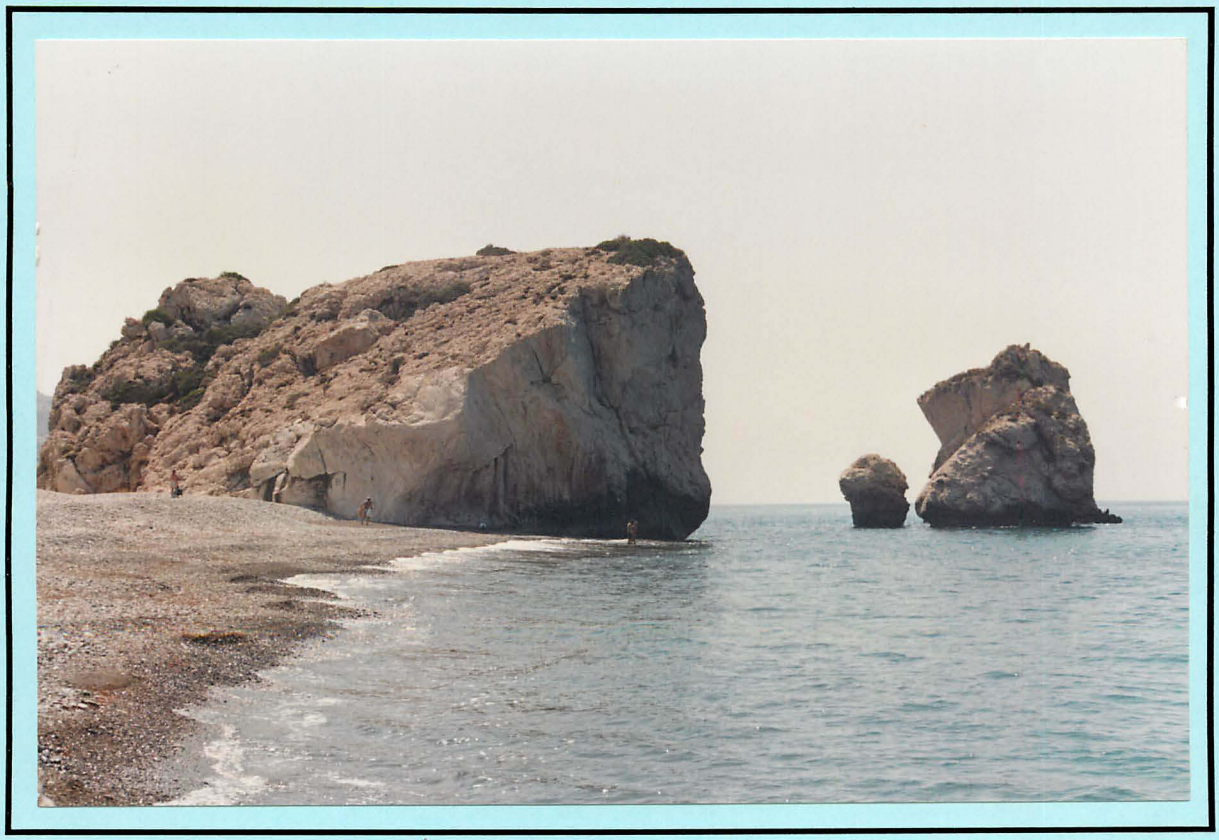
THE COASTS OF CYPRUS



YAACOV NIR

1993

GEOLOGICAL SURVEY OF ISRAEL

GEOLOGICAL SURVEY DEPARTMENT
MINISTRY OF AGRICULTURE ,
NATURAL RESOURCES AND ENVIRONMENT
CYPRUS

"The shore is an ancient world, for as long as there has been an earth and sea there has been this place of meeting of land and water".

RACHEL CARSON

THE COASTS OF CYPRUS

Yaacov Nir

Geological Survey of Israel, 30 Malkei Israel St., Jerusalem 95501

ISRAEL

(With special chapters on the mineralogical composition of the coastal clastic components by Dr. Eleni Morisseau, and the Geology of Cyprus by Dr. Costas Xenophontos, both of the Geological Survey Department, Nicosia).

Jerusalem-Nicosia 1993

מינהל למחקר מדעי
הגיאולוגיה
10-08-1994

P R E F A C E

The study of the coasts of Cyprus by Dr Y. Nir arose out of two basic reasons. In the first place there was the mutual interest of the Geological Surveys of Cyprus and Israel to initiate a cooperation in various geological fields. In the second place both Cyprus and Israel, being coastal countries, had particular reasons to need to study every aspect related to their coasts.

The Geological Survey Department of Cyprus recognizing the vital importance of the coastal zone, the urgent need to control its further degradation and in order to regulate the development versus its protection, has taken a number of measures, one of which has been the comprehensive study of all beach related aspects.

The study of the coasts of Cyprus by Y. Nir, the procedures and results of which are presented in this report, falls within the above framework and its outcome will no doubt contribute to the better understanding of the different coastal regions and to the definition of the necessary measures for the protection and improvement of the coasts of Cyprus and of Israel as well.

Y. Nir starts with the subdivision of the coast of Cyprus into 15 coastal regions or cells on the basis of a number of criteria and proceeds with the comprehensive description of the morphology of each region taking into consideration the prevailing geological and tectonic situation. He goes on to study the role of the rivers to sediment supply to the beaches and the composition and mode of transport of the littoral sediments along the coast. He then examines human intervention on the coastal system in the last few decades and points to the mostly adverse consequences of this intervention.

The report ends with a number of conclusions and recommendations based on the evaluation of the results of the study. The delicacy and fragility of the already poor and in bad condition coastal system is stressed and the need to safeguard it from irrational human intervention is emphasized. Although the

.../2

evaluation of the data expresses the views of the author, I belive that these are realistic and our intention is to consider them seriously in our plans future for the development and management of the coastal zone.

The report by Y. Nir will constitute a valuable reference to coastal engineers, town planners, tourism developers, municipalities and everybody engaged in the management and rational development of the coastal zone.

On behalf of the Cyprus Government, the staff of the Geological Survey Department and myself I would like to express my appreciation for the methodical and scientifically sound research carried out.

G. Constantinou
Director
Geological Survey Department
Cyprus

April, 1994

SK/PL
Preface

The Coasts of Cyprus

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THE COASTS OF CYPRUS

Abstract

Cyprus coasts are very poor in clastic sediments (sand, pebbles, etc.,), resulting from the composition of the parent rocks that make the island. Until quite recently, not enough attention has been given to the beaches, and besides sand and gravel mining at sites adjacent and on the beaches, practically no other economic exploitation took place. Since the end of World War II, two main dramatic changes occured: the 'boom' of concrete construction, which consumed beach material on the one hand, and the ever-increasing 'beach tourism' on the other.

The mining of beach material depleted the beaches, in addition to the negative influence of river damming, harbours, marinas, detached breakwaters, impermeable groynes, etc., which has captured voluminous amounts of beach sediments - resulting in a severe deficit in sediments, and accelerated erosion conditions. Beaches became narrower, lacking the natural protection from the erosive action of the sea.

A controversy has evolved between the economic forces involved in the development of the beaches on the one hand, which require the construction of various types of offshore installations, and those who oppose artificial shore stabilization and try to introduce shore protection measures which has much less environmental effects, on the other.

Although beach nourishment involves the permanent import of large quantities of fit sand, it could have solved, through fair expenses, the stabilization of many of Cyprus already ruined beaches. This method, although almost not implemented in Cyprus yet, should be considered as an urgent solution for the island beaches.

Damming of the main rivers, the main supply source of the beach sediments, also dropped drastically sediment import to the beaches, resulting irreversible damage to the beaches and their backshores.

The Cypriot authorities should therefore, at their earliest, create a multidisciplinarian committee which will be responsible for the basic study of the present inventory and beach conditions. This committee will conduct and direct the future tendency of beach development and preservation, the result of which will, become a master plan for Cyprus coasts.

Introduction

This report deals mainly with the Cyprus Republic coasts from south of Famagusta in the east, along the southern and western coasts, to the Tillyria region in the northwest (Kato Pyrgos). The northwestern, northern and northeastern coasts, found at present in the Turkish Army occupied area, are just briefly described, a description based mainly on pre-occupation aerial photos, geological and other reports.

The littoral system is a very dynamic one, and whenever there are waves and adequate supply of coarse clastic sediments – beaches form. This system is ever changing to meet the sea attack, resulting in changes in width, steepness, location, and sometimes even grain-size. Therefore, every man-made changes should take into consideration the side effects of each structure, morphological, sedimentological as well as environmental.

During the past two to three decades, Cyprus coasts were, in many regions dramatically developed, mainly in regards with the tourist industry. Large number of detached breakwaters, impermeable groynes, marinas, sea walls and piers are amongst the main artificial structures constructed. Understandably therefore, holiday resorts, including hotels of various types, beach constructions, and other relevant installations have developed around many of the most beautiful coasts of the island: examples are Protaras, some regions along Kyrenia's range coastal plain, Ayia Napa, Ktima and many others. Holiday resorts and many privately owned beaches have also sprung up in many of the most attractive beaches. Panayiotou (1992) shows, in his table 1, that development along the southern and western coastal zones of the island has more than doubled in length from 31km in 1971, to 79km in 1991.

Authorities in the past while planning land use and resource utilization were not aware enough to the environmental implications, mostly because those principles were simply not well known or understood correctly. Now, after the enormous wave of "unorganized" development, it is becoming clear that the lack of consideration of environmental principles in the long term inevitably leads to serious problems, and that the use of resources have distinct limits in such as

small island as Cyprus.

There is no doubt that the economic potential of the coastal environment is of a very high grade, a fact that was recognized for many years, resulting in huge investments. These investments and developments to a many extent, do not take into consideration the environment, the effect on beaches located "downstream" of the longshore currents, etc., the result of which is an ever increasing conflict between economical forces and the environment.

Until quite recently, some of the basic characteristics of the coast were, however, not fully understood, and if so, only inadequately. For example:

1. A certain beach is not an independent coastal feature, and in many cases it belongs to a much larger 'littoral cell' where any change or activity in one section automatically affects other parts of the cell, mainly those found 'downstream'.

2. Each single pebble or sand grain found along the beaches belongs there, and every removal as such causes an irreversible damage. Removal of beach material, either through direct mining, or through capture of the sand by artificial offshore structures such as harbours, detached breakwaters, etc., causes sand deficit resulting in accelerated beach erosion.

3. Many of Cyprus coasts receive their sediments from inland sources via the rivers. Every change in river supply and flow, resulting mainly from damming and 'river material' mining, causes an abrupt cut in the supply which increases beach erosion and intervens in its sediment budget.

4. In most cases an 'injured' coast can never return to its original shape and conditions as most of the destructive processes are irreversible - once a beach or its backshore cliff were demolished and removed, there is almost no way to restore it.

It appears therefore that natural limits to the carrying capacity of the entire system - the coast and the inland regions involved in sediment supply should be more adequately appreciated. In effect this means that if the authorized agencies are to derive the optimum benefit from the natural limited resources, held by all components of the

coastal environment - that is, coastal land, beach sediments, rivers, rocky and cliffy shores, and the shallow offshore waters - they must plan development in such a way that the utilization of one component will not cause undue danger to others. Therefore, governmental authorities should, at their earliest, sponsore intensive investigations of the various components of the coastal problems to enable future better and more limited exploitation of the coastal ecosystem.

There is no doubt that Cyprus offshore shallow waters have a very high potential of submarine archaeological sites and treasures, some of which were already found and recovered. These are mostly found along the beaches, and represent a few millenia of life and sea-faring, the relicts and wrecks of which are found exposed on the sea bottom, or under loose, or cemented biological sediments. Due to their historical importance, these sites are of extraordinarily importance to humanity and science. It is therefore very important that every new offshore project should take into consideration this important fact, so that sites would not be demolished, and would get the appropriate care.

Unfortunately, the Cyprus coasts, their geography, description, etc., were practically 'terra incognita', as just only two main relevant reports specially deal with the coasts of Cyprus; the first which thoroughly studied the Larnaca and Limassol beaches (Thomas, 1981); and the other, is a very recent project which still runs by the delft hydraulics (Hulsbergen and Hoozemans, 1993).

This work was carried out under the auspeces of the Geological Survey Department of Cyprus during a short visit in August of 1992, and on a sabbatical leave from the Geological Survey of Israel between March and July of 1993.

Chapter 1. Geographic setting of Cyprus coasts

Cyprus lies in the northeastern section of the Levantine Basin, about 65km off Turkey's southern coast, and some 100km west of Syria. Although the official figure for the length of the island's coasts is 772.49km (Lands and Survey Deprtment), each report or publication quotes a different figure (Panayiotou, 1992 - 782km, Delft Hydraulics, 1993 - 735km). About 50% of the coasts are in the area occupied by the Turkish Army at the northern and eastern sections of the island, and about 10% are found in the British Sovereign Bases of Akrotiri and Dekhelia.

Four distinct morpho-geological features determine and characterise the topography and morphology of the island, influencing the shoreline features and components.

a. The Kyrenia Arch in the north (Fig.1), representing a section of the Alpinic orogeny chain of southern Anatolia. It is a narrow ridge, running parallel with the seashore, with hummocky topography, quite high in its western section (1,024m at Kyprissovouno peak, some 3.5km south of Lapithos), sloping gently towards the NNE, to reach around 300m elevations at the Karpasia Peninsula where it fades out. The Kyrenia range stretches for about 150km from east to west, leaving along the northern coast a narrow plain with numerous very short rivers gushing to the sea. Its southern flanks are drained by the Mesaoria Plain rivers to Morphou and Famagusta Bays.

b. The Mesaoria Plain, spans the island from Famagusta Bay in the east to Morphou Bay in the west, some 90km long, and 25km to 45km in breadth. The plain is characterised by small number of rivers having relatively long courses - two rivers drain the eastern and central plain at the Famagusta Bay, while the other three pour their waters to Morphou Bay in the west.

c. The Troodos Massif or Range, is an igneous massif consisting of a core of plutonic rocks surrounded by a zone of intrusives with an outer fringe of pillow lavas along its foothills. The Troodos Range has the highest precipitation rates of the island and is therefore the most important water source of highly torrential rivers. Its highest peak is

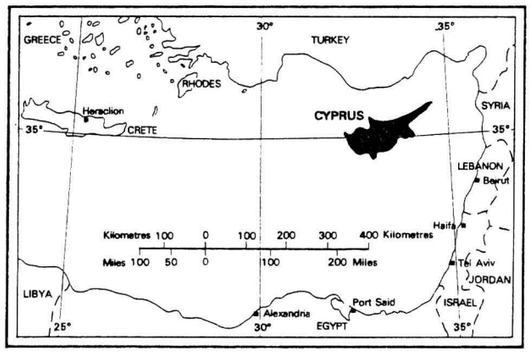
SURVEY OF

CYPRUS

GENERAL USE MAP

Kilometres 5 0 5 10 15 20 Kilometres

Miles 5 0 5 10 15 Miles



REFERENCE

- Asphalted road
- Loose surface road
- Railway line (for carrying ore)
- District boundary
- Sovereign Base Area boundary
- Town
- Village more than 1,500 inhabitants
- Village less than 1,500 inhabitants
- Place Name — Vavilas
- Ancient site (=) and Antiquity of Interest — Palea Paphos
- Monastery, Church, Mosque — Mon. el., el., T.
- River with dam
- Spring
- Lighthouse
- Airport
- Airfield
- Mine
- Heights of principal mountains in metres — 1423 ▲ Kionia
- Contours

Magnetic variation for centre of Sheet January 1976 3° 2' East
Annual change 2' East

Fig. 1. Cyprus, location map

at Mount Olympus, some 1952m high.

d. The Mamonia complex of Hilly South Western Cyprus, characterised by the cherty-shale and sandstone-limestone and chalky sequences. The complex forms the foothills of the high Troodos mountains, gradually approaching the coast. In a few regions the hills reach the sea to form relatively steep and high cliffs.

Many of the coastal regions, especially around Paphos, Kyrenia, and Protaras are composed of unnamed calcarenite formation of Pleistocene age, very rich in clastic carbonate components. This calcarenite forms a cliffy morphology on the one hand, and is the source for the coarse brown sands of certain coastal regions on the other.

The main features of Cyprus coasts and their morphology result from the interaction between its geological components, its active recent(?) tectonic movements, and the sea. Each of the four geological terrains described is very well pronounced in its coastal features. Of the most important morphological features are the numerous capes found all around the island. These capes define the edges of the littoral cells, the beginning of one cell on one side of the cape, and the termination of its neighbour cell on its other side. Besides their highly importance in coastal navigation, most capes have a very high scenery value. The main capes are: Apostolos Andreas, Elea, Greco, Kiti, Gata, Zevgari, Drepanum, Arnauti, and Kormakiti. There are another tens of small capes and 'points' which also influence the longshore transport of the sediments.

Very small islands, practically islets, are found all around the island (Appendix II), mostly off the rocky coastal regions. In most cases these are relictic rocks belonging to the present coastal region, and 'left behind' and not abraded by the sea during the withdrawal of the seashore. With just a few exceptions, most islands do not fit for human habitation, although they are very picturesque and have a high touristic value.

It is clear that the rivers, as sediment source to the becaches is an unstable and very variable source - many years can be dry without any flood, while others can be very rich in water, resulting high sediment transport. Historical records show that through the years

there has been an exceptional flood regime, with a very high peak of river flow every few centuries (Goodwin, 1984). This exeptional situation no doubt could have cereated fit conditions for the voluminous transport of sediments through the river courses to the beaches, creating shallow temporary deltas the material of which, at later stages was spread along the beaches.

Although many of the modern water reservoirs are located at the high section of the river, they decrease to a minimum the river's flow, resulting in an almost total catch of the clastic sediments in the reservoir, which minimize material transport to the beaches. Up till 1988 Cyprus had 99 constructions on its rivers - mostly dams of various types and sizes on most of its northwestern and southeastern rivers. As a result of this very intensive river damming, most of Morphou, Limassol and Famagusta Bays do not receive fresh supply of coarse clastic sediments (sand sizes and larger particles). The present situation of Cyprus beaches is therefore very critical, and most coasts are at starvation stage for sediments. The only source left are the semiconsolidated calcarenites found along the beaches which, through their erosion, supply some clastic sediments to their nearby beaches.

Chapter 2. Description of the Different Coastal regions of Cyprus

For simplicity matters, the island's different shore sections are desribed in a clockwise direction, from Cape Apostolos Andreas in the northeastern most tip, to Famagusta Bay, Protaras, around the island up to Northern Cyprus coasts, in which we included the north Karpasia beaches. Following, is a brief description of each of the different 15 sections, representing mostly the present conditions. A special description and discussion on the nature and results of sand and pebble mining is given separately in chapter 5. The limits or borders of each section are, mostly the capes, which represent in most cases changes in the morphology, and in beach and coastal composition.

The following Table1 lists the 15 different shore sections of the island and their measured lengths , a total of 677km*. or 667.66km**

Name of Coastal Zone	From - to	Length in km *	**
Karpasia Peninsula S. shores - C. Ap. Andreas to C. Elea		70	70.00
Famagusta Bay - C. Elea to S. Famagusta		35	44.55
Protaras & C. Greco Promontory - S. Famagusta to Kermia		24	24.83
Ayia Napa - Kermia beach to Potamos outlet		15	13.37
Larnaca Bay - Potamos to Cape Kiti		44	45.19
The Rocky Coasts of Southern Cyprus - Cape Kiti to Moni		44	45.19
Akrotiri - Limassol Bay - Moni to Cape Gata		30	27.37
Southern Akrotiri Peninsula - Cape Gata to Cape Zevgari		10	10.18
Episkopi Bay - Cape Zevgari to Curium		15	14.00
Southwestern coasts of the island - Curium to Paphos		50	49.65
Western coasts of the island - Paphos to Cape Arnauti		50	48.37
Khrysokhou Bay - Cape Arnauti to Pomos Point		36	35.64
Tillyria - Pomos Point to Karavostasi		28	26.73
Morphou Bay - Karavostasi to Cape Kormakiti		34	35.64
Northern Cyprus - Cape Kormakiti to Cape Apostolos Andreas		185	176.95

* - Meaured by the author with curvemeter.

** - Official figures, provided by the Geological Survey Department.

a. Karpasia Peninsula - Southern Beaches

The southern shores of the Karpasia Peninsula stretch from Cape Apostolos Andreas in the most extreme north-eastern point of the island, to the Cape Elea Promontory in the southwest, a length of about 80km. The Karpasian Peninsula is formed by the easterly section of the Kyrenia Range which commences at Cape Arnauti in the west, a distance of about 150km. This range affects much the topography and morphology of the peninsula and its coasts. The beaches are of the most attractive beaches of the island, untouched, representing various extraordinarilly interesting geological and geomorphological features (Figs. 2-5). It seems that the special isolation conditions of the region are of the main reasons for this unusually good preservation of the long coasts of the entire peninsula.

