# TERRIGENOUS MINERALS IN THE SEDIMENTS OF THE BLACK SEA LITTORAL AND INNER SHELF

Constantina FULGA

National Institute of Marine Geology and Geoecology (GEOECOMAR), 304 Mamaia bd., 900581Constanza, Romania,
costina_fulga@yahoo.com

**Abstract.** The paper presents the terrigenous material discharged in the Black Sea basin, partially accumulated on littoral, its patterns of distribution into superficial sediment layer and the factors leading to the formation of mineralogical provinces and associations. The Danubian terrigenous mineralogical province is characterised by a mixture of some old and new sediments, marine and deltaic. The variety of the heavy mineral associations is due to the existence of a multicycled material proving a coast line migration. The influence of a supplementary supply, the erosion of old sediment belts and the direction of the currents changed the distribution of the heavy minerals.

**Key words**: littoral sediments, heavy minerals, mineralogical provinces, Black Sea Shelf sediments

## INTRODUCTION

American Deep Sea Drilling Project (Roos *et al.*, 1978, Stoffers and Muller, 1974,Dimitrov and Novicova 1979, Novicova, 1973), GeoEcoMar program in the 1996-2000 EROS (European River and Ocean System), geological maps 1:50,000 in Black Sea Shelf zone and Mineralogical data base, made by Fulga and Fulga (1996) in 1982-2003 are the data support of this paper.

## MATERIALS AND METHODS

General mineralogical investigation is based on Parfenoff and Pomerol methods (Parfenoff and Pomerol, 1970). Qualitative and quantitative mineralogical studies of the fine arenites (grain-size 0.250-0.063 mm) with a significant interest to the heavy minerals were done on average samples collected in some representative profiles, in the bottom sediments from the sampling interval 0-32 cm. Terrigenous minerals, generally siliciclastes, accumulate in the grain size interval 0.250-0.063 mm, corresponding to fine sands (0.250-0.125 mm) and very fine sands (0.125-0.063 mm).

## RESULTS AND DISCUSSIONS

The sediment derived from the Danube river solid discharge has a high siliciclastic ratio. The heavy mineral input is scarce. The proportion of organogenous sands present in the beach structures has thus increased in comparison with river sand sediments. In Cap Singol-Vama Veche mineralogical zone, littoral deposits have a high carbonatic ratio, terrigenous material is replaced by shell debris ($CaCO_3$ to 85-95%).The concentration of the fine and very fine sand fraction in sediments has a large variation range (0.01-96.28%), with a mean concentration of 13.21%. However, due to the scarcity of near-shore stations, the research area is characterized by its low participation in the sediment constitution, more than 50% of the samples containing less than 3% fine and very fine sand (median = 2.22%). Contents greater than 28% appear on restricted areas in the Danube Delta Front, and in Danube Prodelta, reaching southward in the shelf zone - Danube influence area, to the shelf break area.

The main components of the sandy fractions are: *lithoclastes* (rock fragments) – represented by petrographic terms characteristic to the different sources of terrigenous detritic material (crystalline schists, limestone, quartzite); they have a scarce occurence in the sediments analysed; *authigenic minerals* – glauconites, pyrites, gypsum – appear sporadically, as a rule in the outer shelf sediments; *organoclastes* – shells and shell fragments of mollusks, foraminifera, ostracodes representing the main source of calcium carbonate in the sandy fractions and generally concentrating in the coarser sand fraction; *terrigenous minerals* (generally siliciclastes and oxides) – are composed from a *light fraction* and a *heavy fraction*. The participation of the terrigenous minerals to the sediment composition is more important in the Delta Front area, Danube Prodelta, Sinoe Prodelta (Figs. 1-4; Table I)

*Heavy minerals***,** accessory minerals of the pre-existent rocks, which sometimes are relict minerals, concentrate in the fine arenites. Their chemical and morphological characteristics show almost standard crystallization conditions, allow the use of the heavy minerals as important pointers of the source areas and sediment maturity. At the same time, their mechanical and chemical resistance and the high resistance of some of them to abrasion make them accurate indicators of the sediment maturity. The highly rounded granoclastes represent regularly recycled products from old epiclastic deposits.

Heavy minerals average over 1% out of the terrigenous minerals only in Danube Delta Front, in Danube Prodelta, and in sediment samples from shelf offshore Constantza. The mean value is 0.95%, but the median one is 0.1% indicating the absolute dominance

of low concentrations in the research area and the anomalous character of the higher contents appearing locally when the hydrodynamic sedimentary conditions favoured the heavy mineral accumulation.
More than 40 heavy minerals have been identified, the greatest mineralogical diversity being recorded in Danube Prodelta and south of it, on the continental shelf. Most of them have scarce or occasional participations, just six heavy minerals constitute more than 90% of the heavy fraction.

