Detrital mica: Environmental significance in north Portugal Continental shelf sediments

By

JOÃO M. ALVEIRINHO DIAS*, ORRIN H. PILKEY** & VICTOR M. HEILWEIL**

Key-words: Sediment transport; Continental Shelf; Portugal; Sediments; Mica, Marine Geology.

Abstract: Sand size mica is hydraulically equivalent to finer sizes of quartz grains and is assumed to be highly vulnerable to winnowing processes because of its platey shape. Because of its relative ease of transport the distribution of mica on a high energy, wave dominated shelf such as that of the North Portugal Shelf study area is assumed to be a reflection of modern processes even where the mica is a component of a relict shelf sediment cover. This assumption seems to be verified by the results of this study of cross-shelf distribution of mica flakes in different size fractions of the shelf sediment cover. Surface textures on mica flakes, studied by SEM, reflect a strong abrasion history. The results suggest that both mica flake abundance distribution and surface textures hold promise as tools for determination of sediment sources and dispersal in micaceous shelf sediments, ancient or recent.

Palavras-chave: Dinâmica sedimentar; Plataforma Continental; Portugal; Sedimentos; Mica; Geologia Marinha.

Resumo: A mica da classe dimensional da areia é o equivalente hidráulico de grãos de quartzo com dimensões significativamente menores. É ainda, geralmente aceite, que devido ao seu hábito em palhetas, a mica é altamente vulnerável aos processos de alteração. Assim, e devido à relativa facilidade com que é sujeita a transporte, presume-se que, em plataformas continentais altamente energéticas, dominadas por processos de ondulação, como é o caso da plataforma norte-portuguesa, os padrões de distribuição da mica são o reflexo dos processos subajacentes, mesmo quando a mica se encontra integrada em sedimentos relictuais da plataforma. Esta hipótese parece ser confirmada pelos resultados obtidos com o presente trabalho, em que se estudaram as distribuições da mica presente nas diferentes frações granulométricas da área da cobertura sedimentar da plataforma continental norte-portuguesa. O estudo das superfícies das palhetas de mica existentes nos sedimentos desta plataforma, efectuado com microscópios eletrónicos, revelou que estas refletem uma história de intensa abrasão. Os resultados obtidos com o presente trabalho sugerem que os padrões de distribuição das palhetas de mica e as marcas detectáveis nas superfícies dessas palhetas poderão ser auxiliares importantes na determinação da origem e dispersão dos sedimentos em plataformas continentais de cobertura sedimentar micácea.

INTRODUCTION

Detrital mica is normally a minor constituent of modern continental shelf sediment covers, and, as a consequence, it has rarely been studied by shelf sedimentologists. Recent studies, however, have shown that the abundance and physical characteristics of mica flakes may hold strong potential as paleoenvironmental tools. For example, the abundance of mica has been used to distinguish zones of active winnowing and active deposition on shelf environments (DOYLE et al., 1968; ADEGOBE & STANLEY, 1972) and to trace the dispersal patterns of fine sediment across upper continental margins (DOYLE et al., 1979). J. NEIHESEL (1965) and M. PAMERANC- BUM, (1966) both suggest that sand size mica flakes are the hydraulic equivalent of clay sized material. However, L. DOYLE et al. (1983), on the basis of settling experiments, suggested that sand size mica is equivalent to 4 to 12 times smaller quartz spheres. These experiments indicated that mica in the fine to very fine sand sizes is equivalent to quartz spheres in the silt size range.

The relative softness of mica flakes and the consequential ease of formation of surface textures also is the basis of a potential paleoenvironmental tool using mica flakes. F. FRANKEL (1977) observed extensive biological degradation of mica flakes, especially biotite, in Connecticut estuarine sediments.

(*) Serviços Geológicos de Portugal, Rua da Academia das Ciências, 19-20, Lisboa, Portugal.

(**) Duke University, Department of Geology, Durham, N.C. 22708, U. S. A.
Y. Park & O. Pilkey (1981) examined, under scanning electron microscopy, mica flakes from the Southeastern United States continental margin and observed a variety of surface structures including ones of both biogenic and physical origin. The wide variety of surface textures observed suggested to these workers that further study of the mica "tool" might be useful for distinguishing a variety of sedimentary environments.

