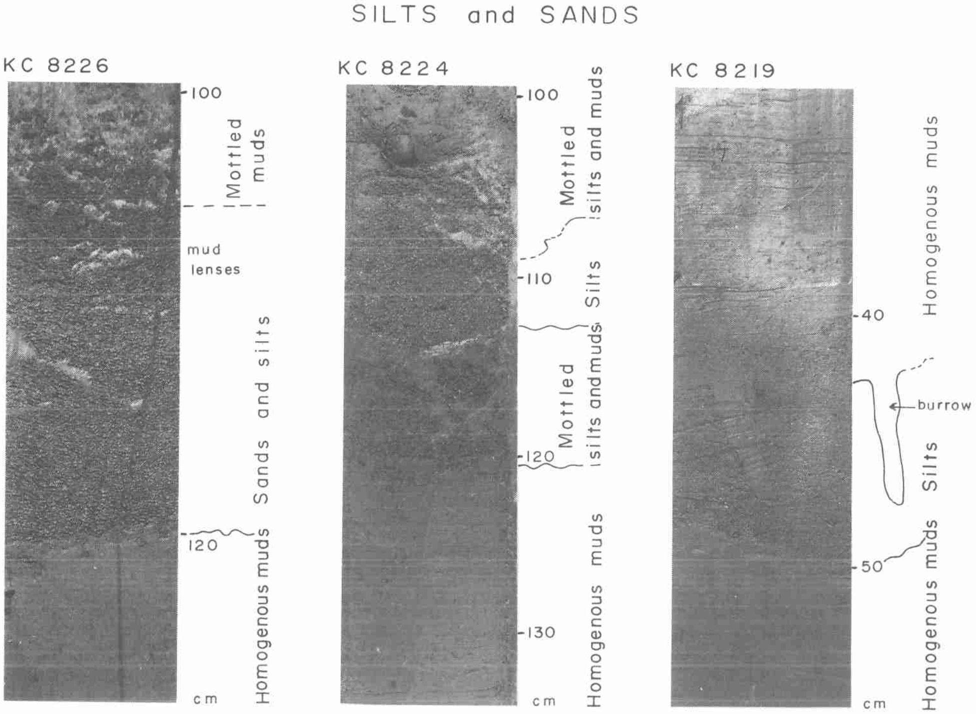


FIG. 3. Photographs of core sections with mottled silt and mud, and homogeneous mud contourites. Sharp and erosive bed contacts shown by solid lines, gradational contacts shown by dashed lines.

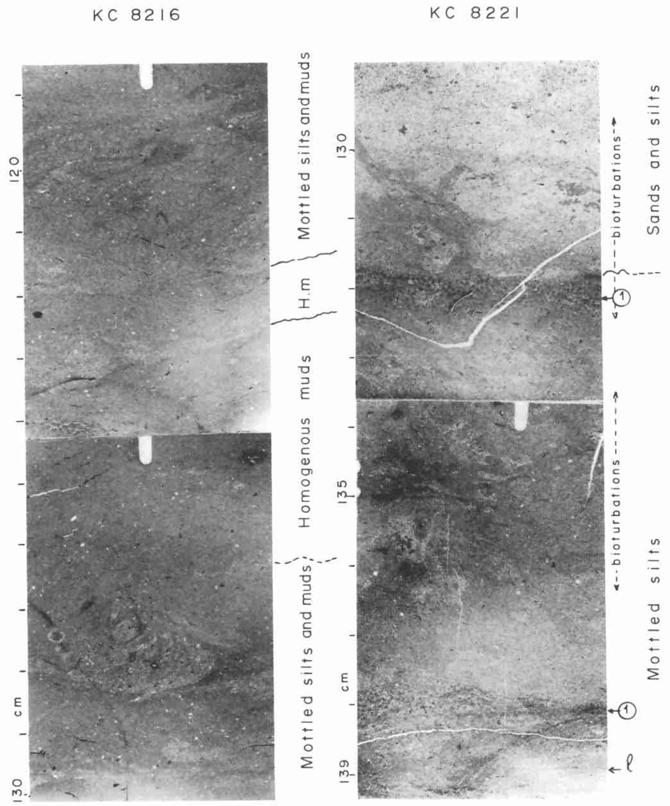


FIG. 4. Thin sections photographs of impregnated slabs of sections of two cores, showing detailed structures of different contourite facies. Note, in particular, nature of contacts and bioturbation. *Teichichnus*-like burrow indicated with 'b'. Mottled aspect at levels 1 is an artefact.

of the beds cored, although the presence of ripple marks and other current bedforms on the present-day sea floor would suggest that many of the sandy layers were originally laminated. Rarely, there are discontinuous and indistinct clayey laminae within the sands, although their origin is unclear.

Size grading within the sands and silts is often present but very variable in nature (Figs 5 and 11). Positive and negative grading occur equally commonly and may be relatively continuous through a bed or occur irregularly in rapid succession. Several of the thicker beds increase in grain-size from the base towards the middle, where there are pockets of coarser (often shelly) material, and then decrease in size towards the top.

Biogenic structures

Bioturbation is the most common structure encountered, although in many of the sands it is only visible as an indistinct mottling (cm-scale) on X-radiographs (Figs 3 and 10). Bioturbation at the top and bottom contacts of beds introduces pockets of sand into the adjacent sediment and wisps or streaks of mud into the sand. Large (up to 10 cm long) mud-filled or sand-filled burrows occur as straight isolated protrusions some of which appear to be *Lophoctenium*, or as a tortuous network of smaller diameter tubes.

Texture

Although some of the silts and sands contain rare coarse (up to 5 mm) shell fragments, they are mostly relatively fine-grained with a mean grain-size between 30 and 50 μm (Figs 4, 5 and 6). They are mostly, therefore, medium-coarse grained silts with 20–40% sand and less than 10% clay. More rarely, the fine sand fraction is dominant. They are mostly moderately well sorted. The shape of the cumulative frequency grain-size curves (Rivière 1977) tends towards parabolic or to a combination of hyperbolic (coarse tail) and parabolic (fine tail). This relatively large fine tail is found even in the middle of the thicker beds, which suggests that it is not solely due to

