Intergovernmental Oceanographic Commission

Workshop Report No. 89

IOC-ICSEM Workshop on Ocean Sciences in Non-Living Resources (OSNLR)

Held during the XXXIInd Congress and Plenary Assembly of ICSEM

Perpignan, France
15-20 October 1990

UNESCO

IOC Workshop Reports

The Scientific Workshops of the Intergovernmental Oceanographic Commission are sometimes jointly sponsored with other intergovermental or non-governmental bodies. In most cases, IOC assumes responsibility for printing, and copies may be requested from:

Intergovernmental Oceanographic Commission - UNESCO
7, place de Fontenoy, 75352 Paris 07 SP, France

No.	Title	Languages
1	CCOP-IOC, 1974, Metallogenesis, Hydrocarbons and Tectonic Patterns in Eastern Asia (Report of the IDOE Workshop on); Bangkok, Thailand, 24-29 September 1973 UNDP (CCOP), 138 pp.	E (out of stock)
2	CICAR Ichthyoplankton Workshop, Mexico City, 16-27 July 1974 (UNESCO Technical Paper in Marine Sciences, No. 20).	E (out of stock) S (out of stock)
3	Report of the IOC/GFCM/ICSEM International Workshop on Marine Pollution in the Mediterranean; Monte Carlo, 9-14 September 1974.	E, F E (out of stock)
4	Report of the Workshop on the Phenomenon known as 'El Niño'; Guayaquil, Ecuador, 4-12 December 1974.	E (out of stock) S (out of stock)
5	IDOE International Workshop on Marine Geology and Geophysics of the Caribbean Region and its Resources; Kingston, Jamaica, 17-22 February 1975.	E (out of stock) S
6	Report of the CCOP/SOPAC-IOC IDOE International Workshop on Geology, Mineral Resources and Geophysics of the South Pacific; Suva, Fiji, 1-6 September 1975.	E
7	Report of the Scientific Workshop to Initiate Planning for a Co-operative Investigation in the North and Central Western Indian Ocean, organized within the IDOE under the sponsorship of IOC/FAO (IOFC)/UNESCO/EAC; Nairobi, Kenya, 25 March-2 April 1976.	E, F, S, R
8	Joint IOC/FAO (IPFC)/UNEP International Workshop on Marine Pollution in East Asian Waters; Penang, 7-3 April 1976.	E (out of stock)
9	IOC/CMG/SCOR Second International Workshop on Marine Geoscience; Mauritius, 9-13 August 1976.	E, F, S, R
10	IOC/WMO Second Workshop on Marine Pollution (Petroleum) Monitoring; Monaco, 14-18 June 1976.	E, F E (out of stock) R
11	Report of the IOC/FAO/UNEP International Workshop on Marine Pollution in the Caribbean and Adjacent Regions; Port of Spain, Trinidad, 13-17 December 1976.	E, S (out of stock)
11 Suppl.	Collected contributions of invited lecturers and authors to the IOC/FAO/UNEP International Workshop on Marine Pollution in the Caribbean and Adjacent Regions; Port of Spain, Trinidad, 13-17 December 1976.	E (out of stock), S
12	Report of the IOCARIBE Interdisciplinary Workshop on Scientific Programmes in Support of Fisheries Projects; Fort-de-France, Martinique, 28 November-2 December 1977.	E, F, S
13	Report of the IOCARIBE Workshop on Environmental Geology of the Caribbean Coastal Area; Port of Spain, Trinidad, 16-18 January 1978.	E, S
14	IOC/FAO/WHO/UNEP International Workshop on Marine Pollution in the Gulf of Guinea and Adjacent Areas; Abidjan, Côte d'Ivoire, 2-9 May 1978.	E, F
15	CPPS/FAO/IOC/UNEP International Workshop on Marine Pollution in the South-East Pacific; Santiago de Chile, 6-10 November 1978.	E (out of stock)
16	Workshop on the Western Pacific, Tokyo, 19-20 February 1979.	E, F, R
17	Joint IOC/WMO Workshop on Oceanographic Products and the IGOSS Data Processing and Services System (IDPSS); Moscow, 9-11 April 1979.	E
17 Suppl.	Papers submitted to the Joint IOC/WMO Seminar on Oceanographic Products and the IGOSS Data Processing and Services System; Moscow, 2-6 April 1979.	E
18	IOC/UNESCO Workshop on Syllabus for Training Marine Technicians; Miami, 22-26 May 1978 (UNESCO reports in marine sciences, No. 4 published by the Division of Marine Sciences, UNESCO).	E (out of stock), F, S (out of stock), R
19	IOC Workshop on Marine Science Syllabus for Secondary Schools; Llantwit Major, Wales, U.K., 5-9 June 1978 (UNESCO reports in marine sciences, No. 5, published by the Division of Marine Sciences, UNESCO).	E (out of stock), E, S, R, Ar
20	Second CCOP-IOC Workshop on IDOE Studies of East Asia Tectonics and Resources; Bandung, Indonesia, 17-21 October 1978.	E
21	Second IDOE Symposium on Turbulence in the Ocean; Liège, Belgium, 7-18 May 1979.	E, F, S, R
22	Third IOC/WMO Workshop on Marine Pollution Monitoring; New Delhi, 11-15 February 1980.	E, F, S, R
23	WESTPAC Workshop on the Marine Geology and Geophysics of the North-West Pacific; Tokyo, 27-31 March 1980.	E, R
24	WESTPAC Workshop on Coastal Transport of Pollutants; Tokyo, 27-31 March 1980.	E (out of stock)
25	Workshop on the Intercalibration of Sampling Procedures of the IOC/ WMO UNEP Pilot Project on Monitoring Background Levels of Selected Pollutants in Open-Ocean Waters; Bermuda, 11-26 January 1980.	E (superseded by IOC Technical Series No. 22)
26	IOC Workshop on Coastal Area Management in the Caribbean Region; Mexico City, 24 September-5 October 1979.	E, S
27	CCOP/SOPAC-IOC Second International Workshop on Geology, Mineral Resources and Geophysics of the South Pacific; Nouméa, New Caledonia, 9-15 October 1980.	E
28	FAO/IOC Workshop on the effects of environmental variation on the survival of larval pelagic fishes. Lima, 20 April-5 May 1980.	E
29	WESTPAC Workshop on Marine Biological Methodology; Tokyo, 9-14 February 1981.	E
30	International Workshop on Marine Pollution in the South-West Atlantic; Montevideo, 10-14 November 1980.	E (out of stock) S
31	Third International Workshop on Marine Geoscience; Heidelberg, 19-24 July 1982.	E, F, S
32	UNU/IOC/UNESCO Workshop on International Co-operation in the Development of Marine Science and the Transfer of Technology in the context of the New Ocean Regime; Paris, 27 September-1 October 1982.	E, F, S
32 Suppl.	Papers submitted to the UNU/IOC/UNESCO Workshop on International Co-operation in the Development of Marine Science and the Transfer of Technology in the Context of the New Ocean Regime; Paris, 27 September-1 October 1982.	E
33	Workshop on the IREP Component of the IOC Programme on Ocean Science in Relation to Living Resources (OSLR); Halifax, 26-30 September 1963.	E
34	IOC Workshop on Regional Co-operation in Marine Science in the Central Eastern Atlantic (Western Africa); Tenerife, 12-17 December 1963.	E, F, S
35	CCOP/SOPAC-IOC-UNU Workshop on Basic Geo-scientific Marine Research Required for Assessment of Minerals and Hydrocarbons in the South Pacific; Suva, Fiji, 3-7 October 1983.	E
36	IOC/FAO Workshop on the Improved Uses of Research Vessels; Lisbon, 28 May-2 June 1984.	E
36 Suppl.	Papers submitted to the IOC/FAO Workshop on the Improved Uses of Research Vessels; Lisbon, 28 May-2 June 1984.	E
37	IOC/UNESCO Workshop on Regional Co-operation in Marine Science in the Central Indian Ocean and Adjacent Seas and Gulfs; Colombo, 8-13 July 1985.	E
38	IOC/ROPME/UNEP Symposium on Fate and Fluxes of Oil Pollutants in the Kuwait Action Plan Region; Basrah, Iraq, 8-12 January 1984.	E
39	CCOP (SOPAC)-IOC-IFREMER-ORSTOM Workshop on the Uses of Submersibles and Remotely Operated Vehicles in the South Pacific; Suva, Fiji, 24-29 September 1985.	E
40	IOC Workshop on the Technical Aspects of Tsunami Analysis, Prediction and Communications; Sidney, B.C., Canada, 29-31 July 1985.	E
40 Suppl.	IOC Workshop on the Technical Aspects of Tsunami Analysis, Prediction and Communications, Submitted Papers; Sidney, B.C., Canada, 29-31 July 1985.	E
41	First Workshop of Participants in the Joint FAO/IOC/WHO/IAEA/UNEP Project on Monitoring of Pollution in the Marine Environment of the West and Central African Region (WACAF/2); Dakar, Senegal, 28 October-1 November 1985.	E
43	IOC Workshop on the Results of MEDALPEX and Future Oceanographic Programmes in the Western Mediterranean; Venice, Italy, 23-25 October 1985.	E
44	IOC-FAO Workshop on Recruitment in Tropical Coastal Demersal Communities; Ciudad del Carmen, Campeche, Mexico, 21-25 April 1986.	E (out of stock) S
44 Suppl.	IOC-FAO Workshop on Recruitment in Tropical Coastal Demersal Communities, Submitted Papers; Ciudad del Carmen, Campeche, Mexico, 21-25 April 1986.	E
45	IOCARIBE Workshop on Physical Oceanography and Climate; Cartagena, Colombia, 19-22 August 1986.	E
46	Reunión de Trabajo para Desarrollo del Programa "Ciencia Oceánica en Relación a los Recursos No Vivos en la Región del Atlántico Sud-occidental"; Porto Alegre, Brazil, 7-11 de abril de 1986.	S
47	IOC Symposium on Marine Science in the Western Pacific: The Indo-Pacific Convergence; Townsville, 1-6 December 1966.	E
48	IOCARIBE Mini-Symposium for the Regional Development of the IOC-UN (OETB) Programme on 'Ocean Science in Relation to Non-Living Resources (OSNLR)'; Havana, Cuba, 4-7 December 1986.	E, S
49	AGU-IOC-WMO-CPPS Chapman Conference: An International Symposium on 'El Niño'; Guayaquil, Ecuador, 27-31 October 1986.	E
50	CCALR-IOC Scientific Seminar on Antarctic Ocean Variability and its Influence on Marine Living Resources, particularly Krill (organized in collaboration with SCAR and SCOR); Paris, France, 2-6 June 1987.	E
51	CCOP/SOPAC-IOC Workshop on Coastal Processes in the South Pacific Island Nations; Lae, Papua-New Guinea, 1-8 October 1987.	E

CONTINUED ON INSIDE OF BACK COVER

Intergovernmental Oceanographic Commission

Workshop Report No. 89

IOC-ICSEM Workshop on Ocean Sciences in Non-Living Resources (OSNLR)

Held during the XXXIInd Congress and Plenary Assembly of ICSEM

Perpignan, France
15-20 October 1990

SC-93/WS-49

TABLE OF CONTENTS

PART II:

SUBMITTED PAPERS 21

FOREWORD

The Ocean Sciences in Relation to Non-Living Resources (OSNLR) programme of the Intergovernmental Oceanographic Commission (IOC) run jointly with the United Nations (Office of Ocean Affairs and the Law of the Sea) was introduced in 1982. Its aim is to perfect the knowledge of the origins and distribution of useful substances in the marine environment. The notion of the environment is linked to this programme because of the harmful effects that exploitation of these substances could cause.