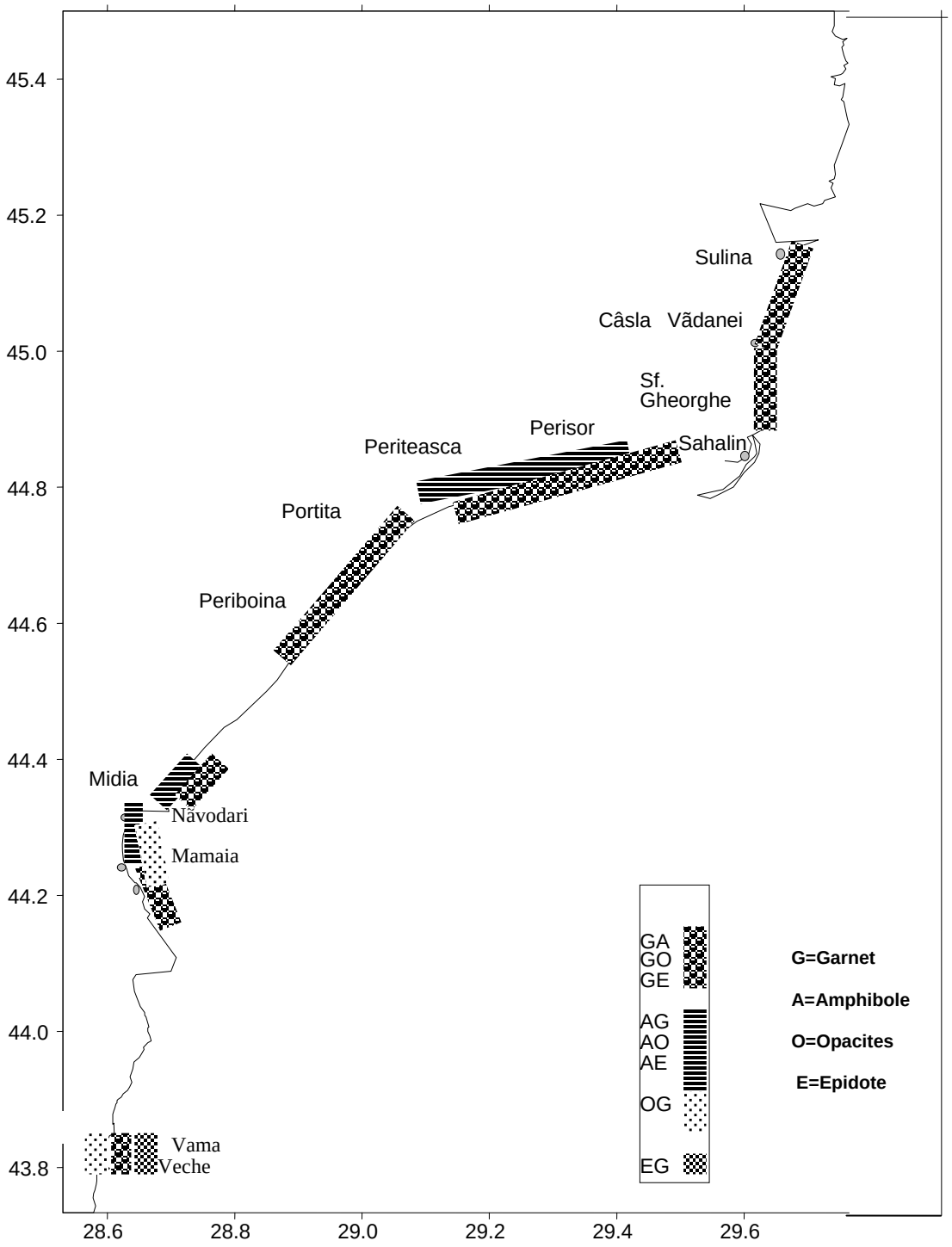


**Fig. 1** Heavy minerals associations littoral zone - Profiles: Sulina-Vama Veche

Standard profiles from Sulina tol Vama Veche, on the beaches are following the mineralogical pattern. All the data about heavy mineral associations in the littoral zone, on the morphological sites, backshore, foreshore and inshore are presented with the details in Cap Midia-Cap Singol (Northern part of Constantza).

