MATRIX PROVENANCE OF UPPER MIOCENE GYPSIFEROUS CONGLOMERATIC SANDSTONES

by

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Introduction

Along the northern rim of Upper Miocene evaporites occur in the Mediterranean area conglomeratic sandstones that are gypsiferous only in the eastern and central parts. These sands either represent a series of river mouths, or they are part of the bedload of a continuous current within the evaporite basin. In the former instance, there should be no similarity among samples from different locales.

Work published todate indicates that these sandstones could have been deposited by a generally westward current as shown by:

1. a progressive decrease in maximum grain size. An unlikely interpretation would be that gradients of tributaries were lower in the west, steeper in the east.
2. the direction of cross bedding in various localities.
3. the indicated presence of brackish waters by:

a. isotopic evidence for the contamination of Messinian evaporitic sediments by major quantities of brackish waters or fresh waters (e.g. Longinelli and Ricchiuto, 1979; Kushnir, 1982).

b. occurrence of brackish-water pelecypods, ostracods, diatoms, and other fossil groups, intercalated in the gypsiferous sequence. They migrated alive to their present sites of deposition. Brackish faunas were encountered even some 40 m below the Miocene/Pliocene boundary in intercalations within a gypsum sequence in bore hole 124 in the center of the Balearic Sea (Schrader and Garsonde, 1978), or overlain by lesser amounts of gypsum in bore holes in the eastern Mediterranean Sea.

4. the sense of rotation of the earth. This imposes vertical and horizontal Coriolis components that impart a westward direction to any surface currents along the Mediterranean north shore. A bottom counter current would develop in the opposite direction (along the north shore) only wherever the sea floor was deep enough. Apparently such was not the case.

Procedure

To evaluate the bedload movement, samples of the finely grained matrix of gypsum-bearing conglomeratic sandstones were first collected from a selected number of localities. The result of this preliminary investigation has been reported by Sonnenfeld et al. (1978). A second more detailed set of samples was collected at localities from the Dardanelles through the Aegean Sea to Crete, from the Ionian Islands to Toscana and Romagna, from the Molise Belt to Calabria and Sicily (Fig. 1). The boulder component of the conglomerates was likely of local origin, but the finer matrix could contain components sedimented by a longshore current.

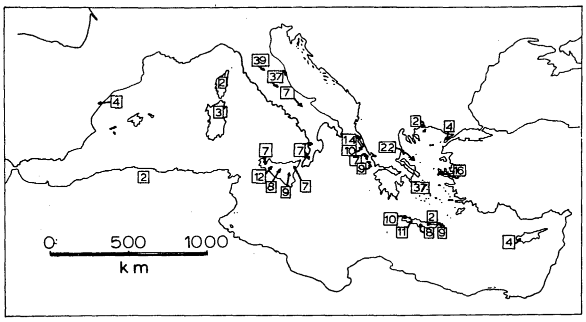

Fig. 1. Location and number of sampling sites.

Heavy minerals were separated with tetrabromoethane from the 0.125 - 0.150 and the 0.150 - 0.250 mm fraction of each sample and the proportion of different heavy minerals was determined. Sixteen variables determined from 141 sampling points give a total of 2,256 data points as sampling base for multivariate statistical analyses.

A stepwise analysis compares the chosen variable (the dependent variable) against the remaining variables, and chooses those that correlate best with it in a stepwise, or progressive fashion. Thus a model is built up that gives a mathematical relationship of the dependent variable to the independent variable. In this case, distance was taken as the dependent variable (both as straight distance and as logarithm of distance). Independent variables were the individual heavy mineral types, as well as certain groups and ratios of the heavy minerals. The analysis was done on the entire sample group, as well as on the Aegean and Ionian samples separately from the Italian and Sicilian samples. To break down the sampling sites into smaller groupings would not have provided statistically significant sets.

Results and discussion

The stepwise regression showed that:

1. the magnetite/ilmenite assemblage correlates best with distance, followed by rutile, hematite/limonite, zircon, and garnet, in that order.

2. the proportion of rutile, magnetite/ilmenite, hematite/limonite, and zircon decrease with distance from east to west, whereas the proportion of garnet increases. The model so obtained is statistically significant to greater than 99 percent probability, with a correlation coefficient (R) of at least 0.612.

3. Iron oxide minerals (hematite/limonite and magnetite/ilmenite) had the most significant correlation with distance: the iron minerals decreased as the distance increased. Magnetite/ilmenite is principally responsible for this difference. Hematite/limonite tends to be relatively constant with distance. This was true for the whole group, as well as the subgroups. However, the Sicilian samples gave a much lower rate of decrease. The Aegean set appears to be very homogeneous, with the iron oxide minerals being the most significant mineral family followed by zircon and rutile. In the Italian set the iron minerals are still the dominant grouping, but the correlation coefficients are somewhat lower. A comparison of factor analyses of Aegean, Italian and Sicilian sets shows the same relationship of slightly lesser homogeneity in Italian samples.

4. The minerals of preponderantly igneous connotation (idiocrase, diopside, spinel, magnetite, pyroxene, epidote and zircon) showed an overall decrease with distance in the total sample, but a local increase in the Aegean samples.

5. The staurolite/andalusite - garnet comparison indicated an inverse relationship: as staurolite/andalusite increased, the garnet decreased. The meaning of this relationship is not clear, but may be related to the relative stability of these minerals.

Both the stepwise regression and the factor analyses suggest that a river or current moved through the Aegean Sea and joined a main current somewhere near Crete. This main current picked up several further tributaries.

Samples from Sardinia, Corsica, Catalonia, and Algeria are said to be Messinian sandstones, but they are without a gypsum matrix. They show a dearth of heavy minerals except for euhedral pyrite and marcasite which predominate. It is significant that none of the Sicilian, Italian, Greek or Turkish samples contained any pyrite.

An explanation must be sought in a difference of the post-depositional environments: the sandstones in the eastern and central Mediterranean Sea remained in an oxygenated environment after deposition, but post-depositional anaerobic conditions prevailed around the basin fringes of the Messinian Balearic Sea. There, anaerobic bacteria stripped gypsiferous sandstones of their sulfate, produced H_2S that led to a neoformation of authigenic pyrite and marcasite crystals and fossil fragment replacements.

It is noteworthy that this distribution of anoxic environments is opposite to the sapropel distribution in Quaternary sediments in Mediterranean deeps.

It is furthermore very significant that the gypsiferous sandstones in the eastern Mediterranean area have remained in an oxygenated environment, as the gypsum and the oxide minerals were preserved. This would not have been possible if drainage from the brackish Paratethys Sea had floated on top of Mediterranean brines, separating them from atmospheric oxygen.

Acknowledgements:

The authors thank Drs. C. Orszag-Sperber and M. Rouchy for kindly supplying samples from circum-Balearic localities and N.A.T.O. for financial support.

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