The composition of multi-disciplinary teams, capable of intervening in research, particularly in developing countries, is of urgent necessity, in view of the number and diversity of the problems to be resolved: the type of resources, the mechanisms of their generation and origins, their location in the ocean, to cite only the most essential. In this context, the training component has a very important role to play in liaison with the programme. The international IOC Training, Education and Mutual Assistance in the Marine Sciences (TEMA) programme takes into consideration the requirements of the OSNLR programme in suggesting appropriate solutions which could be used as worldwide benchmarks.

Analyses carried out by specialist groups of experts have shown the urgent necessity to develop studies on the coastal environment. The dispersion of useful substances in this milieu is influenced as much by hydrodynamical as by morphological factors (coastal and seabed). Fluxes linked to different elements caracterising the continent/ocean interface, such as those associated with the modification of coastal areas, should be well known as they influence the many parameters of the evolution of the environment. Within these fluxes there are fluxes of organic matter in which breakdown begins to occur, influencing the chemical balance of the oceans.

However, a global approach and the development of the OSNLR programme can only be considered in a more precise manner when several conditions, such as scientific interest in the proposed programme and its plan of application, existence of regional projects and the availability of the necessary resources (equipment, finance and groups of specialists), are available.

Thus, the Officers of the OSNLR programme adhere to the conditions of implementation, within the regional context, well-defined research not only with a view to increasing knowledge, but also to make possible the training of scientists and technicians. In order to do this, groups of regional and sub-regional experts are gradually being formed (Western Pacific, Caribbean, Indian Ocean, Central Eastern Atlantic, South-West Atlantic) to organize research activities, training and development, on the basis of close collaboration with the Guiding Group of the Programme working from IOC.

In this way, and taking into account the similarities between the research programmes of IOC and ICSEM (International Commission for the Scientific Exploration of the Mediterranean Sea), a regional component relative to the Mediterranean could be established associating the two Commissions through the OSNLR programme. This decision was taken during a joint meeting held in Monaco (14-15 December 1989) during which a regional group of experts was formed.

The first work accomplished under OSNLR considered the coastal process with priority given coastal sediments dynamics (insular and deltaic).

A series of conference and lectures took place on the occasion of the Congress at Perpignan which concerned various aspects of these sedimentary processes, and the regional Mediterranean investigations will be of help in this, and will make a considerable contribution to the knowledge of these phenomena and their consequences.

The understanding of the coastal environment is of an increasingly important priority among the world's environmental problems. The Mediterranean, thanks to the variety of models it provides, is becoming a particularly promising field of investigation. Planned regional programmes will, without doubt, provide much useful knowledge.

M. VIGNEAUX
Chairman, OSNLR Programme

AVANT-PROPOS

Datant de 1982, le programme OSNLR (Ocean Sciences in Relation to Non-Living Resources) est un programme conjoint de la COI (Commission océanographique intergouvernementale) et des Nations Unies (Bureau des affaires maritimes et du droit de la mer) qui a pour objectif essentiel de parfaire les connaissances sur la genèse et la distribution des substances utiles dans la domaine marin. La notion d'environnement est liée à ce programme en raison des nuisances que l'exploitation de ces substances ne peuvent qu'engendrer.

La constitution d'équipes pluridisciplinaires, susceptibles d'intervenir dans les recherches, en particulier pour les pays en voie de développement, est une obligation d'application urgente, compte tenu du nombre et de la diversité des problèmes à résoudre: nature des ressources, mécanismes de leur genèse et localisation en domaine océanique pour ne citer que les plus fondamentaux. Dans ce contexte, la composante formation joue un rôle déterminant en liaison avec le programme.Le programme international TEMA (Training, Education and Mutual Assistance) de la COI prend en considération les impératifs du programme OSNLR afin de proposer des solutions appropriées susceptibles de servir de référence mondiale.

Les analyses réalisées par des groupes d'experts spécialisés ont mis en relief l'urgente nécessité de développement des études sur les envionnements côtiers. Dans ces milieux, la dispersion des substances utiles obéit tant aux facteurs hydrodynamiques que morphologiques (littoraux et fonds marins). Les flux liés aux différents éléments caractérisant l'interface continent/océan comme ceux associés aux modifications des franges côtières, doivent être bien connus car ils conditionnent de multiples paramètres de l'évolution de ces milieux. Dans une cinématique semblable, se meuvent les flux de matière organique qui sont le théâtre des premiers stades de dégradation et influencent la balance chimique des océans.

Cependant, une approche globale ne peut être envisagée et le programme OSNLR ne peut concevoir son développement qu'au travers d'action plus ponctuelle dans la mesure où diverses conditions sont remplies, dont les principales sont: intérêt scientifique de l'intervention projetée et du modèle d'application; existence d'une proposition régionalisée et obtention des moyens nécessaires à sa réalisation (équipements, financements et groupes de spécialistes).

Les responsables du programme OSNLR se sont donc attachés aux conditions de mise en oeuvre, au sein d'ensembles régionaux, d'actions de recherches bien délimitées susceptibles de faire avancer les connaissances mais aussi de servir de support à la formation des scientifiques et techniciens. Pour ce faire, des groupes d'experts régionaux et sous-régionaux sont mis progressivement en place (Pacifique Ouest, Caraïbes, Océan Indien, Atlantique du Centre Est, Sud-Ouest Atlantique) et ont pour mission d'organiser, sur la base de réseaux des activités de recherche, formation et développement, en coordination étroite avec le Comité directeur du Programme, oeuvrant à la COI.

Dans cet esprit, et compte tenu de grandes similitudes entre programmes de recherches de la COI et de la CIESM (Commission internationale pour l'exploration scientifique de la mer Méditerranée), une composante régionale relative au domaine méditerranéen pouvait être établie en association entre les deux Commissions concernées par le programme OSNLR. Cette décision a été prise lors d'une réunion commune tenue à la Principauté de Monaco (14-15 décembre 1989) au cours de laquelle un groupe régional d'experts a été constitué.

Les premiers travaux réalisés dans le cadre d'OSNLR ont abouti à considérer les processus littoraux avec une grande priorité portant spécialement sur la dynamique sédimentaire côtière insulaire et deltaïque.

L'ensemble des conférences qui vont se dérouler à l'occasion du congrès de Perpignan intéressent divers aspects de ces processus sédimentaires et les investigations régionales méditerranéennes aidant, doivent apporter une contribution considérable à la connaissance de ces phénomènes et à leurs conséquences.

La connaissance des domaines côtiers est une priorité de plus en plus grande qui s'inscrit parmi les préoccupations environnementales mondiales. La Méditerranée, grâce à la diversité des modèles qu'elle regroupe, constitue un champ potentiel d'investigations particulièrement prometteur. Les programmes régionaux projetés seront, sans nul doute, riches d'enseignements.

M. VIGNEAUX
Président du Programme OSNLR

PART I

RÉUNION DU GROUPE CONJOINT COI-CIESM D'EXPERTS POUR LA COMPOSANTE MEDITERRANEENNE DE OSNLR

1. INTRODUCTION

Le Programme "L'océanologie et les ressources non vivantes" (OSNLR) est un programme conjointement soutenu par le COI et les Nations Unies (Bureau des affaires maritimes et du droit de la mer). Il a pour objectif de promouvoir des recherches sur les ressources marines non vivantes, en priorité celles des zones côtières: parmi celles-ci la zône côtière en elle-même (CZAR: Zone côtière considérée comme une ressource en soi).

Le développement du Programme s'effectue au plan régional dans le cadre de projets spécifiques adaptés aux différentes régions, à leurs caractéristiques naturelles, aux moyens humains, matériels et financiers disponibles. Il est également réalisé dans le cadre de la coopération avec d'autres programmes et organismes.

Lors de la réunion *ad hoc* COI-CIESM consacrée à l'élaboration d'une composante méditerrannéenne du Programme OSNLR (Monte Carlo, Principauté de Monaco, 14-15 décembre 1989), il a été accordé un intérêt particulier à l'étude des transferts sédimentaires, en distinguant les systèmes à fort flux continental (zones deltaïques) et les systèmes insulaires, souvent à budget sédimentaire déficitaire.

Les thèmes, relatifs à la distribution des budgets sédimentaires en milieu marin, apparaissent d'une importance particulière pour l'interprétation de l'évolution des zônes côtières et de leur réponse aux modifications de l'environnement littoral en relation avec l'élévation du niveau de la mer ou les perturbations liées aux activités humaines. Les conséquences sont particulièrement nettes en ce que concerne l'érosion côtière à laquelle sont soumis les littoraux de nombreuses îles méditerranéennes, Chypre et Malte notamment.

Aussi, le Groupe d'Experts a retenu au titre d'une composante conjointe COI-CIESM de OSNLR un thème général relatif à la dynamique sédimentaire côtière dont le calendrier des études proposées prévoit trois étapes:

(i) **Systèmes côtiers insulaires de Méditerranée**

(ii) **Systèmes deltaïques méditerranéens**

(iii) **Littoraux méditerranéens.**

Il est envisagé également de conduire des études d'impact de l'environnement qui nécessitent une approche à la fois pluri et interdisciplinaire, comprenant les connaissances des processus marins, l'état de pollution marine, les activités socio-économiques actuelles.

Il apparaît extrêmement important de définir une stratégie favorisant la mise en oeuvre de conditions communes pour la recherche nationale afin de satisfaire les demandes spécifiques et collectives de divers départements (administration, gestion et développement) et des secteurs industriels et économiques concernés.

2. DÉVELOPPEMENT GÉNÉRAL D'UN PROJET CONCERNANT LES SYSTÈMES CÔTIERS INSULAIRES DE MÉDITERRANÉE

La COI dans le cadre de la coopération entre l'UNESCO et la Commission des Communautés Européennes se propose de soumettre à cette dernière pour financement un projet, d'une durée de cinq ans, relatif à la dynamique des milieux côtiers insulaires s'appuyant, en particulier, sur les cas de **Chypre** et de **Malte**, Etats membres de la COI et de la CIESM.

Un avant-projet a été préparé par la COI dont les éléments relatifs au contexte, à la justification et les objectifs à développer sont précisés dans les paragraphes qui suivent. Un texte sur les problèmes d'environnement côtier relatifs à Malte et à Chypre figure à l'annexe I.

2.1 OBJECTIF GENERAL DU PROJET

L'objectif final du projet est de développer les connaissances sur les mécanismes responsables du comportement des environnements côtiers insulaires de la Méditerranée.

L'objectif immédiat est de développer les capacités de recherche des pays méditerranéens participants en matière d'aménagement et de gestion des environnements côtiers. Le projet concerne tout particulièrement (voir annexe) les pays ou partie de pays pour lesquels les environnements littoraux font l'objet d'une exploitation touristique intensive et qui, du fait de leur insularité, posent des problèmes d'environnement très spécifiques: étroitesse du plateau continental, importance économique relative de la zone immergée par rapport aux zônes émergées, surexploitation urbanistique, touristique et économique des zône côtières, conséquences au niveau de l'érosion côtière.

2.1.1. Contexte du Projet

Pour de nombreux pays, la ressource la plus importante de la zône économique exclusive est la zône côtière elle-même. Pour les états insulaires, ou pour les états dont l'environnement insulaire constitue, au plan géographique, une part majeure du territoire national, l'importance économique de la frange littorale est considérable, en particulier pour les îles de petites superficies pour lesquelles la mer (littoral et plateau continental) offre des possibilités d'expansion économique d'autant plus essentielles qu'elles sont rares, à savoir:

- (i) les activités portuaires
- (ii) la pêche et l'aquaculture
- (iii) les ressources minérales: pétrole, gaz, placers, sables, graviers
- (iv) le tourisme.

Trop souvent, le développement de ces possibilités s'effectue dans un climat de connaissances scientifiques insuffisantes. Il s'ensuit des conséquences économiques et/ou environnementales peu prévisibles. Des efforts doivent donc être faits pour développer des connaïssances élémentaires permettant de mettre en oeuvre des politiques d'aménagement et de développement en accord avec les contraintes de l'environnement. Il est important pour cela de faire appel à des études globales prenant en compte l'ensemble des facteurs en présence. Les problèmes rencontrés ne peuvent se résoudre de manière sectorielle, mais uniquement au travers de plans d'action faisant simultanément appel à toutes les disciplines concernées.