Some small sand dune fields are also found in this section, represented by the relatively large and most spectacular region near and around the natural tombolo of Pakhyammos (Figs.4a & 4b). Three other small fields are found further to the southwest, one near Cape Elea, the second opposite Koma tou Yialou, and the third near Ayia Anna. The dunes penetrate inland some few hundred meters at the most.

A very impressive coastal feature was developed in the Karpasia and the northern coasts of the island - a feature which results from the specific tectonic conditions of this part of the Kyrenia Range, and the contact of the geological features with the sea. These are abraded platforms of inclined limestone and chalky layers having their strike parallel with the general trend of the peninsula. The layers were horizontally cut by the sea action to produce a most typical abraded platform with specific morphological features very rarely found elsewhere (Figs.5a & 5b). This type of abraded beaches is also found at the 'roots' of the Karpasia Peninsula on the northern shores, mainly near Kantara.

The northeastern section of these coasts is characterized by very small bights with very shallow veneer of white sandy beaches. In between the bays, the shores are mostly cliffy, with very small cliffs. The central and southern sections of the coasts have, in general, very narrow beaches with little sand. Ayios Simon village beach is an



Fig. 2. The southern Karpasia beaches at Koma tou Yialou.



Fig. 3. Cliffy beaches of southern Karpasia peninsula near Tigania Forest.



Fig. 4a. Pakhyammos peninsula, SE' shores of Karpasia. One of the most pronounced natural tombolos and sand dune field of Cyprus.



Fig. 4b. Aerial photo of the Pakhyammos region: the original small island and its sand tombolo creating the peninsula.
(Flight CY 15, 029; 7.9.57).



Fig. 5a. Semi-tombolo of Moulos. The shoreline is characterized by horizontally-cut limestone layers. (CY 73, 188; 10+11/11/63).



Fig. 5b. Horizontally cut inclined chalky layers at the southern Karpasia coasts, Voukranos Forest region - east of Rhizokarpaso.

exception, and is wider and rich with sand.

b. Famagusta Bay

Famagusta Bay is the largest and widest bay of the island, extending from Cape Elea in the northeast to the southern limits of the city of Famagusta, where the rocky calcarenite terrain of Paralimni region starts to appear, a distance of about 35km. The shape of the bay originates mostly from the following features: the Cape Elea and Cape Greco promontories at its edges, and the 'soft' eastern Mesaoria Plains in the center. The relief of the bay's coasts is very smooth, with the exception of a few calcarenite cliffs north of Famagusta (Fig.6). The main components of the present beaches are derived from the imported clastics of the Yialias and Pedhios rivers, and from the calcarenite layers which are mostly composed of coarse brown carbonate sand (Fig.7). A most pronounced feature are the offshore underwater rocky platforms and barriers which are typical of many sections of the bay, representing relicts of former strata (probably of calcarenite ridges' origin), abraded during and after the Holocene transgression. The main historical Famagusta Harbour implemented as breakwaters relicts of the same offshore ridges located parallel to the shore. Calcarenite ridges of the same system also influenced the shape of the Yialias and Pedhios outlets to the sea, located near and north of Famagusta, forming a small elongated bay (Fig.8) instead of an expected delta. There are no any calcarenite relicts in this small bay itself, either that there has been no deposition of this sandstone, or it has been formed and later removed by the river floods. Relicts of these calcarenitic ridges can also be identified at the shallow shelf, up to 6-700 meters offshore from the present shoreline, probably evincing a large magnitude coastal erosion since the end of the last glacial period, some 6-6,500 years ago when the sea stabilized at its present level. At present, the Famagusta Bay coasts are very poor in sand, and the supply either by the dammed Yialias and Pedhios is negligible. The other streams flowing into the bay bring some clastics, but in relatively small quantities. Some of the narrow beaches are found under severe erosional conditions (Fig.7), resulting mainly from the lack of sediment supply. There is



Fig. 6. Cliffs of the Protaras calcarenite, north of Famagusta. (8.3.93).

Fig. 7. Coarse brown carbonate sand, Salamis Bay, north of Famagusta. (8.3.93).





Fig. 8. Aerial photo of the small elongated bay of the Yialias and Pedheios river outlets. (CY 22, 047; 4.10.63).

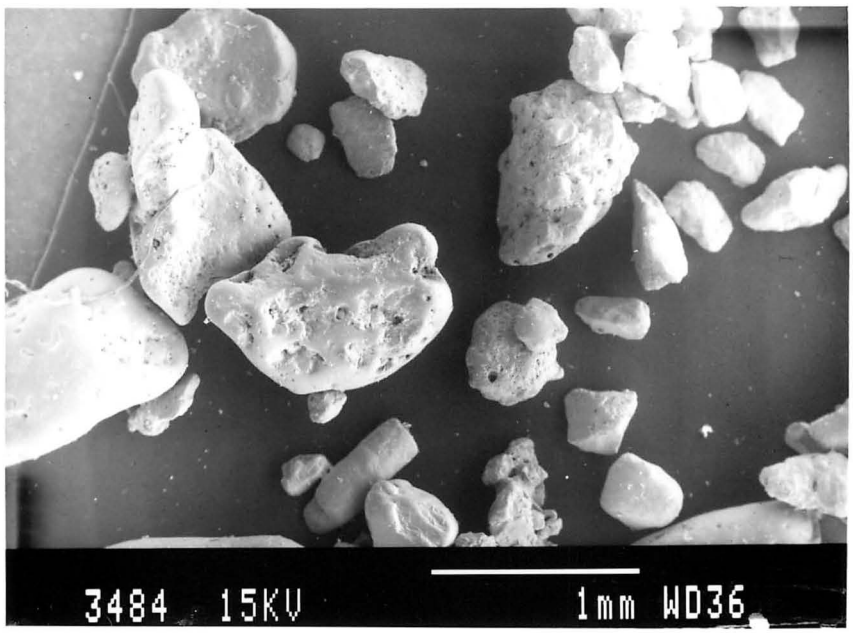


Fig. 9. S.E.M. photo of carbonate sand, (CB53), from Ayia Trias, Paralimni region (Photo by M. Dvoracek, Geological Survey of Israel).

no doubt that the original name 'Ammokhostos' which is the Greek name for Famagusta (meaning 'thick sand'), represents a sand accumulation stage, a situation which disappeared through the construction of the modern city and the enormous sand mining in the Yialias and Pedhios outlets to the sea (See Chap. 5). It also seems that the main load of these two rivers at their lower course, consisted besides sand size grains, large masses of very fine grains (silt and clay sizes), a fact which is indirectly proven by the lack of any submarine delta off the rivers' outlets to the sea.

c. Protaras - Cape Greco Promontory

Although the geological and morphological conditions of the Protaras, and the Greco promonory are different, it has been decided to combine the two into one coastal unit covering the entire region from southern Famagusta, around the small Greco peninsula, to east of the so-called Kermia Beach.

i. Protaras region

The coasts are mostly composed of the rocky, very much developed Pleistocene age calcarenite (proposed herewith to be therefore named the 'Protaras calcarenite'). This formation is defined in the official geological map of Cyprus as belonging to Terrace deposits of the Pleistocene, of the Circum Troodos Sedimentary Succession, and found along many of Cyprus coasts (Anonymous, 1979 - The 1:250,000 Geological Map of Cyprus). Although its composition might differ from one region to another, they all are semifriable, brown in colour, and mainly composed of coarse calcarenitic components (Fig.9). Its origin is both shallow-marine and terrestrial, and in many sites cross-bedding of the different sets can be seen (Fig.10), evincing their terrestrial dunar origin.

The Protaras region is characterized by typical cliffy bights, embedded with rocky substrate (Fig.11), covered by thin veneer of sand and some pebbles. Due to the lack of sizeable rivers, the additional material from outside sources, to that of the abraded calcarenite sand of the beaches is negligible. Some of the beaches



Fig. 10. Calcarenite cliffs of northern Kyrenia range beaches, of probable terrestrial origin (wind-blown cemented sands).



Fig. 11. Protaras calcarenite overlying unconformably inclined layers of white chalks. (3.5.93).

have fairly developed beachrock sets, and in a few bights a very characteristic undercut cliff (nip) is developed (Fig.12). Rocky blocks of various sizes are found in and around many of the bights; representing relicts of the eroded chalks and calcarenites. The shoreline has a 'denticular' shape which is very typical of cliffy coasts of semiconsolidated terrain (Nir, 1992). The shoreline withdrawal is not in a straight line as is the case in sandy 'soft' beaches, but it occurs in 'steps', a feature represented by the uneven and rough shoreline. The offshore abrasional platforms which were mentioned earlier, are probably composed of the same calcarenite, can be easily identified both from the beach (Fig.13), and in aerial photographs (Fig.14). Their appearance offshore, as recorded on aerial photographs, might reach a few hundred meters.

The only sizeable and long beach within this zone, is the 1,100m long sandy beach located in an open bay off Protaras old village, between 3875 and 3876 UTM north coordinates.

ii. Cape Greco Promontory

The souteastern extremity of Cyprus is a termination of a small peninsula and is connected to the mainland by a narrow isthmus, of the Cape Greco pronmontory. This cape is characterized by a most typical reef limestone of the Terra formation of Lower Miocene age. The region have a most pronounced cliffy mountain the continuation of which abruptly fades westwards, producing hard cliffy coasts, that do not allow sediment accumulation, therefore the development of sandy beaches (Fig.15). This is the largest, and the only site composed of this limestone exposed along Cyprus coasts. This rocky shoreline stretches westwards up to Kermia Beach near Ammos tou Kambouri, where the Protaras calcarenite outcrops appear again.

d. Ayia Napa Coasts - Kermia Beach to Potamos outlet

These coasts of southeastern Cyprus extend from Ammos tou Kambouri to the Potamos estuarine. Many sandy bays and bights are found along these beaches, some are quite large, like at Ayia Napa, while others are very small. From Ayia Thekla and westwards, to the



Fig. 12. Undercut cliff (nip) developed in the Protaras calcarenite, Farkonia Beach - Paralimni region. (17.8.92).

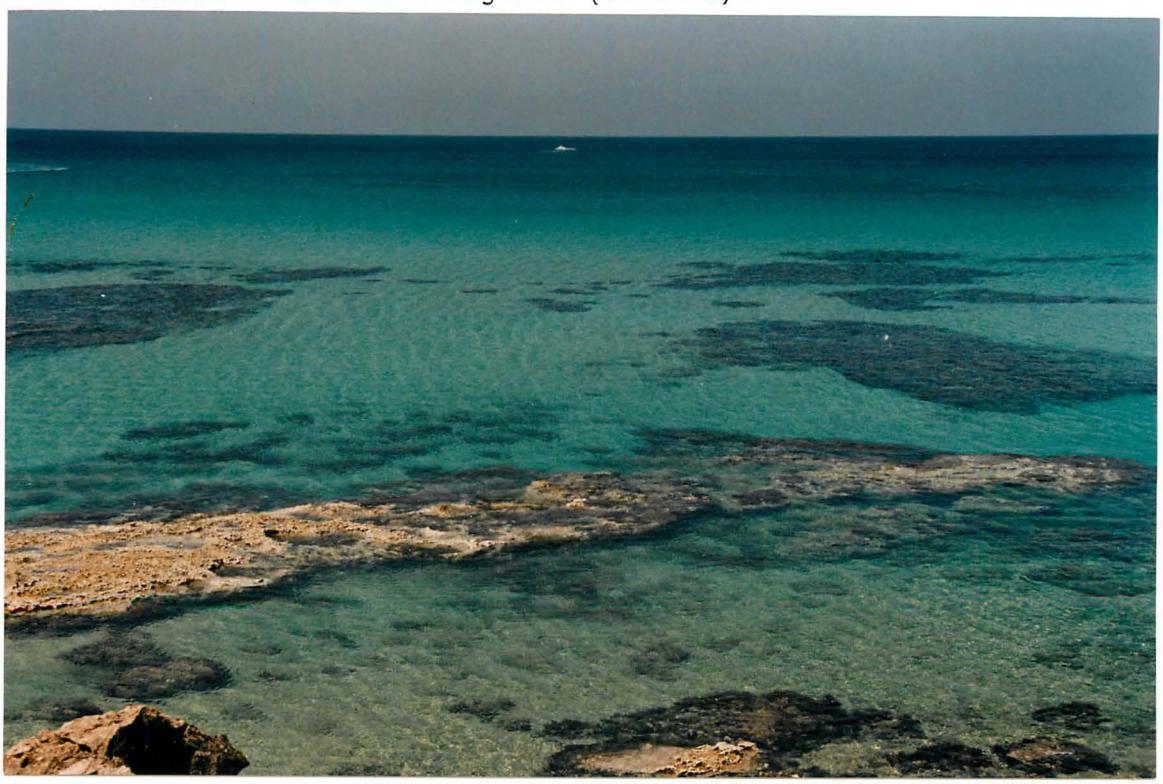


Fig. 13. Relictic abrasional platforms (probably of the Protaras calcarenite), between C. Greco and Protaras village. (3.5.93).



Fig. 14. Aerial photo of offshore abraded rocks and platforms. (Cape Zephyros. CY 17, 185; 2.10.63).



Fig.15. Oblique view from C. Greco towards Kermia beach low cliffs and rocky shoreline. (19.4.93).



Fig. 16. White foraminiferal sandy beaches of Ayia Napa region. (17.6.93).



Fig. 17. S.E.M. photo of foraminifera test from Nissi island beach (CB39, Peneroplis sp. - identification by Dr. A. Almogi, and Photo by Mr. M. Dvoracek, both of the Geological Survey of Israel).

Potamos outlet, the beaches are rocky, and have just a very thin veneer of sand. The most significant feature of this coastal section are the white sandy beaches (Fig.15), with its special foraminiferal composition, which is a unique phenomenon not found elsewhere on the island. This white sand originates from the erosion of a most specific local calcarenite rock which is different in its composition from other calcarenitic exposures found around the island - in addition to the 'common' variety of carbonate particles, it has a relatively high percentage of white foraminifera tests (Fig.17).

The Protaras calcarenite is found all along this coastal section, its relief is low, and is topographically much less developed (Fig.18) than in other parts of the island. Well developed white calcarenite rock exposures were found around Ayia Thekla coasts and westwards along the shallow and flat rocky beaches.

Some small sand dunes existed not long ago around Ayia Napa, but these were mostly mined, or covered by constructions (G. Constantinou, pers. comm.).

e. Larnaca Bay - Potamos outlet to Cape Kiti

For practical and simplicity matters it is suggested to divide this bay into three main units: the eastern, from Potamos outlet around the Cape Pyla peninsula to Dhekelia Power Station, Dhekelia to southern Larnaca city (Scala), and from S. Larnaca to Cape Kiti.

The Cape Pyla promontory coasts are mostly bare, very rocky (Fig.19), with just a few tiny and poor sandy patches. These beaches originate from nearby rocks that represent three main geological formations: the Koronia reef, a Fanglomerate formation of Pleistocene age, and small 'intercalations' of the Protaras calcarenite formation (Anonymous, 1981).

An elevated marine terrace, some 2m high, composed of a conglomerate with very well-rounded small pebbles (Fig.20), mostly of igneous origin, is found between Ormidhia beach and Dhekelia. As a result, the beaches are very rich in well-rounded pebbles. The main part of Larnaca Bay, from Dhekelia to Scala, shows a very smooth curved



Fig. 18. Rocky beaches of Ayia Thekla region, composed mostly of foraminiferal rocks of the Protaras calcarenite. (17.6.93).



Fig. 19. The rocky - hilly coasts of Cape Pyla. Sandy beaches appear in small pockets and are very rare. (21.6.93).



Fig. 20. Ormidhia Beach elevated terrace of small pebbles conglomerate of Pleistocene age. The erosion of these layers supplies the near-by beaches with very rounded pebbles. (18.8.92).



Fig. 21. East Larnaca at Livadhia beach, relatively sand-poor beaches with pebbles as major component of the beach. (21.6.93).

shoreline forming an arc. The beaches are narrow and poor, and in most cases composed of small quantities of sand and some pebbles (Fig.21). The southern Larnaca - Scala beach is totaly composed of coarse size pebbles.

The southern section of the Larnaca Bay, that off the Salt Lake, is much different in its character, and is mostly influenced by the Playa's (Sabkha) flats, and the pebbles' rich Cape Kiti coasts (Fig.22). These pebbles are transported northeasterly by the major longshore currents (Fig.23).

The brown sands found in this coastal section and around Larnaca, no doubt originate in the calcarenite exposures present in the region. Some other components of the beach material originate in the small igneous Troulli Massif, and in the eastern Troodos, and are transported to this region via the Tremithos River.

f. The Rocky coasts of Southern Cyprus - Cape Kiti to Moni

The rocky coastline of southern Cyprus, between Kiti and Moni is characterized by the narrow pebbly and poor sandy beaches (Fig.24). In most of the backshore area there is a flat intensively cultivated terrace, a few meters high. The western section, from Vasilikos and westwards, to Moni, is hilly and mostly composed of the Lefkara formation introducing chalk to the coast (Fig.25). Some occurances of patchy Protaras calcarenite are also present here. In other regions a small cliff develop, composed of either chalky limestone or of red fossil soil (Fig.26).

Five main rivers, the sources of which are at the Troodos main Massif, are reaching these shores, and are from east to west: Pouzis, Xeropotamos, Penthaskinos, Maroni, and Vasilikos. These rivers introduce to the beaches with high percentage of pebbles of igneous origin (Fig.27). Study of a few groynes constructed here, shows asymmetry and uneven deposition in their sediment accumulation: larger volume of sediments on the west side of the obstacle (Fig.28), proving that the main longshore transport direction is from the west towards the east.



Fig. 22. C. Kiti coasts at Meneou. Large pebbles result in high grade slope of the berm. The beach is covered with dead algae (21.6.93).



Fig. 23. An Oblique aerial photo of C. Kiti region, showing the easterly directed longshore drift (bottom left). (20.10.92).



Fig. 24. Very narrow, pebbly and cliffy beaches between Maroni and Penthaskinos. (13.6.93).



Fig. 25. The most beautiful, chalky and steep cliffs of Governor's Beach. (23.6.93).



Fig. 26. Small, relatively friable cliffs of the elevated terrace East of Penthaskinos. Narrow beach with mixed pebbles. (13.6.93).



Fig. 27. A mixture of carbonate and igneous origin flat pebbles typical of many beaches. Some 5km west of Penthaskinos. (13.6.93).

Akrotiri Bay - Limassol Bay - Moni to Cape Gata

Akrotiri, or Limassol Bay stretches from Moni to Cape Gata, at the southeastern corner of Akrotiri Peninsula, a distance of about 30km. The coasts from Amathus, located some 6km west of Moni, to Limassol city southern boundaries, are of the most damaged coasts of Cyprus, both on land and in the offshore shallow waters. Very intensive construction activity took place on land, and a huge number of detached breakwaters and other marine constructions, mostly impermeable groynes, are present here in the very shallow water (Fig.31). This is one of the most dense and active regions of land and marine construction in Cyprus. Many hotels were erected along the narrow beaches and coastal plain, and numerous detached breakwaters and groynes were built in the shallow water. Besides these there are two harbours at Limassol and a big marina near Ayia Varvara (Sheraton Hotel Marina). Many of the offshore structures lack any sand accumulation - although there has probably been much expectations for such as an accumulation, an idea probably provided by the constructors... Two big rivers, originating in the eastern and central Troodos Massif drain into Akrotiri Bay: Yermasoyia and Garyllis, supplying mostly material of igneous origin. The beach gravels are composed of both igneous and sedimentary rocks, mostly chalks and limestones, while the sands present are mostly dark with low carbonates components.

The coasts from the new Limassol harbour to Cape Gata, along the eastern shores of the Akrotiri Peninsula, named Lady's Mile Beach, are more smooth and are much affected by the Salt Lake and its banks, the 'Sabkha' (Playa) terrain. Large quantities of pebbles are present in the viscinity of the harbour, are gradually disapearing towards the south, where sand is dominant, indicating a clear and weak southern longshore transport. A more detailed discussion on the Holocene history of the peninsula is given in the next section 'h' of this chapter. The southern most 4km, from the small 'fisheries shelter' to Cape Gata are rocky, with small chalky cliffs and almost clear of sandy beaches.



Fig. 28. Typical assymetric sand and pebble accumulation next to a small groyne barrier, detecting a clear easterly directed littoral drift. (13.6.93).



