Δελτίο της Ελληνικής Γεωλογικής Εταιρίας, τομ. XLVII2013
Πρακτικά 13ου Διεθνούς Συνεδρίου, Χανιά, Σεπτ. 2013

Bulletin of the Geological Society of Greece, vol. XLVII 2013
Proceedings of the 13th International Congress, Chania, Sept. 2013

THE APPLICATION OF GRAIN SIZE TREND ANALYSIS IN THE FINE GRAINED SEABED SEDIMENT OF ALEXANDROUPOLIS GULF

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Abstract

Grain size trend analysis is a method that determines sediment transport direction, based on the relationship of grain size parameters (mean size, sorting, skewness). The application of the method in the seabed sediments of Alexandroupolis Gulf showed that there are three different sub areas of distinctive sediment movement of bottom sediments (water depths <40 m):(i) the eastern part, which is mainly influenced by the Evros river water/sediment influxes; (ii) the central part that is primarily controlled by the wave activity; and, (iii) the western part that is mainly influenced by the wind driven and/or thermo-saline coastal circulation.
Key words: *sediment transport pathways, grain size, NE Aegean Sea.*

Περίληψη

Η ανάλυση της τάσης των κοκκομετρικών παραμέτρων είναι μία μέθοδος που καθορίζ ει την διεύθυνση μεταφοράς των ιζημάτων με βάση τη σχέση μεταξύ των κοκκομετρικ ών παραμέτρων (μέσο μέγεθος, διαβάθμιση, ασυμμετρία). Η εφαρμογή της μεθόδου στα επιφανειακά ιζήματα του Κόλπου της Αλεξανδρούπολης έδειξε ότι υπάρχουν τρεις διαφορετικές υποπεριοχές με διαφορετική μεταφορά των επιφανειακών ιζημάτων (βάθη <40m): (i) το ανατολικό τμήμα, το οποίο επηρεάζεται κυρίως από την παροχή νερού/ιζήματος από το ποτάμι του Έβρου, (ii) το κεντρικό τμήμα το οποίο ελέγχεται κυρίως από την κυματική δραστηριότητα και (iii) το δυτικό τμήμα το οποίο επηρεάζεται από την ανεμογενή και/ή θερμοαλατική παράκτια κυκλοφορία.
Λέξεις κλειδιά: *διάδρομοι μεταφοράς ιζημάτων, κοκκομετρία, ΒΑ Αιγαίο.*

1. Introduction

A variety of techniques have been developed to assess sediment mobility and transport pathways (e.g. McLaren, 1981; McLaren & Bowles, 1985; Gao & Collins, 1991, 1992, 1994; Le Roux, 1994). The application of these methods is based on the spatial relationship between grain size parameters (i.e., mean size, sorting, skewness) of seabed sediments. The primary assumption of grain size trend analysis models is that spatial variations in grain size parameters are the result of sediment transport processes, such as abrasion, selective transport and the mixing of sediments from varying sources. Relative variations in grain size parameters also indicate two dominant trends: (i) sediment are better sorted, finer and more negatively skewed in the direction of transport; and (ii) sediment become better sorted, coarser and more positively skewed in the direction of transport.

These techniques have been applied in a variety of environments i.e. beaches, rivers, continental shelves. Among these applications of sediment trend analysis, the two dimensional and most widely used in open marine environments for the definition of trend vectors approach is the Grain Size Trend Analysis (GSTA)method, introduced by Gao and Collins (1991; 1992; 1994) and assessed positively by Poizot (2006).The technique can be applied to inner continental shelves and coastal environments and has been appliedin several cases with varying success (e.g. Rhone River coast by Masselink (1992), La Salie beach at Southwest French coast by Gao et al. (1994), the Belgian continental shelf by Pedreros et al. (1996) and Van Wesenbeeck & Lanckneus (2000).

One basic requirement of the technique is that its application should not extend beyond the boundaries of a particular sedimentary environment (Gao and Collins, 1992), being characterised by (at least) one major process response mechanism. However, most frequently there are several mechanisms acting either independently in different parts of the system or sequentially within the same area (Reineck & Singh, 1973).

The purpose of this contribution is to investigate sediment transport pathways in the Alexandroupolis Gulf (water depths from 5 up to 40 m) with the application of the Grain Size Trend Analysis (GSTA) method of Gao and Collins (1992).