2.1.2 Justification du Projet

L'une des préoccupations majeures de diverses îles de la Méditerranée, en matière d'environnement, est la lutte contre l'érosion marine (voir annexe 1). Les raisons de cette dégradation peuvent être d'origine naturelle: remontée du niveau de la mer, subsidence de certaines régions. Le plus souvent, elle est la conséquence des activités humaines dans la région considérée. Les ouvrages à la côte (jetées, épis), les travaux sur les cours d'eau (barrages, dragages) diminuent le volume des sédiments apportés à l'océan. L'utilisation des sédiments de plages comme matériaux de construction entraîne une diminution de stock sédimentaire disponible, diminutition que la mer compense en érodant le littoral.

L'aménagement du trait de côte accroît la réflexion des houles, et renforce la turbulence des courants de retour.

Des pompages de la nappe phréatique peuvent entraîner un affaissement du littoral et faciliter l'action érosive de la mer. La construction des digues et épis répond trop souvent à un problème local sans prendre en compte l'ensemble des facteurs du milieu. Leur construction devrait être précédée d'études de la dérive littorale et des processus hydrodynamiques, au risque de seulement déplacer plus en aval la zône où s'exerce l'action érosive de la mer.

Sur certains rivages, les herbiers (zostères et posidomies) jouent un rôle prépondérant dans la fixation des matériaux meubles. Ces herbiers sont cependant très sensibles à la pollution et au rejet de matériaux. En Méditerranée, leur développement est un danger risquant de perturber non seulement la dynamique sédimentaire mais également tout l'écosystème.

En résumé, les processus s'exerçant sur la zône côtière sont étroitement liés; toute action sur l'un d'eux entraîne une réaction en chaîne aux conséquences souvent imprévues. Lorsqu'un aménagement du littoral s'avère nécessaire, le choix du site, les moyens à mettre en oeuvre passent nécessairement par une étude préalable basée sur: la connaissance des données naturelles, les mécanismes de l'évolution, et le suivi du système "après construction".

2.1.3 Les objectifs à développer

La gestion et la protection du littoral en général nécessitent des études, pour la plupart de caractère pluridisciplinaire, focalisées sur les volets suivants:

(i) Suivi de la configuration du littoral et de son évolution. Levers des profils de plages. Les processus directement soumis aux houles et à la marée seront considérés sur des périodes de temps suffisamment longues et couvrant d'une part les différentes saisons et, d'autre part, les variations annuelles, voire séculaires.

Des études particulières seront consacrées à l'évolution de la configuration du littoral grâce à l'exploitation des données satellites (évolution à court terme) et - quand ils existent - des documents cartographiques anciens dont la qualité et la précision peuvent être considérées comme satisfaisantes depuis une centaine d'années, et qui constituent des données de référence précieuses pour connaître l'évolution des côtes.

(ii) Etablissement des bilans des flux de matériaux fluviatiles à la mer et des transits sédimentaires le long des côtes. Ces bilans et leurs variations dans le temps seront réalisés par des unités spatiales et temporelles de différentes échelles, adaptés aux situations étudiées. Les transports liés aux courants seront envisagés à une échelle saisonnière annuelle et pluriannuelle. Les effets des aménagements sur les flux des matières venant des terres émergées ou transitant sur les littoraux seront interprétées sur la base d'une comparaison des données actuelles et de celles - quand elle existent - antérieures aux aménagements. En l'absence de ces données, une approche de l'évolution des bilans sédimentaires peut etre dégagée de la comparaison des documents cartographiques successifs (voir point (i)).

(iii) Etude géophysique (sismique superficielle haute résolution) et géomorphologique des fonds marins littoraux, en particulier au droit des plages et des zônes principales d'aménagements. L'objectif sera de déterminer les caractéristiques morphologiques et structurale pouvant jouer un rôle dominant sur l'évolution des littoraux et sur leur réponse aux aménagement (tenue des plages, des ports, des constructions en bord de mer, etc.).

(iv) Etudes géologiques des fonds marins notamment: (a) aux alentours des zônes susceptibles de constituer des resources de matériaux meubles transitant sur le plateau ou le long du littoral; (b) au droit des plages soumises à des évolutions importantes; (c) dans les zônes susceptibles de receler des substances économiquement intéressantes: sables et graviers, carbonates, autres substances utiles (dépôts phosphates, glauconitiques, organiques, etc...).

(v) Océanographie physique: étude des courants, des vagues (hauteur, période et longueur d'onde, angle d'approche à la côte, caractéristiques du déferlement.

(vi) Modélisation des processus. A partir de l'ensemble des données recueillies on cherchera à modéliser les processus de transports sédimentaires (modèles mathématiques ou modèles physiques) en essayant, autant que faire se peut, d'appréhender les mécanismes de manière globale et non pas locale.

2.2 CAMPAGNES OCEANOGRAPHIQUES: MALTE ET CHYPRE

Deux campagnes océanographiques sont proposées, ayant pour objectif l'étude de la géologie et de l'hydrodynamique de la zone côtière de Chypre et de Malte.

Afin d'élaborer les plans de travail des croisières océanographiques et de leur suivi ainsi que de déterminer les besoins en équipement et en formation, deux Ateliers sont prévus :

(i) le premier à Malte;
(ii) le second à Chypre.

Ces Ateliers offriront l'occasion de considérer les études à conduire sur les sites significatifs choisis. Malte et Chypre ne disposant pas dans toutes les disciplines envisagées (géomorphologie, sédimentologie, hydrodynamique, télédétection, engineering côtier, impact environnemental, pollution marine, écologie) de l'expertise nécessaire, des solutions devront être étudiées. Certains membres du groupe d'experts se proposent de participer personnellement dans le projet et de trouver des aides auprès d'équipes scientifiques extérieures.

3. **ELABORATION D'UN PROJET D'ETUDE DES SYSTEMES DELTAIQUES *MEDITERRANEENS***

Afin de comprendre les processus qui sont à la base des similitudes et des différences existant entre les deltas méditerranéens, les facteurs qui contrôlent leur caractère doivent, pour chaque delta, être précisés. Parmi ces facteurs sont à considérer : le climat dans le bassin versant, la néotectonique, les processus océanographiques à l'embouchure et la géométrie de la marge continentale. Ceux-ci différeront d'un delta à l'autre et seront la cause des différences rencontrées dans les processus sédimentaires deltaïques.

Les deltas méditerranéens possèdent une particularité unique; celle d'offir une excellente information sur l'histoire des systèmes durant plusieurs milliers d'années grâce au système fermé que représente la Méditerranée. Ceci permettra des comparaisons et ainsi de savoir comment les changements naturels et anthropogéniques affectent le delta grâce à l'archivage sédimenté préservé (paléodelta).

En outre, certains systèmes deltaïques sont actuellement actifs comme ils l'avaient été pendant les bas niveaux marins des périodes glaciaires. Aussi, ils peuvent fournir une information fondamentale pour comprendre et interpréter la sédimentation quand des masses considérables d'apports sédimentaires fluviadiles s'échappent du plateau continental.

Une équipe de scientifiques méditerranéens devra être constituée ayant pour objectif d'entreprendre l'étude d'ensemble des caractéristiques sédimentaires importantes. Elle sera chargée d'examiner chacun des deltas (des 3-5 deltas) de manière cohérente pendant approximativement 1-2 ans. Il s'agira de comprendre comment des combinaisons différentes de processus conduisent à des caractères géologiques spécifiques.

En raison des efforts déjà déployés ou en cours, relatifs aux systèmes deltaïques plus importants comme le Nil, l'Ebre et le Rhône, il s'avère nécessaire de préciser les termes de référence des futures études requises ainsi que de déterminer les lacunes existantes.

3.1 DIFFUSION D'UN QUESTIONNAIRE ET ORGANISATION D'UN ATELIER

Dans ce contexte, il est envisagé de lancer un questionnaire sur l'état actuel des connaissances ainsi que sur l'information disponible et les études en cours ou projetées. L'analyse des réponses donnera lieu à l'établissement d'une synthèse séparée pour chacun des deltas. La liste de destinataires sera composée des adresses pour action de la COI, des adresses fournies par le fichier de la CIESM et enfin, des adresses indiquées par les membres du Groupe d'experts.

Une première synthèse sera effectuée par un comité restreint d'experts et présentée lors d'un Atelier consacré à l'élaboration du projet relatif aux systèmes deltaïques méditerranéens.

La possiblité de l'établissement d'une base de données sera également examinée ainsi que la coopération avec les réseaux existants.

Les travaux de cet Atelier bénéficieront des réflexions menées par l'équipe scientifique qui conduit actuellement des études sur le delta du Po qui est une zône de très forts flux sédimentaires.

Une autre zone devant retenir particulièrement l'attention lors de la tenue de cet atelier est le delta de la Medjerda, en Tunisie. Ce fleuve qui se déverse dans le golfe de Tunis se caractérise par un débit hydraulique moyen d'un milliard de m^3/an et un débit sédimentaire moyen de 20 millions de tonnes/an. Il s'agit donc d'un système à fort flux continental dont l'étude présente un intérêt non seulement pour la Tunisie, mais aussi en tant que référence pour les autres pays du bassin méditerranéen.

La plateforme deltaïque de la baie de Thermaikos, en Grèce, qui présente un grand intérêt sur les plans scientifique, économique et socio-culturel, sera également considérée.

4. LITTORAUX MEDITERRANEENS : ATELIER A ALGER

Ce troisième volet des études relatives à la dynamique sédimentaire de la zone côtière intéressera dans une première phase les côtes de la rive sud de la Méditerranée telles que celles de l'Algérie.

L'Algérie profondément ancrée dans le continent africain borde la Méditerranée avec ses 1.200 kms de côtes. La diversité des climats allant de l'aride à tempéré a déterminé pour une grande part la situation économique et sociale des régions, les contrastes des reliefs ayant aggravé ou favorisé la position des unes par rapport aux autres.

D'ici l'an 2000, la population algérienne passerait à plus de 33 millions d'habitants dont 70% seront concentrés dans la zone Nord qui représent 4% de la superficie totale du territoire. D'où le déséquilibre dans l'occupation de l'espace et les menaces déjà sensibles sur le littoral. De plus, le littoral subit chaque année le choc de 8 millions d'estivants entre juin et septembre. La pollution urbaine et industrielle, avec les eaux usées, les déchets solides et les rejets chimiques qu'elles produisent ont entraîné des modifications notables des milieux côtiers. Les risques naturels : séismes, inondations, tempêtes et autres évènements occasionnels, affectent l'utilisation de ce potentiel et aggravent les difficultés de sa gestion.

Une réunion de spécialistes sera organisée à Alger pour prendre en charge une étude approfondie des mécanismes de transit de sédiments côtiers et de dynamique littorale.

5. PUBLICATION DES CONFERENCES ET COMMUNICATIONS SUR LE THEME OSNLR

Les trois conférences présentées dans le cadre du Congrès de la CIESM par MM. Charles A. Nittrouer et Mahmoud El Sayed et Mme Anna Spiteri (lue par M. Micallef) ainsi que les communications qui ont suivi apparaissent en partie II du présent document.

A N N E X E I

LES PROBLEMES D'ENVIRONNEMENT COTIER EN MILIEU INSULAIRE

I EXEMPLE DE L'ARCHIPEL MALTAIS

1. Présentation générale

L'archipel maltais, situé à 44 milles de la Sicile et 185 milles de la Libye, se compose de trois îles très proches les unes des autre. L'île de Malte est la plus grande avec 246 km², Gozo a une surface de 67 km² et Comino seulement 2,8 km².