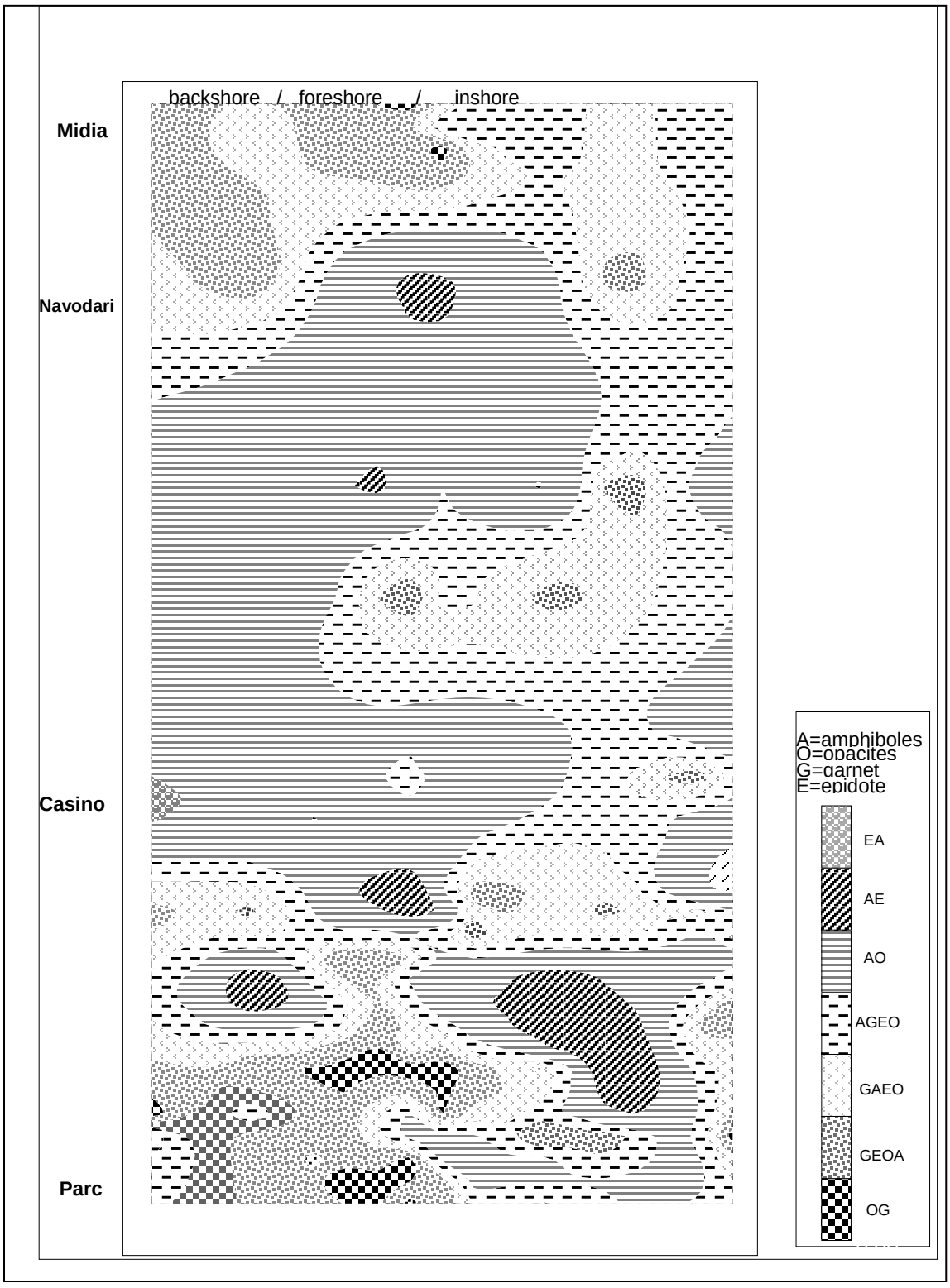


**Fig. 2** Heavy minerals associations – Cape Midia and Navodari-Mamaia beaches

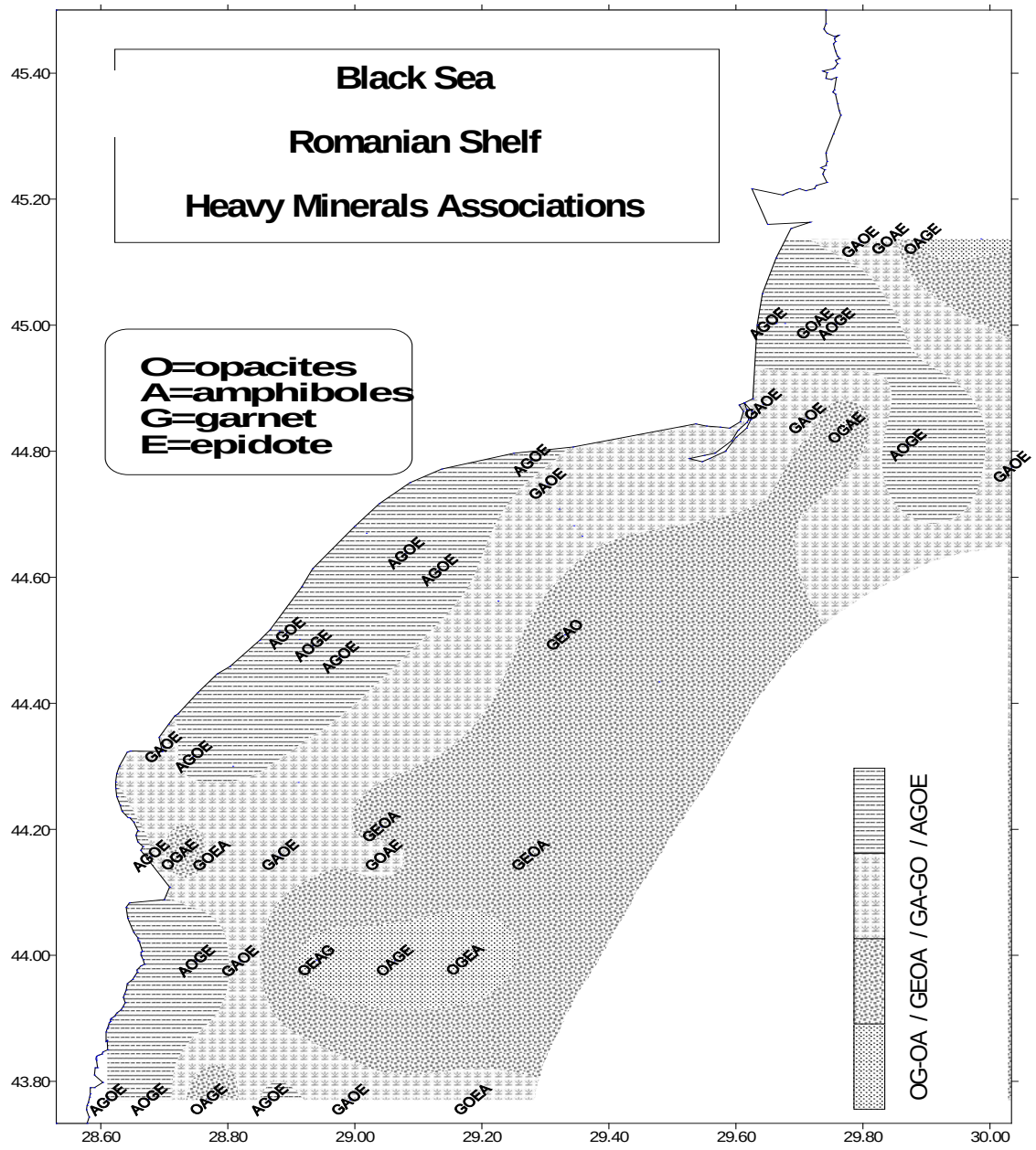


**Fig. 3** Heavy minerals associations – Black Sea Romanian schelf

*Garnet* – the almandine variety – $Fe_3Al_2[SiO_4]_3$ – the most important heavy mineral (Table I), appears in contents exceeding 30% of the heavy fraction. Garnet is the predominant mineral in the Southern Danube Prodelta.

The main *opacites* are: *ilmenite* ($FeOTiO_2$), *magnetite* ($Fe_3O_4$), *leucoxene* ($\approx TiO_2$), *hematite* ($Fe_2O_3$), *limonite* ($Fe_2O_3 \cdot nH_2O$) and, scarcely, *chromite* ($FeCr_2O_4$). In the inner shelf zone, there is a North to South decrease in opacites..

*Amphiboles* – $(Na,K)Ca_2(Mg,Fe,Al)_5[Si_7AlO_{22}](OH,F)$ – have an important participation in the heavy fraction, in many zones marking the heavy mineral associations.