The wave dominated Northern Portugal shelf study area (fig. 1) is an ideal location for this study of the environmental significance of mica flakes. Most importantly, the shelf sediment cover is highly micaceous; typically 2 orders of magnitude more so than the southeastern U.S. shelf. Thus, abundant material is available for study, and extraction of individual mica flakes for study can be carried out with relative ease.

According to J. Dias & C. Nittroer (1984) the inner shelf of the study area is largely covered by recent sediments of very fine to fine sands. These sands are transported southwest from fluvial point sources by the prevailing wave and current conditions. The mid shelf area between 30 and 80 meters depth is dominated by coarse sands and gravel. These are presumed to be relict (or residual) deposits derived by erosion of terrestrial materials by a rising sea level and distribution by littoral processes. During low stands of sea level, the fluvial contribution of terrigenous materials was largely lost seaward through submarine canyons. Below 80 m depth shelf sediments become highly calcareous. Dominant forms are mollusks and foraminifers. Locally outer shelf sediments are highly glauconitic.

Figure 2 summarizes the sediment composition of various depth zones across the Northern Portugal continental shelf. From this figure it is obvious that quartz and feldspar are the most important constituents shelf-wide, but that biogenic components increase seaward dramatically and make up more than half of the outer shelf sand size sediment cover. Mica, which is component # 2 in the diagram, decreases in abundance in a seaward direction.

The purpose of this investigation is two-fold. The first goal is to determine the environmental significance of the abundance distribution of
different size fractions of mica across the Northern Portugal continental shelf. The second objective of our investigation is to determine whether mica flake characteristics (other than mineralogy) can be useful in determining the history of continental shelf processes of sedimentation.

The basic assumption of this study is that all mica on the continental shelf is recent. That is, the presence or absence of and the physical characteristics of all shelf mica grains should be related to present-day shelf physical conditions and source areas and are not inherited attributes. This should be the case even with mica flakes contained within relict sediments. It is believed that because of this mineral’s particular susceptibility to winnowing and cross-shelf transportation processes (DOYLE et al., 1968, 1979) most of it would have quickly been removed if additional grains were not being continually added from onshore fluvial sources.

Methods

The abundance of mica was determined in one-phi size fractions of 130 shelf samples by grain counting. Percentages are expressed as percentage of grains excluding the carbonate fraction. In 24 samples, mica flakes were examined under both reflected and transmitted light with a petrographic microscope for mineralogic and physical attributes of grains. The mica flakes were removed from total, untreated and unsieved samples in order to avoid man-induced effects on grain surfaces. Mica flakes from 3 samples were examined with a scanning electron microscope for surface textures.

Mica Abundance in shelf sands

Figure 3 shows the abundance of mica in very fine, fine, medium, coarse and very coarse sand fractions of the surficial sand on this portion of the Portugal continental shelf. Only the carbonate-free mica abundances in each size fraction (fig. 3) will be discussed. Since the carbonate fraction is largely a shelf or marine environment addition to the sediment, dispersal of river derived sediment across the shelf should be most closely indicated by mica abundances in the non-carbonate fraction.

The most obvious trend in comparison of the maps in fig. 3 is that the finer the grain size of mica, the larger the shelf area covered. 15% of the surficial sediment cover of the North Portugal shelf contains significant amounts of mica in the very coarse sand fraction compared to 84% of the shelf with very fine sand size mica. By comparison, sediments containing significant mica in the coarse sand, medium sand and fine sand size range cover 25%, 47% and 64% of the shelf area respectively.

Another less well defined trend is found in the cross-shelf abundance distribution of mica of a given grain size (fig. 4). With the exception of the 2-3 phi size fraction, mica is always more abundant in nearshore sands than in offshore sands. That is, mica of a given grain size tends to be most abundant on the inner continental shelf. If the shelf sediment cover were entirely relict and were not receiving a significant and continuous
Fig. 3a — The areal distribution of the abundance of mica in the very coarse sand fraction of North Portugal shelf sediments. Percentages are expressed on a non-carbonate basis.

Fig. 3b — The areal distribution of the abundance of mica in the coarse sand fraction of North Portugal shelf sediments. Percentages are expressed on a non-carbonate basis.
Fig. 3c — The areal distribution of the abundance of mica in the medium sand fraction of North Portugal shelf sediments. Percentages are expressed on a non-carbonate basis.