A la fin de 1984, la population de Malte était de 332 000 habitants, avec un taux de croissance de 16,8. La densité de 1 052 habitants par km² est la plus forte d'Europe après Gibraltar.

L'économie est basée sur l'agriculture, la pêche, la construction navale, quelques industries, le pétrole (plusieurs gisements prometteurs ont été récemment découverts). Durant l'année 1985, 528 000 touristes ont effectué un séjour dans les îles de l'archipel maltais.

La zone côtière est une importante ressource intensivement utilisée pour le transport, les communications, la construction navale. Elle est également un lieu de grande productivité biologique et un grand nombre d'anses offre des possibilités - outre celles pour les loisirs - pour le développement de l'aquaculture. En ce qui concerne le tourisme, la plus grande partie du littoral étant bordée de collines, le nombre et l'étendue des plages sont considérés comme trop limités eu égard à la demande.

Malgré l'importance que revêt la frange littorale, la recherche océanographique à Malte est dans sa phase initiale. La recherche scientifique en général, et la recherche marine en particulier, ont été négligées au profit des questions touchant au développement de l'agriculture qui, dans le système éducatif maltais, a bénéficié (pendant longtemps) d'une priorité. La nécessité de renforcer la recherche marine se fait maintenant sentir au travers de deux demandes nationales urgentes : le besoin de diversification des facteurs de croissance économique répondant aux demandes croissantes de la population - les solutions à trouver aux problèmes d'environnement marin résultant d'une utilisation excessive de la zone côtière.

Quelques études réalisées au plan national ont pu apporter des solutions à certains problèmes écologiques. Elles sont toutefois de dimension modeste en raison du nombre insuffisant de spécialistes océanographes, des difficultés des problèmes à resoudre et des ressources financières limitées.

Il serait nécessaire de procéder à une évaluation objective des ressources permettant d'assurer, grâce à une révision de la politique de gestion, un développement équilibré du littoral. Dans ce but, une collaboration étroite entre océanographes, ingénieurs du littoral, économistes, sociologues et gestionnaires, s'avère nécessaire.

2. Les problèmes relatifs à la protection et à la gestion des plages

Le littoral maltais est considérablement utilisé pour de multiples activités socio-économiques. Plusieurs entrées naturelles des îles ont pour cette raison été progressivement converties en port ou élargies pour accueillir de nouvelles constructions. Des séries de brise-lames, de jetées, ont été construites pour protéger ces ports. Ce développement, qui a eu lieu à un rythme très rapide et sans le soutien de données scientifiques fiables, provoque souvent la dégradation des plages pourtant déjà considérées comme insuffisamment étendues. Or une attention particulière doit être accordée à la dégradation du littoral étant donné les répercussions possibles sur le tourisme et l'économie en général.

Au nord de Malte et dans l'île de Gozo, diverses plages montrent déjà des signes de déterioration caractéristiques de l'érosion côtière. Les effets des facteurs responsables de cette dégradation sont localement amplifiés par la structure naturelle du système et notamment l'étroitesse du plateau entourant l'archipel. Le stock de sable disponible au large est, de ce fait, très limité. Dans ces conditions, la diminution, due aux aménagements, des apports de sable venant des terres émergées a des conséquences très sensibles. Les constructions sur le littoral ("bétonnage" pour l'essentiel) ont visiblement privé le trait de côte des apports de matériaux - y parvenant autrefois au moment des précipitations - et qui compensaient les départs de sable dus à l'action des courants.

Parmi les autres facteurs responsables de la dégradation, il faut également mentionner les variations du système des courants côtiers provoquées par la construction de structures : jetées, épis. Il faut également mentionner les conséquences de la pollution marine sur les végétaux tapissant les fonds marins. Les herbiers sont souvent des facteurs essentiels de la stabilisation de ces fonds. Leur disparition peut avoir des conséquences importantes sur les transits sédimentaires. Bien que l'étude des pollutions elle-même sorte du cadre du présent projet, les effets négatifs qu'elles peuvent avoir sur l'évolution morphologique des littoraux ne peuvent pas être négligés.

II LE CAS DE CHYPRE

1. Présentation générale

Située à une vingtaine de milles nautiques seulement des côtes syriennes et libanaises, l'île de Chypre a une superficie de 9 300 km² et une population d'environ 630 000 habitants.

La frange côtière est également utilisée à Chypre de manière intensive. D'importantes concentrations industrielles et portuaires se sont développées à Limassol et Larnaca. Des complexes touristiques ont vu le jour en maints endroits de la côte sud de l'île pour répondre à la pression touristique très forte. Comme à Malte, ces activités s'exercent sans aucun support de données adéquates sur le milieu marin et lorsque des problèmes surgissent, les réponses apportées sont toujours très ponctuelles et sans vision globale des phénomènes.

Il est paradoxal de constater que, malgré l'intérêt que revêt pour un Etat tel que Chypre le domaine marin, celui-ci reste mal connu du point de vue physique. Les données concernant les paramètres hydrodynamiques, les processus sédimentaires ou les facteurs de l'érosion ne sont que peu ou pas étudiés, l'essentiel des études en milieu marin concernent les questions biologiques. Toutefois, parmi les travaux entrepris par le Département des pêches, il importe de remarquer un développement d'études sédimentologiques, bathymétriques et hydrographiques en liaison avec la nécessité reconnue de mieux connaître les paramètres pilotant la configuration, la nature et l'évolution des fonds marins au voisinage de la côte.

Les autorités chypriotes désirent développer un programme d'aménagement de la zone côtière allant de Paphos à l'ouest à Larnaca à l'est et prenant en compte nombre de données telles que l'érosion des côtes, les sites à protéger (archéologiques, touristiques, portuaires), l'évolution de certains secteurs originaux (tombolo de Limassol, lagune de Larnaca), les processus sédimentaires contrôlables, etc. La grande diversité des modèles littoraux du sud de Chypre autorise non seulement une intervention pluridisciplinaire, mais permet de dégager des références autorisant des extrapolations à d'autres régions de la zone orientale de la Méditerranée, voire d'autres régions. Un thème d'intervention du type "connaissance et aménagement de la zone côtière et du proche plateau continental" serait de nature à intéresser au plus haut point les interlocuteurs chypriotes et pourrait par ailleurs s'intégrer dans les thèmes retenus par la communauté scientifique européenne. En effet, sur le plan de la formation, des progrès doivent être réalisés pour donner aux spécialistes nationaux les connaissances élémentaires leur permettant de prendre en compte l'ensemble des phénomènes avec une vision générale et pluridisciplinaire. Pour l'instant, les géologues et ingénieurs chypriotes ne sont pas toujours très familiarisés avec les démarches et méthodes scientifiques indispensables pour l'aménagement et la protection de la frange littorale.

2. Les problèmes rencontrés sur le littoral de Chypre

Les problèmes rencontrés sur le littoral chypriote concernent ici encore principalement l'érosion des côtes. Le littoral est un domaine particulièrement sensible en raison de la pression du tourisme qui est d'un million de personnes par an. Le pays se trouve dans l'obligation de maintenir ou de créer des plages de sable sur le littoral sud de Chypre, de canaliser une urbanisation galopante et de préparer un schéma d'utilisation de l'espace littoral.

Certains secteurs de l'île sont particulièrement touchés par l'érosion, notamment les baies de Larnaca et de Limassol où la disparition de plages à galets menace les zones urbaines et donne une idée de l'importance du phénomène.

Il est indispensable de dégager un programme intégré d'aménagement et de gestion de la zone littorale méridionale de Chypre, de la baie de Larnaca à l'est jusqu'à Paphos à l'ouest. Le rapide développement industriel, urbain et touristique de cette côte, doit en effet prendre en compte l'ensemble des données fondamentales concernant la nature des terrains côtiers, les caractéristiques physiques, écologiques et économiques des sites concernés. Ce programme passe nécessairement par l'établissement d'un bilan de connaissances et par des interventions pluridisciplinaires de recherches en vue d'une bonne appréhension des évolutions naturelles ou provoquées de ces régions.

Les mesures prises jusqu'à maintenant pour protéger la côte ont été la construction d'ouvrages de défense, mais sans que des études précises quant à leur impact réel aient été faites. Des brise-lames ont par exemple été construits à l'est de Limassol pour protéger un important complexe touristique, mais malgré leur efficacité relative ils entraînent des processus d'érosion accrus au-delà de ce secteur.

On peut également dénoncer les prélèvements de sable et de gravier sur les plages ou la construction de barrages dans l'arrière pays, qui ont favorisé l'érosion de la côte.

Divers travaux doivent être menés dans ce domaine:

- étude des caractéristiques physiques de l'environnement sur la côte sud chypriote ;

- évolution ancienne et tendances évolutives de la zone littorale. A ce titre pourrait être entreprise une étude détaillée d'une zone urbanisée comme par exemple les baies de Larnaca et de Limassol ;

- étude du secteur compris entre Zygi et le cap Kiti qui est une zone sauvage en projet d'aménagement ; cette étude permettrait d'appliquer les connaissance de l'océanologie côtière à l'aménagement d'une zone littorale vierge en sauvegardant autant que possible les caractéristiques naturelles.

ANNEX II

LISTE DES PARTICIPANTS

I. Experts

Prof. Salvino BUSUTTIL (Président)
Malta Oceanographic Commission
Foundation for International Studies
University of Malta
St. Paul's Street
Valletta
MALTE
Tel: 233218
Tlx: 1673 Found HZ
Fax: 230551

Dr. Miquel CANALS
Departamento de Geologia Dinamica, Geofisica y paleontologia
Universidad de Barcelona
Nueli Universitari de Pedarlbes
08071 Barcelona
ESPAGNE
Tel: (34-3) 639 07 68
Fax: (34-3) 330 05 77

Dr. Georges CHRONIS
National Centre for Marine Research
Aghios Kosmas
16604 Hellinikon
GRECE
Tel: 9820214
Tlx: 863 22 41 35 NCMR GR
Fax: (01)9833095

Dr. Mahmoud EL SAYED
Department of Oceanography
Faculty of Science
University of Alexandria
Alexandria
EGYPTE
Tel: 49 22 918
Tlx: 54 467 UNIVY UN

Dr. Mauro FRIGNANI
Istituto di Geologia Marina
CNR
Via Zamboni 65
40127 Bologna
ITALIE
Tel: 51 244 004
Fax: (39) 51 24 31 17
Tlx: 51 13 50 CNR BO

Dr. Anton MICALLEF
Director
Euro-Mediterranean Centre for Marine Contamination Hazards
c/o Foundation for International Studies
St. Paul's Street, Valetta
MALTE
Tel: (356) 234221
Tlx: 1673 FOUND
Fax: (356) 230551

Dr. André MONACO
Laboratoire de Sédimentologie et Géochimie Marines
Université de Perpignan
Avenue de Villeneuve
66025 Perpignan
FRANCE
Tel: 68 66 62 84
Fax: 68 67 12 21

Dr. Andreas PANAYIOTOU
Ministry of Agriculture and Natural Resources
Geological Survey Department
Nicosia
CHYPRE
Tel: (357)(2) 30 22 58
Tlx: 4660 MINAGRI CY
Fax: (357)(2) 44 50 19

Dr. Ahsene SAADALI
Directeur des Infrastructures Maritimes
Ministère de l'Equipement
110, rue Didouche Mourad
Alger
ALGERIE

Dr. Moncef SLITI
16 Av. Habib Bourguiba
Rades
TUNISIE
Tel: (1) 483 969
Fax: (1) 792 115
et

Center JAM JOUM
P.O. Box 7012
Jeddah 21462
ARABIE SAOUDITE
Tel: 009662 6691133
Fax: 009662 6609788

Dr. Umit UNLUATA
Institute of Marine Sciences
Middle East Technical University
PK 28
Erdemli-Icel
TURQUIE
Tel: 90 7585 1842
Tlx: 821 67796 DMS TR