*Epidote* – the pistacite variety – $Ca_2FeAl_2[Si_2O_7][SiO_4](O,OH)$ together with *zoisite* exceed 10% of the heavy fraction in most samples; in the Northern zone, epidote contents are much lower.

The main *pyroxenes* – $(Na,Ca)(Fe,Mg,Al)[Si_2O_6]$ – are augite, hyperstene and in diminished percentage aegirin, diopside, enstatite and bronzite. There is an increase in pyroxene content from North to South, on the beaches and on the shelf zone too.

*Zircon* – $Zr[SiO_4]$ - In Danube Prodelta the content of zircon with grain size over 0.063 mm averages 30 ppm, maximum value, over 110 ppm, being recorded in Odessa subprovinces.

**Table 1** Basic Statistical Parameters of the Important Heavy Mineral Distribution (% in the heavy fraction). Romanian Black Sea Shelf

| Minerals | Garnet | Opacites | Epidote | Amphiboles | Pyroxene | Tourmaline | Disthene | Staurolite | Titanite | Rutile | Zircon |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Mean | 31.88 | 16.91 | 14.94 | 18.25 | 6.81 | 2.53 | 0.95 | 1.73 | 1.7 | 0.45 | 0.51 |
| Md | 31.99 | 15.21 | 13.77 | 18.68 | 5.93 | 2.47 | 0.63 | 1.69 | 1.57 | 0.92 | 0.49 |
| Xmin | 22.6 | 12.1 | 8.97 | 6.14 | 4.95 | 1.86 | 0.53 | 0.75 | 1.33 | 0.49 | 0.17 |
| Xmax | 40.13 | 28.33 | 21.89 | 24.8 | 9.86 | 3.19 | 2.23 | 3.25 | 2.54 | 1.13 | 1.13 |