2. Study Area

The Gulf of Alexandroupolis, which belongs to the inner continental shelf of the NE Aegean Sea (Samothraki Plateau), has a smooth subaqueous relief with very low gradients (<1%). Seabed has a zonal granulometric distribution with the nearshore sediments (<10m depth) consisting of sand, those extending in the middle area (10-30m depth) consisting of fine–grained (muddy) material, while sediments in the offshore area (water depths >30m) being characterized as muddy sandsrepresent a transitional zone to relict sand deposits (Karditsa & Poulos, 2013) that extent from water depths>40m) up to 60m (Perrisoratiset al., 1988; Pehlivanoglou, 1989; 2000).

The study area, as part of the North Aegean Sea, is a tideless environment with astronomical tidal range <10 cm (Tsimplis, 1994), although, meteorological forcing induced by southerly winds may occasionally increase sea level up to 0.80 m (HHS, 2005). In terms of wind-induced waves, the coast of the Gulf is predominately exposed to SW (4.8%), S (1.8%) and SE (0.8%) directed waves.The overall offshore water circulation in Alexandroupolis Gulf is mainly controlled by the fringes of the Samothraki anti-cyclone, which implies an eastward circulation in the offshore waters of the Gulf (Zervakis & Georgopoulos, 2002; Olson et al., 2007). However, wind driven currents formed under strong winds are able to change offshore current direction (Kourafalou & Tsiaras, 2007). In addition, a cyclonic circulation along the northern coast has founded to exist during summer period (Zervakis & Georgopoulos, 2002) and, in particular, under the influence of southerly winds (Androulidakis & Kourafalou, 2011).

The distribution pattern of Evros river plume is mainly directed either southwards under the influence of Samothraki anticyclonic circulation or westwards under the influence of Coriolis Effect and the prevailing NE winds. In addition, plume dispersion has also identified within the nearshore zone having also a westward direction and being associated with nearshore wave induced currents (Georgopoulos, 2002; Kanellopoulos et al., 2009; Karditsa, 2010).

3. Methodology

A total of fifty-three (53) bottom sediment samples were collected from the area under investigation, with the use of a VanVeen grab, during a sampling campaign in September 2008 (Figure 1). After the granulometric analysis of the sediment samples, the grain size parameters, mean size (Mz), sorting (σ_I) and skewness (Sk_I) (according to Folk, 1980) were defined.Kurtosis is not considered a measurement that can provide any further information onthe grain-size distribution, for use in the interpretation of sediment transport (McLaren,1981).

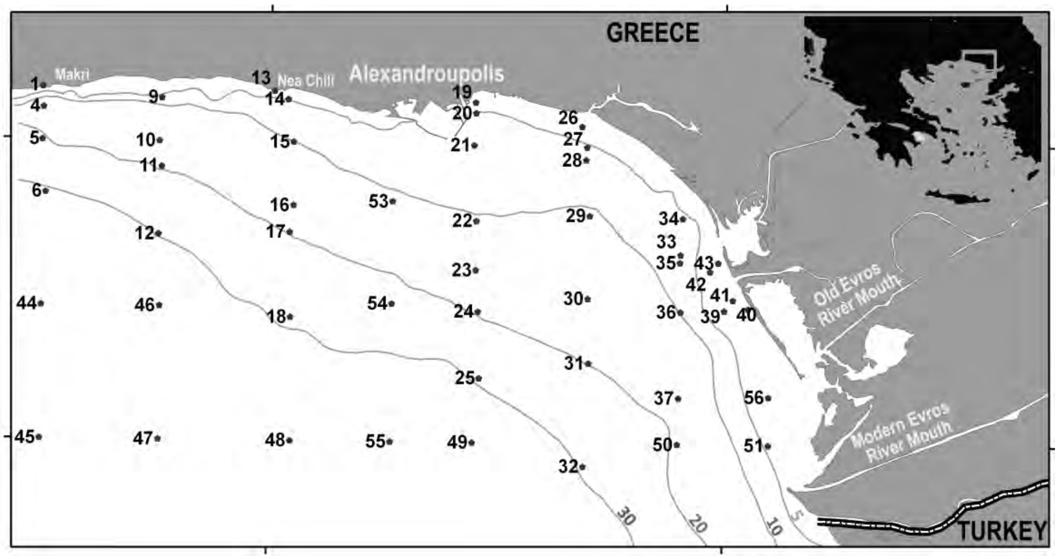

Figure 1- Sampling sites for the seabed sediments.