Prof. Michel VIGNEAUX
Président du Groupe Directeur du Programme OSNLR
COI-UNESCO
7, Place de Fontenoy
75700 Paris
Fax: 33-1-40569316
Tlx: 20446

II. Observateurs

M. Jean BOISSONNAS
Programme MAST
Commission des Communautés Européennes
200, rue de la Loi
B-1049 Bruxelles
BELGIQUE

Dr. Dalila AIT KACI
Département de Géologie
Université Houari Boumédienne
Institut des Sciences de la Terre
B.P. 9
Dar El Beida
Alger
ALGERIE
Tel: (02) 75.12.85, poste 451

Dr. Charles A. NITTROUER
Marine Science Research Center
State University of New York
Stony Brook
NY 11794-5000
USA
Fax: 516-632-8820

III. Secrétariat de la COI

Dr. Gualter SOARES
COI, Unesco
7, Place de Fontenoy
75700 Paris
Tél: (33-1) 45-68-39-91
Tlx: 204461
Fax: (33-1) 40-56-93-16
Tlm: IOC.Secrétariat

Dr. Claude LATOUCHE
Consultant,
Institut de Géologie du Bassin d'Aquitaine
Université de Bordeaux I
351, Cours de la Libération
33405 Talence Cedex
FRANCE
Tél: (56) 80-60-50
Fax: (56) 37-07-74

PART II

SUBMITTED PAPERS

SEDIMENTARY BUDGET DEFICIT OF CONTINENTAL SHELVES NATURAL AND/OR MAN-MADE CAUSES OF BEACH EROSION THE CASE OF THE PERINSULAR SHELF OF MALTA

ANNA SPITERI
Co-ordinator, R&D Sector
Malta Council for Science and Technology

Abstract

The small size and the lack of natural resources of the Maltese Islands makes the coastline, which is only 190 km long, a major focus of great economic importance. Decisions to develop new economic sectors on the coast, namely that of shipping and the tourist industry often prove conflicting, mainly because of lack of baseline information. An understanding of coastal processes especially of sedimentary dynamics which is essential to such decisions is not available. Phenomenae like beach erosion, which can prove detrimental to the tourist industry causes concern but has not yet been properly understood. A comprehensive overall scientific study is needed to allow for the optimum and rational use of the coast.

The origin and present profiles of various beaches are examined, but their evolution can only be explained through a study of a series of parameters which go beyond the present geographic zone under discussion. This paper attempts to present a regional scenario in which natural factors, like the geo- and hydrodynamics affecting the Maltese Islands can only be understood if studied in a wider Mediterranean context. When these are grasped it is then possible to proceed to study what type of effects urbanization has on the coast, especially on beach equilibrium. Aerial photographs, geological and survey maps, available literature and on-site investigations were employed to draw specific examples of some local sites.

INTRODUCTION

The Maltese Archipelago is a group of small islands situated in the central Mediterranean approximately 96 km from Sicily and 290 km from North Africa.

The islands are situated within the Malta-Hyblean Platform (Figure 1), that occupies the foreland margin of the African Plate, and covers some 17000 sq. km. most of which is today covered by shallow shelf-seas. (Pedley, 1990). The Islands lie on the Malta-Ragusa Rise which is part of the submarine ridge which extends from the Ragusa Peninsula of Sicily to the North African coasts of Libya.

The sea between the Islands and Sicily (the Sicilian Channel) reaches in places a maximum depth of 200 m but is mostly less than 90 m; the Malta Channel which is between the Islands and North Africa is much deeper, in places reaching more than 1000 m, for example, it reaches 1100 m in the Malta Basin, the NW trending Pantalleria graben, 15 km SW of Malta (Schembri, 1990).

The Islands have a collective area of 316 sq. km., and a shoreline of 190 km in length, with a submerged area (to 100 m from the shore) of 1940 sq. km. Due to the rocky nature of the shore, less than 40 percent of the shoreline is classified as accessible and only 2.5 percent is made up of sandy beaches.

It has been observed by various visiting experts that most of these beaches seem at present to be undergoing erosional processes, which if not checked would further limit the available beach space.

It has yet to be established whether, and to what extent beach erosion in the Maltese Islands is natural, ie., caused by natural phenomena and is cyclical, and whether and to what extent it is caused by human activities. Before this is ascertained, it is not possible to predict whether the suggested marine constructions, in the form of jetties, breakwaters, groynes, dykes, etc., are presently necessary to protect beaches from erosion to keep the equilibrium; and great care is needed to ensure that such measures will not in the long run behave adversely, ie., accelerate the erosion.

No baseline information on seasonal beach profiles, inshore currents, bathymetry, nearshore topography, or sedimentary dynamics in general exists for much of the Maltese coastline, nor of their interrelationships. No sedimentary budget deficit of any beach has yet been measured. Such information is essential before any beach replenishment development projects can be planned and implemented, to avoid unnecessary costs and possible negative impacts on the environment.

BEACH EROSION IN MALTA

The tourist industry and the local population impose high human pressure on the 2.5 percent of the coastline. This pressure leads to a rise in the demand for the building of more tourist facilities on many parts of the coast.

The hypothetical development of erosion of the Maltese beaches would seem to be linked to a group of factors which are:

- natural phenomena, such as climatic change, which is a known historical event and which has involved a natural reduction of the continental sediment supplies. Other factors such as tectonic movements, bay circulation patterns, sea level oscillations, etc., which may have contributed significantly to the erosion, but have as yet not been assessed, and indeed may prove that beach erosion is part of a cyclic natural pattern.

- human activities which have negative impacts on two levels.

The first is the normal urbanization process, in the form of roads, buildings, dams, etc., which causes the abrupt disruption of the occasional torrents which form at the time of the rainy season and which no longer can reach the beaches with sediment from the watercourses.

The second is the uncontrolled construction of works at the head of the beaches or on the beaches, walls for road supports, quays, swimming pools, etc., which allow an increase in the natural erosive effects of the waves and a modification of coastal circulation.

It has been observed that the only coves which still have a substantial volume of sand are those where there exists either no construction whatsoever or a little construction around them. Also many bays lined by a very urbanized coast and having building activities at the top of the beach such as quays, vertical walls for supporting road structures, etc., are said to be characterized by beaches reduced to only a few square metres.

Beaches free from any building amenities (Ramla Bay, Gozo) or where there is construction only on rocky areas but displaying no buildings at the back of the beach (Gnejna Bay, Golden Sands), seem to be balanced. Sandy areas having constructions at the back of the beach (St. Paul's Bay, Mellieha Bay are said to be in the process of erosion. Bays which are very urbanized and support constructions at the back of the beach, (Balluta Bay, St.George's Bay, Xlendi and Marsalforn in Gozo), seem to be affected by erosion processes.

Another reported natural factor that may be contributing to beach erosion is wind action. In some places sand is being swept inland and it has been observed, for example, at Little Armier, that the sand becomes part of the organic process whereby sand is converted into soil, and thus becomes irretrievable.

Erosion by wind can also be seen at Mellieha bay where the sand is blown over the road during easterly winds and into the sea during westerly winds.

Other factors that may have contributed considerably to beach erosion, besides proving detrimental to the environment in general are past development projects. The Risq il-Widien project of the 80's was one such project. The work involved mainly the widening of valley watercourses and the erection of dams across valleys. What actually resulted was accelerated soil erosion, rapid silting up of the watercourses and the catchments areas behind the dams, and therefore also loss of sediment transport to the sandy beaches (Schembri, 1990).

So far no quantitative project has been carried out to measure the extent of beach erosion on the Maltese Islands. When this takes place it is important to study the Islands in a broad Mediterranean context. The study of the geo-, and hydro-dynamics of the Mediterranean is essential to the understanding of the coastal processes of the Maltese Islands; as are the effects of trends in urban development on the Mediterranean coast.

GEOLOGY, TECTONICS, AND GEOMORPHOLOGY

GEODYNAMICS OF THE MEDITERRANEAN

The Mediterranean Sea consists of a series of deep sedimentary basins stretching some 4000 km between Gibraltar and the Black Sea. Together with the Alpine mountain chains with which they are closely associated, these basins occupy the junction between the African-Arabian and the Eurasian continents in a zone marked by earthquakes and volcanic eruptions.

The present narrowness of the Mediterranean, where the continental margins join (according to Biju-Duval et al., 1976, only 10 percent of the surface of the Mediterranean basins is situated more than 100 km away from the continental shelves), has provoked a geologically rapid sedimentary aggradation of the basins at a sedimentation rate of around 0.3 mm/year for the last 5 million years. The result is that the crust is buried under ca. 10 km of sediment or more, and that the great deltas (Nile, Po, Rhone, Ebro) continue far undersea.

Owing to the weight of the sediment, the basins in the Western Mediterranean have subsided at least 7 km, and in the Eastern Mediterranean, 6 to 15 km. This movement implies a progressive migration of the flexure of the continental margins towards a subsidence of the coast, overlaying in places the tectonic uplift movements caused by collision or subduction phenomena (Pirazzoli, 1987).

The effect that the above has had on the evolution of coasts, in the form of emergent and submergent movements of the Maltese Islands have not yet been studied. But it can safely be deduced that such movements did and still do have a direct bearing on the past, present and future beach profiles.

TECTONICS

Many parts of the Mediterranean are tectonically active, characterized by earthquakes and volcanic eruptions in the junction between the African-Arabian and Eurasian continents. For thousands of years, vertical earth movements in the Mediterranean have averaged one to five millimetres per year; when looked at more closely - over periods of 15 or 20 years - the range increases from 3 to 20 mm per year.

An especially strong tectonic influence on the structure of coasts is found in the northern and eastern Mediterranean, from Italy to Egypt. For example, in 1908, an earthquake at Messina, Italy, increased the relative sea level by 57 cm, which may have affected the sea-level of the Maltese Islands at the time.

The water balance is made necessarily fragile by these diverse tectonic forces; the Mediterranean is connected with the Atlantic Ocean and the Black Sea by only shallow, narrow straits which are affected by tectonic deformations. If, for instance, the Strait of Gibraltar closed up, as the present water budget shows a loss, the Mediterranean would dry in the space of 3000 years with a probable drop in the sea level of some thousand metres. This phenomenon is certainly not new: it occurred during the Messinian (between 9 and 6 million years ago) when evaporite layers were deposited on the bottom of the basins. The sea-level rise which followed in the Pliocene, as soon as the strait reopened, was also some thousand metres high. (The Pliocene period is missing in Malta, which means the islands emerged with the drastic drop of the sea-level; the sea-level rise that followed accounts for some of the Quaternary deposits that are found in some places which implies that the islands were in some areas completely covered with water).

In the Quaternary the Strait of Gibraltar seems to have remained permanently open, although the gap has been gradually shoaling since the early Pliocene (Hsu, 1974), and therefore the Mediterranean was affected by the glacio-eustatic variations of the Atlantic Ocean. The Black Sea, on the other hand, was linked to the Mediterranean only during the main Interglacial periods (Stanley and Blanpied, 1980).

GEOLOGY OF MALTA

An understanding of the geology of Malta (Figure 2) is of importance to the study of beach erosion since it has a direct correlation with the geomorphology, morphology and profiles of the beaches. (The sands of all the beaches are of a calcerous nature reflecting the calcium carbonate composition of the Islands).

The islands are almost entirely made up of marine tertiary sedimentary rocks deposited during the Oligo-Miocene eras, in horizontal layers. Also present are some minor Quaternary terrastrial deposits dating from the Pleistocene.

The original horizontal layout of the strata was broken up by faulting caused by earth movements that were probably initiated in the Pleistocene period and continue to the present. The whole block of islands is tilted eastwards, raising the cliffs on the west to about 244 metres and drowning the valleys on the eastern and south-eastern side. The dominant structural feature on the islands is a series of normal faults striking east to west. In the northern part, between the faults, are upthrown and downthrown blocks, that form horsts and graben respectively.