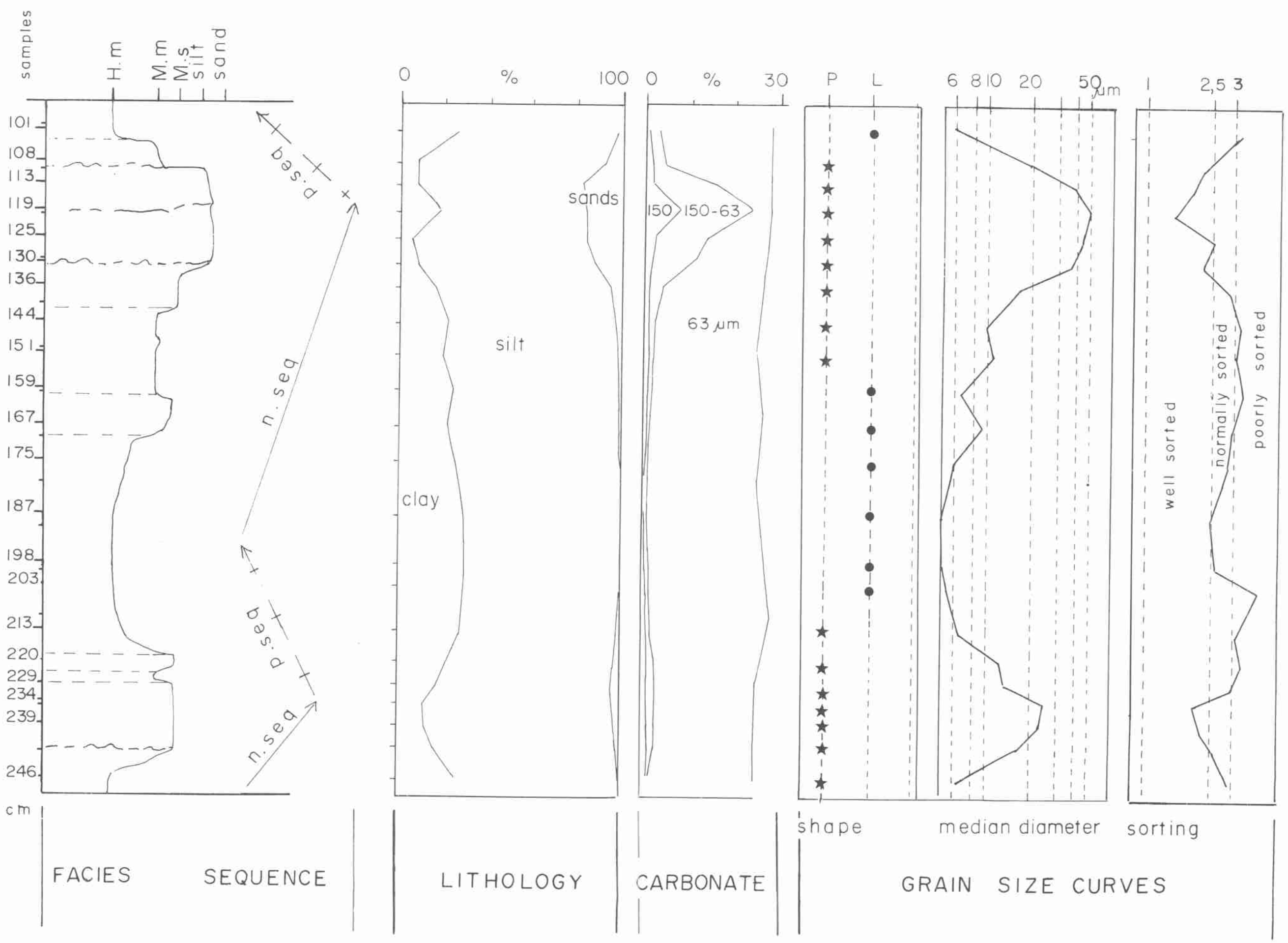


FIG. 5. Lithological and textural analyses through a 150 cm section of core (KC 8221). Note characteristics of homogeneous mud (Hm), mottled mud (mm) and mottled silt (Ms), and silt/sand contourite facies. Shape of grain-size curves, denoted by P (parabolic) and L (logarithmic), following Rivière (1977); p. seq = positively graded sequence, n. seq = negatively graded sequence.

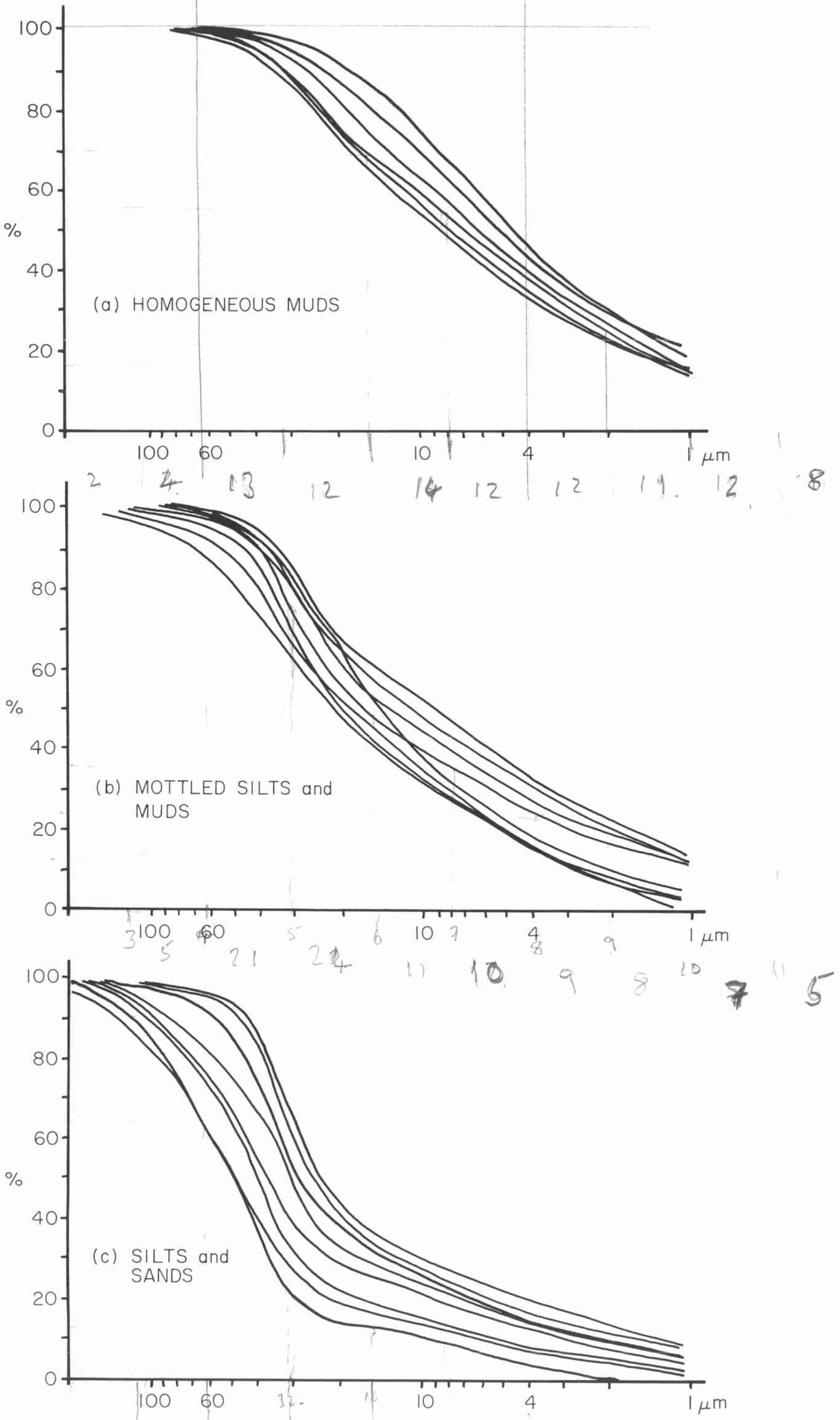


FIG. 6. Typical grain-size cumulative frequency curves plotted on semi-logarithmic paper for the three main contourite facies identified.