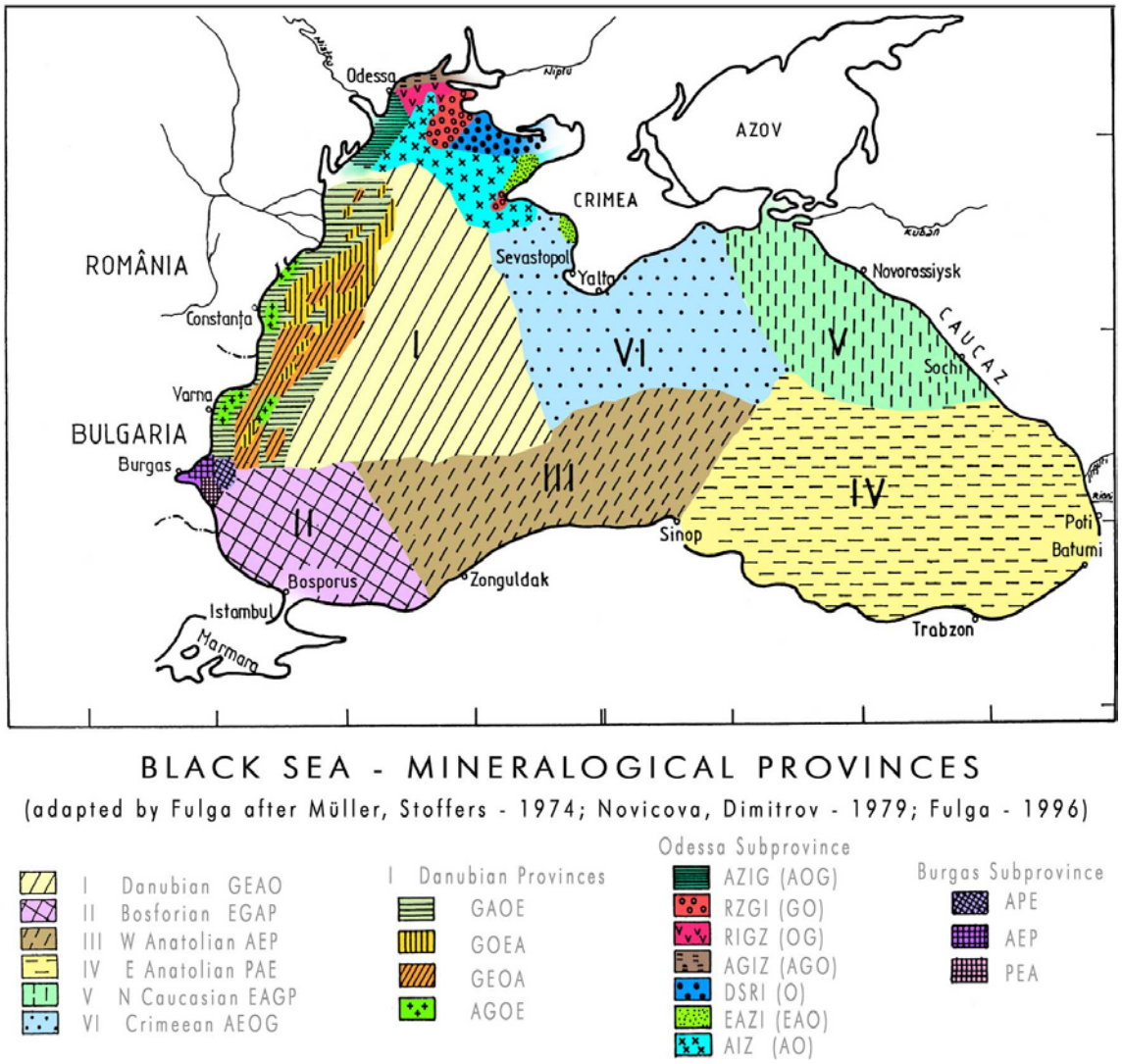


**Fig. 4** Mineralogical Provinces and Subprovinces

Main Heavy minerals: G = Garnet; E = Epidote; A = Amphiboles; O = Opacites; P = Pyroxenes

Subordinate heavy minerals: Z = Zircon; I = Ilmenite; R = Rutile; S = Staurolide; D = Disthene

The main *heavy mineral associations*, in *Danubian provinces*, according to the order of their participation to the heavy fraction are: *garnet* dominated associations; *amphiboles* dominated associations; *opacites* dominated associations, only in few zones (see Figs. 1-4).

Source areas of terrigenous minerals for the research zone are the drainage basins of Danube (the main source), fluctuations in the spreading of different mineralogical associations are determined by the hydrodynamic regime, proximity of alluvial sources, morphology of the sedimentation basin, factors leading to the coexistence of actual deltaic sediments with predominantly marine, relict or palimpsest, sediments.
Heavy mineral associations, dominated by garnet, appear in the Southern Danube Prodelta and on the continental shelf under the influence of the Southward drift of Danube borne sediments (Fig. 4).

The results of the mineralogical analyses, corroborated with previous mineralogical data from my own data bank (mineralogist C. Fulga, GeoEcoMar - Constantza), clearly demonstrate a significant continuous diminution of the sandy grain-size fraction and implicitly siliciclastes and heavy minerals participation in sediments, over the last decade. The effects of selective segregation are increased, the areas characterized by the clear dominance of one heavy mineral over all the others being more extended.

The correlation of chemical analyses of the sediments with mineralogical quantitative composition of heavy fraction partly assign high contents of Fe and relative high contents of Mg and Al to heavy minerals of terrigenous fraction. The increased contents of Ti and Zr are correlated with increases of ilmenite, leucoxene, titanite, rutile and respectively zircon contents. The anomalous presence of other heavy metals is not explained by mineralogical composition of sandy fraction.

All this data are in accordance with the studies done for the entire Black Sea basin, and in the Figure 4, in the map, is presented a synthetic image, an assemblage between the Romanian mineralogical data with the others existed data (Dimitrov and Novicova, 1979, Fulga and Fulga, 1996, Stoffers and Muller, 1974).

The reduction in time of the quantitative input of Danubian sediments into the Black Sea as well as the great coastal hydrotechnical work have changed the coastal morphological balance and has also generated changes in the mineral and grain size composition of the Romanian Black Sea littoral sediments.

## CONCLUSIONS

The Danubian terrigenous mineralogical province is characterised by a mixture of some old and new sediments, marine and deltaic, palimpsest sediments. The variety of the heavy mineral associations is due to the existence of a multicycled material proving a coast line migration. The influence of a supplementary supply, the erosion of old sediment belts and the direction of the currents changed the distribution of the heavy minerals. The high mineralogical variety characteristic to the Northern and Southern extremities of the outer shelf argue the contribution of further source provinces besides the Danubian one (the Russian and Moesic platforms).

We have been investigating, for the last 20 years, around 4000 samples to establish the mineralogical pattern of the sediments in the ecosystem Danube-Danube Delta-Littoral-Black Sea basin (especially Romanian shelf). The general background of the mineralogical provinces and source area exist.

All the future investigation could be compared with the existing data in GeoEcoMar mineralogical data base, sedimentological maps 1:50,000, and few papers, like this one.

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