For the identification of sediment transport pathways, the GSTA method (Gao and Collins, 1992) was applied, which is based on the spatial relationship between grain size parameters (mean size, sorting, skewness) of seabed sediments. The major assumptions of the GSTAmethodare: (i) trend vectors are defined within a grid of sampling site by comparing sediment samples with all its neighbouring samples within a characteristic distance (D_{cr}) that is defined as the space-scale of sampling.; (ii) at each sampling site, vectors are summed to produce a single trend vector; (iii) An average of the sediment trend vectors is applied for the characteristic distance (D_{cr}) used; and (iv) a statistical test can be performed to validate the significance of the transport vectors. In addition, one principal consideration of the method is that Sediment trends can predict the direction of the transport but not the magnitude(Gao and Collins, 1994); this indicates that assigning a vector length, other thanunity, will create a bias towards one of the grain size parameters.

Taking into consideration that problems often arise during the comparison of samples collected on the basis of an irregular grid and in order to increase the spatial resolution of the method, transformation of the data sets can be made by applying an interpolation method. This acceptance is based on the principle that, in any sedimentary environment where the basic requirements of the trend analysis are fulfilled, the grain size parameters of the surficial sediments can be considered as regionalised (i.e. spatially continuous) variables (Davis, 1986).

One underlying requirement of the technique is that its application should not extend beyond the boundaries of a particular sedimentary environment (Gao and Collins, 1992). Therefore, the technique would not promise a successful application in the complex environment of Alexandroupolis Gulf. In order to overcome the limitations of the technique it is applied only to the fraction of the fine grained material (<0.0625 mm), whose origin is primarily associated to Evros terrestrial influx.

In order to describe transport patterns, the application of the GSTA method Gao and Collins (1992) is based on the spatial relationship of the granulometric parameters (M_z,σ_I, Sk_I)between two successive points A and B.Considering that the net sediment transport is from A to B,the derivation of the transport trendscould be identifiedon the basis of two cases:

- Case A:$\sigma_I B \leq \sigma_I A$, $M_z B \geq M_z A$ και $Sk_I B \leq Sk_I A$

- Case B: $\sigma_I B \leq \sigma_I A$, $M_z B \leq M_z A$ και $Sk_I B \geq Sk_I A$

Since the method requires a regular grid, 2 km cells were created after transformation with an interpolation (krigging) method. In addition, in order to avoid edge effects only the sites within the grid were used.

4. Results and Discussion

Following the application of GSTA method only to the fine grained (<0.625mm) fraction of the seabed sedimentthe distribution patterns of mean grain size, sorting and skewness coefficients are shown in Table 1 and in Figure 2. Mean grain size pattern shows that sediments become finer to seawards, while relatively finer sediment observed in front of the Evros mouth areas and along a N-S belt trending offshore from the west area of Alexandroupolis port. Sorting improves to seawards with the eastern area to present relatively poorer sorting than the western part, with respect to port location. The best sorted sediments are associated with Evros river delta front area (depths 5-10 m).High positive skewness values are located at water depthsbetween 10 and 20 m to the west of the port and secondarily at the Evros river mouth area; the former is related to the erosion of coastal Quaternary formations of Makri, while the latter to riverine sediment inputs. Generally, in water depths greater than 30m, fine-grained sediment are characterised by mean sizes >7.5 φ, are less poorly sorted (<1.9 φ) and almost symmetrical ($Sk_I \approx 0$).

Table 1 – Granulometric parameters results.