2 3 4 5 6 7 8 9 10 phi

10 26 44 8 6 4 2

bioturbation with the adjacent finer sediments but has a primary dynamic origin.

Composition

The sands and silts clearly have the largest proportion of coarse fraction (>63 μm) of the three main facies (Figs 5 and 7). The fraction >150 μm is dominantly biogenic, with roughly equal proportions of benthonic foraminifera, planktonic foraminifera and shell debris (mainly bivalves), and rather less ostracods and other species. The mean size of the planktonics is noticeably less than either the benthonics or shell fragments, but larger than the rare traces of quartz, mica, pyrite and amber. The 63–150 μm fraction contains notably more (60–70%) terrigenous material (quartz, mica, iron-coated grains, pyrite, rare glauconite), similar amounts of benthonic and planktonic foraminifera and rather less shell debris. The total carbonate content of the whole sediment varies between 30–40%, whereas the clay fraction is mostly less than 10%.

Many of the larger biogenic grains are fragmented and, more rarely, iron-stained. The quartz grains are subangular to subrounded.

Mottled silts and muds

The mottled silts and muds form a visually distinctive facies that comprises either a rapid alternation of thin irregular mud, silt (and sand) layers or, more commonly, a completely irregular arrangement of these sediment types in pockets, lenses and streaks (Figs 8, 9 and 10). The facies can be further subdivided with respect to the relative proportions of sand, silt and clay: mottled silts containing lenses and mottles of mud and mottled muds containing lenses of silt. They form about 20% of the cored section in 'beds' that average 10–20 cm in thickness, but that vary from a few cm to 70 cm thick. They occur in association with both the sands-silts and the homogeneous muds.

Primary sedimentary structures

The top and bottom contacts of the mottled intervals, as with the sand-silt facies, may be sharp and planar, erosive or gradational, or any combination of these types (Figs. 8, 9 and 10). Similarly, the pockets and lenses of different sediment types appear as more or less distinct bodies both to the naked eye and on X-radiographs. It is again difficult to distinguish primary dynamic from bioturbational contacts.

Lamination is commonly evident, especially on X-radiographs, but it is always irregular and wavy. There is a lamination, continuous across the width of the core, that is a more or less distinct alternation of silty and muddy laminae; a more discontinuous lamination marked by the horizontal alignment of flattened lenses of silt or mud; and a gradation between these two types (Figs 9 and 10). Although the discontinuity of the laminae may be due to bioturbation, it seems clear that there remains at least some evidence of an original dynamic regime.

Alternate positive and negative grading is evident on a small-scale within the mottled intervals, but there is also commonly a more gradual increase of grain-size upwards from an underlying homogeneous mud or decrease upwards from a sand through a thickness of 10–50 cm (Figs 5 and 11).

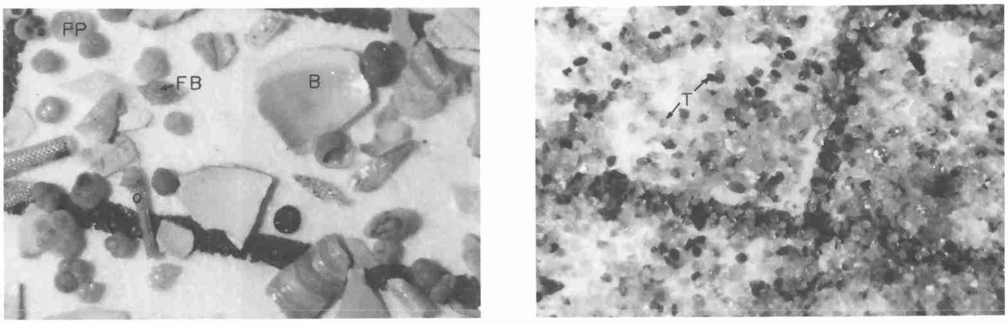
Biogenic structures

The dominant feature of this facies is a thorough bioturbational mottling which occurs at a millimetre and centimetre scale, together with other more or less distinct and isolated pockets and streaks at a millimetre or centimetre scale (Fig. 8). Certain more regular or internally structured forms are also recognized and can tentatively be identified as specific trace fossils (Figs 9 and 10). These include, the small (μm-cm scale) elongate lenses and tubes, sometimes so densely-spaced as to form an interlocking network, that are probably a form of *Chondrites*; the more regular oval and elipsoid forms that are most likely *Planolites*; and some larger (centimetre diameter) chevron-structured burrows that appear similar to *Scolicia* and *Teichichnus* (Werner & Wetzel 1982). At certain horizons there are also very thin, long iron-sulphide filaments and larger pyrite-filled burrows.

The bioturbation and burrowing has clearly been a continuous process that has served to modify or destroy much of the original sedimentary structure. Several superimposed episodes of bioturbation are commonly evident.

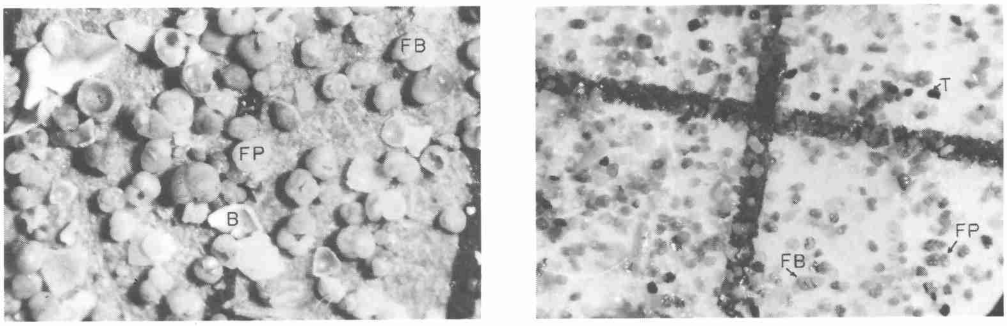
Texture

The mottled facies is clearly very heterogeneous and comprises pockets or layers of variable grain-size (Figs 4, 5 and 6). Our analyses have attempted to homogenize this variability by using relatively large samples, and have shown a gradation from a more clay-rich very poorly-sorted sediment (mean size, 8–16 μm) to a coarser silt, with poor but slightly better sorting (mean size, 16–30 μm). The grain-size curves are nearly all parabolic, with a relatively small or absent coarse



