WOODS HOLE OCEANOGRAPHIC INSTITUTION
Woods Hole, Massachusetts

REFERENCE NO. 70-5

THICKNESS OF UNCONSOLIDATED SEDIMENTS IN THE EASTERN MEDITERRANEAN SEA

by

How-Kin Wong and
Edward F. K. Zarudzki

February 1970

TECHNICAL REPORT

Submitted to the Office of Naval Research under contract Nonr-4029(00); NR 260-101, and partially supported by National Science Foundation Grants GP-2370 and GA-283.

Approved for Distribution [signature]
J. R. Heirtzler, Chairman
Department of Geology and Geophysics

HOW-KIN WONG
EDWARD F. K. ZARUDZKI
Woods Hole Oceanographic Institution, Woods Hole, Massachusetts 02543

Thickness of Unconsolidated Sediments in the Eastern Mediterranean Sea

ABSTRACT

The unconsolidated sedimentary layer in the eastern Mediterranean Sea becomes more variable in thickness toward the east. The distribution pattern suggests that the primary sources of sediment in Cenozoic times have been the Nile River, elevated areas of Cyrenaica, the Taurus, and the Apennines.

INTRODUCTION

During cruises 43 (1963) and 61 (1966) of the *R/V Chain*, a series of continuous reflection profiles were made in the eastern Mediterranean Sea (Fig. 1). From an analysis of these profiles, we are able to show the distribution pattern of the upper, unconsolidated, sedimentary layer.

Many investigators have divided the sediments of the Mediterranean Sea into two distinct units, one consisting of unconsolidated sediments, and the other of consolidated or lithified sediments (Gaskell and Swallow, 1953; Gaskell and others, 1958; Ewing and Ewing, 1959; Moskalenko, 1965). The boundary between these units is observed as a distinct reflecting horizon throughout most of our continuous seismic profiles, as illustrated in Plate 1*. In the Levant Sea, this horizon can be correlated with the top of the 4.3 to 4.7-km/s layer of consolidated deposits, to which a Cretaceous age has been ascribed (Moskalenko, 1966). By measuring the travel time required for the seismic waves to traverse the sedimentary strata above this reflector and by assuming a compressional wave velocity of 2 km/s (*following* Gaskell and others, 1958; and Ryan and others, 1965), the thickness of unconsolidated sediments can be calculated. The velocity assumed may be a little high for the topmost sedimentary layer; its over-all effect would be to increase the computed layer thickness slightly. The distribution chart of Figure 2, in addition to the measurements just described, also includes published data from 24 seismic reflection and refraction stations and 2 oblique reflection profiles (Gaskell and Swallow, 1953; Ewing and Ewing, 1959; Kovylin, 1964; Yelnikov, 1966; Moskalenko, 1966).

ACKNOWLEDGMENTS

The authors are greatly indebted to F. W. McCoy for compiling the data on sedimentation rates in the eastern Mediterranean, and to R. H. Meade and E. T. Bunce for critically reviewing the manuscript. *R/V Chain* cruise 61 was supported by the Office of Naval Research under contract Nonr-4029, and cruise 43 by the National Science Foundation Grant GP-2370 and by Nonr-4029. Data analysis has been supported by NSF Grant GA-283.

THICKNESS OF UNCONSOLIDATED SEDIMENTS

The distribution pattern of unconsolidated sediments in the eastern Mediterranean shows a number of interesting features (Fig. 2). In the Ionian Sea, the unconsolidated sediment cover is comparatively thin (0.2 to 0.7 km) and is conformable with the underlying consolidated layer. Farther east, in the Levantine basin, it thickens to more than 1 km, and local variations in thickness are also substantially greater. The thickest sections are found off the shores of Libya, Egypt, Israel, Lebanon, Turkey, and eastern Sicily. In the southern Aegean, the sediment cover is thin, and there is an area off Port Said covered only by a thin veneer of unconsolidated sediments (less than 0.25 km). This distribution pattern suggests that the primary sources of Neogene and Palaeogene sediments are the Nile River, Cyrenaica, the

* See Plate Section for all plates.