Station	x (Greek Grid)	y (Greek Grid)	Mz(φ)	σ_I(φ)	Sk_I(φ)
37	414214,33	4512932,24	7,42	1,93	0,02
36	414288,64	4515582,97	8,12	1,6	0,04
39	415643,37	4515613,66	7,81	1,73	0,02
38	416382,43	4515675,59	7,32	1,69	0,13
40	415908,74	4515945,56	7,28	1,82	0,06
41	415959,76	4516104,11	7,18	1,71	0,19
42	415208,59	4516823,23	7,13	1,73	0,18
43	415457,77	4517094,23	7,06	1,64	0,27
35	414279,55	4517104,09	7,35	1,88	0,04
34	414362,83	4518466,86	6,79	2,08	0,01
33	414296,40	4517344,44	6,95	1,7	0,21
1	394613,31	4522597,07	6,59	1,69	0,2
4	394632,49	4521971,31	7,35	1,88	0,05
5	394597,13	4520970,66	6,8	1,96	0,11
6	394683,67	4519350,21	7,3	1,78	0,06
12	398168,89	4518031,92	7,27	1,83	0,1
11	398276,39	4520121,51	5,91	1,99	0,52
10	398208,47	4520905,22	5,85	2,04	0,55

Station	x (Greek Grid)	y (Greek Grid)	Mz(φ)	σ_I(φ)	Sk_I(φ)
9	398284,36	4522230,99	6,54	1,73	0,09
13	401773,43	4522426,17	6,6	1,86	0,14
14	402194,35	4522165,21	7,09	1,84	0,11
15	402355,52	4520856,64	7,13	1,96	0,05
16	402338,11	4518900,91	6,87	2,04	0,08
17	402221,80	4518078,99	6,75	1,97	0,17
18	402236,41	4515460,37	7,8	1,7	0,08
25	408063,93	4513561,16	7,19	1,8	0,1
24	408031,78	4515615,53	6,85	1,94	0,15
23	407966,10	4516893,14	6,8	2,04	0,14
22	407991,98	4518408,32	6,38	2,12	0,23
21	407933,85	4520738,75	6,72	1,95	0,09
20	407988,32	4521726,21	6,89	1,92	0,14
19	407982,68	4522063,06	6,9	1,86	0,09
26	411261,88	4521312,36	7,02	1,75	0,17
27	411410,20	4520672,19	7,11	1,97	-0,01
28	411380,13	4520274,71	6,64	2,1	0,08
29	411488,89	4518558,07	7,71	1,98	0,01
30	411421,77	4516005,32	6,9	1,94	0,09
31	411441,49	4514010,35	7,12	1,85	0,09
32	411261,30	4510827,98	7,57	1,74	0,08
46	398190,50	4515822,12	7,44	1,79	0,02
44	394534,27	4515873,33	7,68	1,92	0,01
45	394475,62	4511756,75	7,8	1,83	-0,01
47	398133,88	4511705,54	7,92	1,85	-0,03
48	402214,24	4511650,57	7,8	1,87	-0,01
55	405309,67	4511610,36	7,84	1,85	-0,02
54	405364,08	4515865,67	7,82	1,86	-0,01
53	405404,32	4519010,92	7,85	1,86	-0,02
49	407842,30	4511578,42	7,84	1,86	-0,01
50	414173,85	4511502,37	7,85	1,86	-0,02
51	416987,86	4511470,31	7,84	1,86	-0,01
56	417004,45	4512950,41	7,84	1,86	-0,01
36	414288,64	4515582,97	7,84	1,86	-0,01