Fig. 29. A series of 4 twin detached breakwaters constructed at a relatively great distance offshore, the result of which is the absence of tombolo or beach widening. Eastern Limassol beaches east of Posseidonia Hotel. (13.6.93).

Southern Akrotiri Peninsula (C. Gata to C. Zevgari)

The Akrotiri Peninsula is a very interesting and of the most important sedimentological features of Cyprus. Its shape and morphology resemble a huge 'tombolo' that was deposited between the natural 'detached breakwater' - the Zevgari-Gata ridge with its easterly offshore 20-25km long underwater continuation (shown in Hall, 1981), and the mainland with its original shoreline of pre-tombolo times, located between Curium and Limassol. The length ratio of Zevgari-Gata natural 'breakwater' to its distance from the original shoreline is about 1:1, a ratio which allows most fit conditions for the development of a perfect tombolo in the 'shaded' northern side of the ridge (Nir, 1982).

The historical map of Ortelius (Ortelius, 1573), shows the Kouris River hadthen two outlets: one pouring to the sea in the west, near Curium, while the other poured to the region where the present Salt Lake is found. This map also shows a large gap in the shoreline on the eastern side of the present peninsula, the results of which was a great shallow inland bay. Recent field studies and observations confirm the general accuracy of the main features of this section of his map which suggests that the eastern shores of the peninsula, those beaches known at present as 'Lady's Mile Beach' are very young, beaches that were deposited and formed quite 'recently'. The unequality in sediment load of the rich western branch of the Kouris River, and the relatively poorer load of the Garyllis on the east, could have also influenced the unbalanced formation of the Akrotiri peninsula: fast deposition in the west, connecting the mainland with the offshore Cape Zevgari ridge, and a much slower deposition in the east side of the freshly built peninsula, connecting the mainland with Cape Gata at a much later period. The second, eastern outlet of the Kouris, that was pouring into the ancient bay, no doubt was flowing into the sea south of Limassol via the eastern coastal bar gap, keeping this gap from becoming silted or closed by a newly deposited bar. We assume that tectonic, and/or anthropogenic changes of the Kouris outlet regime, has caused the closure of the eastern shores of the peninsula and resulting among

others, the formation of the semi-detached Salt Lake. As a result of this isolation the salinity of the lake has since increased.

The 10km long shores between C. Gata and C. Zevgari are mostly rocky, denticular, somewhat cliffy, with very narrow and sporadic small patchy beaches.

i. Episkopi Bay - Cape Zevgari to Curium Bay

These 15km long coasts of the Episkopi Bay are influenced by two dominant factors, the Gata - Zevgari ridge in the south, and the Kouris River sediments in the central and northern sections. The southern section is rocky, somewhat cliffy with very small and narrow beaches, while the central and northern sections are mostly pebbly, with a clear tendency of decrease in boulder and pebble sizes from the Kouris outlet in the north towards Cape Zevgari in the south (Figs.31a & b). These pebbly beaches are of the most rich pebble fields in Cyprus, extending on the average up to one hundred meters inland, and probably a few tens of meters offshore. The major part of the pebbles are of igneous origin although there are also some carbonate rocks present too. These inland pebble accumulations were very intensively mined and supplied much of the southern island demands in coarse construction materials (see chapter 5).

From the Kouris outlet and northwards the pebbles abruptly decrease in size and quantities, disappearing almost entirely in the western beaches of Curium Bay which are purely sandy. Episkopi Bay in general shows a clear and dominant southerly longshore drift, although some minor drift towards the north exists also.

j. The Southwestern Coasts of Cyprus - Curium Bay to Paphos

This section of the island combines various types of coasts, although they are all quite poor in beaches and clastics.

The Episkopi - Evdhimou shores are very cliffy, with a most significant feature of 'stair' bluffy promontories shoreline (Fig. 32).

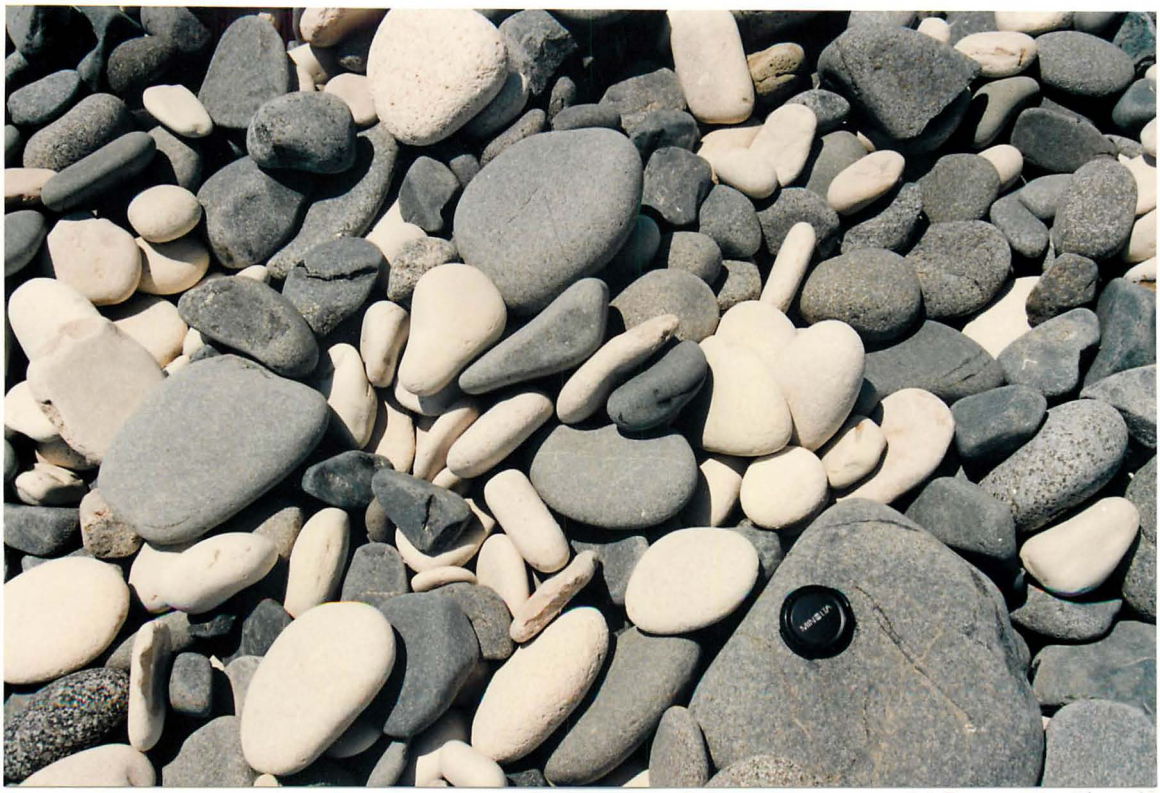


Fig. 30a. Igneous large blocks and limestone pebbles at the Kouris outlet. The strong stormy longshore currents sort the pebbles and carries them southwards towards Cape Zevgari. (30.6.93).

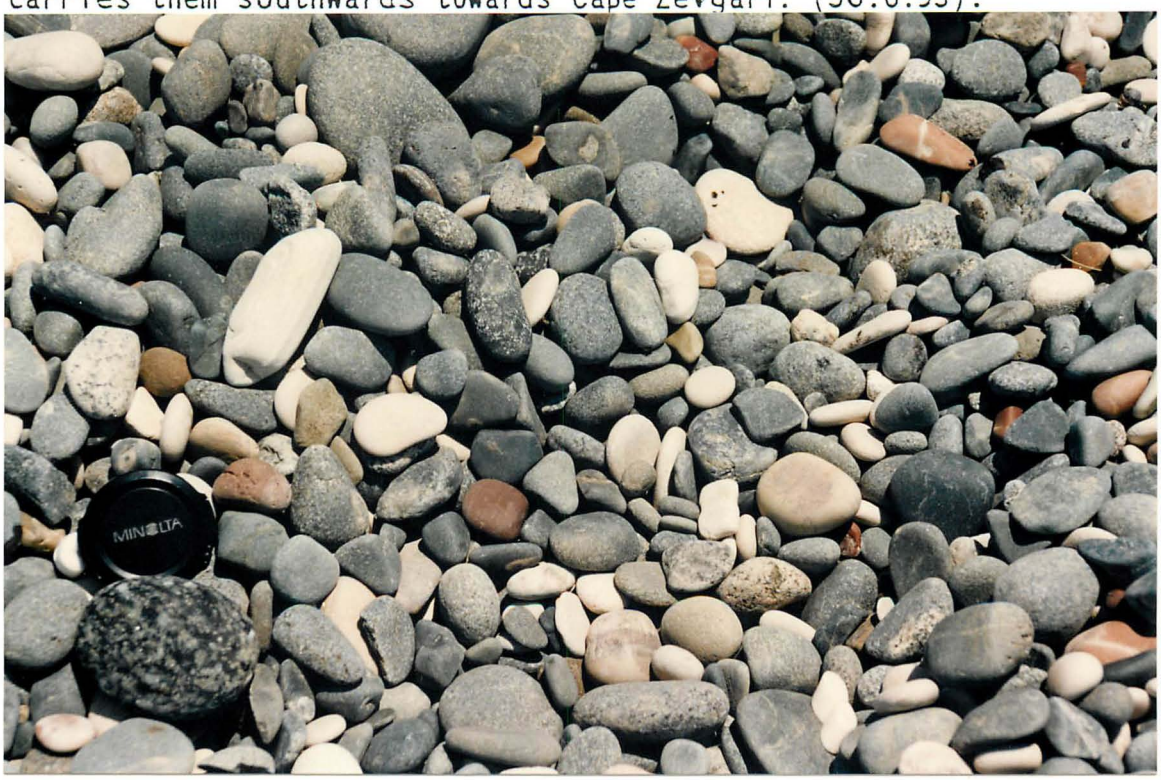


Fig. 30b. Small pebbles of the southern section of the Episkopi Bay beaches, very well rounded and much smaller than the Kouris river outlet pebbles. (30.6.93).

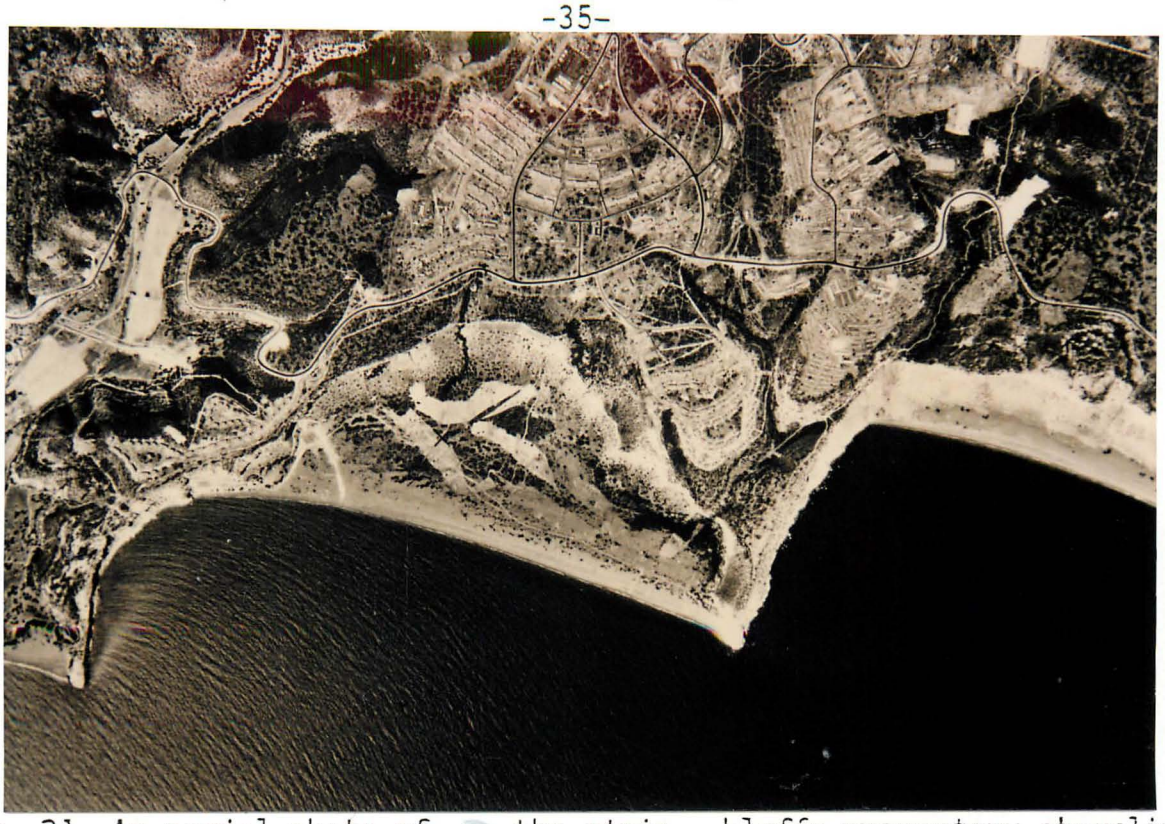


Fig. 31. An aerial photo of the stair - bluffy promontory shoreline of Episkopi region. (CY 4, 036; 27.8.57).



Fig. 32. The typical cliffs of Episkopi region with artificial 'pond' structures created for economic sand accumulation. This system and the sand mining affects the 'downstream' coastal regions which suffer from severe erosion!. (30.6.93).

Each promontory has a protected small sandy bay receiving its sediments via the easterly directed longshore drift. A very intensive sand mining took place until very recently in the easterly most bay, close to Curium (see chapter 5), where large quantities of sand were accumulated next to artificial breakwaters which played as a barrier to this easterly directed longshore sand drift (Fig.33).

With a few exceptions, such as the Evdhimou or Pissouri Bays, most of the shores are rocky and cliffy, having only small bights with some sandy and pebbly patches (Fig.34).

This high relief coastal region gradually fades and lowers towards Kouklia, where the beaches are less cliffy, containing narrow, but quite uniform pebbly beaches. The Protaras calcarenite reapear near Cape Zephyros, with outcrops extending all the way down to Paphos and further northward, introducing coarse calcareous brown sand of local origin to the beaches. These carbonate sands are dominant, although in small quantities, in the western section of the beaches described, from Cape Zephyros to Paphos.

Four large rivers originating in the high Troodos have their outlets in this coastal section and are from east to west: Khapotami, Dhiarizos, Xeros Potamos, and Ezousas. These introduce to the beaches sediment load composed of a mixture of sand and pebbles of both igneous and sedimentary origin.

The general northwest - southeast direction of the coasts of this section results in a preferred southeasterly longshore sediment drift, mainly caused by the westerly storms and swell.

k. Western Cyprus - Paphos to Cape Arnauti

This section is influenced by two main factors, these are: the rocky terrain of its coasts, and their exposures to the open sea on the west.

The southern and central sections have small bights and some bays - such as Coral Bay, composed mostly of rocks, sand and pebbles. Other shores are cliffy and poor in sand or pebbles. From Cape Drepanum and north, towards the Lara Nature Reservation, there are a few wide sandy



Fig. 33. The small rocky cliff of Timi beach, with poor narrow pebbly beach (12.8.92).

beaches (Fig.35), which terminate in the southern rocky extention of the Akamas Peninsula.

The western, and eastern shores of the Akamas are very rocky (Fig.36), characterized by small cliffs, abrasional platforms, and some very narrow pebbly or sandy beaches. The configuration of the peninsula no doubt creates a preferred southerly directed longshore drift along its western, and has a southeasterly directed longshore drift along its eastern shores.

l. Khrysokhou Bay - Cape Arnauti to Pomos Point

This is one out of two bays in Cyprus facing and opened to the west, (the other is Morphou Bay), a fact, the result of which are higher wave energies on the beach, and the dictation of the main longshore drift which is mostly towards the east and northeast. Cape Arnauti is located at the northwestern extremity of Cyprus. The western slopes of the cape are steep, while the eastern side has more graduate slopes towards the beaches.

The northwestern section of the bay, the one belonging to the Akamas Peninsula, has about 8km of rocky cliff-beaches, with just a few coves and bights with some pebble and sand beaches. From the Baths of Aphrodite and eastwards to Latchi, the coasts are very narrow. Around Latchi and Polis there is some beach widening, and they are sandy with some pebbles (Fig.37). From Polis to Pomos Point the beaches are very narrow, mostly pebbly with some sand and beachrock (Fig.38). The northeastern section of the bay is rocky and is opened to the west, creating small bights in the that hard rocky terrain. This section of the bay has beaches poor in sediments, while its southwestern section which is less exposed to the open sea, is more 'smooth' containing sand and pebble beaches.

m. Tillyria - Pomos Point to Karavostasi

This region has different and specific geological conditions as the northwesterly extention of the Troodos Massif reaches the coasts of



Fig. 34. Aerial photo of the sandy bay of the Lara Nature Reserve. (3874300N). (CY 54, 162; 3.10.63).



Fig. 35. Aerial photo of the rocky west Akamas Peninsula poor-sand cliffy beaches. (CY 67, 067; 6.11.63).

Tillyria. In many localities the highly sloped mountains approach the shoreline. This is an exceptional situation which influences directly the beaches: resulting in cliffy - hilly shoreline (Fig.39) on the one hand, and the purely igneous components of the beaches on the other. With the exception of the Katouris River outlet at Kato Pyrgos, forming there a relatively long pebbly beach (Fig. 39), most of the beaches are rocky with just a few small bights with sand and mainly pebbles.

n. Morphou Bay - Karavostasi to Cape Kormakiti

The Morphou Bay developed at the western part of Mesaoria Plain, between the slopes of the Tillyria Mountains in the southwest and the rocky Cape Kormakiti in the northeast. The southern section of the bay, from Karavostasi to Syrianokhori receives sediments from the Troodos Massif igneous rocks via its rivers, while the northern section, from Aloupos river to Cape Kormakiti Promontory receives its sediments from the Mesaoria and the southwestern flanks of the Kyrenia Range.

The beaches of the southern section of this bay are mostly pebbly, forming a very wide strip from the present shoreline inland. The inland pebble deposits of this region, are known to have been quite rich, therefore were quarried and used as construction matterial source for many years (see Chap. 5). The beaches of the northern section are more sandy, containing less pebbles. Dune sand fields, perhaps representing extra sand accumulation and large reserves, along these specific beaches, were developed in the Ayia Irini region, penetrating inland as tounges of up to 1km long (Fig. 40). The Kormakiti peninsula western shores are denticular, with small rocky, cliffy bights.

o. Northern Cyprus - Cape Kormakiti to Cape Apostolos Andreas

Due to insufficient data and information about the northern section of Cyprus coasts, it has been decided to combine the entire northern shoreline into one descriptive section. As a result of this combination, this is the longest shoreline section described here, commencing in Cape Kormakiti in the west, running along Cyprus northern



Fig. 36. Brown sand with some pebbles, Latchi beach near Polis. Notice the Latchi Marina at the background. (5.7.93).



Fig. 37. Narrow sandy beaches with beachrock sets, and cliffy background, Nea Dhimmata. (10.8.92).

coasts to Cape Apostolos Andreas in the east, a distance of about 185km. The shoreline has a general east - west direction in its westren and central sections, changing its direction towards the northeast near the city of Kyrenia, following in general this azimuth up to Cape Apostolos Andreas.

A few major geomorpholgical features influence the northern coasts of Cyprus: the Kyrenia Range with its relative high relief and elevations found at small distances inland from the sea; the flat and very narrow coastal plain found between the mountains and the sea, and the low relief topography of the Protaras calcarenite ridges forming many of the coasts under discussion.

In general, the beaches are cliffy, the shores are denticular, with great number of rocky and pocket micro bights, some of which are used as fisheries shelters, and sporadic sandy and pebbly beaches (Fig.41). Most of the Kyrenia range rivers are short, draining small areas, having their outlets in small bays with no pronounced deltas. Exceptionals are a few rivers located west of Ayios Amvrosos, as they do have small deltas. The parallel layers' flat abrasional platform beaches, similar to the type described along the southern Karpasian coasts, are also present here, with the first exposure located east of Stazousa Point, creating 'tombolo' shape beaches (see Fig.4b). A quite developed sand dune field is found at Ronnas Bay, representing some exceptional situation of sand surplus along the near by beaches. The main components of these dunes are fine grained sands of carbonate origin (Fig.42). The largest 'sattelitic' islands are located east of Cape Apostolos Andreas, these are the Klidhes Islands (see appendix II).



Fig. 38. The pebbly bay with 'cross-breakwaters' of Kato Pyrgos bay. The newly built marina is at the background. (6.7.93).



Fig. 39. The cliffy and rocky shores of Tillyria, with the small islet of Petra tou Limniti. (View taken from Vouni, 16.5.93).