Geological Society of America Bulletin, v. 80, p. 2611–2614, 2 figs., 1 pl., December 1969

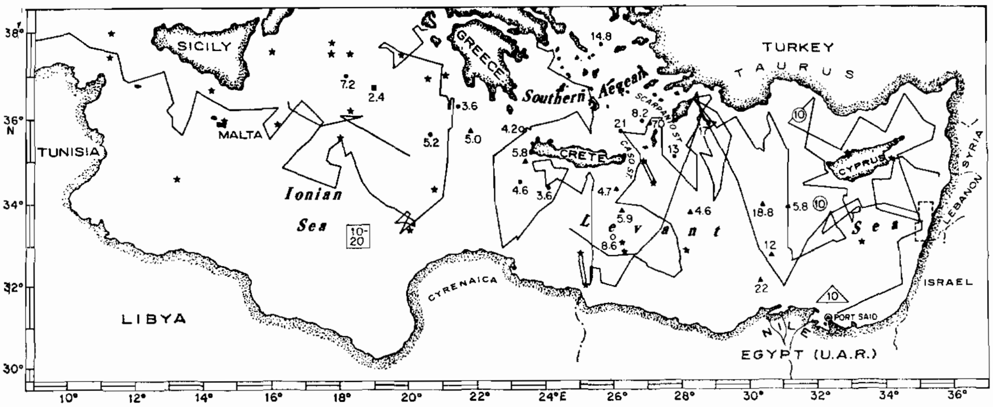


Figure 1. **Chart showing data coverage and a compilation of sedimentation rates in the eastern Mediterranean. □ detailed survey area (*Chain* 43); — survey tracks (*Chain* 61 and 43); ★ seismic stations (data used in Fig. 2); ★=★ continuous reflection profile (data used in Fig. 2); 5.2 sedimentation rate in cm/1000 yrs. ▲ Swedish deep sea exploration: Olausson, 1961; Parker, 1958; ∘ *Vema* 14: Ninkovich and Heezen, 1965; • *Vema* 10: Ninkovich and Heezen, 1965; ■ *Chain* 61: E. Olausson (personal commun.); ○ estimates from Ryan and others, 1966; □ estimates from Ryan and others, 1967; △ estimates from Emery and others, 1966.**

Taurus, and the Apennines. The Nile, which supplies some 120 million tons of sediments annually (Holeman, 1968; Shukri, 1950, reported 57 million tons; Babbs, 1893 reported 54 million tons), is probably by far the most important source. Previous investigators (Emery and Bentor, 1960; Emery and George, 1963) have established that Nile sediments are being carried northward by the presently observed regional circum-Mediterranean circulation (Ovchinnikov and Fedoseev, 1965). Our results indicate that at least some of these sediments must have been transported northwestward to form a thick accumulation off western Egypt, as has also been observed by Hersey (1965). Morphological studies by G. F. K. Giermann (1969, personal commun.) indicate that the thinly sedimented area off Port Said corresponds to the top-set and fore-set beds of a relict position of the Nile delta during the time when the eustatic level of the sea was low. Since the delta subsequently regressed southward to its present position as the sea encroached the shores of Egypt, the unconsolidated sediment cover here is not expected to be very thick. Our results therefore are in agreement with those of Giermann. The Aegean Sea is sealed off from a major sediment source (the Nile) by the Hellenic trench to the south and the Caso and Scarpanto sills in the southeast (Fig. 1); its deposits are mostly derived from the Greek and Turkish mainlands and the Aegean islands.

Studies on the distribution of sediment types show that the bottom material in the eastern Mediterranean is mostly terrigenous but contains a significant admixture of shells of Foraminifera and pteropods in the deeper parts (Yemelyanov, 1961; Bezroukov, 1961; Nekritz, 1963). Detrital material from Cyrenaica, the Taurus, and the Apennines is carried either by winds or rivers and is distributed over the nearby continental shelf and slope. Sediment ponding, particularly within abyssal plains, is very common. Frequent seismic disturbances presumably trigger sliding and turbidity flows that carve out steep submarine valleys, particularly in the Messina cone. Volcanic eruptions have added numerous widespread ash horizons to the unconsolidated sediments, and the frequent occurrence of sapropelic layers in recent deposits indicates periods of stagnation (Ninkovich and Heezen, 1965; Emery and others, 1966).

Recent sedimentation rates in the eastern Mediterranean as determined from cores by various investigators (Parker, 1958; Olausson, 1961; Ninkovich and Heezen, 1965; Ryan and others, 1966; and Ryan and others, 1967) are plotted in Figure 1. They show a general agreement with the distribution pattern of Figure 2, but the correspondence should not be overstressed as the sedimentation rates apply only to the Quaternary, while the unconsolidated sediments have perhaps been deposited since Cretaceous times.