Fig. 3d — The areal distribution of the abundance of mica in the fine sand fraction of North Portugal shelf sediments. Percentages are expressed on a non-carbonate basis.
contribution of fluvial detritus, the most abundant mica might be expected to be in outer shelf sands. This is because under circumstances where new material is not being supplied, the mica fraction should have been winnowed from shoaler waters on this high wave energy shelf and deposited in less energetic environments of the outershelf.

On the wave dominated Southeastern U.S. Atlantic shelf, mica abundance increases slightly on the inner shelf or shoreface in depths less than 10 or 15 meters, relative to the rest of the shelf (Doyle et al., 1968; Doyle et al., 1979). The sample pattern of the present study is too broadly spaced to discern such a trend on the North Portugal shelf if it exists. In fact, no samples from less than 10 m depth were utilized in this investigation. Moreover, the overall abundance of mica on the wave dominated, relict Southeastern U.S. shelf is much less than on the shelf of Portugal. For example, the maximum observed percentage of total mica of sand on the Southeastern U.S. shelf is of the order 0.25%, compared to the greater than 35% on the Portugal shelf.

Another important Portugal shelf trend revealed by the comparison of abundance of mica flakes in various sand size fractions (fig. 3) is the close relationship between abundance anomalies and river mouths. The coarser the size fraction the more obvious this relationship is. (See especially the very coarse sand size fraction, fig. 3a). Investigation of this relationship in more detail would require a much closer sampling pattern, but even with the available samples the trend is demonstrable, at least in coarse sizes. The major exception to the rule of micaceous shelf sands just seaward of river mouths is the Vouga River. Here the shelf is essentially mica-free except in the very fine sand sizes (fig. 3e).

The Vouga River is the only river along this portion of the Portugal coast which is separated from the sea by a lagoon. The lack of mica contribution on the shelf seaward of this river mouth very likely reflects trapping of coarse sediments in the lagoon. Only fine sediment, hydraulically equivalent to very fine sand size mica, escapes to the sea.

Fig. 3c—The areal distribution of the abundance of mica in the very fine sand fraction of North Portugal shelf sediments. Percentages are expressed on a non-carbonate basis.
The lack of mica on the Vouga River shelf is a good demonstration of the sensitivity of mica flake abundance as a tool to discern present-day shelf-estuarine processes. This observation holds out the promise that dispersal paths of fluvial sediments in this shelf system may be much more sharply outlined with detailed sampling.

![Fig. 4](image)

**Fig. 4** — Plots of the average abundance of mica of various sizes at continental shelf 20 meter depth intervals.

Mineralogic and Physical Characteristics of Shelf Mica Flakes

Table 1 summarizes various mineralogic and physical attributes of mica flakes from 24 samples.

<table>
<thead>
<tr>
<th>% Sample</th>
<th>Biotite</th>
<th>Muscovite</th>
<th>Biotite + Muscovite</th>
<th>Muscovite</th>
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The dominant mica minerals are muscovite and biotite. Muscovite ranges in abundance from 27 to 100 percent of the mica in various samples and averages around 60%. On the basis of the small number of samples studied, regional mica mineralogy trends in shelf sands were not evident.

Percentages of twinned grains are small (Table 1) ranging from 4 to 11%. Grains with crystal inclusions are much more abundant, ranging from 18 to 62%. Twinned grains seem to be most abundant on shelf areas in front of the Ave and Douro Rivers. Mica flakes with crystal inclusions seem to be more or less randomly distributed on the shelf.
Other distinctive characteristics of mica flakes observed with the petrographic microscope include frosted grains, hematite (?) stained grains. An abundance anomaly of hematite stained mica grains is found on the shelf adjacent to the Douro River mouth.