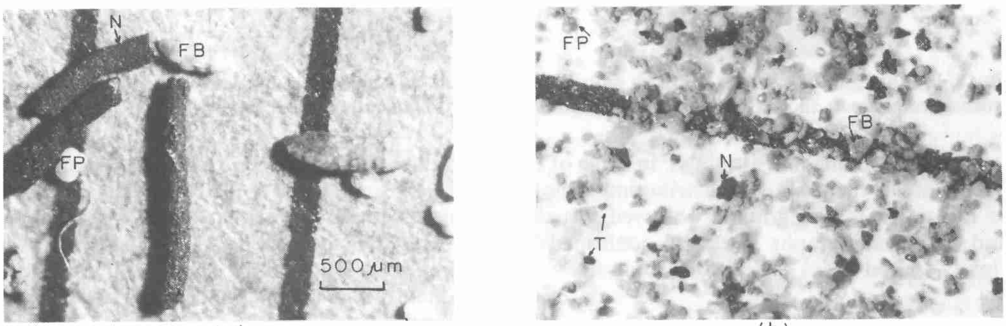
(a) (b)

SANDS and SILTS



(a) (b)

MOTTLED SILTS and MUDS



(a) (b)

HOMOGENOUS MUDS

FIG. 7. Composition of the sand fractions of each of three contourite facies: (a) 150μm fraction, (b) 150–63μm fraction. FP = planktonic foraminifera; FB = benthonic foraminifera, B = other biogenic fragments, T = terrigenous grains, N = iron sulphide grains or tubes. Views through binocular microscope, scale at bottom left.

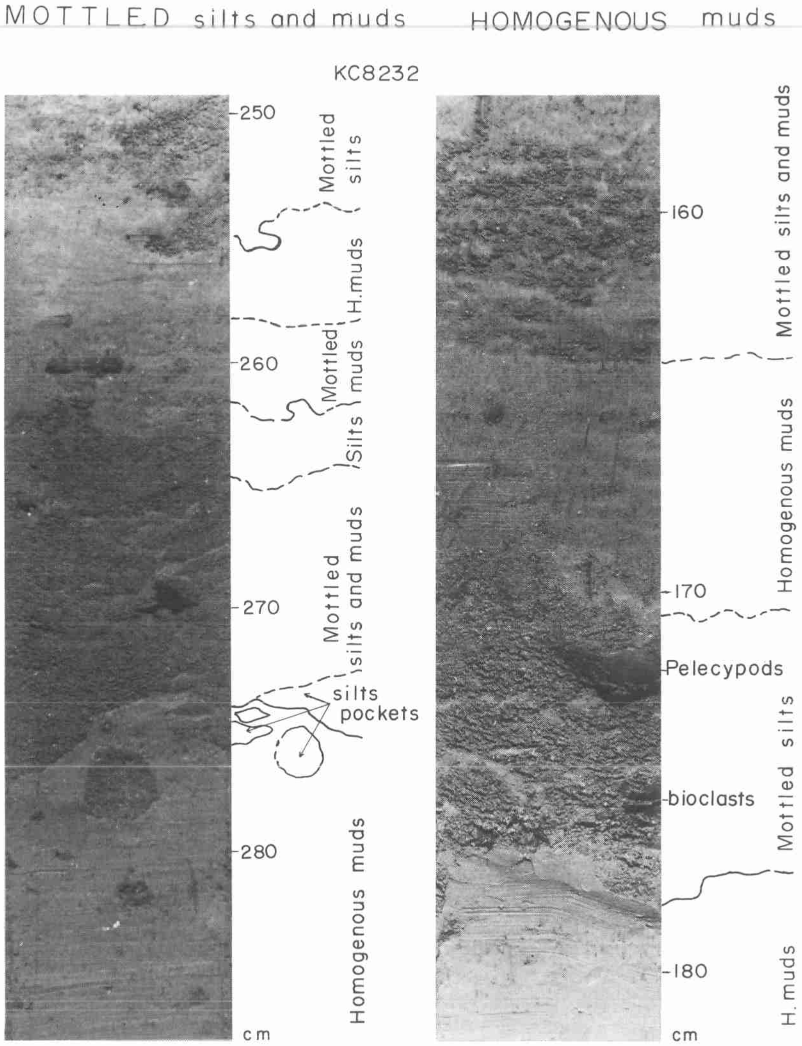


FIG. 8. Photographs of core sections with mottled silt and mud, and homogenous mud contourite. Sharp and erosive bed contacts shown by solid lines, gradational contacts shown by dashed lines.

tail and a large fine tail; although, in some of the finer samples the grain-size distribution is closer to logarithmic. The grading observed visually, and on X-radiographs is clearly confirmed by closely-spaced series of grain-size analyses.

Composition

There is also a relative heterogeneity in the coarse fraction (> 63 μm) composition of different samples of this facies (Figs 5 and 7). The three major components are benthonic foraminifera, planktonic foraminifera and terrigenous debris (especially quartz, silt and micas), as for the sands and silts, but their relative proportions are very variable. The shelly debris is less important, and is mostly a similar size to the benthonic and planktonic foraminifera; many of the larger elements are fragmented. The total carbonate fraction averages 20–30% and the clays 10–30%, comprising mainly illite with minor chlorite, kaolinite and smectite.

Homogeneous muds

The homogeneous muds are the finest-grained, visually most monotonous and most abundant of the three contourite facies, forming nearly 70% of the cored section in intervals of a few centimetres