Five different formations are present and these are in order of sequence from the surface and also in order of increasing age:

Upper Coralline Limestone
Greensands
Blue Clay
Globigerina Limestone
Lower Coralline Limestone

The Upper Coralline Limestone varies considerably in thickness, and being the topmost bed, it has undergone severe erosion. On the plateaux and ridges the preserved thickness averages less than 30 metres, but in the graben, it is nearly 65 metres.

The Greensand occurs as two varieties, a green glauconite marl, and a rust coloured, sandy-textured limestone. The marl thickness ranges from 0.5 metres to 1.5 metres, with a 0.7 metres average; the sandy limestone, which is discontinuous and lenticular in form, has a maximum thickness of 13 metres at Dingli and 18 metres on Gozo.

The Blue Clay is composed of blue-grey,-green and marly clays. Its thickness varies from 80 metres, with an average of 30 metres. The Blue clay increases in thickness from east to west on Malta, varying from 0 to over 65 metres. In Gozo it is generally thicker than in Malta rising to 80 metres.

(Beaches with clayey outcrops in the immediate hinterland, such as at Gnejna Bay, where it slumps out in the form of ca. 45° taluses over the underlying rock, contribute to a type of clayey beach sand with a high cementation factor, which in turn contributes towards the stability of the beach).

The Globigerina Limestone varies from white and marly to a very soft-textured yellowish colour. The average thickness of the rock is about 75 metres. This rock nearly makes up for 70% of most of the surface of Malta and Gozo. The Globigerina Limestone makes for very smooth coastal shores with very little irregularities.

Lower Coralline Limestone is like the Upper Coralline Limestone, semi-crystalline but rather harder. The thickness above sea level averages about 120 metres. It is generally found exposed on cliff sides facing the sea, in the south , southwest and west coasts, rising from the sea to heights of about 70 to 130 metres, such as at Fomm ir-Rih, in Malta, and at Sannat in Gozo.

The above distinct formations allow for the easy identification of the source of the coastal sediments that are transported to the bays.

GEOMORPHOLOGY OF THE BEACHES

Coastal sediment is supplied from various sources such as by rivers or streams, waves, wind and organisms, and it undergoes various geomorphological processes when deposited.

Most of the sediment on coasts was transported there by rivers from the eroding landscape. Direct wave erosion accounts for only perhaps 10 percent of the material moving along coasts. Wind blows sand and dust into coastal water downwind, but the mass contributed by the wind is very small. Waves bring sediment onshore from deeper water, but most of this sediment was previously carried by rivers. (This will be discussed in more detail below).

The grain size and chemical composition of sediment brought to coasts by rivers are primarily determined by the nature of the bedrock over which the rivers have flowed. In Malta these distances are very small and in many instances the most active part of the erosion processes takes place at the immediate hinterland of the bay. In many cases this is the steepest gradient of the valley leading to the beach. The sand deposited on beaches is generally of a sub-angular to angular shape, which signifies that the time of transport was slight, and that it has been submitted to energy of small value. (This requires further study). An analysis of sand taken from beaches above the water shows that two colours of sand have been identified: ochre and grey, which verify that they are derived directly from the parent rocks of the immediate hinterland. Hence Golden Bay has a reddish colour which reflects the colour of the Upper Coralline Limestone outcropping on to the bay.

Wave erosion of sea cliffs initially produces poorly sorted sediment. As the waves cut away the foot of a cliff, landslides bring down great masses of unsorted, broken rock to the shore. This is happening to the headlands at Ras il-Wahx, Il-Karraba and Ras il-Pellegrin, on the North-west coast of Malta. However, waves and nearshore currents are particularly efficient at sorting sediment by size and specific gravity. Along the beaches that are enclosed by the above headlands, it can be observed that beach sand or gravel becomes finer in size, more rounded, and better sorted according to the direction it has travelled. For example at Ghajn Tuffieha bay the prevailing northwesterly currents hit the headland, "Il-Karraba", move in a circular motion first depositing the broken rock, and eventually shingle, along the south part of the beach, and then pushing the finer sediment to the north, which is the most sheltered part of the beach.

Sandy beaches are usually in a dynamic equilibrium state as long as the governing conditions do not change permanently. This means that such beaches do remain stable, in a broader sense, but that temporary changes may be caused by gales, for instance. In locations with strong seasonal characteristics this can clearly be seen: the beaches in north-west Europe show a winter profile and a summer profile, but will generally not vary beyond those. Although in Malta such drastic profile differences do not usually occur, it has been observed several times, for example, at Mellieha Bay, that during a severe storm the whole beach disappears under water, and it is assumed that sand is carried out and then brought in again by inshore currents during a quiet period.

(Comparing the development of sandy beaches on aerial photographs of 1967 to those of 1988, it is not obvious which bays have undergone erosion, or accretion, and which have not, with the notable exception of Balluta Bay; and which have altered profile, in length, width and thickness. Drawing conclusions when comparing an aerial photograph of a specific year, day and time to another specific year, day and time twenty years later may prove misleading if such phenomena as changing profiles are not accounted for).

Other processes happening on some coasts are those generated by organisms. In many instances organisms provide most or all of the sediment supply. Although this may not be the case on the Maltese Islands, biological activity on the coast does take place. Biological action may remove material from within the rock by boring and excavation. A wide variety of organisms are involved, including molluscs, algae, and echinoderms, (all present on the Maltese shores), and both feeding, i.e. boring, and protection strategies are involved. As yet no detailed studies of bioerosion in Malta have been undertaken.

NEARSHORE TOPOGRAPHY

Studies of beaches are not just restricted to the exposed beach face. It seems highly probable that the nearshore submerged topography and the beach face are related dynamically and, if so, the total zone under wave activity should be considered in questions concerning 'beach equilibrium' and 'sediment budget'. Sediment transfer within the zone of wave-induced motion on low angle sandy coasts is, frequently, intimately related to the initiation, growth and migration of large-scale bedforms, known under the general term of subaqueous bars. (The sand bar at Mellieha Bay is built up by the backwash of the waves and it never emerges above the water level).

Spits, on the other hand, differ from offshore bars in that they spring from the coast and are supplied with material mainly by longshore drift and not from the sea floor. Broadly speaking there are two main types: those which diverge from the coast at a marked angle and those which run approximately parallel to the trend of the coast.

The orientation of coastal features such as bars and spits is largely governed by dominant wind and wave directions.

It is evident that sediment circulation patterns, rates of sediment movement, and the resulting dynamic equilibrium of the beach, are strongly dependent on the morphology and dynamic nature of the bed topography.

No bathymetric chart of the whole periphery of the nearshore of the Maltese Islands is at present in existence. Those that exist, mainly around the harbour area, dating back to the 50's, are now outdated.

CLIMATIC VARIATIONS AND SEA-LEVEL OSCILLATIONS

CLIMATIC CHANGES

The Maltese Islands emerged only at the end of the Tertiary, i.e. during the Pliocene. This makes only the recent geological period, the Quaternary, of interest for the study of climatic change.

The glacial periods that occurred during the Quaternary did not extend south to the Maltese Islands, but the Pluvial periods are the cause of the transportation of sediment that was initially deposited on the present beaches.

During the pluvial period of the Quaternary, (the Pleistocene and which must have continued in the Holocene), the watercourses of the Maltese valleys, which are all presently situated at the downstream point of valleys, were continuously supplying the beaches with sediments. This implies great volumes of sand deposited on the beaches by runoff. (The sediments found at the bottom of Marsaxlokk Bay, recently dredged by the Malta Freeport Project, have been identified as dating from the Holocene, confirming this idea). The glacio-eustatic variations mentioned earlier (together with other factors), must have checked the continuity of this geomorphological process and may account for the reason why no large accumulated beaches are presently found on the islands.

The climatic change that occurred later reduced the amount of rainfall and today, watercourses are only drained occasionally by sediment carrying torrents during the rainy season.

SEA-LEVEL OSCILLATIONS

The causes of sea-level changes are mainly due to climatic changes and tectonic movements as mentioned earlier. In Malta, changes in sea level, caused by tectonic movements, have submerged the mouth of some valleys where they extended to the coast, giving rise to headlands, creeks and bays. Prime example being the wide Pwales valley at Xemxija Bay, the valley is also a graben between the two horsts, the Bajda and Wardija ridges.

No surveys as yet have been done about former sea levels round the coasts of the Maltese Islands but many have been identified along other Mediterranean coasts.

MEAN SEA LEVEL

The mean sea surface topography of the Mediterranean Sea, deduced from data from the SEASAT satellite, shows the presence of differences in elevation as high as 50 m between a low situated in the Eastern Mediterranean and a high in the Gulf of Lions (Barlier et al., 1983). The accuracy of this representation of the surface topography has been estimated to be better than 0.5 m on a global scale.

In the Western Mediterranean there is a generally increasing slope of 3 to 7 m of the sea surface between North Africa and Europe. The difference in elevation reaches ca. 20 m between Libya and the Gulf of Genoa and more than 15 m between the Ionian Sea and the North Adriatic. Steep slopes appear near southern Italy.

In the Eastern Mediterranean, the most striking feature, however, is the marked depression in the Eastern Mediterranean, around the Hellenic arc, which marks the Ionian Trench, where subduction is active west of Crete, and stretches as it deepens around the transform faults of Pliny and Strabo. The slope of the mean sea surface topography is particularly abrupt between this depression and the neighbouring Aegean Sea, which obviously constitutes a gravimetric sill between the Eastern Mediterranean and the Black Sea.

HYDRODYNAMIC FACTORS

GENERAL OCEANIC CIRCULATION

The Mediterranean Sea has two main basins, separated by a submarine ridge between Sicily and Africa, (on which the Maltese Islands stand). Each has its own separate counterclockwise current. There are three principal water layers: a surface layer of variable thickness, an intermediate layer of warm, saline water from the eastern Mediterranean, and a homogeneous deep layer reaching the bottom.

The North-West current that traverses from the west to the East of the Mediterranean is also the predominant current that influences the longshore drifting of the Maltese Islands. (This current seems to fall into and follow the path of the Pantalleria rift). (See Figure 3).

WAVES, SWELL AND TIDES

There are many types of waves and they all play different roles in shaping coastal landscapes by direct wave action and transport of sediment.

Swell, which is the regular pattern of smooth, rounded waves that characterizes the surface of the ocean during fair weather is usually composed of several wave trains of different wave lengths. These are often moving outward from more than one generating area. The direction of swell is not always easy to distinguish especially when it enters local wind fields. The visual observations that were carried out at Delimara point, at the entrance of Marsaxlokk Port over a period of 9 years, 1979-1987 conclude that the main swell direction is "southerly". From the data recorded, it is doubtful though whether the observer distinguished between the direction of the "sea" and that of the swell.

As deep-water swell approaches a coast, the form of the waves change. As the water depth decreases, the orbital motion beneath the waves is distorted from a circle to an ellipse, then to a to-and-fro linear motion, changing the wave period. This was recorded by the Malta Free Port during observations made at Pretty Bay, Birzebbugia, on February 17, 1988. A long period swell was measured, (T - time being approximately 10 seconds), whilst the wave pattern recorded at the harbour entrance, had a much shorter mean period.

Sediment in the nearshore zone is also moved along the coast by longshore currents generated by waves, winds, and tides. Most of the sediment is moved in the surf zone, (littoral drifting). A smaller amount of sediment is moved by the oblique wash of waves on beaches when the waves are approaching the shore at an angle. (The linear beach at L-Imgiebah, on the north-west coast of Malta may be the result of longshore drifting).

The extent of the work of waves on a beach are also determined by the tidal range. This range is very limited in the Mediterranean and any intertidal notch formed has therefore a correspondingly limited vertical development. The tidal fluctuation around the Maltese Islands is around half a metre.