SEM examination of grain surfaces of 6 coarse sand size mica flakes each from samples 93, 174 and 211 indicated the presence of abundant surface scratches (fig. 5) similar, in some cases, to those observed by Y. PARK & O. PILKEY (1981). These are obviously abrasion scratches. They almost always consist of a relatively deep and wide pit followed by a long narrow scratch or trough which becomes shallower with distance away from the impact pit (fig. 5 A and B). Presumably the pit (fig. 5 C) is the point of initial impact of the grain onto another object. In some cases (fig. 5 D) the scratches cover most of the grain surface and form a complete pattern of randomly oriented lines. Other grain surfaces may only have a few isolated scratches while some of the grain surfaces are smooth and featureless. It is suggested that the featureless grains are those which have recently cleaved forming a new surface. The number of scratches on other grains may reflect both transportation history and also the time between cleaving «events» causing formation of a fresh crystal surface. In other words, numerous scratches may be as much an indication of an «old» surface as an indication of abrasion intensity.

Dimensions of the scratches range from .016 mm x .002 mm to .17 mm x .003 mm. The most common length/width ratios is about 8:1. Some of the troughs formed from scratches appear to be lined up with other troughs, end to end (fig. 5E), perhaps caused by a grain skipping across an abrading object or vice versa. Most of the troughs display ragged, zipper-like edges.

Mica surface texture studies in Southeastern U.S. shelf sediments (PARK & PILKEY, 1981) and Connecticut estuarine sediments (FRANKEL, 1975) revealed numerous micro-cavities and troughs of obvious biogenic origin. In our limited number of observations of Portugal shelf mica flakes we found virtually no structures of certain biogenic origin. However, a possible biogenic «scratch» is shown in fig. 5 F. In fig. 5 F the groove shown is on the grain edge. L. FRANKEL (1975) notes that most biogenic alteration occurs on grain edges where protection is offered by cleavage planes. This groove (fig. 5 F) has a higher relief than most of the presumed abrasion scratches, has rounded non-zipper like edges and the groove does not shoal in one direction. Conceivably the paucity of biogenic features in Portugal mica flakes, relative to the Southeastern U.S. Atlantic shelf, may be due to differences in sea-floor environmental conditions. Much more work will be needed to define the varying degrees of impact of biogenic activities on mica grains from different shelf areas.

CONCLUSIONS

1. The relative abundance of mica in different size fractions has been shown to be useful in determining the dispersal of the present-day sediment contribution to the largely relict sediment cover of the North Portugal shelf. The study of cross-shelf flake distribution should have wide application on other relict shelves.

2. The distribution of mica in North Portugal shelf sediments shows that the modern fluvial contribution of fine sand to clay sizes is being distributed in cross-shelf equilibrium fashion. Fine grain sizes are the most widely dispersed and coarser sizes exhibit the least dispersal.

3. Within individual size fractions, there is a fairly well defined tendency for mica flakes to be more abundant in nearshore zones (landward of the 50 meter contour) relative to the outer shelf.

4. Coarse mica flakes tend to be concentrated in surficial shelf sediment near river mouths with the exception of the Vouga River. This river is the only one on the North Portugal coast which empties into a lagoon. The lagoon apparently traps coarse sediment before it reaches the shelf.

5. Scanning electron microscope studies of Portugal shelf mica flakes reveals an abundance of physical abrasion marks and scratches on the grains.

6. Mineralogy of the mica fraction, frosting of grains and the percentage of twinning in individual flakes all may offer promise in determining the areal distribution and hence the dispersal of sediments from specific source rivers across the shelf.
Fig. 5 — Scanning electron microscope photos of surface textures of mica flakes from the study area. Sample locations are shown in fig. 1.

A — Typical trough-shaped physical abrasion scratch with impact at left, shallowing out towards right. Sample 174. Whites of dashed line 1 μm.

B — Trough-shaped scratch with impact at bottom, shallowing towards top. Sample 93. Whites of dashed line 10 μm.
Fig. 5 — Scanning electron microscope photos of surface textures of mica flakes from the study area. Sample locations are shown in fig. 1.

C — Scratches with impact pits. Sample 93. Whites of dashed line 10 μm.

D — Elongate-trough scratches approximately 2 mm long. Sample 93. Whites of dashed line 10 μm.
Fig. 5 — Scanning electron microscope photos of surface textures of mica flakes from the study area. Sample locations are shown in fig. 1.

E — Scratches made by skipping objects (?). Sample 174. Whites of dashed line 10 μm.

F — Possible biogenic burrow along grain edge. Sample 174. Whites of dashed line 10 μm.
REFERENCES


Manuscript received on Nov. 1984.