Fig. 40. Aerial view of the largest sand dune field of Cyprus at Ayia Irini. (CY 13, 030; 6.9.57)



Fig. 41. Small rocky bight, composed of the local calcarenite, northern coasts of the island. (12.5.92).

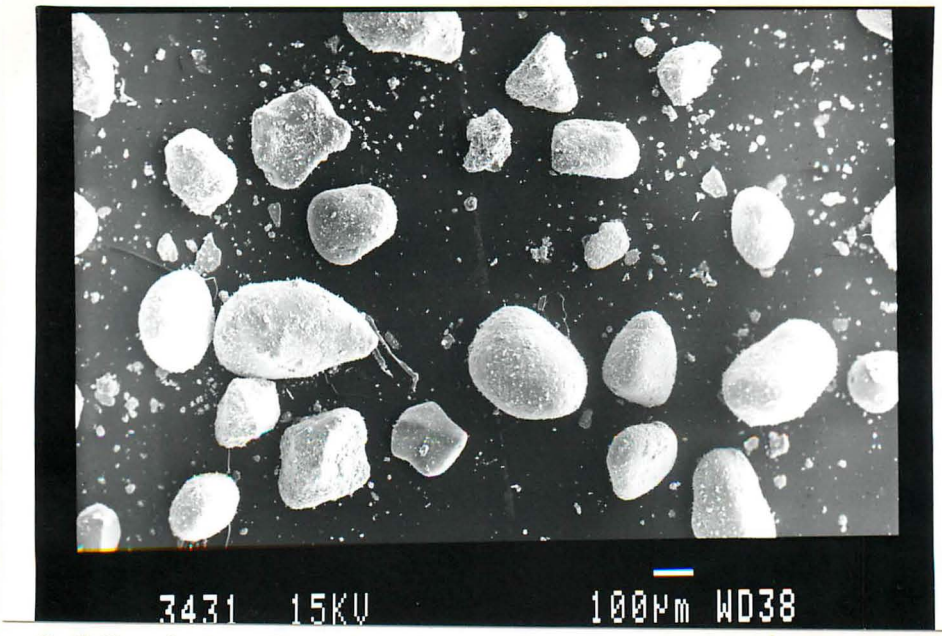


Fig. 42. S.E.M. photo of carbonate sand grains from the Ronnas Bay dune field (CB5), northern Karpasia Peninsula.



Fig. 44. Detached beachrock strata, with small elongated lagoon resulting from large sand deficit. East of Limassol. (13.6.93).

Chapter 3. The Rivers of Cyprus, their Drainage Basins, Dams, and sediment load

As the syngenetic and local-erosion sources of sediments of Cyprus beaches are very minor, the beaches are totaly dependent on 'import' of clastic sediments from 'foreign' sources - the inland. Langbein and Schumm (1958) showed that in most cases the annual yield of a stream is related to the annual precipitation and its drainage area. Long term changes in the precipitiation, could have therefore result in changes in sediment supply to the beaches. Therefore, Cyprus rivers play a most important role in the sediment supply to the beaches, and their study is vital for the overall understanding of the coastal sedimentary balance and regime. The coasts of Cyprus receive terrestrial waters which have been gathered in numerous rivers in the four main landscape regions described: Troodos, Mamonia, Kyrenia and Mesaoria. The southeasterly most region of the island, the triangular shaped region found between Larnaca, Famagusta and Cape Greco, covering an area of some 550km2, has a very undeveloped drainage system, and its input to the overall water and sediment budget of the coasts is very poor.

Most of the island's rivers originate in the Troodos Massif and its foothills, therefore their load components are mostly of igneous rocks of various types: the core of the massif, providing with plutonic rocks such as serpentinite, dunite, gabbro, etc., while the lower areas of the 'sheeted lavas' supplies mostly with basaltic gabbro, diabase, volcanoclastic, etc.

The precipitation chart of Cyprus shows a very clear dependence of rainfall to elevation: the central Troodos for example receives the highest values ranging between 500-1,000mm/yr on the average, while most of the Mesaoria Plains have only 300-400mm/yr. This high rainfall in the high mountains, with the steep morphological relief, results in torrential rivers gushing in a very high gradient courses.

The Department of Water Development of the Ministry of Agriculture and Natural Resources has divided the entire island of Cyprus into 9 hydrological regions (Fig.43):

1. Paphos, 2. Tillyria, 3. Morphou, 4. Kyrenia, 5. Karpas, 6. Mesaoria, 7. Mesaoria (SE), 8. Larnaca, and 9. Limassol (Kypris and

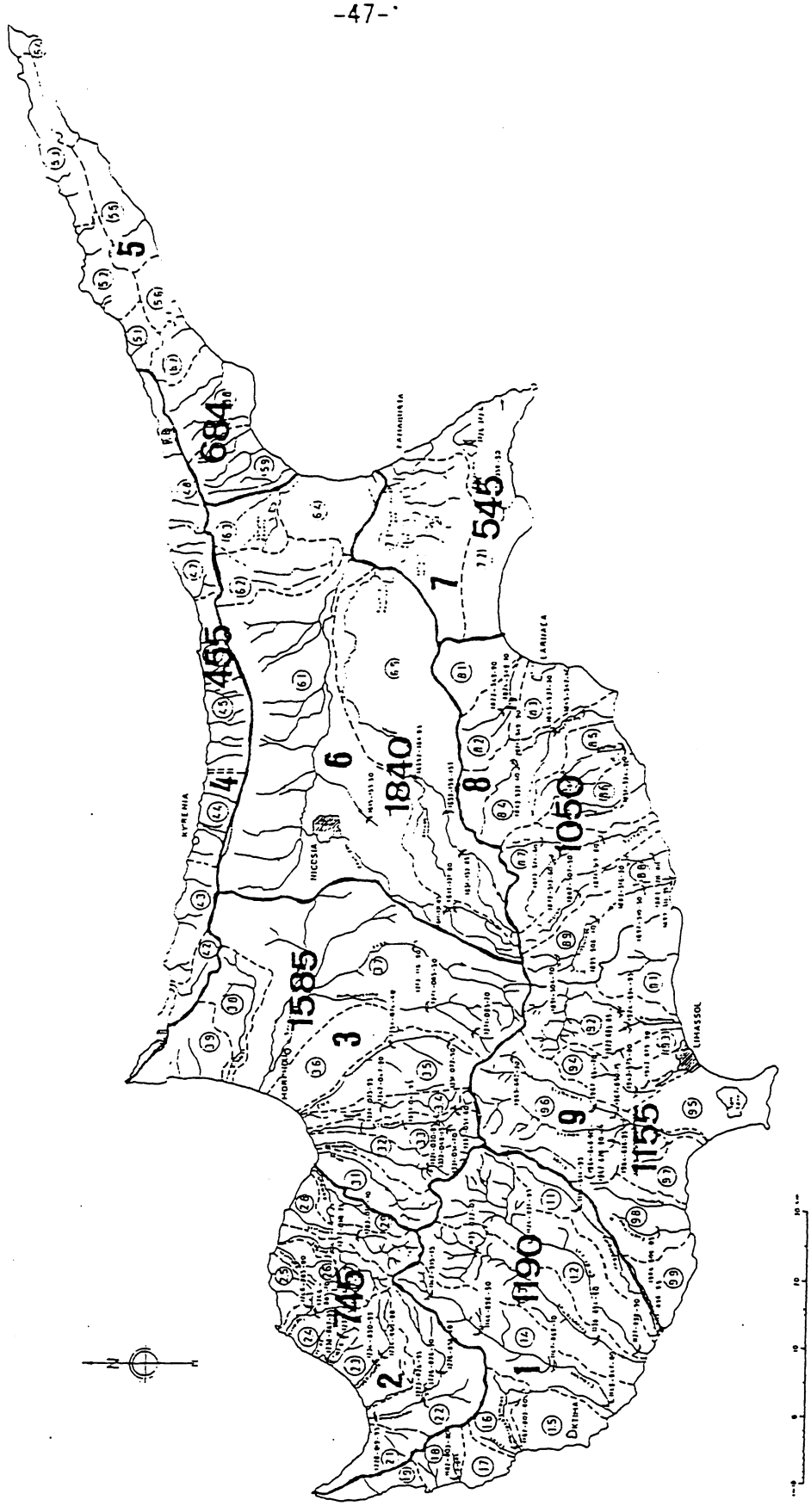


Figure 43. Map of the 9 hydrographic zones of Cyprus, and their specific watershed areas (sq. km). (From Kypris and Neophytou, 1989).

Neophytou, 1989). Their report with its most detailed maps and tables, and in addition a most valuable table provided to the author by Mr. Christos Ioannou of the Water Development Department, Nicosia, are the basis for many tables and other data represented within this report.

The island is characterized by three main river patterns: a. the very short rivers of the northern and northeastern flanks of Kyrenia Range, b. the very long rivers of the Mesaoria Plains (5 main rivers), and c. the main Troodos Massif rivers, originating mostly in the high elevations, the courses of which are draining to the sea in a more or less 'radial' pattern. Inspite of the radial pattern, these specific and tectonic conditions of the circum Troodos terraine created a most peculiar phenomenon of close and parallel river courses found just a few kilometers apart. The high elevations of the massif on the one hand, and its relative close distance to the sea on the other, resulted in high gradient courses enabling very high load-capacity and transport.

The sediment load of the rivers differ from one zone to the other, and the beaches reflect, in most cases, the strtigraphy of their feeding rivers' drainage basins - although some sediments are transported from other river outlets by the longshore currents. The Troodos rivers are known for their heavy and coarse load - resulting in pebbly coasts, while the Mesaoria rivers, due to their long courses and very low river-bed gradients, supply the coasts with sands and finer sediments.

Thomas, in his final report on 'Erosion on the Southern Coastline of Cyprus' (Thomas, 1981, p.25-26), tried to study river contribution to the Limassol area through the comparison of pre-dam and post-dam topographic changes of the imported material at the reservoirs. Although the quantities measured are obviously not the exact ones reaching the sea under normal conditions, his figures might well represent an order of magnitude of load transport via the rivers.

Unfortunately, there has been large discrepencies between the two periods of topographic mapping involved, a fact which made comparison almost impossible. The reason could have originated mainly from the unmeasured and 'unofficial' removal of material for

construction or agricultural purposes from the bottom of the reservoirs during the dry seasons. Inspite of the above mentioned limitations, Thomas estimated the average annual load of the Garyllis (1970-74) to be in the order of 8,000m3, the Tremithios (1974-78) to be 3,500m3, and that of the Yermasoyia to be as large as 13,000m3. These figures no doubt relate to the overall sediment income of these rivers, and include large portion of fine and very fine clastic sediments, the contribution of which to the beaches is negligible. Therefore, the effective input to the coasts should be much smaller, as just the sand and coarser particles are deposited along the beaches, while the fines are sorted and transported to the continental shelf where they are distributed according to grain sizes, coarse sizes in shallow, and the fines in deeper waters.

According to Kypris and Neophytou (op. cit.), most of Cyprus's rivers have a high sediment load transportation capacity, and that most river beds show frequent changes after every flood - evidence for a highly effective downstream sediment transport.

As Cyprus coasts receive most of their material from the inland, via the rivers, every cut in this supply results in a very harmful erosion to the beaches. Any change in flood pattern, or water regime on the one hand, and gravel mining on the other, causes destruction along the relevant coasts of a certain littoral cell.

The damming of many of Cyprus main rivers is an operation which already started at the dawn of the 20th. century, with the gathering of the Yialias and Pedhieos river waters at the Kouklia Reservoir west of Famagusta. This trend of damming was somewhat dormant until the mid fifties, when dam construction reached 'high gear', and many rivers were dammed either for open water reservoirs, or for recharge purposes. In both cases the damming has abruptly cut the sediment load, which is since deposited on the artificial reservoir bottom.

The following table No. 2 summarizes the nine drainage zones of Cyprus, their various rivers, the areas of their basins, maximal discharge, average rainfall in their drainage basins. The table is based upon data from Kypris and Neophytou, 1988; and from table provided by Mr. Chris Ioannis of the Water Devel. Dept., Nicosia.

Table No. 2. Description of the different rivers of Cyprus.

Region and River	Length (km)*	Drainage Basin(km2)	Average yr. Rainfall (mm.)
1. Paphos			
Khapotami	32	115.5	647
Dhiarizos	44	277.5	683
Xeropotamos	41	251.6	650
Ezousa	37	250.9	647
Ktima Region		93.7	481
Mavrokalimbos	13	62.1	617
Xeros	6.3		
Peyia Region		37.2	502
Avgas + Michos		53.7	565
W. Akamas Region		47.3	491
2. Tillyria			
E. Akams Region		64.4	521
Khrysokhou	29	204.7	642
Makounda Region	15	143.1	577
Livadhi Region	12	66.9	551
Kokkina Region		35.6	483
Katouris	10	34.4	521
Pyrgos Region	20	56.9	635
Limnitis	22	89.4	617
Kampos	9	49.4	506
3. Morphou			
Xeros	22	95.0	511
Marathasa		91.2	561
Karyotis	26	96.6	618
Atsas	25	64.9	431
Elea	30	164.3	442
Komitis		154.4	308
Serakhis	36	727.8	404
Ovgos	32		

Aloupos	20	90.5	390
Ayia Irini		100.0	425
4. Kyrenia - general		455.0	490
5. Karpasia Peninsula		684.5	486
6. Mesaoria			
Pedhios (1a)	93	265.0	420
Pedhios (1b)	78	500.0	420
Levkoniko Region		155.5	400
Syngrasi Region		80.0	455
Limnis Region		130.0	350
Yialias	85	598.5	364
7. S.E. Mesaoria		545.5	
8. Larnaca			
Oroklini Region		83.7	325
Aradhipou		77.5	340
Meneou-Aliki Region		99.4	365
Tremithos	30	173.7	400
Pouzis	15	78.7	402
Xeropotamos	14	94.4	407
Syrgatis=Pentaskinos		173.1	537
Maroni	27	110.5	508
Vasilikos	27	158.7	527
9. Limassol			
Moni		117.5	443
Yermasoyia	30	176.8	595
Ayios Athanasios		35.0	478
Garyllis	24	101.2	528
Akrotiri Region		141.9	431
Kouris	37	338.1	689
Episkopi Region		55.6	454
Evdhimou	12	119.4	521
Paramali	15		
Pissouri Region		69.4	458

* - As to lack of official figures for Cyprus rivers, their lengths were measured upon 1:100,000 scale maps with a hand-curvemeter.

Chapter 4. The Beaches

a. Composition and sources of the Beach Sediments

The beaches of Cyprus are entirely dependent on local sediment supply reaching the coasts from the mainland, as there is no additional matter deposited on the beaches from any non-Cypriot source. The principle source of Cyprus beach sediments are the mountain rivers, which carry large quantities of clastic sediments from the mountains directly to the coast, the unconsolidated material of the eroded sea-cliffs, and local material of biological origin, such as bivalve shells, coral fragments, foraminifera, etc. These sediments are transported along the beaches of the same littoral cell* through the means of the longshore currents. Rocky coasts are relatively stable, and their erosion is usually a much slower process. Three main petrographic ssources are found along the beaches:

a. The rocks and minerals derived from the Troodos and other igneous massifs,

b. The rocks and minerals derived from the Circum Troodos sedimentary terrain, and

c. Sand grains originating in near-by fossil deposits of the Protaras calcarenite.

Another source, quantitatively very minor, is that of biologic origin supplying the beaches and shallow water with broken material originating mostly in mollusca communities, and is found almost all around the island.

Due to its natural problematic conditions on the first hand, and man intervention by the removal of beach components through every possible way on the other (mining of beach and river-bed material, dams in rivers, capture of beach material by artificial structures, etc.), the beaches of the island are very poor in clastic components. With a few exceptions, most of the beaches are very narrow, and most of the island's beaches are in bad shape. In regions where sand and/or pebbles were mined, there is a most pronounced withdrawal of the shoreline,

reaching in some areas a few tens of meters, a situation very well seen in areas where detached beachrock layers are present (Fig.44). This beachrock was left detached from the present shoreline as a result of this sand and/or pebbles deficit, forming an elongated narrow lagoon. In some places the beach was left totaly exposed of its loose clastic sediments, bare and rocky.

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* - Littoral cell is "a segment of coastline that is involved in a complete cycle of littoral transportation and sedimentation. Such cell contains a complete cycle of littoral transportation and sedimentation, including sources and sinks of sediment and transport paths" (Inman and Frautchy, 1966).

b. Summary on the geology of Cyprus.

The following chapter on the geology of Cyprus was written by Dr. Costas Xenophontos of the Geological Survey Department, Nicosia, to whom the author is very grateful!

"Three geologic terranes have come together since the Late Cretaceous to form the island of Cyprus. These are: 1) The Troodos terrane which comprises the exposed part of the Late Cretaceous ophiolite and its adjacent areas to the north (Mesaoria Plain), and south where ophiolitic rocks are covered by Tertiary autochthonous sediments, 2) The Mamonia terrane in SW Cyprus where a tectonically complex of Late Palaeozoic to Late Cretaceous volcanosedimentary sequence with minor metamorphic rocks was welded onto the Troodos terrane at the end of the Cretaceous (Maastrichtian) prior to the deposition of the Tertiary sedimentary cover, and 3) The Kyrenia terrane in the north, an equally tectonically complex assemblage of Late Palaeozoic to Neogene sedimentary and minor metamorphic rocks.

The Troodos ophiolite forms roughly an oval area of some 3,000 km2 across the south central part of the island. A complete and underformed ophiolite sequence ranging from pillow lavas (overlain in places by manganoan sediments) at the top through sheeted dykes, gabbros and ultramafics, to tectonised harzburgite at the base is present,

Representative lithologies are basalt lava, jasper, diabase plagiogranite, gabbro, olivine-gabbro, wehrlite, pyroxenite, dunite and harzburgite (serpentine). Rapid, pulsed uplift since the Late Tertiary in response to regional tectonism and as a result of diapiric uprise of serpentinite beneath, Mt. olympus has produced a massif, 1952m at its (present) highest point. Concomitent erosion has produced a rough annular outcrop pattern with the deepest rock type, the tectonised harzburgite, exposed at the centre around Mt. Olympus, giving way outwards to structurally higher units with the highest, pillow lavas, exposed along the periphery.

North of the ophiolite outcrops, the Mesaoria is a rather flat intermontane plain that stretches from Morphou Bay in the west to Famagusta Bay in the east. It is floored by the ophiolite and is known to be covered by as much as 2,700m of flat-lying Tertiary sediments. Up to about 400 meters of these sediments have been deposited in the last 2Myrs indicating quick deposition concomitant with the rapid uplift and erosion of the Troodos Massif. These autochthonous sediments are represented among the beach deposits by such rock types as chalk, silicified chalk, chert, calcarenite and reefoidal limestone.

South and west of the Troodos ophiolite, rocks of the Mamonia terrane are exposed in windows eroded through the overlying autochthonous Tertiary sediments. Their lithology (sandstones, pelagic limestones, radiolarian cherts, mudstones, alkali basalts, reefoidal limestones and minor metamorphics) represents a collapsed passive margin sequence which, together with oceanic islands and associated reefs, have been accreted into the trench of the north-dipping, Late Cretaceous subduction zone. The tectonics of this allochthonous assemblage was made even more complicated by the Maastrichtian rotation of the Troodos terrane and its juxtaposition with the Mamonia.