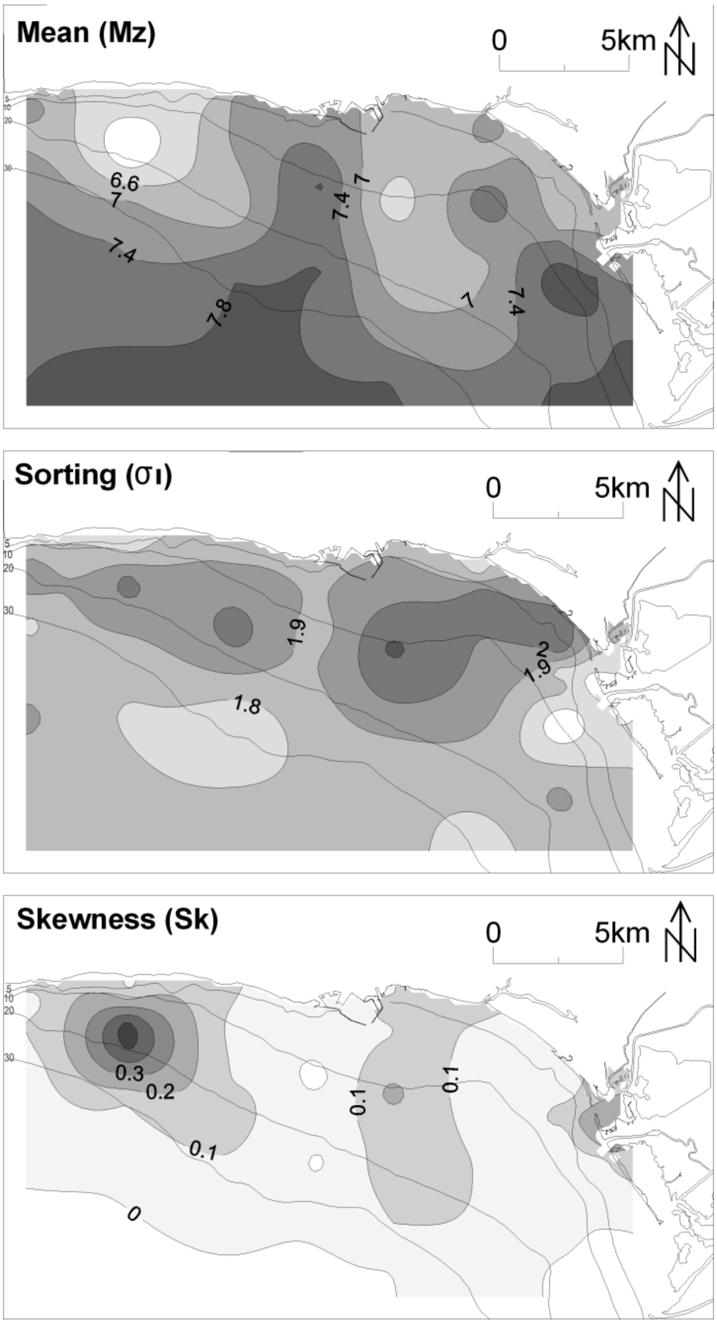

Figure 2- Distribution of grain size parameters (mean, sorting and skewness) (in *φ* units).

In Table 2 and Figure 3, sediment transport pathways of the surficial seabed sediments are presented schematically, after the application of the GSTA method. On the basis of these results and assuming that they are the product of the prevailing hydrodynamic conditions, three different sub areas of distinctive directions of sediment movements in the Alexandroupolis Gulf have been identified; these are: (i) the eastern part (A), where the dominant direction of sediment movement is towards the SW, indicating the influence of the river Evros plume and associating with offshore dispersion of muddy sediment; (ii) the central and SE part (B), where fine grained seabed sediments are generally directed northwards, primarily, controlled by the hydrodynamic (wave) processes related to seabed sediment resuspension and transport (Karditsa & Poulos, 2013), which are modified by the NW dispersion of Evros plume from its current mouth; and (iii) the coastal north-western part (C), where the NW directed sediment transport, indicates that in addition to wave activity other factors are being participated, such as the advection of fine-grained products of coastal erosion (e.g., Makri Quaternary formations) and their offshore transport in suspension by the wind driven and/or thermo-saline coastal circulation.

Table 2 – Grain Size Trend Analysis results.

Number	x (Greek Grid)	y (Greek Grid)	Vector length	Vector Direction
1	394475,63	4510828,00	1,03	10,19
2	396978,81	4510828,00	1,29	0
3	399482,03	4510828,00	2,03	353,14
4	401985,22	4510828,00	1,41	355,06
5	404488,44	4510828,00	1,09	12,88
6	406991,63	4510828,00	0,43	58,97
7	409494,84	4510828,00	0,43	58,97
8	411998,03	4510828,00	0,63	11,18
9	414501,25	4510828,00	0,33	0
10	417004,44	4510828,00	0,94	348,82
11	394475,63	4513182,00	1,09	12,88
12	396978,81	4513182,00	1,13	8,2
13	399482,03	4513182,00	1,53	356,98
14	401985,22	4513182,00	1,16	4
15	404488,44	4513182,00	0,79	5,9
16	406991,63	4513182,00	0,26	66,61
17	409494,84	4513182,00	0,14	145,37
18	411998,03	4513182,00	0,38	12,39
19	414501,25	4513182,00	0,27	323,93
20	417004,44	4513182,00	1,06	360
21	394475,63	4515535,50	0,43	58,97
22	396978,81	4515535,50	0,44	47,94
23	399482,03	4515535,50	0,71	353,42
24	401985,22	4515535,50	0,07	359,99
25	404488,44	4515535,50	0,18	360
26	406991,63	4515535,50	0,59	146,96
27	409494,84	4515535,50	0,28	145,38

