MUD REDEPOSITIONAL PROCESSES AS A MAJOR INFLUENCE ON MEDITERRANEAN MARGIN-BASIN SEDIMENTATION

Daniel Jean Stanley
Division of Sedimentology
Smithsonian Institution
Washington, D. C. 20560

The premise of this synthesis is that to understand Mediterranean margin and basin sedimentation one must focus on, and try to understand, the role of mud transport. The reasoning would appear fairly straight-forward: it is estimated that mud (a term herein loosely applied to various mixes of silt and clay size particles) accounts for more than 80% of the volume of the Plio-Quaternary cover on the Messinian and older consolidated sediments in the Mediterranean.

Until recently the basic shelf-to-basin sedimentation model applicable to world oceans emphasized the downslope transport of sands by gravity emplacement (largely turbidity currents) and that of muds by slumps and hemipelagic (suspensate "rain" settling through the water column) processes. As a result of the moderately good, if still uneven, sediment coverage by piston and gravity cores and DSDP drill sites now available throughout the Mediterranean, we recognize that this sedimentological concept is neither adequate nor accurate. Moreover, application of such a simplistic model can result in serious misinterpretation of the sediment record and of Neogene to recent events.

It has long been my contention that the Mediterranean Sea — a quasi-closed physical, chemical and biological system — serves as an excellent natural sedimentation laboratory in that it offers a remarkable variety of settings and conditions resulting in a diversity of deposits. Continuing study has as purpose the refining of earlier generalized surveys of Plio-Quaternary Mediterranean depositional patterns by focusing more closely on some major controlling conditions of sediment dispersal and accumulation. One essential key to understanding Neogene sedimentation is the recognition that a considerable proportion of silt to clay size sediment has been emplaced by gravity flows and/or fluid-driven (bottom current) mechanisms rather than by suspensate "rain". To confirm this requires identification of the different types of muds that comprise the bulk of the post-Miocene cover, and recognition of the plexus of transport mechanisms responsible for their emplacement. From this stage, one can then proceed to better formulate sedimentation models applicable not only to surficial and subsurface Mediterranean sequences but also to other world ocean margins and basins and, in some cases, to ancient sedimentary deposits exposed in the circum-Mediterranean region.

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A comprehensive overview of Plio-Quaternary sedimentation patterns in Mediterranean margins and basins includes some major points (Stanley, 1985):

1. Most of the unconsolidated sedimentary cover seaward of the shelfbreak consists of mud-rich facies which have been emplaced by gravity transport processes (mass flows, sediment gravity flows) and, to a lesser extent, by suspension "rain" and bottom current traction.

2. Large-scale regional differences in Plio-Quaternary sediment thickness and geometry and sediment types result from the interplay of tectonic activity, eustatic-paleoceanographic factors, margin configuration and basin plain depth, provenance and dispersal. In spite of overall rapid accumulation rates (for the most part >20 cm/1000 yrs), structural framework is the major control rather than sedimentation processes on most margins, with the exception of those seaward of major deltas.

3. Mud facies include end-members of largely gravity-driven origin (slump, debris flow, turbidite, faintly laminated and uniform mud) and, to a lesser extent (<30%), of largely hemipelagic origin (including sapropels), and of combined gravity flow and suspension settling origin (finely laminated mud). Distribution of these facies is closely related to depositional environment and transport mechanism (Stanley and Maldonado, 1981).

4. Combined 3.5 kHz subbottom profile and coring surveys across slope-basin sectors indicate that mud-rich series generally accumulate at a higher rate in more distal regions beyond the base-of-slope than coarser-grained sediments in more proximal slope settings. This preferential distribution beyond the base-of-slope and in basin plains is the basis for a turbid layer-bypass model (Stanley et al., 1980).

5. Close correlation among Late Quaternary lithofacies distribution, stratigraphic continuity, depositional environment, and accumulation rates provide strong evidence for the overall importance of gravity-driven redepositional processes for mud-rich series in different Mediterranean settings. It is recognized that, at times, bottom currents and suspensate rain mechanisms also have played a significant role.

6. Two significant factors affecting regional depositional patterns mapped on Mediterranean margins are (a) climatic oscillations and eustatism which induce large-scale regressions and transgressions, and (b) structural setting which in tectonically more active areas trigger mass failure and downslope sediment gravity flows on a more local scale.

7. A gravity transport-transformation model emphasizes a downslope-directed progressively less dense continuum of processes resulting from the alteration of grain-support mechanisms during flow (i.e. slump to debris turbidity current to low concentration turbid layer flow as discussed by Stanley and Maldonado (1981).

8. Basinward textural homogenization results from the bypassing of seafloor relief features by gravity flows and by the progressive removal (filtration) of coarser and/or denser fractions in depressions traversed by the flows. As a result of this process faintly laminated to almost uniform muds, or unifites (Stanley, 1981), are concentrated almost essentially in basin plains. These unifites show a fining-up trend with a decreased content of sand-sized terrigenous components directed away from basin margins.

9. A conservative estimate would indicate that about two-thirds of the muds on Mediterranean margins and basins are redeposited series which comprise displaced pelagic and benthic tests. In consequence, stratigraphic analyses involving faunal, isotopic and radiocarbon analyses can give rise to questionable time-stratigraphic, paleoecological and paleoceanographic interpretations. Therefore, paleoenvironmental and stratigraphic studies should be undertaken carefully in conjunction with sedimentological examination of the lithofacies.

10. Periodic deposition of dark, organic-rich sapropel muds record the effects of episodic climatic changes which induced basin-wide oceanographic changes. These primarily include development of better-defined water mass stratification which, in turn, leads to anoxic conditions. Petrologic studies confirm that such organic-rich deposits are largely of suspension origin, and they appear best developed on physiographic highs, and that many such layers in depressions are diluted and expanded by incursions of redeposited sediment, such as turbidites, within the sapropels.

11. Finely laminated muds, deposited preceding and during times of sapropel formation, are believed to result from a more complex process involving dispersal of mud-rich flows into well-stratified water masses. Particles from gravity flows and also pelagic settling become concentrated on pycnoclines and in near-bottom nepheloid layers before settling to the seafloor and accumulating over large areas of the basin as varve-like couplets (Stanley and Maldonado, 1981; Stanley, 1983).

12. Variable depositional rates, sediment thicknesses and geometry need to be evaluated in light of basin physiography, the relation between volumes of sediment introduced relative to margin-basin catchment area where this sediment is deposited, and dispersal (primarily degree of accessibility).

13. There is a surprizingly low amount of sand relative to mud in the small Mediterranean basins surrounded by adjacent highlands and abundant terrestrial source material. This low sand content is in part explained by (a) very localized entrapment of sand in smaller slope basins, submarine valleys and behind tectonic dams, (b) regionally much wider distribution of muds by sediment gravity flows, and (c) an artifact of compaction whereby mud undergoes considerably greater compaction than sand upon burial and consolidation.

14. Approximately 40% of layered Plio-Quaternary mud-rich series on lower slopes and basin plain margins constitute deep-sea fans of diverse sizes, shapes and origins which are variants of some basic fan models developed for the rock record and some world oceans (Stanley, 1985). Study of these -- and equally important -- of layered deposits

not organized as fans (covering more than 50% of the seafloor) should be of interest to the petroleum industry and also to geologists attempting to better distinguish the origin of fan from non-fan deposits in the rock record.

In conclusion, it is essential to be cognizant of the role of mud transport in order to interpret Mediterranean margin and basin sedimentation patterns, and it should be particularly rewarding to more precisely evaluate the role of redepositional processes in fine-grained sediment transport.

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