In the north the Kyrenia terrane, forming the Kyrenia Range, an arcuate ridge of considerable complexity along the northern coast of the island was elevated to its present position during the Quaternary. It is made up of allochthonous Permian to Cretaceous

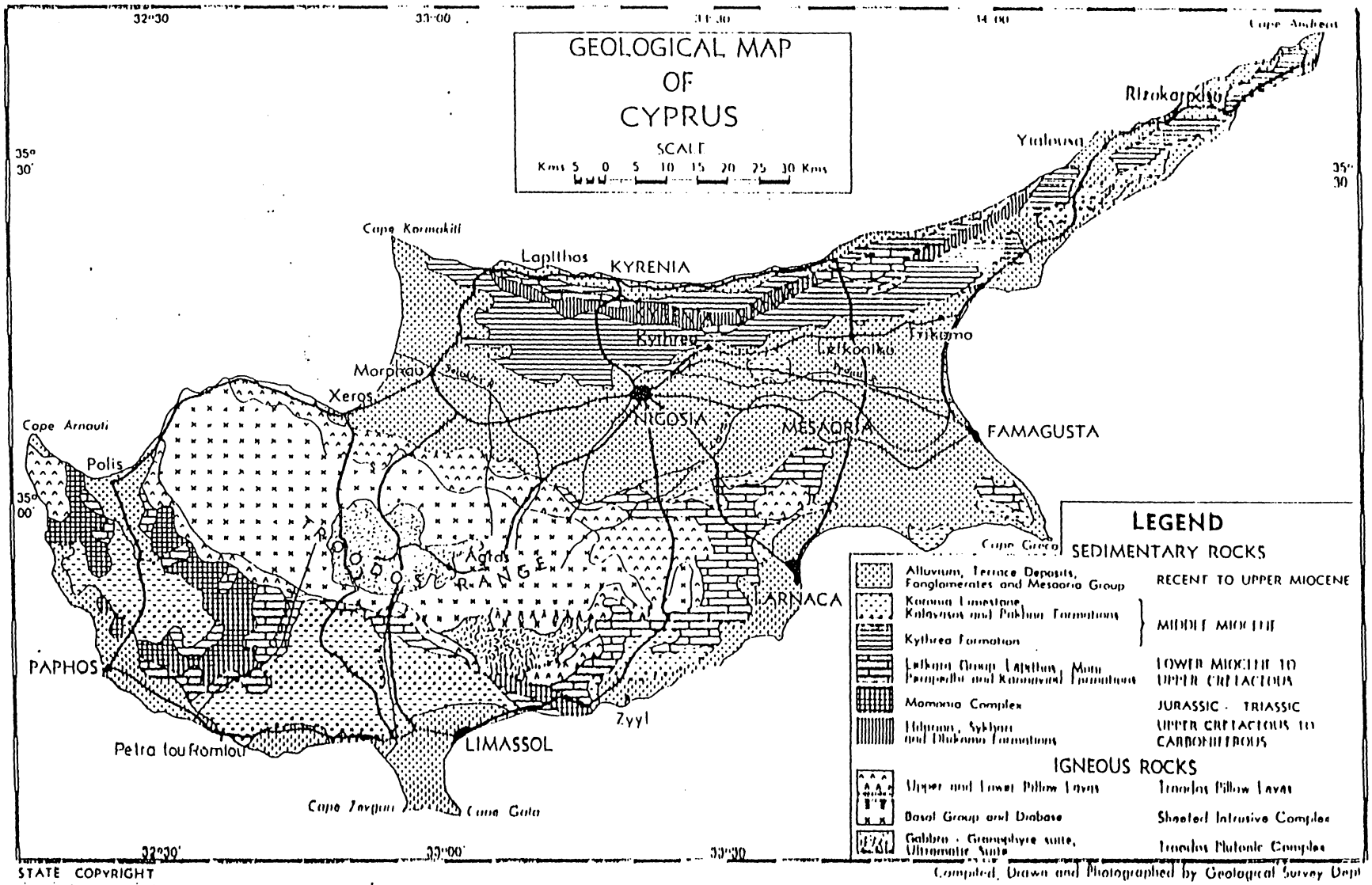


Figure 45. Simplified geological map of Cyprus.

shallow water recrystallized carbonates (light to dark-grey dense, recrystallized limestones, are dominant and are accompanied by minor amounts of micaceous limestone, grey to greenish phyllites, chloritic schists, serpentinite sandstones, chalks and calcarenites) initially juxtaposed with the Troodos terrane in the Late Eocene. Subsequent compressive and extentional episodes were more pronounced in their effects along this zone than in the Troodos microplate.

The existing configuration of the island is the result of uplift since the Miocene this beeing most rapid in the Late Pliocene to Pleistocene periods".

Scanning Electron Microscope study (S.E.M.) that was done by Mr. M. Dvoracek of the Geological Survey of Israel, and detailed mineralogical study done by Dr. E. Morriseau of the Geological Survey Department, Nicosia, show that the composition of the main beach fine components (exclusive the pebbles), is a direct mirror of the inland petrographic column. The sands are in general of two different types, the so called 'dark sands', and the 'light brownish sands'. The dark sands originate in the igneous terrain and are mostly composed of diabase, lavas, plagioclase, magnetite, epidote, serpentine, and ilmenite; while the light brownish sands originate mostly from the sedimentary terrain, especially the eroded coastal calcarenites, and are therefore mostly carbonates of various types.

The following table No. 3 shows the various samples studied under the SEM, their locations (see map, p. 87), and their main constituents.

Sample No.	Location	Main components
CB4	Glykiotissa	Mostly calcite, foraminiferas
CB5	Ronnas Bay	Mostly calcite
CB7	Pakhyammos (Karpasia)	Mostly calcite, some alumosilicates
CB8	Komma tou Yialou	Calcite and quartz
CB9	Boghaz	Mostly calcite
CB16	Limassol	Dark sand, some gypsum
CB17	Limassol	Dark sand, serpentines, qz.,
CB20	Ayios Yeorgios	Dark sand, some calcite
CB24	E. of Zyyi	Dark sand,
CB28	Meneou Beach	Dark sand, some qz.
CB31	Voroklini	Dark-light sand,
CB33	Kermia Beach	Mostly calcarenite + diatomes
CB39	Nissi	Mostly calcarenite, foraminifera
CB40	Ayia Thekla	Mostly calcarenite, foraminifera
CB50	Coral Bay	Mostly calcarenite, qz., corals
CB52	Ayios Yeorgios	Mostly calcarenite, qz., corals
CB53	Ayia Triada	Mostly calcarenite, corals
CB63	Latchi	Mostly qz., some carbonates
CB65	W. of Pyrgos	Black sand, qz.
CB66	Pakhyammos (Polis)	Mostly black sand, some calcite
CB68	Argaka	Serpentines, qz., calcite + diatoms
CB71	Pissouri	Mostly calcarenite, some qz.
CB73	Petra tou Romiou	Mostly black sand, some calcite
CB75	Zephyros Point	Mostly qz., foraminiferas,
CB78	Near Paphos	Mostly calcarenite

Study of the geological map of the island, and the excellent chapter quoted above, by Xenophontos, show the basic poorness of the geological column in coarse clastics such as sandstones, etc.

The large number of sedimentary littoral cells which the island's shorelines are composed of, a basic concept which should be always taken into consideration, results in beaches of various qualifications: from very poor to relatively rich clastics' beaches.

c. Littoral Sediment Transport along Cyprus Coasts

The clastic loose sediments found on the beaches are affected by two main transport vectors perpendicular to each other: a) alongshore, and b) offshore - onshore (also defined as 'cross shore' transport (delft hydraulics, 1993). When waves approach the coast at an angle, they result longshore currents which transport the available clastic sediments. In rocky coasts on the other hand, wave erosion is usually a slow process. The direction of the waves' front dictates, according to its angle of approach, the resultant longshore current. In order to have a complete picture of the longshore transport regime, a full knowledge of the bathymetric conditions, wind and wave climates is vital. Due to severe lack of this type of information, we tried to analyse the surface wind data from coastal stations on the one hand (Anonymous, 1986), and field relations of sediment accumulation around artificial and natural shore obstacles on the other. The onshore - offshore sediment movement is very well known as a seasonal phenomenon - where beaches exhibit distinct seasonal cycles. These cycles are represented by sediment transport to the offshore during the winter storms, and opposite onshore movement during summer, and mainly during automn. This onshore offshore sediment movement dictates the width of the beaches - depending on the sediment availability of a certain coastal system. Therefore, beaches in general are very narrow during winter time, and wide to very wide during summer and automn respectively. ('Winter' starts with the first serious storm).

Cyprus has numerous littoral cells, created mostly by the capes, 'points' and other promontories and small peninsulas that do not allow further longshore drift. Each littoral cell has a preferred net longshore drift direction.

Most sediment is transported between the upper beach limits and depths of around 15m, natural sorting occurs during this transport - resulting in grain-size decrease with increase in water depth.

Many coasts may show longshore transport in opposite directions, e.g., the direction might vary from one season to another, and from day to day. In most cases the total value, or sediment volume transported to the opposite directions is not equal, the difference of which is the 'net transport' and the prefered direction at a certain point.

The report on the surface winds in Cyprus (Anonymous, 1986), summarizes the gradient wind directions of the island which are in generalized picture: Winter - SW to E; Spring - W to NE; Summer - W to N, and Automn - W to NW. Tables given in that same report show that the general measured force of the local winds, is quite weak. The Limassol Port station for example did not have winds stronger than 11 knots (around 20km/hr) - (Table 4.3, averages for the years 1981-1985). Estimations, and studies of other parts of the Levantine basin storms' regime advocate much more energetic and faster winds than those reported above.

Another indication that provides most valuable information about shore sediment transport are the sizes, shapes, and location of sand bodies (such as tombolos), accumulated near natural or artificial offshore structures such as small islets, groynes, detached breakwaters, etc. The shape of the sediment body and its preferable side of accumulation in relation with the obstacle (Fig.28), detect its preferred net transport. The spread of the coarse clastics - sand and pebbles of a certain known origin and its petrographic composition around beaches located far away from river mouths, no doubt proves about the transport direction. The fact that many of the pebbly Cyprus

coasts are located in quite large distances from their source - the river mouths, undoubtedly proves that there is another energy source to the local waves, a source that generates waves and longshore currents much larger and more energetic - these are the swell waves generated by long distance fetch. Thomas (1981) believes that the swell produced drift far exceeds the drift caused by locally generated waves, an idea entirely accepted by the author.

It is clear that the longest possible fetch for Cyprus is about 2,000km and is from the west and southwest, resulting in an easterly directed longshore currents resulting net transport on all 'fit' beaches of the island, those having an east - west orientation. This fetch potential gradually decreases in length while rotating direction towards the south and the east, to only 400km, and 180km respectively. As a result, all beaches exposed to the western fetch will show a more pronounced net easterly drift. The western shores of the island behave somewhat differently and will, in most cases, show a southeasterly directed drift.

The following map, (Fig.46) ia a suggestion for the cardinal longshore sediment transport directions around the island. This map is mostly based upon field observations and aerial photos study. The north-south orientated coasts, and the numerous capes, behave somewhat differently from the main drift, resulting small variations to the main easterly transport. The map expresses well how complicated is the definition of the local drift, and shows the difficulties in the definition of separate and independent littoral cells.

It should be mentioned that although the net direction of transport is clear on many of the coasts, its volume is totaly unknown.

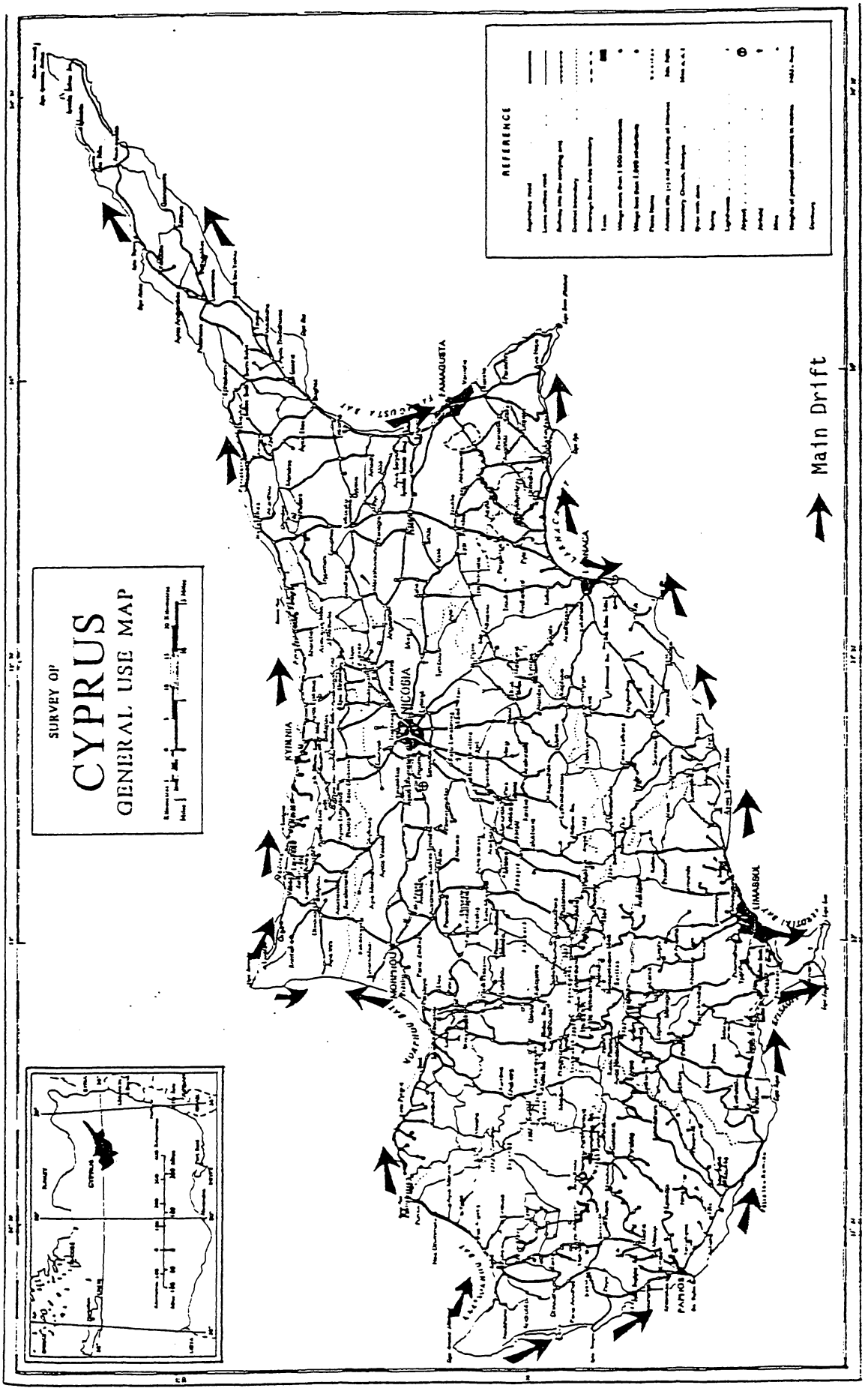


Figure 46. The main trend of the longshore drift of sediments around Cyprus, as suggested through aerial photographs, field trips and study of the main wind directions.

d. Sediment budget for Cyprus beaches

The morphology, historical geology, and the lithology of Cyprus main rock columns which are very poor in coarse clastics such as sandstones, combine together with other factors such as the island's tectonic uplift movement, to result poor sandy beaches. The beaches therefore behave like a mirror to the inland poorness in fit clastic sediments. This basic concept should be always kept in mind while studies and planning of any scale take place. The beaches are almost totaly dependent on the source-rocks of the island which belong to three main petrographic groups (for more detailed description see above:

a. Igneous of the Troodos Massif and its two sattelites - the Akamas and the Troulli small massifs.

b. The sedimentary circum Troodos rocks of the foothills, including the elongated Kyrenia range metamorphics and other rocks, and, c. The semiconsolidated Neogene and Pleistocene age clastic formations such as the Protaras calcarenite which is found along many coasts, etc.

The island has numerous littoral cells, each dependent on its own local source of supply, and there is practically no by-pass of coarse sediments beyond the cell's edges - the capes and 'heads'. The beaches are therefore dependent on permanent supply from two main sources: either the rivers, or the erosional products of semiconsolidated formations at the near-by coastal plain. The primary poorness of the beaches is also reflected in the relatively and sporadic small, poor, and thin sand dune fields found around the island coasts. These are usually being developed when sand surpluses are accumulated along the beaches, and the topographic conditions allow aeolian inland sand transport. Although some parts of the island are known to have (or have had until very recently) sand dune fields, their overall coverage on the one hand, and the total volume of the sand accumulated there on the other, are minute.

Hypothetically, sand can also disappear from the beaches to be transported offshore, and deposited in deeper water of the continental shelf, or even reach the continental slope. This sand is transported via submarine canyons, the upper tributaries of which approach the shallow shelf. A brief bathymetric study of Cyprus offshore regions through marine charts, shows that there are no such as channel features that reach the shallow shelf, and it is almost certain that there are no losses to the bathyal. The sand is spread therefore on the beaches and in the shallow shelf, from the shoreline to about 15-25m water depth, as the situation is in many other shelves. Grain sizes spread and sorting with depth depend on many factors such as sea energy, water depth, distance from shore, shelf gradient etc.

The natural conditions existed along Cyprus's beaches until the beginning of the twentieth century evinced a big change, resulting from an abrupt cut of sediment supply through the rivers, and the enormous gravel, sand and pebble mining in and around the beaches. Many of the big rivers' evinced the construction of dams, leaving the beaches in a permanent condition of starvation for sediments. Gravel mining in many of the river beds also added to this deficit situation. Sand and gravel mining along many of the island's beaches and river channels, an activity that ceased just recently (although it is informed that the Turkish occupied teritory's beaches are still being effectively mined!), caused an irreversible situation. Beaches were practically cleared from most of their clastics, resulting in enormous erosional and ever narrowing conditions.

The sediment budget is obtained by assesing the sedimentary contributions and losses to a certain littoral cell. Each cell has its specific conditions and it contains a complete cycle of sediment transportation and deposition.

The following scheme illustrates the main trends of sediment budget of Cyprus coasts.

sources	sinks
From the mainland through the rivers	to sand dune fields
From the erosion of coastal coarse clastics such as Protaras calcarenite	to deep cont. shelf (?)
Syngenetic mollusca shell fragments	by mining

Chapter 5. Pebble, Sand, and Gravel mining along Cyprus coasts and Rivers

This chapter is mostly based upon personal communication provided by Mr. Glavkos Kronides, Director of the Mining Department of Cyprus, Nicosia, data supplied by Dr. E. Morriseau of the Geological Deptment, Nicosia, and from Thomas (1981). Altogether, more than 12 million tons were mined and quarried along Cyprus coasts since the ninteenfifties, which is, undoubtly a very high figure. Although there are no estimations for the total volume of clastic sediments that were found in pre-mining times along the island beaches, (on land and in shallow water), the huge quantities undoubtly removed and robbed many beaches, leaving them rocky and sand starving.

The traditional Cypriot building was mostly Portland-cement free until the ninteen twenties?, and only when cement was more widely implemented, additives such as gravel and sand were consumed. Coarse size components for concrete were originating mainly from crushed limestone of the Pentadaktylos range, and sand and gravel from the beaches, and/or from backshore subrecent deposits of gravel and sand. The crushed limestone produced some 20% of its material in the sand sizes as a by-product.

The concrete industry demands for gravel and sand are equal, (1:1 ratio), therefore for each ton of concrete, 500kg of crushed limestone, (around 400kg originated from the beaches, and the other 100kg of sand sizes which were produced as by-products of the crushed limestone) were consumed. The Department of Mining estimates that the officially permitted, combined with the illegal sand mining reached up to 1974 accumulated figure of a few million tons.

Since 1974, when many of the traditional clastic material sources were cut as a result of the Turkish occupation of the Pentadaktylos range, there has been a large expansion of new sources in order to supply with the ever increasing demands resulted from the large scale building and road construction. These two are very large consumers of

clastic material, the result of which was the much thorough and dangerous exploitation of the coastal gravel and sand reserves.

With just a few exceptions such as minor illegal mining that still exists, there is no any mining activity along Cyprus coasts since it became the Cyprus Government official policy, which has been a most vital step towards preservation of the beaches. The conditions along the northern occupied sector are not fully known, although there is some information about 'wild' mining that still takes place in many coastal sites (see Fig.47a&b).

As menttioned above, the mining of beach material has further depleted the coastal system, an activity that seriously reduced the potential of the beach as a protector from the erosive action of the waves.

The following are qualitative and quantitative descriptions of the specific sites at which construction material has been mined and removed.

Famagusta - Up to 1974 there has been a relatively intensive building activity in and around the city. The main fine material for the concrete production originated at the Salamina region, at the Pedhios and Yialias outlets to the sea. It is estimated that some 1.5 million tons of sand (equals to 1,150,000m3) were quarried from this 2km long shore front (average of some 550m3 for each 1m of beach front!).

Xylophagou - One of the most active and important gravel and sand source, are the so-called elevated terraces of Xylophagou Peninsula, where terraces composed of various clastic formations of Miocene Koronia formation are exploited. According to Mr. Kronides, material reserves here are not large, and can be totaly consumed during the coming 4-6 years, leaving Cyprus construction industry in a very bad situation.

Akrotiri - Although the main mining activity was concentrated on subrecent material found a few tens of meters inland (some 60-65m inland from the shoreline), it is estimated that quite large quantities



Fig. 47a. Active Pebble quarries near Syrianokhori.



Fig. 47b. Active pebble quarry, Syrianokhori beach.

of beach material were also illegaly and unpurposly removed during the years. Altogether some 3 million tons of pebbles were quarried here, operation which ceased only recently - 1989-90.