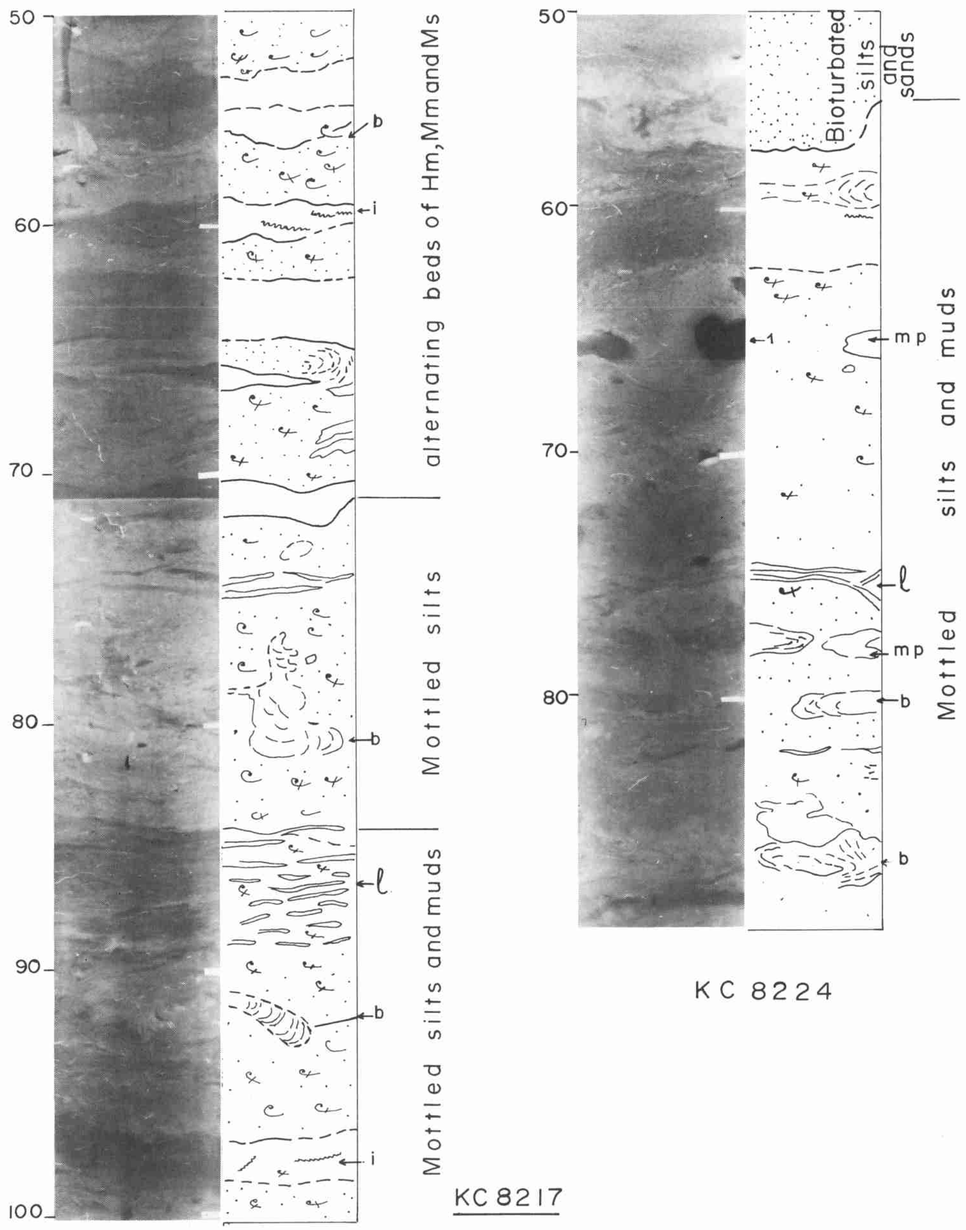


FIG. 9. X-radiographs of core sections showing typical primary and biogenic structures in the different contourite facies. Hm = homogeneous mud, Mm = mottled mud, Ms = mottled silt, b = burrow (? *Scolicia*), l = discontinuous lamination, mp = mud pocket (? *Planolites* burrow), i = iron sulphide mottle or mycelia. Scale in centimetres.

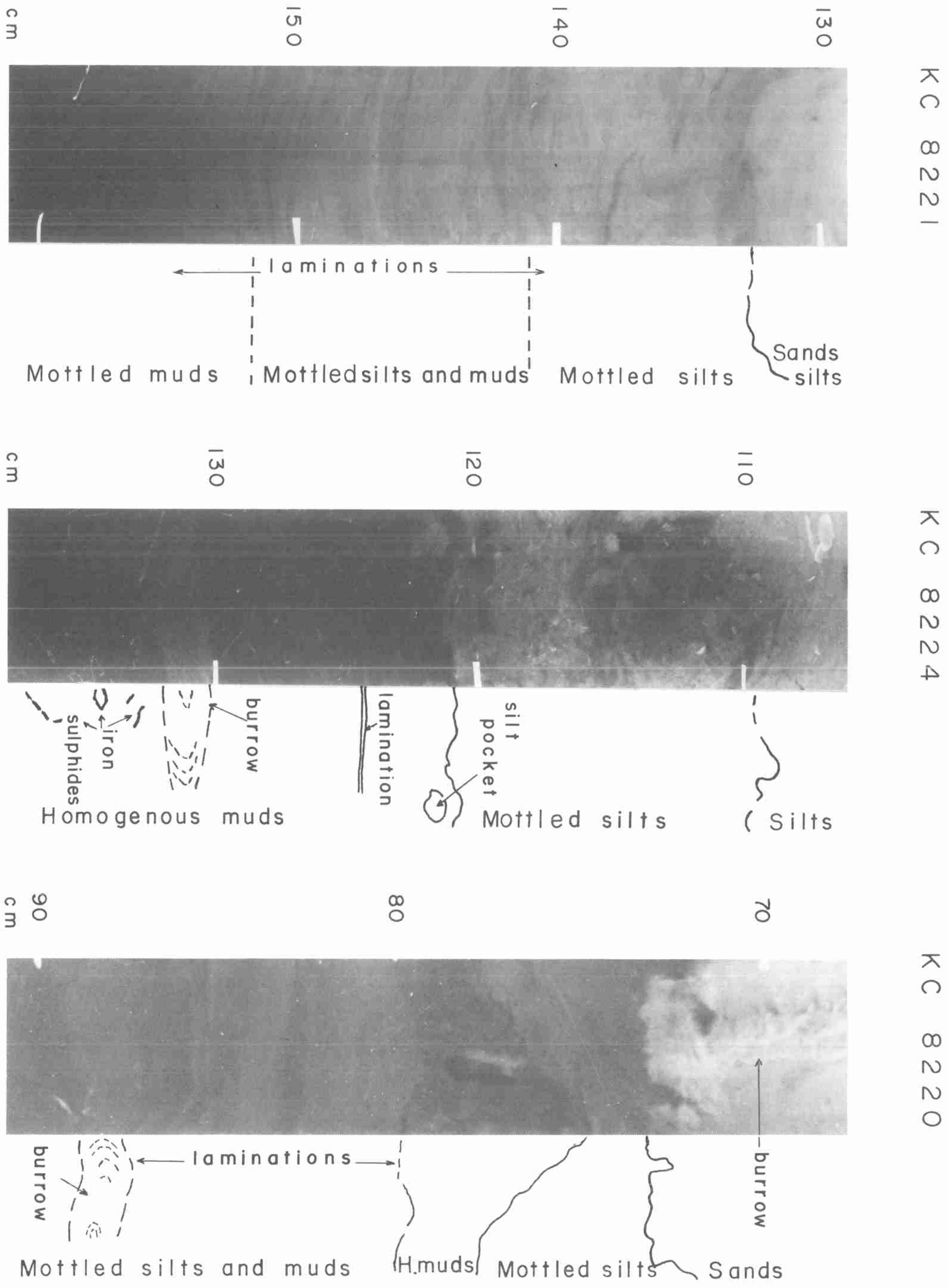


FIG. 10. X-radiographs of core sections showing typical structures of contourites (cf. Fig. 9).

to a few metres in thickness. Although to the naked eye they appear more or less structureless or massive, X-radiography and detailed sampling has shown that they are not strictly 'homogeneous' (Figs 8, 9 and 10).