WINDS

The prevailing winds in Malta, especially during the winter months are the westerlies, the most common being the North Westerly wind, which blows on average one in three days of the year. This wind follows the North-Westerly current mentioned earlier. The North East Wind blows at the time of the equinoxes in March and September. It is a strong wind that can effectively cause erosion because of its long duration each time it blows. The winds over the Malta Islands vary considerably from year to year.

On a regional scale winds also affect sea level and are very important in generating vertical convection and deep water formation.

URBAN DEVELOPMENT ON THE COAST

ECONOMIC DEVELOPMENT

An understanding of the "natural" components discussed above on a regional scale will always serve as a necessary background scenario to any urban coastal development plan that has to do with the Maltese Islands. And for the same reasons, knowledge of the pattern of tourist trends and urban coastal development of some of the Mediterranean countries may also prove useful when it comes to the Maltese Islands.

The Mediterranean coastline is approximately 46,000 km long, 40 percent of which is accounted for by islands. Slightly more than half is rocky, the rest made up of low, sedimentary shores. These beaches have been subjected to the strongest human pressure. It has been said that beach erosion in the Mediterranean is in many cases directly attributed to human activities.

It was estimated that 51 million foreigners and 45 million nationals spent their holidays in the Mediterranean coastal regions in 1984.

The Maltese Islands also have a fair share of the Mediterranean international tourist market and since the islands were opened to tourism in the 1950's, the tourist industry has steadily grown. In 1980 almost 730,000 arrivals were recorded, in 1989 the figure reached more than 900,000.

Impact of tourism on land resources in the Mediterranean has been studied on the basis of accommodation capacity and the number of guest-nights, bearing in mind that tourism uses both accommodation facilities and amenities for sport, cultural, or recreational activities. The table below provides an estimate of tourist accommodation capacity and corresponding site coverage for all the Mediterranean countries in 1984. Altogether, about 2200 sq. km. were used by specifically tourist accommodation in the countries of the Mediterranean basin. If this surface area is doubled to take account of urbanization regulations and necessary infrastructure (such as service roads etc.), total site coverage amounts to about 4400 sq. km.

Urban development of the Maltese Islands has been steadily increasing during the past 30 years. Land area occupied by buildings increased from 5 % in 1957, to 16 % in 1983. The development connected with the tourist industry has particularly mushroomed in the coastal areas.

An accompanying factor of this intense development was increased road construction. For example, the 893 km of roads existing in 1957 became 1482 km in 1987, a 66 % increase (Schembri 1990).

Urban development usually denotes progress but as discussed earlier, it can also result in negative impacts on the coast, one of these being beach erosion. To prevent this from happening, intelligent infrastructural coastal planning is imperative.

PREVENTION OF COASTAL EROSION AND REPLENISHMENT OF BEACHES

INFRASTRUCTURAL PLANNING

Infrastructural planning of the coast can only begin after, first a thorough knowledge of all that is involved in natural coastal processes is studied and understood; and second, the impact that urban development can cause on these processes. Especially in disturbing the sedimentary dynamics and in causing beach erosion.

Although the sedimentary budget of Balluta Bay has never been measured, the aerial photograph of 1967 does show a few square metres of sand in the south corner, which was probably fed by a former valley which is now a road. The present bay has very little sand present, and the high wall erected to support the road, plus the building of the swimming pool, leaves no doubt that in this case urban development was the direct cause of erosion. As other past experiments have demonstrated, trying to dump sand in this bay to again create a beach, as has been suggested, would be futile because the same urban negative factors will again apply.

Another experiment was that carried out in St. George's Bay (St. Julians) in 1980, when imported sand was used to replenish the beach. One year later, all the additional sand had been swept away because of lack of careful planning. During the rainy season, the existing rainwater runoff culvert, allows strong torrents of water from the road to descend upon the beach, washing all the sand into the sea. This culvert will require re-routing towards another part of the bay before and if any decision is taken to replenish the beach. (A Unit Hydrograph of the area, drawn up by a hydrologist, will be useful to plan re-routing).

The same fate, but for different reasons, may befall the present dumping of sand at Wied Buni, at Birzebugia. The dumped sand may find itself back where it was originally dredged from, i.e. the entrance of Marsaxlokk harbour, because of the bay circulation patterns.

The construction of roads at the back of a beach have many times been blamed for causing beach erosion, because of halting the supply of sand from the watercourses to the beach. This may be true in some cases but some examples show that this factor is overruled if the gradient of the hinterland is high enough to traverse the stretch of asphalt road between the source and the beach.

The Pwales bay is a drowned valley, the water is shallow quite far out in the bay. The track road on the north side of the Pwales bay, allows the only source of sediment from the valley to reach the bay. This must happen in winter when the velocity of the water downstream crosses the coast road and deposits a certain amount of sediment on the beach.

Run-off from Wied Qoton still must supply sediment to Pretty Bay during storms. In the case of this Bay, the jetty erected at the other end of the bay has offered some protection to the bay, especially since the shape of the beach in the bay denotes that there is a inshore circular current. Without the jetty the sand would have been swept away. This proves at first glance, that the construction of the jetty proved beneficial.

Gnejna Bay is fed by two valleys bypassing a knoll to reach the beach. Even though one is a road, the steep gradient enables the sediment that accumulates from the sides of the valley to reach the beach and replenish it. (When comparing aerial photographs of '67 and '88 the bay shows no sign of having been eroded).

The behavior of the above examples of dredging, road and jetty constructions may already serve as important case studies to allow better future planning.

The existing Government regulations such as the Building Permits (temporary Provisions) Act 1988, which is the legal instrument which allows such interim protection / or town planning, should consider building and road construction near the beach with special attention. It should also consider innovative ideas, e.g. the construction of an elevated road near a sandy beach that would allow run-off of sediment from watercourses to reach the beach.

The sand (preservation) Act, 1949 (Act XVI of 1949), is another regulation that should be enforced. This act prevents the removal of sand and shingle from any beach, seashore or any other place without specific permission. It has been reported that contractors are taking sand from Ramla Bay, Gozo for building purposes, without permission.

CONCLUSION

The Maltese Islands face major conflicting interests when it comes to making a rational use of the coastal zone. Projects implemented in one area may inadvertently affect another adjacent coastal area. For example, one area designated for industrial use may have an adverse affect on an adjoining area which has been earmarked for touristic development. Moreover, both decisions may also produce dire consequences to the equilibria of the many facets of the marine environment, one of these being beach stability.

To ensure rational use of the coastal zone and protect beaches from man-made erosion, it is necessary for the country to undertake a specific project that will deal exclusively with the coast and erosion. One of the prerequisites of this project would be, to have an adequate number of scientists and engineers in various fields, especially in oceanography, marine geology, geomorphology, hydrology, urban geography, climatology, meteorology and coastal engineering. It is furthermore imperative to set up a Marine Centre that would have as one of its tasks, continuous monitoring of the sedimentary budgets and beach profiles of selected beaches of prime importance.

Thus, equipped with the professional human and physical resources the coastal zone and the dynamics involved would be better understood and hence better managed.

REFERENCES

Ananth P.N., and Sundar V. 1988. Sediment budget for Paradio Port, India.
Ocean and Shoreline Management 13 (1990), pp. 69-81.

Anderson E.W., and Schembri P.W. 1989. Coastal zone survey of the Maltese Islands report.
Planning Services Division, Works Department, Government of Malta, pp. xii + 121.

Barlier F., Bernard J., Bouiri O., and Exertier P. (1983). The geoid of the Mediterranean Sea deducted from SEASAT data.
Proc. 2nd Intern. Symp. Geoid in Europe and Mediterranean area (Rome 1982).

Barthe X. (1989). Report assignment in Malta, pp.12 (Internal document).

Bloom A.L. (1975). The surface of the earth.
Foundations of Earth Science Series, Open University setbook, Prentice Hall International, Inc. London, pp.152.

Charlier R.H., and Vigneaux M. 1985, Study of management and economic conflicts in the coastal zone (Part I).
International Journal of Environmental Studies, 1986, Vol.26. pp. 177-189.

Eicher D.L. 1975. Geologic Time.
Foundations of Earth Science Series, Open University setbook, Prentice Hall International, Inc. London, pp.150.

Garland, G.G. 1989. Sand mass density and borrow material compatibility for beach nourishment.
Ocean and Shoreline Management 13, 1990, pp. 89-98.

Grenon M., and Batisse M. 1989. Futures for the Mediterranean Basin, the Blue Plan. Oxford University Press, p.279.

Gribbin J. (Ed.), 1978. Climatic change.
Cambridge University Press, p.280.

Hails J. and Carr A. (Eds.) 1975. Nearshore sediment dynamics and sedimentation. John Wiley & Sons, p.316.

Holmes A. and D.L. 1978. Principles of physical geology.
Thomas Nelson and Sons Ltd. p.730.

Hyde H.P.T. 1955. Geology of the Maltese Islands.
Lux Press, Malta. p. 135.

Lisitzin E. (1974) Sea-level changes.
Elsevier Oceanography Series 8, Amsterdam: Elsevier.

Pedley H.M. 1978. A new lithostratigraphical and palaeo-environmental interpretation for the coralline limestone formations (Miocene) of the Maltese Islands.
Overseas Geology and Mineral Resources, No.54, p.17.

Pugh D.T. 1984. Tides, surges and mean sea-level.

Quelennec R.E. 1987. A coastal erosion in West and Central Africa: an outlook on natural and man-made causes and consequences for the protection and management of coastal areas.
Nature and Resources, Vol. XXIII, No.3/4, July-December 1987, pp. 2-9.

Ransley N. A geography of the Maltese Islands.
St. Aloysius College Publication, Hamrun, Malta, p.60.

Rizos C. 1983. Plate tectonics in the Mediterranean area and implications for the long term stability of the geoid.
Proc. 2nd Intern. Symp. Geoid in Europe and the Mediterranean area. Rome, 1982.

Schembri P. 1990. The Maltese coastal environment and its protection. La protezione dell'ambiente mediterraneo ed il piano della Commissione delle Comunita Europea,
Quaderno N. 43 pp.107-112.

Schembri P. 1990. Malta structure plan sub study 5: Conservation, preservation and natural resources - report of survey.
Malta University Services and Department of Biology, University of Malta, pp.105 (draft version).

Sparks B.W. 1972. Geomorphology. Geographies for advanced study.
Longman Group Ltd., p.530.

Trudgill S. 1985. Limestone Geomorphology.
Geomorphology texts 8, Longman Group Ltd. p.196.

Pirazzoli P.A. 1987 Sea-level changes in the Mediterranean.
Sea-level changes pp.152-181 (Ed. Tooley J. and Shennan I).

Vigneaux M. 1989. Action programme on the Maltese seashore.
Maltese Report, p. 15. (Internal document).

Wong P.P. 1989. The geomorphological basis of beach resort sites - some Malaysian examples.
Ocean and Shoreline Management 13, 1990, pp.127-147.

--- 1988. Wave penetration into Marsaxlokk Bay.
By order of Malta Freeport (internal document).

--- 1989. Connaissance et gestion de la frange littorale et du proche plateau continental, cours intensif européenne (Bordeaux, France, 15-28 septembre 1985). Réseau de coopération scientifique et technique AESTM.
Conseil de l'Europe, Strasbourg 1989.

--- 1989. High and Dry, Mediterranean Climate in the Twenty-first Century.
UNEP, p. 48.

--- 1990. Soil investigation for dredging project, Marsaxlokk Bay.
By order of Malta Freeport (internal document).