Episkopi - A very intensive sand mining activity used to take place some 1.5km west of Curium, where 'Zapalo' company mined sand from the beach and shallow water. In order to catch the easterly directed drifting sand, impermeable groynes and detached breakwaters were constructed here (Fig.32), and were used as traps for the sand. This activity started in 1965 and lasted up to 1991. The average annual crop was around 150,000 tons, (which also is a probable figure for the annual easterly directed longshore drift in this region). Altogether some 3,75 million tons were removed within this span of 26 years mentioned. These 'wet' quarries supplied Paphos, Limassol and the British Bases at their viscinity.

Paphos - Due to the general poorness of sand around the Paphos southern and eastern coasts, resulting among others from the shape and open sea beaches exposed to the longest fetch, mining of beach material in general was minute. The biggest shore quarries of the region operated opposite Mandria, where the 'Church' mined sand from both beach and inland sources. Local needs for crushed material came from Khlorakas, where local calcarenite was consumed. As mentioned above, most of the sand consumed recently in Paphos used to come from Episkopi offshore quarries.

Tillyria and Khrysokhou Bay - Some beach material was used to be quarried between Mansoura and Kato Pyrgos. Quantities are unknown, but seem to be small. Mr. Kronides suspects that illegal mining still exists in those "remote" beaches, and around the Khrysokhou Bay beaches also.

Karavostasi - Located at the southwestern corner of Morphou Bay, is also reported to have had some removal of beach material from the river bed near the village of Pendayia. Although the gravels quarried did not directly come from the beaches, their mining no doubt has had a

negative influence on the beaches near the river's outlet which starved for clastic material.

Syrianokhori - Located at the southwestern Morphou Bay, near the outlet of the Serakhis river. These large scale quarries used to be, up to 1974, of the main sand and gravel sources for Nicosia region. Although quarrying licenses allowed quarrying not closer than 10-15m from the shoreline, practice showed that present beach material was also removed. The estimated quarried quantities reached some 200,000 tons/year for the registered 15 years (1960-1974), i.e. that some 3 million tons were quarried altogether. According to visit in the site during 1991 (G. Wagner, pers. com.), this removal of beach material still exists (Fig.47a&b), with probable much smaller quantities involved.

Mr. Kronides also reports that in many of the beach quarries all around the island, all pebbles smaller than 4cm were removed, while the +4cm were left in place, an important fact that should be taken into consideration while studying beach components and grain and pebble sizes. Therefore, the present composition of many of the island's beaches might be somewhat distorted and does not represent the real, natural conditions.

There are many evidences that there has also been sand and pebble mining from many other beaches which are not mentioned by the Mining Department, such as Kiti, Limassol, Larnaca, Ayia Napa, Protaras, etc. reported by Thomas (1981, Limassol and Larnaca), and by Dr. G. Constantinou (personal communication).

The following table No. 5 summarizes the various focii of beach material removal around Cypru beaches (based mainly upon information supplied by Mr. G. Kronides of the Cyprus Mining Department). This table does not include 'small' illegal removal of clastics around the island beaches, activity which undoubtfully causes large damage!

Table Nc. 4. Sand and Pebble mining along Cyprus beaches.

Region	Years of Activity	Type of material	Quantity/tons
Famagusta	up to 1974	Sand, some gravel	1,500,000
Xyiophagou	to the present	Gravel and sand	?
Akrotiri	1965-1990*	Gravel and Sand*	3,000,000
Episkopi	1965-1991	Sand, some gravel	3,750,000
Mandria	up to 1989	Sand	Unknown
Polis		Gravel and sand	Unknown
Pyrgos - Mansoura		Gravel and sand	Unknown
Karavostasi	up to 1974**	Gravel and sand	Unknown
Syrianokhori	up to 1974**	Gravel and sand	3,000,000
		Total (tons)	11,250,000

* - Most of the material was quarried inland, but estimated large quantities were also removed illegaly from the beaches.

** - According to northern Cyprus newspapers and other relevant publications, quarrying and mining activities did not cease and still continue at quite significant quantities (see Fig. 47).

Table No. 5. From Delft hydraulics, Table 7.2 (p. 49).

M1 - Larnaca Bay	1955-1965	illegal	sand	100,000
M2 -	1955-1970	legal	sand/gravel	300,000
M3 - Limassol	1955-1965	legal	sand	10,000
M4 - Akrotiri	1965-1990	legal	sand/gravel	1,000,000
M5 - S. of Paphos	1965-1980	legal	sand/gravel	300,000
M6 -	1975-1980	illegal	sand	10,000
M7 -	?	illegal	sand/gravel	?
M9 - Polis	1960-1980	illegal	sand/gravel	60,000
M10- NE Tillyria	1970-80 today	legal/illegal	s/g	20,000?

Chapter 6. Harbours, Marinas, Fisheries shelters, and other marine artificial structures

The specific morphology of Cyprus coasts produces numerous bays of various sizes, bights, pocket bays and coves, allows very large number of natural sea shelters - 'mini ports' or Fishing Shelters and small harbours (Goodwin, 1984). These bays which measure from a few tens of meters to some kilometers in length, exist all around the island. The initial poorness in sand of the entire coastal system results in minimum silting - which is an important factor concerned with the regular maintanance of such as installations - be it natural or artificial. Goodwin (op. cit.) in his table of the chronological events of Cyprus lists amongst others, some data about the island's harbours and sea shelters (Table 6, and Appendix IV). During the present study of the island's coasts, most, if not all harbours, marinas, fishing and other shelters were visited by the author and by G. Wagner. Boats occasionally shelter next to small points and in coves.

Cyprus has five sites of big harbours, three in the Repulic's southern part - Paphos, Limassol and Larnaca, and two at its eastern and northern sections (at present under Turkish Army Occupation) - Famagusta and Kyrenia. Famagusta used to be the principal port of the island. It has and outer and an inner harbours, both sheltered by a line of calcarenite iselts and shoals parallel to the shoreline. Since the 1974 occupation, the Turkish authorities have constructed a very large 'marina' (east of the old harbour of Kyrenia), practically used as a port! As a result of the tourist 'boom', many marinas of various sizes were developed around the island, some are just a combination of detached breakwater and small groin (Fig.48). Only one natural inland fisheries shelter exists around Cyprus coasts, at the estuary of the Potamos river (Fig.49). Table No.7 summarizes the island's different coastal artificial structures classified according to their functioning.



Fig. 48. A typical 'micro-marina' formed next to curved groyne, Ledra Hotel, Paphos. (12.8.92).



Fig. 49. The only estuarine-marina, fisheries shelter in Cyprus, at Potamos outlet. (19.4.93).



Fig. 50. The Pomos small and modern marina built inside a small bay. (8.92).

Many artificial structures such as breakwaters, semipermeable groins, sea-walls, etc. were errected around Cyprus coasts since the sixties. These structures were constructed mainly in order to accumulate sand on the one hand, and protect poor beaches on the other. Although the author have got no evidence, it seems that quite a large portion of the big 'ocean front' hotels and their near-by neighbours consumed their own beach-sands for construction purposes, and later starved for a 'plage'...). Limassol and Larnaca which suffered from very severe erosion already in the seventies (Thomas, 1981), constructed more than 50 structures, mainly groynes and breakwaters. Just in a few cases the results were satisfactory from sand accumulation point of view. In most cases the beaches remained in their half 'naked' condition, and contain just a narrow strip of sand and/or pebbles.

Although there has been a limited improvement in the areas protected by artificial structures, the natural beaches located 'downstream' of the longshore drift, suffered, in most cases from sediment starvation, and as a result they were eroded more effectivelly. It seems that in many sites some by-passing of the sediment may occur, but as most of the erosional effects are irreversible, the ruined beaches would never be able to return to their original 'healthy' condition.

Table No. 6. Harbours, marinas, and fisheries shelters around Cyprus.

Harbours	UTM coordinates	Remarks
Kyrenia	530350E/3911300N	'Marina' = Harbour
Gastria	587850E/3909150N	North of Boghaz
Famagusta	586300E/3888400N	
Vasilikos	528450E/3842400N	New Breakwater
Vasilikos	528950E/3842200N	Aerial Ropeway
Larnaca	558750E/3865400N	Sand accumulation on S. side
Limassol	501500E/3834500N	
Paphos	445800E/3846150N	
Karavostasi	483200E/3889500N	Jetty Berth

* The above list fits with that given by Lloyd's, 1985, 'Ports of the World' pp. 395-396.

Marinas		
Latchi	444750E/3878000N	
Pomos	459600E/3892700N	
Kato Pyrgos	470150E/3894500N	
Glykiotissa island	526750E/3911900N	breakwater
Kyrenia	529300E/3911200N	Old Kyrenia Harbour
Ayia Trias	593400E/3879450N	
	594700E/3878000N	
Ayia Napa	591650E/3871500N	Old Fisheries Shelter
Ormidhia	570600E/3871250N	
Larnaca	558500E/3864250N	The largest marina in Cyprus
Larnaca	558450E/3862400N	
Ayia Varvara	514500E/3841200N	The Sheraton Marina
Limassol	503950E/3836700N	The old harbour
Maa	441750E/3857400N	North of Coral Bay
Ayios Yeorgios	437650E/3862550N	Near Cape Drepanum

Fisheries and other Shelters

Pissouri and Evdhimou		Trading station - iron pier
Cape Gata	503000E/3825700N	
Moni	517600E/3840800N	Small Harbour
Dekhelia Power St.	566700E/3871150N	175m long breakwater
Xylophagou	576350E/3868900N	
Potamos estuary	582000E/3870500N	
Famagusta	594700E/3878000N	
Boghaz south	586600E/3908350N	
Boghaz north	587800E/3909150N	
Fishing Farm	589000E/3909700N	'inlet'
Koma tou Yialou	602600E/3919300N	
Panayia Apakou	628800E/3938800N	Khelones, Entrance on W. side
Yialousa	610400E/3935700N	Ayia Glykeria
Ayios Prokopios	602600E/3919350N	Entrance on SE side
Akanthou	566100E/3917250N	
Ayios Amvrosos	555400E/3913000N	Stazousa Point
Karavas	517700E/3912800N	
Xeros	485200E/3889100N	Pier
Karavostasi	483250E/3889700N	Pier
Vavilas	510800E/3913600N	
Mansoura	466750E/3894300N	
Limni Mine	450250E/3879750N	Jetty

The numerous artificial structures built along Cyprus coasts during the past 4 decades are very crucial to the longshore transport of sediments. Any artificial structure of the types mentioned interrupts sand and gravel transport resulting in local accretion on one side of the structure, and severe erosion 'downstream', on the other side of the structure. In a few cases, due to the increased erosion effect on

the downcurrent beaches, conditions might get worse, and a need for additional protection and/or artificial nourishment becomes vital. If protective measures are not taken, as is the case in many coastal sites, 'chain reaction' developes resulting an ever advancing beach erosion.

Chapter 8. Summary and Conclusions

Many of Cyprus coasts suffered from the above described harmful phenomena, while coastal development problems were supposed to be solved, in many cases, by unfit offshore structures that caused fairly high damage to the originally bad-shaped beaches. In coasts where shoreline retreat has been serious, and, or there has been a need for beach widening, artificial structures were built perpendicular (groins), or parallel (detached breakwaters) to the shoreline. These structures highly intervene in the natural longshore drift and cause large damage to the downdrift zone. Anything that prevents the waves from moving the sediment, or that decreases wave energy interferes with the littoral system the result of which is beach erosion.

Cyprus is basically poor in wide sandy beaches, a situation directly resulting from its geological components and the total absence of fossil sand deposits. This poorness is reflected in most coastal sites, and is also echoed in the small number of sand dune fields.

The lithology and mineralogy of the coastal material - mostly sand and pebbles, is dependent on its inland sources, and therefore it reflects the composition of most of the rocks represented in the geological column of the island. The large number of capes and 'points' around the island increases the number of littoral cells, a situation which affects the relative short distance of longshore sediment transport on the one hand, and the variety and differences in composition of the cells on the other.

Man intervention and activity in the entire coastal system through different activities such as sand and pebble quarrying on the beaches, the construction of dams on the main rivers and of coastal structures such as harbours, marinas, detached breakwaters, groins, sea walls, etc., has further depleted the beach material.

Mining of several millions of tons of sand and pebbles around Cyprus coasts depleted enormously this natural source. The entrapment of coastal material by artificial structures such as harbours, marinas,

fisheries shelters, detached breakwaters and so on, has seriously, and in some regions totally, reduced the supply of clastics to the beaches where it serves to protect them from the erosive action of the waves.

The combination of the poor natural beach conditions on the one hand, and the additional damage caused by man on the other, resulted in this delicate beach situation where many beaches at present are in a very critical condition, while others almost totally disappeared. The permanent deficit of beach material (which reached at least 12 million tons of beach material!), drastically increases shoreline withdrawal and the erosion of the backshore.

1. Coastal erosion along Cyprus poor-sand beaches is very serious. This erosion could have been much less serious if there were sufficient natural sand accumulations on the beaches.

2. Due to the fact that Cyprus sunny beaches are of the most attractive touristic objects, beach material (mainly sand), is a valueable recreational asset and should be treated as such.

3. Beach material, be it sand or pebbles, should never be removed from the coastal region. Inland and offshore fossil deposits of sand and pebbles which may fit use on beaches, should be protected and preserved for the purpose of future beach nourishment.

4. There is no doubt that <u>every single</u> offshore or coastal structure has its negative, sometimes harmful effect on the coastal system. It is quite accepted by coastal engineers that a groyne or groyne system can cause erosion of downdrift shores if the system is not artificially filled with suitable sand contemporaneously with the construction. Therefore, each planning of such as structure should be very thoroughly checked before construction takes place. It is clear that the entire coastal system is so delicate that it can easily collapse. Therefore, such as constructions should be approved only for high priority national necessities.

5. The Government of Cyprus should urgently decide on the creation of 'coastal water committee' which should be responsible on policy and on every construction and planning activity around the island coasts.

6. The offshore sand reserves of the island found in economic feasibility (although vaguely known in just a few localities, Panayiotou, 1992), these and others should be located and studied in order to be implemented in future beach replenishment (never should these be implemented for any other then nourishment use).

7. The increased interest and use of the coastal zone emphasizes the need to better understand shore processes and establish improved guidelines for planning and maintanance of a certain beach.

8. Special attention should be given to submarine archaeological sites, known, or freshly discovered. Every new project should, at its first steps of research, find out the potentiality of the region involved.

It is worth quoting Inman and Brush (1973) two conclusive paragraphs from their 'Coastal Challenge', defined as the Freeway Effect (growth breeds growth)... : "The undirectional animus specially threatens the coastlines, because it encourages one to believe that it is beneficial to build unlimited numbers of marinas, to erect increasing numbers of power plant, to construct housing developments adjacent to existing housing developments, ..."

"If planning efforts are ineffective and ill-informed, then people are inclined to proceed with each of the foregoing proposals as though the others should give way before it. An informed and concerned public reaction of hitherto unknown magnitude may possibly lead to solutions for the problem of slowing and redirecting the machine, without wrecking the machinery: that is the coastal challenge".

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MAPS

1:50,000 scale

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1. Polis - 1988; 2. Kambos - 1973; 3. Morphou - 1988;
4. Ayia Irini - 1988; 5. Lapithos - 1973; 6. Kyrenia - 1988;
7. Lefkoniko - 1988; 8. Trikomo - 1988; 9. Yialousa - 1988;
10. Rizokarpaso- 1973; 11. Famagusta - 1988; 12. Cape Greco - 1988;
13. Larnaca - 1988; 14. Pano Lefkara - 1988; 15. Zyyi - 1988;
16. Limassol - 1988; 17. Pissouri - 1988; 18. Paphos - 1988.

1:100.000 maps

4 sheets of the entire island, published by the Lands and Surveys, Cyprus, Revised edition, 1991; Series D.L.S. 18.

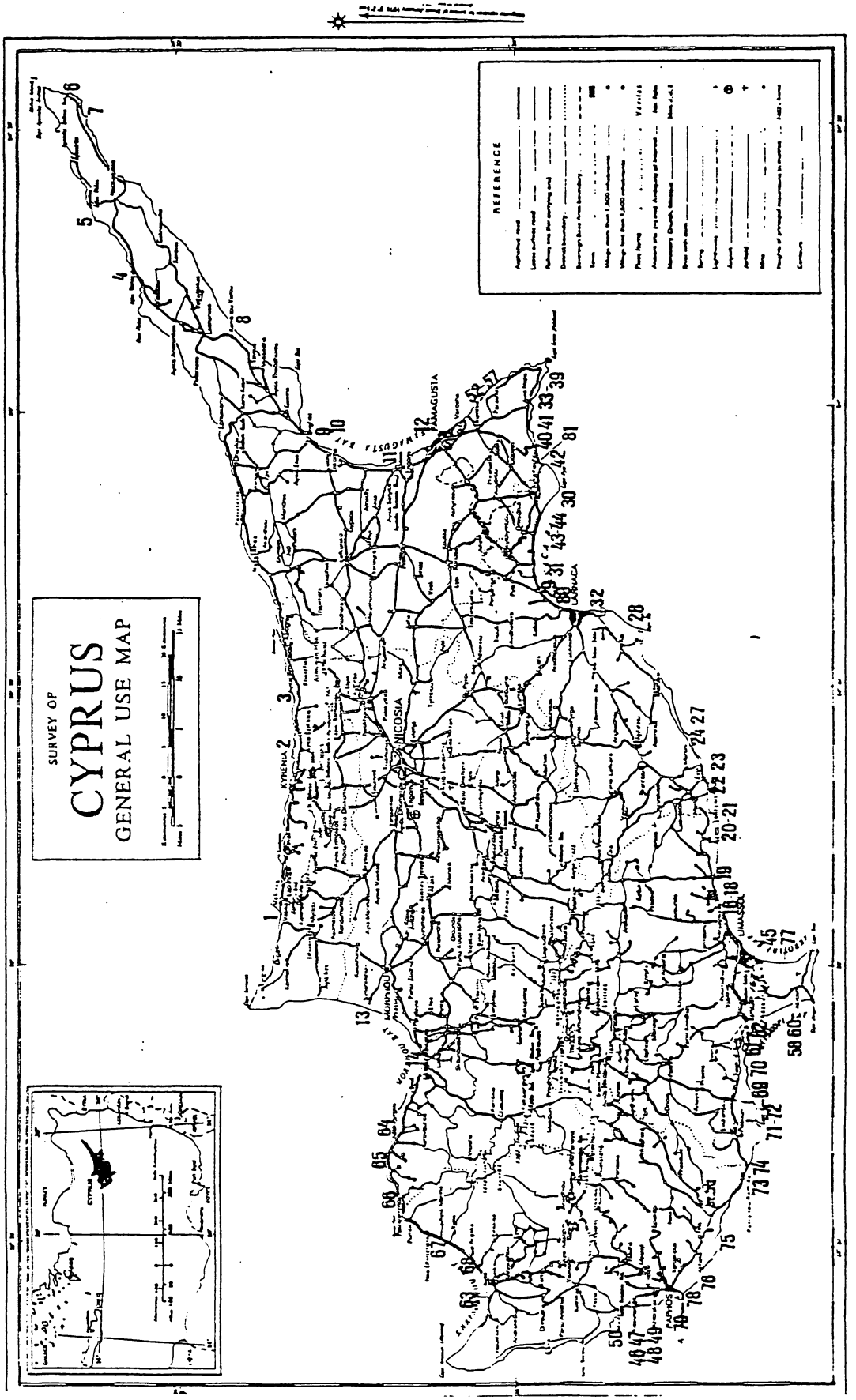
Appendices
Appendix I

Sample List for Cyprus Coasts

All samples were collected during March and July of 1993 - for the northern occupied section, old samples of the Geological Survey Department Stores were studied; CB numbers stand for Cyprus Beaches. Fore sampling locations (see map, p. 88).