Primary sedimentary structures

The homogeneous muds are most commonly in gradational contact with the mottled facies in sequences that are either positively or negatively graded. Less commonly, the contacts are sharp or erosive. Lamination occurs in some sections and may be very fine, distinct and planar, or less well-defined and wavy. It is sometimes accentuated by very thin parallel filaments of iron sulphides.

Biogenic structures

Where not laminated, the homogeneous muds appear to have been thoroughly bioturbated, although the mottles, pockets and streaks visible on X-radiographs are mostly faint, indistinct and of a very small size (mm scale). Some small lenticular tube-like structures may be *Chondrites*, but none of the larger burrow types encountered in the other facies are visible. Iron-sulphide traces and pyrite-filled burrows are locally very common.

Texture

Although fine-grained, these muds contain a large proportion of mostly fine and medium grade silt (40–60%), up to 50% clay and very little sand grade material (1–8%) (Figs 5 and 6). The mean size is less than about 10 or 12 μm and the sorting is poor to moderate. The grain-size curves are close to logarithmic in shape with a small coarse tail giving a hyperbolic tendency.

Composition

The small sand fraction contains mainly planktonic and benthonic foraminifera in approximately equal but variable proportions, and minor amounts of terrigenous and shell material (Figs 5 and 7). The total carbonate percentage is relatively low (mostly 20–30%) so that much of the silt fraction is terrigenous (especially quartz), with clay minerals dominating the finer fractions. Many of the planktonic foraminifera, bivalve and *Dentalium* shells and ostracods are whole rather than fragmented, and the sizes of the planktonics tend to be greater than those of the benthonics.

Vertical 'sequence' of facies

Description of sequences

Although we hesitate to use the term 'sequence' for fear of confusion with the concept of a distinctive *type* sequence, such as for turbidites, we do recognize that the vertical succession or arrangement of the three main facies may be of two characteristic types: a negatively-graded sequence in which the grain-size increases, and a positively-graded sequence in which the grain-size decreases upwards. These sequences are mostly between 10 and 100 cm thick (Figs 5 and 11).

The complete negative sequence begins at the base with a fine-grained homogeneous mud, passes upwards through a clay-rich and then silt-rich mottled facies and is topped by a coarse silt or fine sand bed. Contacts between facies near the base are gradational but, towards the top, sharp and erosive contacts are more common. Each of the component facies may show the range of variability as described in the previous section, although the overall succession of facies is accompanied by progressive structural, textural and compositional changes. There is thus a tendency towards an upward increase in erosive contacts, increase in the size of burrows and bioturbational mottles, increase in mean grain-size and percent sand fraction, change in shape of the grain-size curves from logarithmic through parabolic to hyperbolic-parabolic, increase in the relative proportion of benthonic foraminifera, shell debris and total carbonate, and decrease in the relative size of the planktonic foraminifera compared with other biogenics.

The positive sequence is the exact reverse, showing an upward change from the sand-silt through the mottled to the homogeneous mud facies, together with the corresponding structural, textural and compositional changes.

There is considerable variability in these two sequences as they occur in different parts of the Faro Drift, particularly with respect to their thickness but also in terms of their completeness (Fig. 11). Commonly, the silt-sand facies is missing and, less commonly, part of the mottled facies or the homogeneous mud. The vertical succession of individual sequences through the cores is also variable. They are most often coupled negative-positive sequences, although these are not necessarily symmetrical, but either sequence can also occur independently. They may be very widely-spaced, separated by up to a metre or more of homogeneous mud, very closely-spaced without significant separation by a mud facies, or occur with a frequency somewhere between these two extremes.

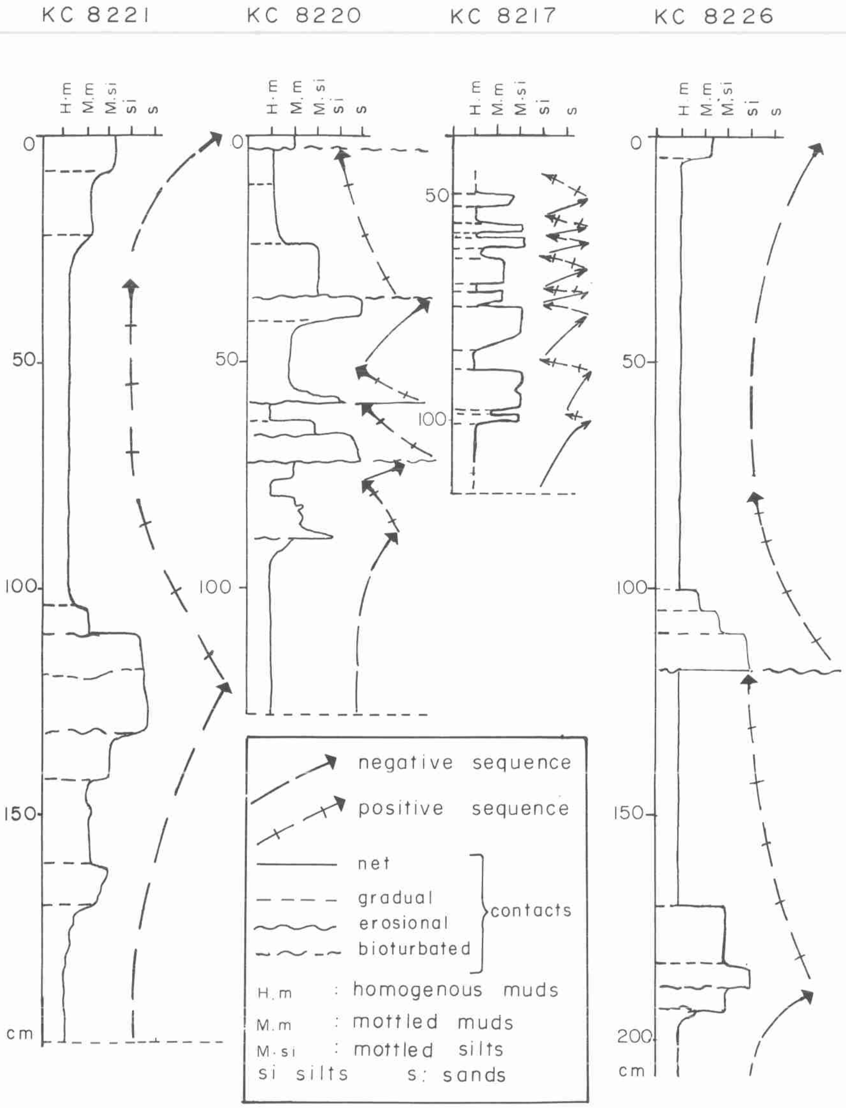


FIG. 11. Sketches of core sections showing the different types of vertical sequence of contourite facies.