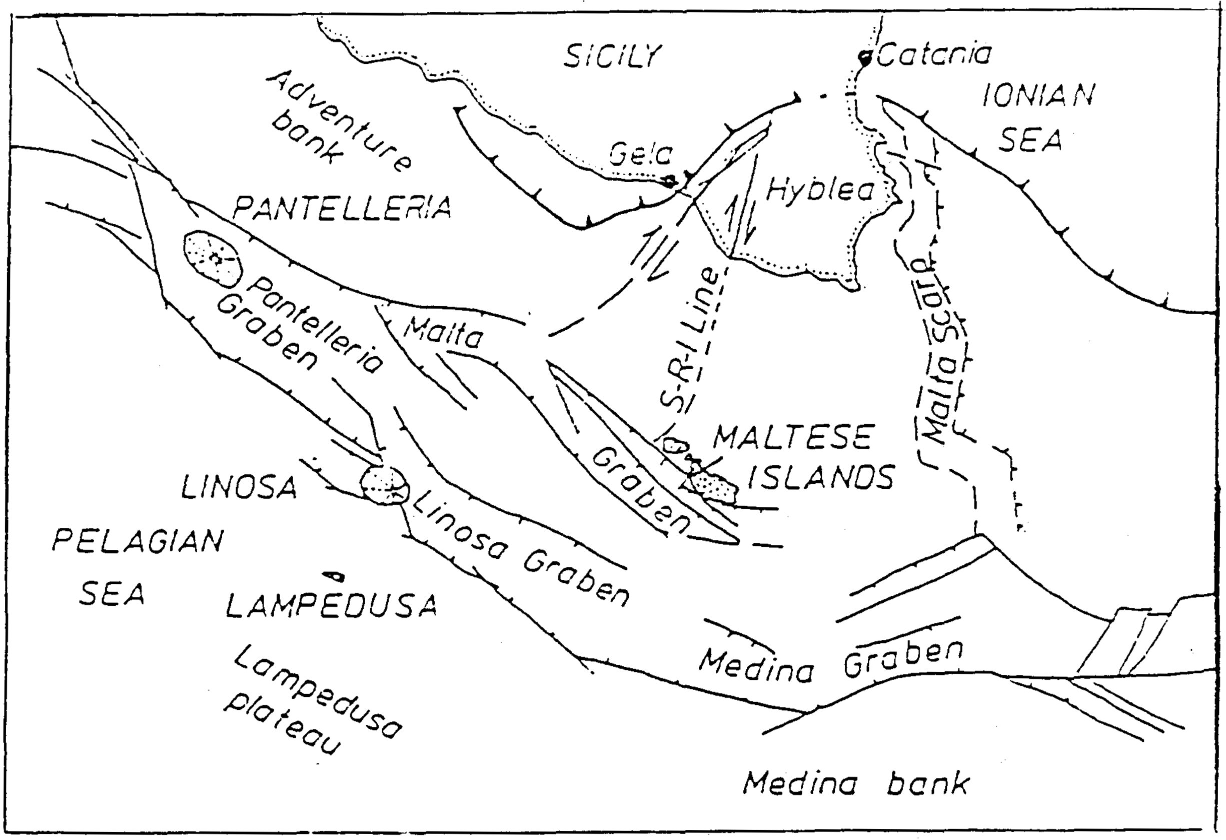


Fig. 1 Main structural elements of Malta/Hyblean Platform (Pedley, 1990)

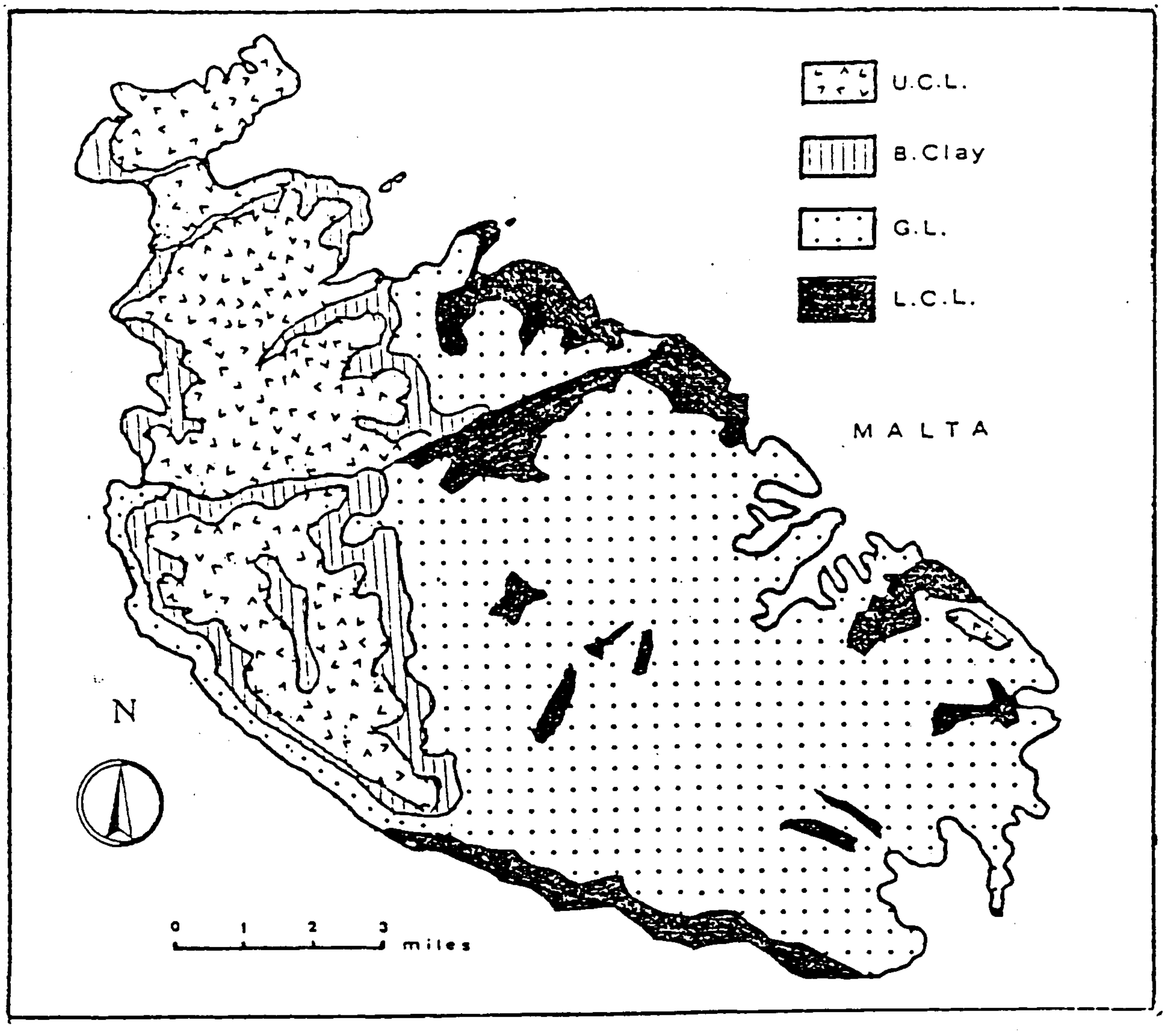
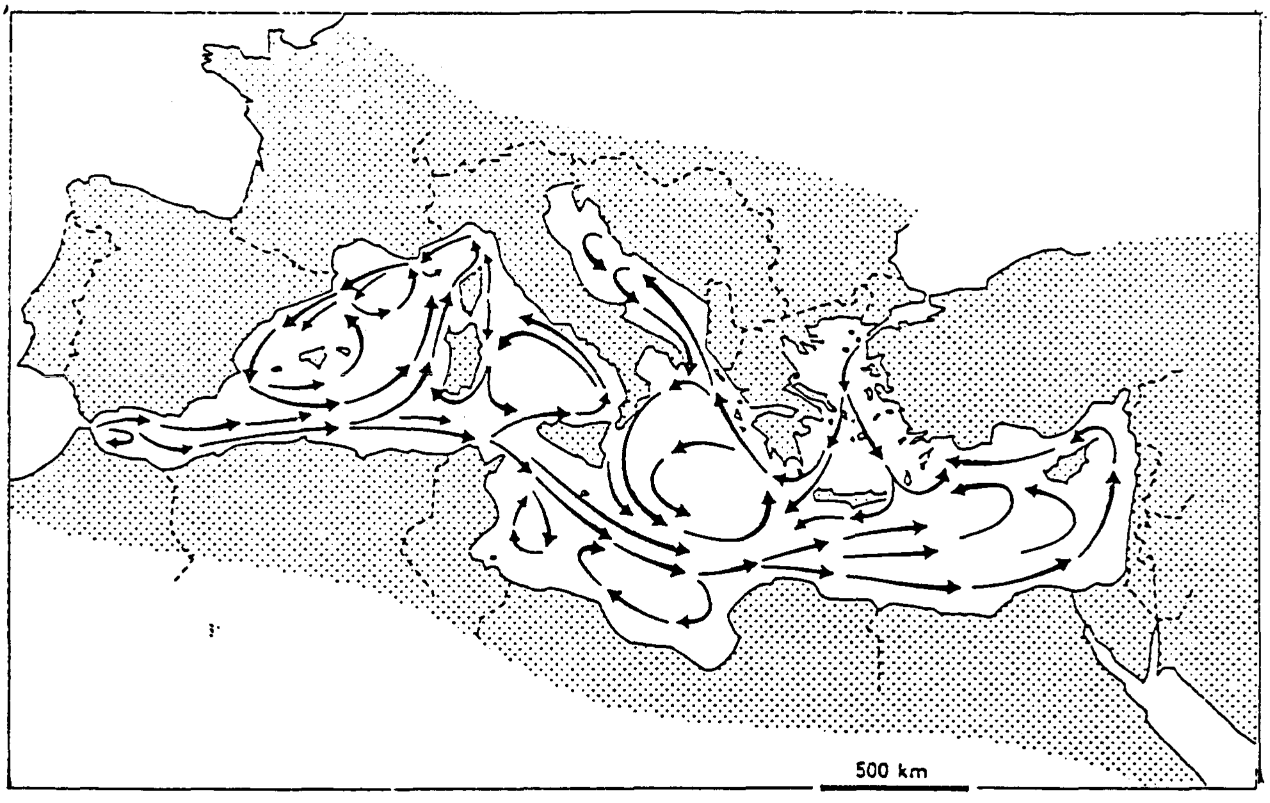


Fig. 2 Map of geology



General trends of surface currents in summer. The flow of water in and out through the Strait of Gibraltar is highly complex. Water of lower salinity from the Atlantic enters on the surface, while an almost equivalent amount of Mediterranean water leaves at depth. It is, however, the relatively small difference between the two amounts which provides the major contribution for balancing evaporation and maintaining the level of the Mediterranean.

Source: adapted from H. Lacombe and P. Tchernia (1974).

Fig. 3 From The Blue Plan 1989

Capacity and site coverage of hotels and other lodgings, 1984

	No. of hotel beds (000s)	Site coverage (1,000 m²)	No of other beds (000s)	Site coverage (1,000 m²)
Spain	840	33.600	8.923	624.610
France	1,590	63,600	10,894	762.580
Italy	1,598	63.920	5.854	409.780
Malta	14	560	41	2.870
Yugoslavia	319	12,760	1,127	78.890
Greece	323	12,920	324	22.680
Turkey	68	2.720	182	12.740
Cyprus	27	1.080	137	9.590
Syria	23	920	71	4.970
Israel	65	2.600	162	11.340
Egypt	48	1.920	218	15.260
Libya	9	360	24	1.680
Tunisia	72	2.880	77	5.390
Algeria	27	1,080	37	2.590
Morocco	59	2.360	152	10.640
TOTAL	5,082	203.280	28.223	1,975.610

Note: The different types of tourist lodging (hotel and other, including related areas) occupy an average surface of 25-100 m² per bed:

rented, self-catering accommodation	50 m² per bed
hotels	30 m² per bed
youth hostels	30 m² per bed
holiday villages	100 m² per bed
camping and caravan sites	50 m² per place
car-parks	20 m² per place

The average reached is 40 m² per bed for hotel accommodation and 70 m² per bed for other accommodation.

Table 1 From The Blue Plan 1989