Sample No.	UTM Coordinates	Location and short description
CB1	508000E/3912450N	Ay. Yeorgios (Lapithos)
CB2	529400E/3911050N	Kyrenia region, calcarenite
CB3	543000E/3910250N	Daoud region
CB4	610300E/3935600N	Glykiotissa
CB5	621550E/3940300N	Ronnas Bay, dunes
CB6	642550E/3947500N	Ap. Andreas Monastirio, Calcarenite
CB7	640750E/3945850N	Pakhyammos, dunes
CB8	602600E/3919400N	Komma tou Yialou, sand
CB9	586000E/3907700N	Boghaz region, sand
CB10	586000E/3907700N	Boghaz region, pebbles
CB11	582050E/3895120N	Salamina Bay, sand
CB12	Non in situ	Famagusta, calcarenite
CB13	493100E/3898250N	Syrianokhori, pebbles
CB14	484700E/3888900N	Karavostasi, pebbles
CB16	511000E/3840750N	Limassol, sand (near Posseidonia H.)
CB17	512200E/3840950N	Limassol, sand (near Avenida Hotel)
CB18	512600E/3841050N	Amathus, sand
CB19	514000E/3841450N	Ayia Varvara, sand
CB20	521750E/3840750N	Ay. Yeorgios beach, sand (Limassol)
CB21	521750E/3840750N	Ay. Yeorgios beach, pebbles
CB22	525800E/3842500N	Governor's beach, sand
CB23	531150E/3843150N	Zyyi, sand
CB24	533400E/3843550N	E. of Zyyi, sand and pebbles
CB25	535000E/3844500N	Between Maroni and Pentaskinos, sand
CB26	543300E/3848500N	W. of Petounda Point, sand
CB27	543300E/3848500N	W. of Petounda Point, pebbles
CB28	556400E/3856250N	Meneou beach, pebbles and sand
CB29	560300E/3869400N	Voroklini beach, pebbles
CB30	576900E/3868400N	Cape Pyla, sand and pebbles
CB31	560300E/3869400N	Voroklini beach, sand
CB32	558300E/3863700N	Scala - Larnaca, pebbles
CB33	595000E/3870700N	Kermia beach, sand & fauna shells
CB34	595000E/3870700N	Kermia beach, pebbles
CB35	593400E/3871300N	E. of Ayia Napa, sand
CB36	592350E/3871850N	E. Ayia Napa, sand
CB37	591700E/3871700N	West Ayia Napa, sand
CB38	589700E/3871900N	E. of the 'Peninsula', sand & Calcar
CB39	588350E/3872300N	Nissi beach, sand
CB40	585450E/3871250N	Ayia Thekla, sand
CB41	585450E/3871250N	Ayia Thekla, calcarenite with micro

CB42	584300E/3871100N	Ayios Etsathios, foraminiferal rock
CB43	571350E/3871250N	Ormidhia beach, fauna
CB44	571350E/3871250N	Ormidhia beach, pebbles and sand
CB45	500950E/3833250N	Lady's Mile beach, pebbles
CB46	444350E/3855050N	Potima Bay, pebbles
CB47	444350E/3855050N	Potima Bay, pebbles
CB48	444650E/3850900N	Khlorakas, sand
CB49	444650E/3850900N	Khlorakas, calcarenite
CB50	442400E/3857400N	Coral Bay, sand
CB51	Non in situ	Empa Village concrete mound
CB52	592650E/3879850N	Ay. Yeorgios, Fam., sand and pebbles
CB53	593300E/3879400N	Ay. Trias, near small marina
CB54	5944250E/3878650N	Two groynes near the 'villa'
CB55	594650E/3877900N	Golden beach marina, beachrock
CB56	594700E/3877700N	Golden beach, sand and pebbles
CB57	596050E/3875900N	North of the small bay,
CB58	494000E/3828300N	Episkopi Bay, near wreck, sand
CB59	494000E/3828300N	Episkopi Bay, near wreck, pebbles
CB60	494000E/3828300N	Episkopi Bay, near wreck, beachrock
CB61	488200E/3836250N	Curium Bay, pebbles
CB62	488200E/3836250N	Curium Bay, sand
CB63	444000E/3877950N	Latchi, sand and pebbles
CB64	470500E/3894100N	Kato Pyrgos, pebbles
CB65	469300E/3894700N	W. of Pyrgos, sand
CB66	462100E/3892550N	Pakhyammos (Polis), sand
CB67	456150E/3888000N	Nea Dhimatta, sand
CB68	452000E/3881200N	Argaka - Lama beach, sand
CB69	479000E/3835250N	East Evdhimou, sand
CB70	478750E/3835300N	West Evdhimou (Melanda Beach), sand
CB71	474600E/3834450N	Pissouri, sand
CB72	474600E/3834450N	Pissouri, pebbles
CB73	465750E/3836200N	Petra tou Romiou, sand
CB74	465750E/3836200N	Petra tou Romiou, pebbles
CB75	456850E/3839850N	Zephyros Point, sand and calcarenite
CB76	449300E/3844150N	Yeroskipos, sand and pebbles
CB77	500600E/3831400N	S. Lady's Mile beach, sand
CB78	447800E/3844750N	Near Imperial Beach Hotel, sand+calc
CB79	445500N/3848500E	Tombs of the Kings, Paphos, Calcarenite
CB80		Farkonia Beach Apts., Larnaca
CB81	582300E/3870250N	Potamos Beach



Sampling location map of Cyprus beaches.

Appendix II

Small Islands, islets, and 'rocks' off Cyprus
(from 1:50,000 topographic map of Cyprus)

SW of Pomos	457900E/3890250N	
Rostos tou Skaphon	464300E/3893400N	
Petra tou Limniti	476200E/3893450N	
Nissi tou Kormakiti	492800E/3918150N	
Glykiotissa Nissi	526550E/3912000N	
"Breakwater"	526600E/3911900N	
Kalamoulia and Trasha	521400E/3911850N	
Nisha	616150E/3938300N	
Pyra khoraphkia	627000E/3944750N	
Lefkoniso	628600E/3846000N	
Jila Island	620250E/3930100N	
Aspro Island	629050E/3939500E	
Glaro Island	630750E/3946950N	
No name	631450E/3941500N	
Ardhylia islands (4)	638800E/3949700N	
Klidhes Islands from	644150E/3951750N	to 645450E/3953300N
Galounia	586600E/3923350N	
Famagusta Harbour	586750E/3887750N	small islets
Moulia Rocks	448500E/3842700N	
Yeronisos	437200E/3862300N	
Nisarka	442900E/3856350N	3 islets
No name	443950E/3849800N	
Kinos Island	433800E/3876200N	
Nisi tis Sklinijas	434350E/3876550N	
Kanoudhion Islands (2)	433650E/3877700N	
Mazaki Island	434500E/3885900N	
Khamilis Island	436850E/3882700N	
Ayios Yeorgios	439350E/3881800N	

Appendix III
Artificial Structures along Cyprus Coasts

Name of structure	UTM GRID	Remarks
Detached Breakwaters, Groynes and other offshore structures		
Potamos tou Kambou	483200E/3889450N	
Old Pier	485200E/3890000N	
Glykiotissa Island	526600E/3911900N	Breakwater on SE side
	526500E/3911700N	Causeway
Mavroli Jetty	450250E/3879750N	
Limassol groyne	503200E/3836500N	
groyne	503300E/3836600N	
groyne	505600E/3838250N	
7 groynes	506000E to 507000E	
19 groynes	507700E to 509500E	
3 groynes	510700E to 510900E	
groyne	511400E/3840750N	
6 groynes	511800E to 5124500E	
Moni Power Station	516700E/3841000N	
Moni Cement Fact.	517250E/3840900N	
Vasilikos aerial ropeway	528750E/3842400N	
Customs House Jet.	531050E/3843525N	
Ay. Mina	533425E/3843525N	
Larnaca groyne	558900E/3866990N	
groyne	558950E/3867150N	
groyne	559350E/3867750N	Sand transp. from S. to N.
groyne	560550E/3869300N	
twin breakwaters	561600E/3869300N	50m. apart
twin breakwaters	563200E/3870850N	Developed tombolos
groyne	564700E/3871200N	
two breakwaters	568150E/3871150N	
Dekhlia Jetty	567350E/3871370N	
Ayia Trias Breakw.	593400E/3879400N	

Appendix IV

Various maritime operations in Cyprus Harbours and Fisheries shelters (After Goodwin, 1984).

342 AD	Porto Constanzo at Salamis destroyed by earthquake
1879	Limassol harbour silted up
1881	New pier at Limassol
1882	New pier at Larnaca
1886-1891	Harbour improvements at Kyrenia
1906	Port improvements at Famagusta completed
1908-1911	Harbour improvement at Kato Paphos
1910-1930	Abandonment of most of the 'mini ports'
1912-1913	Harbour improvements at Kyrenia
1955	Harbour improvements at Kyrenia
1959	Harbour improvements at Kato Paphos
1962	Port improvements at Famagusta
1963	Construction of Fishing Shelters: Ayios Amvrosis (the first of many), Mansoura (which had to be abandoned because of intercommunal fighting).
1966	Construction of Fishing Shelters at Koma tou Yialou
1967	Construction of Fishing Shelter at Khelones
1969	Construction of Yialousa Harbour Improvement to that at Lachi
1970	Storm damages to Mole harbour Construction of Fishing Shelters at Vavilas and Potamos tix Xylophagou
1973	Larnaca Port improvements Fishing Shelters at Akhantou and Boghaz
1974	Completion of new port at Limassol Mole Harbour renovated
1978	Floating quay installed at Larnaca's Port
1979	Breakwater extention at Larnaca's Port Port improvements at Vasilikos

Appendix V

Petrographic description of the beach and sand samples (identified by Dr. E. Morriseau of the Cyprus Geological Survey, Nicosia).

Sample	Main Petrographic and Mineralogical components
CB1	Brownish limestone (80%), few diabase and glassy lava.
CB3	List. (80%); Minerals: (20%), mainly cal. some feld. qz. pyr.
CB4	List. (>90%); Traces of zeolites and pyroxenes.
CB5	Limestone (>90%); Some traces of quartz (<10%).
CB7	Limestone (>90%); Some traces of igneous rocks.
CB8	Limestone (70%); Few quartz, and traces of red jasper.
CB9	Limestone (70%); Few quartz and red jasper (10%).
CB11	Limestone (60%); Quartz (20%), few plagioclase.
CB16	Igneous (30%); Pyr., plag. (70%), some epid. and magnetite.
CB17	Diabase, lava, some list. (60%); few plagiogranite; Pyr. plag.
CB19	Pyr. plag. & mag.; Some feld. ep. traces of calcite.
CB22	Igneous (50%); Plag. pyrox.; tr. of calcite; red jasper.
CB24	Glassy lava, diabase (50%); Epid. & pyr., magnetite, calcite.
CB26	List. and gl. lava (50%); Pyroxenes, some epi., few quartz.
CB30	Diabase (>90%); some list. tr. gabbros. Traces of quartz (MF).
CB31	Lava (20%); Plag. pyr. & epi. (80%), some cal., few magnetite.
CB33	Limestone (90%); Fossils (10%); Traces of quartz.
CB36	List. (70%) + foramin., tr. lavas & serp.; few qz. tr. zeolites
CB37	Limestone (90%); traces of quartz and glassy lava.
CB38	Some list. (20-10%); Foramin.+debris of microfossils (80-90%).
CB39	Limestone (80%); Microfauna (20%); Traces of quartz.
CB40	Limestone (70%); Microfossils (30%); Traces of quartz.
CB45	Diabase (20-30%), some lavas, carb.; Feld./plag., pyr., mag., some calcite, ilmenite, epidote, quartz?
CB47	List. (>90%), quartzites?, tr. serpen.; Few plag. and quartz.
CB48	List. (80%); Few glassy lava, pyrox. and quartz; tr. magnetite.
CB50	Limestone (>90%); Few igneous and magnetite; Traces of quartz.
CB51	Mainly list., few serp. (70%); Few pyrox., tr. qz. mag. (30%).
CB52	List.+forams, (80%); Traces magnetite, red jasper (20%).
CB53	Limestone (90%), tr. serpentine and glassy lava; Few qz. (10%).
CB55	Limestone (90%) + few forams; Few quartz, traces pyroxene.
CB56	Limestone + microfossils (90%); Traces of quartz (10%).
CB57	List. (>90%) + microfossils; Tr. gl. lava & diab., qz., ep.
CB58	Tr. of serp. (?) (10%); Mainly plag. (90%), Some epidote, pyr.
CB62	Limestone (40%); Mainly plag., some ep., few qz., tr. of mag.

Remarks:

1. For sample location see map on p. 87.
2. Abbreviations used in the above table:
cal. = calcite; Diab. = diabase; Ep. = epidote; Forams = foraminifera; Gl. = glassy; List. = limestone; Mag. = magnetite; Plag. = plagioclase; Pyr. = pyroxene; Qz. = quartz; serp. = serpentine; tr. = traces;

Appendix VI. Pebble composition of various beaches around Cyprus (Petrographic and mineralogical definitions by Dr. E. Morriseau of the Geological Survey Department, Nicosia).

Sample	Main Composition
CB1	Limestone, chert.
CB3	Calcarenite, limestone, chert.
CB10	Calcarenite, limestone.
CB13	Lavas, diabase, gabbro, plagiogranite.
CB14	Lavas, diabse, gabbro, lavas flows.
CB19	Diabase, Harzburgite, gabbro, plagiogr., dunite?, calcarenite, chert, chalks, limestone.
CB21	Lavas, diabase, chalk, cherts.
CB23	Diabase, plagiogr., gabbro, lava, serp., sil. chalk, list.
CB24	Diab. plagiogr., lava, serp., gab.?, sil. chalk, chalk, chert.
CB27	Lavas, diab., plagiogr., microgab., list., sil. chalk, chalk.
CB32	Lavas, diabase, gabbro, plagiogr., sil. chalk, chert, list.
CB44	Diabase, lavas, plagiogranite, red jasper.
CB45	Diab., lavas, gab., harzburg., plagiogr., list., sil. chalk.
CB59	Diab./melagab./pegmatitic, lavas, diab., wehrlite, plagiogr., chalk, chert.

Remark: The above table represents the major components of the pebbles' suites, although the analyses were carried according to size classes. For locations of samples see map on p. 87.
The following are abbreviations used above: diab.= diabase; gab.= gabbro; list.= limestone; melagab.= melagbbro; microgab.= microgabbro; plagiogr.= plagiogranite; serp.= serpentinite; sil. chalk= silicified chalk;

Appendix VII

Grain size analyses of representative sandy beach samples

Grain size analyses of various sand samples from around Cyprus beaches. The analyses were run at the Sedimentological Laboratory of the Geological Survey of Israel, Jerusalem by Mr. Yaacov Lakatosch.

CB no.	>V.C.S.	V.C.S.	C.S.	M.S.	F.S.	V.F.S.	<V.F.S.
CB4	0.21	0.11	4.79	90.78	3.79	0.02	0.04
CB5	0	0	0.50	30.20	65.77	1.42	1.21
CB7	0	0.01	2.01	77.96	19.55	0.17	0.11
CB8	0	0	0.13	38.92	60.72	0.04	0
CB16	0.05	0.03	0.29	34.79	60.94	3.64	0.13
CB17	0.36	0.83	6.85	66.94	23.92	0.72	0.05
CB20	2.39	1.14	20.51	71.55	3.65	0.43	0.35
CB24	0	0.21	5.01	72.56	21.98	0.08	0.01
CB28	55.27	8.51	3.19	3.06	24.28	5.50	0
CB31	3.62	0.89	2.09	8.25	48.23	36.87	0.04
CB33	1.17	0.04	5.87	83.29	9.48	0.04	0
CB39	0.02	0.17	8.06	79.99	11.61	0.02	0
CB40	0.81	5.08	33.53	57.90	1.87	0.17	0.14
CB50	0	0.02	0.11	53.79	45.79	0.03	0.01
CB52	3.45	40.16	29.88	18.66	7.35	0.11	0
CB53	0.29	8.69	34.93	43.91	11.69	0.25	0
CB58	0.01	0	0.01	4.23	87.73	7.79	0
CB63	3.74	66.46	28.38	1.27	0.01	0	0
CB65	1.69	0.57	7.22	75.84	13.67	0.66	0.21
CB66	34.98	0.28	1.87	19.56	33.07	3.91	0.03
CB68	12.27	54.61	11.86	4.12	14.58	2.26	0.09
CB71	0.08	0.26	1.75	25.97	70.45	1.45	0.04
CB73	2.92	2.12	9.90	59.18	24.70	0.74	0.02
CB75	14.86	49.67	33.86	1.06	0.40	0.03	0
CB78	0	0.77	51.55	45.03	2.42	0.02	0

Remark:
The following abbreviations were used: V.C.S. = very coarse sand (1,000-2,000 microns); C.S. = coarse sand (500-1,000 microns); M.S. = medium sand (250-500 microns); F.S. = fine sand (125-250 microns); V.F.S. = very fine sand (62-125 microns).

A glossary of coastal terms

(From: U.S. Army, Corps of Engineers, Coastal Engineering Research Center, 1972)

Accretion - May be either natural or artificial. Natural accretion is the buildup of land solely by the action of the forces of nature on a beach by deposition of waterborne or airborne material. Artificial accretion is a similar buildup of land by reason of an act of man, such as the accretion formed by a groin, breakwater or beach fill deposited by mechanical means.

Alongshore - Parallel to and near the shoreline; same as longshore.

Backshore - That zone of the shore or beach lying between the foreshore and the coastline and acted upon by waves only during severe storms, especially when combined with exceptionally high water. Also Backbeach. It comprises the berm or berms.

Bathymetry - The measurement of depths of water in oceans, seas, and lakes; also information derived from such measurements.

Beach - The zone of unconsolidated material that extends landward from the low water line to the place where there is marked change in material or physiographic form, or to the line of permanent vegetation (usually the effective limit of storm waves). The seaward limit of a beach - unless otherwise specified - is the mean low water line. A beach includes foreshore and backshore.

Beach erosion - The carrying away of beach materials by wave action, tidal currents littoral currents or wind.

Bluff - A high steep bank or cliff.

Boulder - A rounded rock more than 24 cm in diameter; larger than a cobblestone.

Breakwater - A structure protecting a shore area, harbour, anchorage, or basin from waves.

Bypassing - Sand, Hydraulic or mechnical movement of sand from the accreting updrift side to the eroding downdrift side of an inlet or harbour entrance. The hydraulic movement maay include natural as well as movement caused by man.

Cape - A relatively extensive land area jutting seaward from a continent or large island which prominently marks a change in, or interrupts notably, the coastal trend; a prominent feature.

Chart Datum - The plane or level to which soundings (or elevations) or tide heights are referenced (usually Low Water Datum). The surface is called a tidal datum when referred to a certain phase of tide. To provide a safety factor for navigation, some level lower than Mean Sea

Level is generally selected for hydrographic charts such as Mean Low Water or Mean Lower Low Water.

Cliff - A high, steep face of rock; a precipice.

Coast - A strip of land of indefinite width (may be several kilometers) that extends from the shoreline inland to the first major change in terrain features.

Coastline - (1) Technically, the line that forms that boundary between the coast and the shore. (2) Commonly, the line that forms the boundary between the land and the water.

Continental Shelf - The zone bordering a continent and extending from the low water line to the depth (usually about 100 fathoms) where there is a marked or rather steep descent toward a greater depth.

Cove - A small, sheltered recess in a coast, often inside a larger embayment.

Current, Coastal - One of the offshore currents flowing generally parallel to the shoreline in the deeper water beyond and near the surf zone. They are not related genetically to waves and resulting surf, but may be related to tides, winds, or distribution of mass.

Current, Littoral - Any current in the littoral zone caused primarily by wave action, e.g., longshore current, rip current.

Current, Longshore - The littoral current in the breaker zone moving essentially parallel to the shore, usually generated by waves breaking at an angle to the shoreline.

Datum, Plane - The horizontal plain to which soundings, ground elevations, or water surface elevations are referred. Also Reference Plain. The plain is called a Tidal Datum when defind by a certain phase of the tide. A common datum used on topographic maps is based on Mean Sea Level.

Diffraction - (of water waves) - The phenomenon by which energy is transmitted laterally along wave crest. When a part of a train of waves is interrupted by a barrier, such as a breakwater, the effect of difraction is manifested by propagation of waves into the sheltered region within the Barrier's geometric shadow.

Divergence - In refraction phenomena, the increasing of distance between orthogonals in the direction of wave travel. Denotes an area of decreasing wave height and energy concentration.

Drift (noun) - (1) Sometimes used form for Littoral Drift (2) The speed at which a current runs. (3) Also floating material deposited on a beach (driftwood). (4) A deposit of continental ice sheet, as a drumlin.

Dunes - (1) Ridges or mounds of loose, wind-blown material, usually sand. (2) Bed Forms smaller than bars but larger than ripples that are out of phase with any water-surface gravity waves associated with them.
Eolian Sands - (or Blown Sands) - Sediments of sand size or smaller which have been transported by winds. They may be recognized in marine deposits off desert coasts by the greater angularity of the grains compared with waterborne particles.

Erosion - The wearing away of land by the action of natural forces. On a beach, the carrying away of beach material by wave action, tidal currents, littoral currents, or by deflation.

Escarpment - A more or less continuous line of cliffs or steep slopes facing in one general direction which are caused by erosion or faulting. Also scarp.