Number	x (Greek Grid)	y (Greek Grid)	Vector length	Vector Direction
28	411998,03	4515535,50	0,38	120,85
29	414501,25	4515535,50	0,11	133,25
30	417004,44	4515535,50	0	163,93
31	394475,63	4517889,50	0,7	44,16
32	396978,81	4517889,50	0,44	33,39
33	399482,03	4517889,50	0,97	4,79
34	401985,22	4517889,50	0,31	15,18
35	404488,44	4517889,50	0,89	0
36	406991,63	4517889,50	0,28	196,72
37	409494,84	4517889,50	0,1	308,28
38	411998,03	4517889,50	0,37	180
39	414501,25	4517889,50	0,31	195,18
40	417004,44	4517889,50	0,06	0,01
41	394475,63	4520243,00	0,26	66,62
42	396978,81	4520243,00	0,18	66,62
43	399482,03	4520243,00	0,75	12,39
44	401985,22	4520243,00	0,53	351,16
45	404488,44	4520243,00	1,11	0
46	406991,63	4520243,00	0,56	0
47	409494,84	4520243,00	0,36	0
48	411998,03	4520243,00	0,17	29
49	414501,25	4520243,00	0,31	164,82
50	417004,44	4520243,00	0,4	197,47
51	394475,63	4522597,00	0,7	15,18
52	396978,81	4522597,00	0,56	360
53	399482,03	4522597,00	1,4	0
54	401985,22	4522597,00	1,29	360
55	404488,44	4522597,00	1,23	0
56	406991,63	4522597,00	1,12	353,78
57	409494,84	4522597,00	0,4	342,53
58	411998,03	4522597,00	0,31	336,62
59	414501,25	4522597,00	0,13	246,62
60	417004,44	4522597,00	0,2	246,62

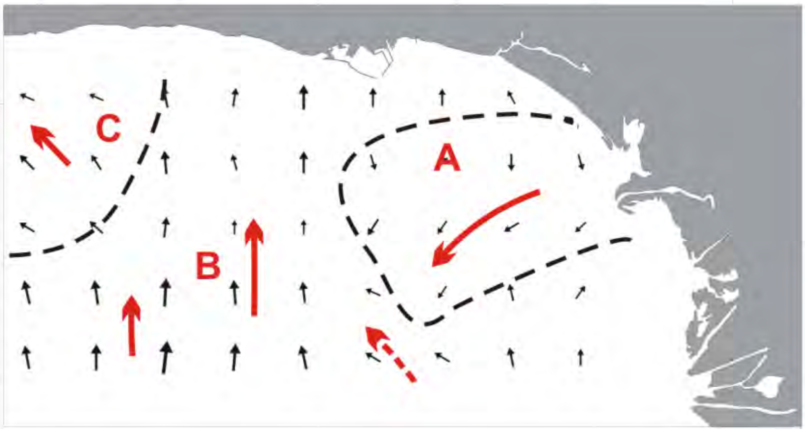

Figure 3- Sediment transport pathways over the fine grained seabed sediments of the Alexandroupolis Gulf.

5. Conclusion

The application of GSTA method in the fine grained material of the surficial sediments of Alexandroupolis Gulf describe three distinct trends of sediment transport: a SW movement at its eastern part, a general N movement at its central and southeastern part and a NW movement at its coastal north-western part. These sediment pathways are associated with the prevailing hydrological conditions, i.e. the westward Evros river plume dispersion, the wave induced hydrodynamic activity and coastal circulation pattern.

6. Acknowledgments

Dr A. Karditsa acknowledges the State Scholarship Foundation for the financial support during data collection and analyses. In addition, during the preparation of this manuscript the authors were supported by the co-financed by the European Union (European Social Fund – ESF) and Greek national funds through the Operational Program "Education and Lifelong Learning" of the National Strategic Reference Framework (NSRF)- Research Funding Program: THALES- MARE (MIS: 375655). Investing in knowledge society through the European Social Fund.

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