Hydrodynamic interpretation

This vertical variation in the contourite facies is probably related to variation in velocity of the transporting current rather than to variation in supply to the system (see later discussion). Thus, a coupled negative-positive sequence in a given core represents a gradual increase, a maximum and then gradual decrease in current velocity at that particular site (Fig. 12). Such fluctuations can be slow and progressive, as shown by the thicker gradational sequences, or much more rapid and sudden, as shown by thinner sequences and sequences with erosive surfaces and sharp contacts. Although our relative dating of the cores is not yet complete, there are clearly parts of the Faro Drift where current velocities capable of transporting and depositing coarser silts and sands have been very rarely attained, and fluctuations through the Late Quaternary have been infrequent. In other parts, however, the current velocities have been generally higher and fluctuations much more frequent.

These fluctuations in time at any one site may be due either to a velocity change or pulsation of a

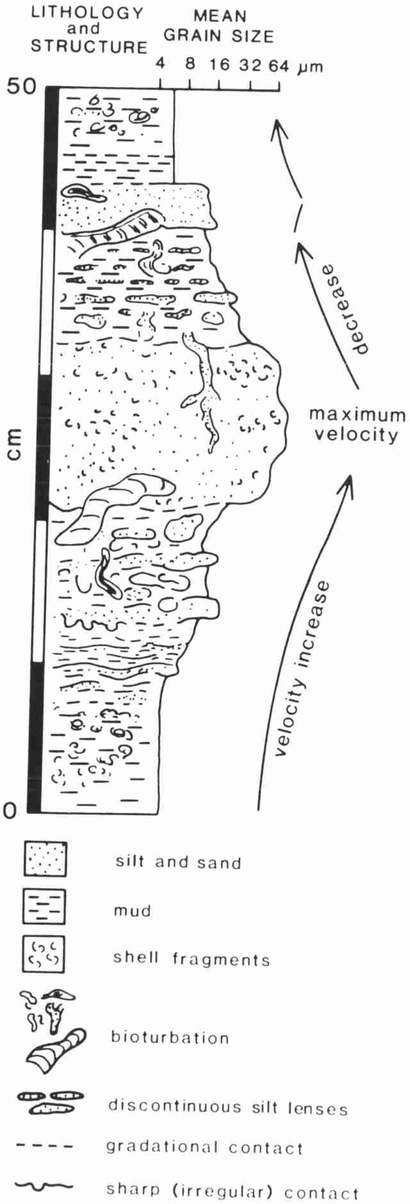


FIG. 12. Schematic vertical sequence of contourite facies from the Faro Drift showing the typical superposition of coarsening-upward (negatively-graded) and fining-upward (positively-graded) sequencies over 50 cm of section. The variation in mean grain-size can be interpreted in term of an increase and then decrease in bottom current velocity (inferred maximum of 10–15 cm/s) (from Faugères *et al.*, in press).

general or local scale, or to a displacement in space of the whole or part of the current. We do not yet have sufficient data from the Faro Drift to comment on the latter possibility, but note that current instability and velocity pulsation has been shown to be a common characteristic wherever sufficiently long-term measurements have been made (Luyten 1977; Shor *et al.* 1980; McCave *et al.* 1980). However, the time-scales of these velocity variations are clearly very different from what we observe in the Faro Drift sediments, so that the facies changes in these cores would represent changes in the long-term average velocity of the Mediterranean outflow.

We can make some estimate of this average velocity at the present day from current measurements, bedforms seen in bottom photographs and the grain-size of surface sediments (Faugères *et al.*, in press; McCave, this volume). The channelized flow to the south of the drift attains a velocity of between 50 and 80 cm/s, whereas that to the north may be similar or slightly lower. Surface sediments over most of the drift are muddy silts and our one camera station shows a partly buried and bioturbated ripple field. These features suggest a current velocity less than about 20 cm/s, although there may be a narrow vein of higher velocity flow over part of the drift marked by lack of deposition or slight erosion seen on the 3.5 kHz records (Faugères *et al.*, in press).

For velocity fluctuations during the Late Quaternary, we must rely on the vertical sequences of grain-size variation observed. In a recent paper, McCave (this volume) has seriously criticized the use of Hjulstrom's (1939) well-known erosion-transport-deposition diagram, particularly with regard to fine-grained sediments. McCave has therefore constructed a new transport and deposition diagram for the finer sediments based on a large amount of observational and theoretical data. We have used this diagram (McCave, this volume, Fig. 26) to calibrate a typical coupled negative-positive sequence from the Faro Drift in terms of current velocity. McCave's shear velocity (U_*) has been converted to flow velocity using an average value for the drag coefficient of 2.5×10^{-3} (Daily & Harleman 1966). Using the median grain-size we see that the velocity varies from 8 to 18 cm/s; whereas, using the 5th percentile the velocity would be 15–25 cm/s. We prefer the lower estimate and suggest that the 5th percentile, although theoretically more reasonable, is unduly influenced by coarser more buoyant biogenic grains.

Discussion

Are they contourites?

There is little doubt that the sediments recovered from the Faro Drift are true contourites. Even without reference to their sedimentary characteristics there is the combined evidence of an isolated drift morphology parallel to the continental margin, seismic records of its mode of construction since the early Pliocene, oceanographic evidence for an intermediate level water-mass derived from the outflow of Mediterranean water, and direct current measurements and bottom photographs that show strong bottom currents in the vicinity of the drift.

In addition, we cored thick-bedded coarse sandy turbidites in the Faro Canyon area (Cores 30 and 35) and two very thin fine-grained turbidites interbedded with the normal (contourite) sediments at the western end of the drift (Cores 31 and 32). Structurally and texturally these are classical turbidites (Bouma 1962; Piper 1978), and comprise a mixed terrigenous-biogenic suite that is significantly different from the other drift sediments, but very similar to some equally distinctive sandy turbidites from a slope core to the north (Core 29). In particular, the turbidites are richer in glauconite, quartz, feldspar and a varied suite of accessory minerals.