Estuary - (1) The part of a river that is affected by tides. (2) The region near a river mouth in which the fresh water of the river mixes with the salt water of the sea.

Feeder Beach - An artificially widened beach serving to nourish downdrift beaches by natural littoral currents or forces.

Fetch - The area in which seas are generated by a wind having a rather constant direction and speed. Sometimes used synonymously with Fetch Length.

Fetch Length - The horizontal distance (in the direction of the wind) over which a wind generates seas or creates a wind setup.

Foreshore - The part of the shore lying between the crest of the seaward berm (or upper limit of wave wash at high tide) and the ordinary low water mark, that is ordinarily traversed by the uprush and backrush of the waves as the tides rise and fall.

Groin (British, Groyne) - A shore protection structure built (usually perpendicular to the shoreline) to trap littoral drift or retard erosion of the shore.

Gulf - A large embayment in a coast; the entrance is generally wider than the length.

Harbor (British, Harbour) - Any protected water area affording a place of safety for vessels.

High Tide, High Water (HW) - he maximum elevation reached by rising tide.

Hydrography - (1) A configuration of an underwater surface including its relief, bottom materials, coastal structures, etc. (2) The description and study of seas, lakes, rivers, and other waters.

Jetty - (1) (U.S. usage) On open seacoasts, a structure extending into a body of water, and designed to prevent shoaling of a channel by littoral materials, and to direct and confine the stream or tidal flow. Jetties are built at the mouth of a river or tidal inlet to helpdeepenand stabilize a channel. (2) (British usage) Jetty is synonymous with "wharf" or "pier", also Cay.

Knot - The unit of speed used in navigation. It is equal to 1 nautical mile (1852 meters) per hour.

Lagoon - shallow body of water, as a pond or lake, usually connected to the sea.

Littoral Drift - The sedimentary material moved in the littoral zone under the influence of waves and currents.

Littoral Transport - The movement of littoral drift in the littoral zone by waves and currents. Includes movement parallel (longshore transport) and perpendicular (on-offshore transport) to the shore.

Littoral Transport Rate - Rate of transport of sedimentary material parallel to or perpendicular to the shore in the littoral zone. Usually expressed in cubic meters per year. Commonly used as synonymous with Longshore Transport Rate.

Littoral Zone - In beach terminology, an indifinite zone extending seaward from the shoreline to just beyond the breaker zone.

Load - The Quantity of sediment transported by a current. It includes the suspended load of small particles, and the bed load of large particles that move along the bottom.

Longshore - Parallel to and near the shoreline.

Longshore Transport Rate - Rate of transport of sedimentary material parallel to the shore. Usually expressed in cubic meters per year. Commonly used as synonymous with Littoral Transport Rate.

Marsh, Salt - Marsh periodically flooded by salt water.

Mean Sea Level - The average height of the surface of the sea for all stages of the tide over a 19-year period, usually determined from hourly height readings. Not necessarily equal to Mean Tide Level.

Mole - In coastal terminology, a massive land-connected, solid-fill structure of earth (generally revetted), masonary, or large stone. It may serve as a breakwater or pier.

Nearshore (Zone) - In beach terminology an indifinite zone extending seaward from the shoreline well beyond the breaker zone. It defines the area of Nearshore Currents.

Nip - The cut made by waves in a shoreline of emergence.

Nourishment - The process of replenishing a beach. It may be brought about naturally, by longshore transport, or artificially by the deposition of dredged materials.

Offshore - (1) In beach terminology, the comparatively flat zone of variable width, extending from the breaker zone to the seaward edge of the Continental Shelf. (2) A direction seaward from the shore.

Onshore - A direction landward from the sea.
Parapet - A low wall built along the edge of a structure as on a seawall or quay.

Peninsula - An elongated body of land nearly surrounded by water, and connected to a larger body of land.

Perched Beach - A beach or fillet of sand retained above the otherwise normal profile level by a submerged dike.

Permeable Groin - groin with openings large enough to permit passage of appreciable quantities of littoral drift.

Pier - A structure, usually of open construction, extending out into the water from the shore, to serve as a landing place, a recreational facility, etc., rather than to afford coastal protection.

Pocket Beach - A beach, usually small, in a coastal reentrant or between two littoral barriers.

Point - The extreme end of a cape, or the outer end of any land area protruding into the water, usually less prominent than a cape.

Port - A place where vessels may discharge or receive cargo; may be the entire harbour including its approaches and anchorages, or may be the commercial part of a harbour where the quays, wharves, facilities for transfer of cargo, docks, and repair shops are situated.

Quay (Pronounced Key) - A stretch of paved bank, or a solid artificial landing place parallel to the navigable waterway, for use in loading and unloading vessels.

Recession (of a beach) - (1) A continuing landward movement of the shoreline. (2) A net landward movement of the shoreline over a specified time . Also Retrogression.

Reflected Wave - That part of an incident wave that is returned seaward when a wave impinges on a steep beach, barrier, or other reflecting surface.
Refraction (Of Water Waves) - (1) The process by which the direction of a wave moving in shallow water at an angle to the contours is changed. The part of the wave advancing in shallower water moves slowly than that part still advancing in deeper water, causing the wave crest to bend toward alignment with the underwater contours. (2) The bending of wave crests by currents.

Revetment - A facing of stone, concrete, etc., built to protect a scarp, embankment, or shore structure against erosion by wave action or currents.

Ridge, Beach - A nearly continuous mound of beach material that has been shaped up by wave or other action. Ridges may occur shingly or as a series of approximately parallel deposits. British usage, fulls.

Rubble - (1) Loose angular waterworn stones along a beach. (2) Rough, irregular fragments of broken rock.

Salt Marsh - A marsh periodically flooded by salt water.

Sea Cliff - A cliff situated at the seaward edge of the coast.

Seashore - The shore of a sea or ocean.

Shallow Water - (1) Commonly, water of such as depth that surface waves are noticeably affected by bottom topography. It is customary to consider water of depths less than one-half the surface wavelength as shallow water. (2) More strictly, in hydrodynamics with regard to progressive gravity waves, water in which the depth is less than 1/25 the wavelength. Also called Very Shallow Water.

Shingle - (1) Loosely and commonly, any beach material coarser than ordinary gravel, especially any having flat or flattish pebbles. (2) Strictly and accurately, beach material of smooth, well-rounded pebbles that are roughly the same size. The spaces between pebbles are not filled with finer materials. Shingle often gives out a musical sound when stepped on.

Shore - he narrow strip of land in immediate contact with the sea, including the zone between high and low water lines. A shore of unconsolidated material is usually called a beach.

Shoreline - The intersection of a specified plane of water with the shore or beach (e.g., the high water shoreline would be the intersection of the plane of mean high water with the shore or beach).

Stockpile - Sand piled on a beach foreshore to nourish downdrift beaches by natural littoral currents or forces.

Suspended Load - (1) The material moving in suspension in a fluid, being kept up by the upward components of the turbulent currents or by colloidal suspension. (2) The material collected in or computed from samples collected with a suspended load sampler.

Tide - The periodic rising and falling of the water that results from gravitational attraction of the moon and sun and other astronomical bodies acting upon the rotating earth. Although the accompanying horizontal movement of the water resulting from the same cause is also sometimes called the tide, it is preferable to designate the latter as Tidal Current, reserving the name tide for the vertical movement.

Tombolo - A bar or spit that connects or "ties" an island to the mainland or to another island.
Updrift - The direction opposite that of the predominant movement of littoral materials.

Weir Jetty - An updrift jetty with a low section or weir over which littoral drift moves into predredged deposition basin which is dredged periodically.

Wharf - A structure built on the shore of a harbour, river, or canal, so that vessels may lie alongside to receive and discharge cargo and passengers.

GEOLOGICAL MAP OF CYPRUS

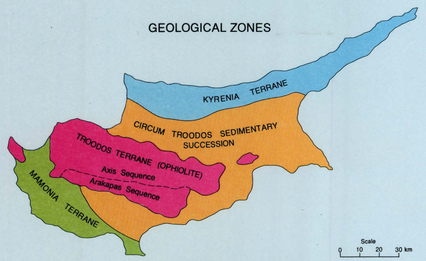
SCALE 1 : 250 000

km 5 4 3 2 1 0 5 10 15 20 km

Compiled, designed and drawn by the Geological Survey Department, Cyprus
Director G.Constantinou, Ph. D. (London),D.I.C., M.I.M.M.

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GEOLOGICAL ZONES



CIRCUM TROODOS SEDIMENTARY SUCCESSION

	LITHOLOGY	FORMATION	EPOCH		PERIOD
H	Sands, silts, clays and gravels	Alluvium-Colluvium	HOLOCENE		QUATERNARY
Qc	Calcarenites, sands and gravels	Terrace deposits	PLEISTOCENE		
Qc	Gravels, sands and silts	Fanglomerate			
Q	Biocalcarenites, sandstones, sandy marls and conglomerates	Apalos-Athalassa Kakkaristra			
Pl	Biocalcarenites, sandstones, silts, gravels, sandy marls, marls, limestones and conglomerates	Nicosia	PLIOCENE		NEOGENE
Mm	Gypsum alternating with chalky marls and marly chalks	Kalavasos	UPPER	MIOCENE	
Mu	Biostrome and bioherm reef limestones (Koronia Member)	Pakhna			
Mi-Mu	Chalks, marls, marly chalks, chalky marls and calcarenites		MIDDLE		
Mi	Biostrome and bioherm reef limestones (Terra Member)		LOWER		
Ku-Ou	Chalks, marls, marly chalks, chalky marls with cherts in places as bands or nodules	Lefkara	OLIGOCENE		PALAEOGENE
Ku-Eu	Variably coloured, poorly sorted debrites with angular clasts upto boulder size in a sand and clay matrix. Most clasts are derived from the Mamonia Complex but some are of Troodos ophiolite lithologies	Kathikas	EOCENE		
Ku-Eu	Melange of older (Triassic-Cretaceous) blocks of yellow quartz sandstone, grey siltstone, serpentinite and other lithologies, entrained in a matrix of silt and bentonitic clay	Moni	PALAEOGENE		
Ku-	Bentonitic clays interbedded with off-white volcaniclastic sandstones	Kannaviou	(Maastrichtian)	UPPER	CRETACEOUS
			(Campanian)		

TROODOS TERRANE (TROODOS OPHIOLITE)

OLYMPOS (AXIS) SEQUENCE

Ku	Hydrothermal and deep-water sediments; umbers, manganoan shales, pink radiolarian shales and mudstones	Perapedhi	UPPER CRETACEOUS (Campanian)	
UPL	Olivine - and pyroxene- phyric, pillow lavas with occasional sheet flows, dykes and hyaloclastites, commonly altered to zeolite facies	Upper Pillow Lavas	VOLCANIC SEQUENCE	UPPER CRETACEOUS (Upper Cenomanian - Lower Campanian)
LPL	Pillowed and sheet lava flows with abundant dykes and sills, altered to zeolite facies and in places stained with green celadonite	Lower Pillow Lavas		
BG	Diabase dykes (>50%) with pillow lava screens, altered to greenschist facies	Basal Group		
Db	Diabase dykes upto 3m wide, aphyric and clinopyroxene- and plagioclase-phyric altered to greenschist facies	Sheeted Dykes (Diabase)	INTRUSIVE SEQUENCE	
g	Trondhjemites, granophyres, diorites, quartz-diorites and micro-granodiorites	Plagiogranite	PLUTONIC SEQUENCE	
d	Isotropic gabbros, uralite gabbros, olivine gabbros and layered melagabbros	Gabbro		
ox	Websterites, clinopyroxenites, orthopyroxenites, and plagioclase-bearing pyroxenites	Pyroxenite		
cn	Wehrlites and plagioclase-bearing wehrlites, massive or layered	Wehrlite		
cn	Dunites with subordinate clinopyroxene-dunites	Dunite		
cn	Tectonized harzburgites with minor dunites and lherzolites	Harzburgite	MANTLE SEQUENCE	
cn	Pervasively serpentinized, tectonized harzburgites with minor dunites and lherzolites	Serpentinite		

ARAKAPAS (TRANSFORM) SEQUENCE

Db	Angular pillow fragments supported by a matrix of brown-red iron rich mudstone	Pillow Breccia
Vis	Fine-grained interlava volcanogenic sediments: (a) sandstones, grits and silts interbedded with laminated iron and manganese-rich mudstones	Lavas and Volcaniclastic Sediments
Vis	(b) Coarse polymict breccias with lava, dyke and isotropic gabbro clasts	
Lvs	Olivine - and /or pyroxene - phyric, aphyric pillow lavas with some hyaloclastites, sheet lava flows and dykes, altered to zeolite facies	
Vpl	Vitrophyric pillow lavas, generally olivine-phyric and/or orthopyroxene-phyric	
	Isotropic gabbros, microgabbros and norites	Intrusive Plutonic Rocks
	Poikilitic wehrlites and plagioclase-wehrlites	
	Serpentinite in subvertical shear zones, 50-500m wide	Sheared Serpentinite

KYRENIA TERRANE

	LITHOLOGY	FORMATION	EPOCH		PERIOD
Mm	Greywacke, marls, sandstones, siltstones, basal conglomerate	Kythrea	MIDDLE	MIOCENE	NEOGENE
Ol-Mi	Grits, greywacke, chalky marls, breccia mainly with chalky matrix. Recrystallized basal breccia, usually very coarse	Kalograea-Ardana	LOWER		
Db Ku-Eu Qtz	Chalks, red and pink marls and cherts, massive recrystallized white limestone	Lapithos	OLIGOCENE		PALAEOGENE
Db Ku-Eu Qtz	Chalks with pillow lavas (b) and rhyolite blocks (R) Recrystallized basal breccia.		EOCENE		
			PALAEOCENE		
			UPPER (Maastrichtian)		CRETACEOUS
Ji-Ki	Recrystallized massive -or medium -to thick -bedded limestones	Hilarion	LOWER		JURASSIC
Tu	Dolomitic limestones mostly recrystallized and brecciated	Sykhari	UPPER		TRIASSIC
Tl-Tu	Thinly-bedded marbles, in places micaceous with thin intercalations of phyllites	Dhikomo	MIDDLE		
			LOWER		
C-P	Massive limestones	Kantara			PERMIAN – CARBONIFEROUS

MAMONIA TERRANE

	LITHOLOGY	GROUP / FORMATION	EPOCH / PERIOD
Ku-	Amphibolite-grade metavolcanics (amphibolites, epidote-hornblende schists), metacherts (quartz-mica schists) and marbles, derived from Dikirzos Group	Ayia Varvara	U. CRETACEOUS
Tm-Km	Siltstones, calcilutites, radiolarian mudstones, calcarenites and quartzitic sandstones (Episkopi Fm). Stylolitic calcilutites with *Halobia* and ammonites (Marona Fm) Quartzose sandstones with fossil plant remains, mudstones and calcarenites (Vlampouros Fm)	Ayios Photios Group	M. CRETACEOUS - M. TRIASSIC
Tm-Km	Vesicular and amygdaloidal lava breccias, volcaniclastic breccias with volcaniclastic siltstones and radiolarian mudstones (Loutra tis Afroditis Fm). Amygdaloidal or vesicular porphyritic pillow lavas intercalated with pink and grey often recrystallized calcilutites (Fassoula Fm) Partially recrystallized reefoidal limestone breccia occurring as large detached blocks (Petra tou Romiou Fm)	Dhiarizos Group	
Sc	Multicoloured chlorite, quartz-chlorite -graphite, quartz-mica, garneteferous mica-epidote and hornblende schists, gneisses and quartzites	Metamorphic Rocks	

Highway, four lane dual
Main road, two lane
Main road, one lane
Minor road, unsurfaced
River, perennial and seasonal
Contours in metres

Geological boundary
Fault
Inferred fault
Thrust (saw teeth on upper plate)

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MINERAL RESOURCES MAP OF CYPRUS

SCALE 1:250,000

kms 5 4 3 2 1 0 5 10 15 20 kms

Compiled, drawn and prepared for lithographic printing by the Geological Survey Department, Cyprus, 1982.
Director, G. Constantinou, Ph.D. (Lond.) D.I.C., M.I.M.M.
Head of Economic Geology Section, A. Panayiotou, Ph.D., M.Sc., M.I.M.M.
(The information has been obtained, mainly from the maps and records of the Geological Survey Department and partly from the maps and records of the Mines Service, United Nations R.F.N.R.E. and Hellenic Mining Company).

MINERAL EXPORTS OF CYPRUS FOR THE YEARS 1931–1980

YEARS

Cu–Fe Sulphides
1931–1940
1941–1950
1951–1960
1961–1970
1971–1980
0 2,500,000 5,000,000 7,500,000 10,000,000 Tons

Chrome ore or Concentrates
1931–1940
1941–1950
1951–1960
1961–1970
1971–1980
0 50,000 100,000 150,000 200,000 Tons

Asbestos
1931–1940
1941–1950
1951–1960
1961–1970
1971–1980
0 50,000 100,000 150,000 200,000 250,000 300,000 Tons

Umber and Ochre
1931–1940
1941–1950
1951–1960
1961–1970
1971–1980
0 50,000 100,000 Tons

Gypsum
1931–1940
1941–1950
1951–1960 635,060 Tons
1961–1970
1971–1980
0 50,000 100,000 150,000 200,000 250,000 300,000 Tons

Bentonite
1951–1960
1961–1970
1971–1980
0 50,000 Tons

Magnetic variation for centre of chart, January 1976, 3° East
Annual change 2' East

LEGEND

SEDIMENTARY FORMATIONS

- N2-Q2 Pliocene to Holocene marl, calcarenite, silt, sand and gravel
- N1g Messinian gypsum
- N1r Middle Miocene reef limestone
- N1f Middle Miocene flysch
- N1l Lower Miocene reef limestone
- K2/N1 Maestrichtian to Middle Miocene chalk, marl, chert and greywacke
- K2 Campanian to Maestrichtian (rock fragments of the Mamonia Complex in clays)
- K2 Campanian to Maestrichtian bentonite
- K2 Campanian radiolarite and umber
- T3 Upper Triassic recrystallized reef limestone
- T1-K1 Lower Triassic? to Lower Cretaceous radiolarian chert, mudstone, quartz, sandstone, limestone, pillow lavas and minor metamorphic rocks (Mamonia Complex)
- P-K1 Permian to Lower Cretaceous recrystallized limestone and dolomitic limestone

TROODOS OPHIOLITE (Age: Cretaceous)

- UPL Upper Pillow Lavas (olivine basalt, picrite basalt)
- LPL Lower Pillow Lavas (oversaturated basalt)
- BG Basal Group (metabasalt)
- Db Sheeted Dyke Complex (Diabase)
- γ Plagiogranite
- δ Gabbro
- ox Pyroxenite
- o3 Wehrlite
- o2 Dunite
- o1 Harzburgite
- o Serpentinite
- mo Serpentinite of Mamonia Complex

CONVENTIONAL SIGNS

- Geological boundary
- Fault, definite and inferred
- Thrust, (saw teeth on upper plate)
- Asphalted road, four lanes, completed and under construction
- Asphalted road, two lanes
- Asphalted road, one lane
- Non asphalted road
- River, perennial and seasonal
- Heights of principal mountains and hills, in metres
- Contours in metres

MINES

P. Producer
Pp. Past producer
Np. Non producer

QUARRIES

- Umber
- Ochre
- Bentonite
- Gypsum
- Crushed stone
- Building stone
- Lime
- Marble
- Clay for bricks
- Chalk for cement industry
- Marl for cement industry

GRADE OF Cu–Fe SULPHIDES

COPPER ZINC

1% Copper or Zinc
2% " "
3% " "
4% " "
5% " "

CHEMISTRY OF THE CHROMITE

Cr : Fe ratio
Cr : Al ratio

SIZE OF DEPOSITS

- < 500,000 tons
- 500,000–2 million tons
- 2–5 million tons
- 5–10 million tons
- 10–20 million tons
- >20 million tons

TYPE OF DEPOSITS

- Massive sulphides >40% S.
- Stockwork < 40% S.
- Chromite
- Chrysotile asbestos
- Umber
- Investigated bentonite deposits
- Celestite
- High quality limestone
- Silica sandstone
- Mineral prospect

DEPOSITS

- Cu-Fe Sulphides
- Cu-Ni-Co-Fe Sulphides
- Chromite
- Manganese
- Chrysotile asbestos
- Magnesite
- Umber
- Bentonite
- Gypsum
- Celestite
- Silica sandstone

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Price £1,500 mils

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25m Digital Terrain Map of Cyprus

Locations of British soundings from
1930s and 1950s 1:50,000 scale surveys

960
940
920
900
880
860
840
820

420 440 460 480 500 520 540 560 580 600 620 640 660