Contourite characteristics and 'sequence'

The drift sediments themselves are very similar to contourites that have been described from a variety of other deep-ocean drifts and from some continental rise sites (see summaries in Stow & Lovell 1979; Lovell & Stow 1981; Stow 1982). Our first contourite facies, the thin irregular and medium-bedded sand and silt, has sharp or gradational bed contacts, is massive and bioturbated, fine-grained and moderately well-sorted, and has a thoroughly mixed terrigenous-biogenic (planktonics and benthonics) composition in which the biogenics are commonly fragmented and iron-stained (cf. sandy contourites of Lovell & Stow 1981). There are no internal primary structures remaining, such as cross-lamination or parallel-lamination, which were considered an important feature of the original contourites described by Hollister & Heezen (e.g. 1972).

The second contourite facies identified from the Faro Drift is the mottled silt and mud facies. This is mostly well-bioturbated with large and small burrows and mottles, but shows some evidence of current deposition in the irregular wavy lamination and sharp or erosive bed contacts. It is fine-grained and poorly-sorted with grain-sizes ranging up to coarse silt or fine sand. The mixed terrigenous-biogenic composition is similar to that of the other facies and shows markedly variable proportions of the different elements.

The third and volumetrically most important contourite facies we have called homogeneous mud because of its massive structureless appearance to the naked eye. X-radiographic or microfacies examination, however, reveals sharp or erosive contacts with intervals of planar or wavy lamination within a thoroughly bioturbated, poorly-sorted, fine silty mud. The mixed terrigenous-biogenic composition has less of the coarser elements than the other facies and is less fragmented.

Both the mottled and homogeneous facies have been described previously as muddy contourites (Stow & Lovell 1979; Stow 1982). However, by recognizing an intermediate (mottled) facies it is possible to document characteristic vertical successions of the three facies. Ideally, we have a coupled negatively-graded to positively-graded sequence up to about 100 cm in thickness (Fig. 12), although in many cases only partial or reduced sequences occur. The full sequence represents more or less continuous deposition from persistent sediment-charged bottom currents. Sharp and scoured bedding contacts indicate short intermittent erosive episodes. The most likely explanation for the variation in grain-size and other features is a long-term variation in the average current velocity superimposed on the short-term variability that is known to occur in bottom currents. Such a long-term variation may be caused by an actual change in current strength as a result of climatic or oceanographic factors, or by lateral migration of the current axis. Variation in the grain-size of material supplied to the system is another possible explanation for the 'sequences' developed in the Faro Drift cores. However, this is considered a less likely alternative for the following reasons:

(a) other current-related features such as sharp or erosive contacts and the shape of the granulometric curve vary in addition to grain-size changes;

(b) variation in the input of biogenic material might be expected to mirror climatic changes to some extent, but in fact the biogenic grain-size varies in parallel with that of the terrigenous material through the sequences; and

(c) the silt and sand facies occur within both the Holocene and last glacial core sections.

Bioturbation of the sediments has kept pace with deposition in most cases so that much of the primary depositional structure and fabric has been destroyed. The high degree of bioturbation is similar to that described from the Eirik Ridge contourites by Chough (1978) and Chough & Hesse (in press) and several 'storeys' or bioturbational depth zones are commonly present (Wetzel 1982; Werner & Wetzel 1982). We suggest that the variation in size and type of burrows and mottles between the different facies is a direct result of variation in grain-size and/or current strength.

Comparison with turbidites and hemipelagites

The contourites described here from the Faro Drift are unlikely to be confused with classical medium to thick-bedded sand-mud turbidites (Bouma 1962), or with other coarser-grained and thicker-bedded resedimented facies (Walker 1978). They are more similar in a number of respects to both fine-grained turbidites and hemipelagites and we concentrate therefore on their distinction from these facies (see also Stow & Piper, this volume).

Fine-grained turbidites show a standard, commonly partial, sequence of primary current-induced sedimentary structures. Close superposition of partial sequences may obscure the individual turbidite units but nevertheless preserve the characteristic structures such as fading ripples, low amplitude ripples, horizontal silt-mud lamination and so on. Bioturbation is restricted to or concentrated towards the tops of units, or may be completely absent. The grain-size is commonly from clay to fine sand size with positive grading through graded laminated units and moderately good sorting within single laminae. The composition is commonly exotic to the region and distinct from the interbedded sediments.

Hemipelagites show no vertical sequence and are mostly monotonous, homogeneous, sandy silty biogenic muds. There is no evidence of any primary current structures and bioturbation is usually very thorough. The burrowing organisms are those that have adapted to fine-grained sediments, slow sedimentation rates and an absence of bottom currents. We suggest that the burrow assemblage is therefore different from that of contourites. The mixed terrigenous-biogenic composition is relatively constant throughout and many of the tests remain intact.

We did not recover any coarse sand or gravel-lag contourites from the Faro Drift, although they may be present in the axes of the flanking troughs. This type of contourite facies would clearly have different characteristics but has not so far been described in the literature other than from bottom photographs (see Heezen & Hollister 1971). Neither did we encounter more purely biogenic contourites such as those described from the Snorri and Hatton Drifts in the North Atlantic (Laughton, Berggren *et al.*, 1972; Montadert, Roberts *et al.* 1979).

Conclusions

(1) The Faro Drift in the Gulf of Cadiz is one of the clearest examples of a relatively small elongate sediment drift almost certainly constructed since the early Pliocene by bottom currents related to the deep Mediterranean Outflow.
(2) A closely-spaced coring programme over the drift has therefore allowed the characterization of contourite facies in greater detail than has previously been possible.
(3) On the continuous spectrum of deposits from muddy to sandy contourites described by Stow & Lovell (1979), we have chosen to document three facies types: sands and silts, mottled silts and muds, and homogeneous muds.
(4) This threefold division has enabled us to recognize the vertical arrangement of facies in both positively and negatively-graded 'sequences'. The complete coupled negative to positive sequence can be interpreted in terms of a long-term regular increase then decrease in average current velocity of the order of 8 to 18 cm/s.
(5) The detailed sedimentary characteristics of the Faro Drift contourites have been compared with those of typical fine-grained turbidite and hemipelagite facies. These should be helpful in the identification of both ancient contourites and modern contourites in areas where the interaction of different processes is more complex.
(6) Further work is in progress on these sediments, particularly with regard to their horizontal and vertical distribution and its interpretation in terms of the late Quaternary pattern and history of outflow from the Mediterranean.

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E. Gonthier and J.-C. Faugeres, Département Géologie et Océanographie, Université Bordeaux I, Avenues des Facultés 33405 Talence Cedex, France.

D.A.V. Stow, Grant Institute of Geology, Edinburgh University, West Mains Road, Edinburgh EH9 3JW, Scotland.