Average sedimentation rates for the area have been estimated at 10 to 30 cm/1000 yrs and 40 cm/1000 yrs by Mellis (1954) and Pettersson (1957), respectively. A somewhat

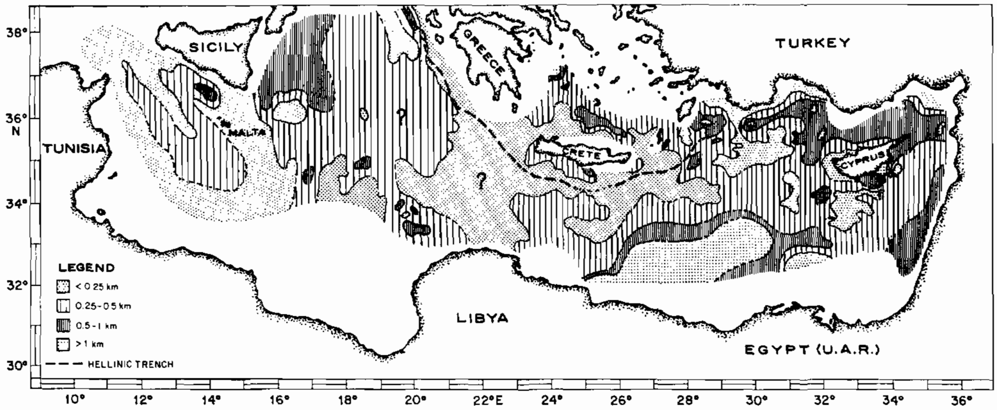


Figure 2. Thickness of the unconsolidated sedimentary layer in the eastern Mediterranean Sea. Data from *R/V Chain* cruises 61 and 43 and from other published sources (*see* text). Thick trench sediments are not shown to avoid congestion.

lower value of 10 cm/1000 yrs, based on radiocarbon dating supplemented by foraminiferal correlations, has also been reported (Emery and others, 1966). Assuming that the Cretaceous age attributed by Moskalenko (1966) to the top of the consolidated layer in the Levant Sea is correct, and taking an average observed sediment thickness of 0.5 km, the mean sedimentation rate since Cretaceous time would turn out to be on the order of 0.5 cm/1000 yrs. A somewhat low value of 2.5 cm/1000 yrs still results, even if a Miocene age is adopted. Hence, the recent sedimentation rate must exceed that which was applicable during Tertiary times.

Note added in proof: Ryan (1969) has noted the occurrence of a widespread reflecting horizon (Reflector "M") in the crustal layer with a compressional wave velocity of 3.4 km/s, to which he attributed an age of 4.3 ± 0.3 m.y. If this reflector were indeed the same as the one we identified, then the average sedimentation rate since the Pliocene would be about 12 cm/1000 yrs., a value close to recent rates as deduced from cores.

REFERENCES CITED

Babbs, C. C., 1893, The sediment of the Potomac River: Science, v. 21, no. 542, p. 342–343.

Bezroukov, P. L., 1961, Investigation of sediments in the northern Indian Ocean: Oceanological Researches-Articles no. 4, Sec. 10, IGY program, Moscow, p. 76–90 and Fig. 2.

Emery, K. O., and Bentor, Y. K., 1960, The continental shelf of Israel: Israel Ministry of Development, Geol. Survey Bull. no. 26, p. 25–40.

Emery, K. O., and George, C. J., 1963, The shores of Lebanon: American Univ., Beirut, Misc. Papers Nat. Sci., no. 1, p. 1–10.

Emery, K. O., Heezen, B. C., and Allan, T. D. 1966, Bathymetry of the eastern Mediterranean Sea: Deep Sea Research, v. 13, p. 173–192.

Ewing, J., and Ewing, M., 1959, Seismic-refraction measurements in the Atlantic basins, in the Mediterranean Sea, on the Mid-Atlantic Ridge and in the Norwegian Sea: Geol. Soc. America Bull., v. 70, p. 291–318.

Gaskell, T. F., and Swallow, J. C., 1953, Seismic refraction experiments in the Indian Ocean and in the Mediterranean Sea: Nature, v. 172, no. 4377, p. 535–537.

Gaskell, T. F., Hill, M. N., and Swallow, J. C., 1958, Seismic measurements made by H.M.S. CHALLENGER in the Atlantic, Pacific, and Indian Oceans and in the Mediterranean Sea, 1950–1953: Royal Soc. London Philos. Trans., v. A251, no. 988, p. 28–83.

Hersey, J. B., 1965, Sedimentary basins of the Mediterranean Sea: Colston Papers, v. 17, 17th Symposium, Colston Research Soc. Proc., Bristol Univ., April 5–9, 1965: Toronto, Butterworth Co. p. 75–91.

Holeman, J. N., 1968, The sediment yield of major rivers of the world: Water Resources Research, v. 4, no. 4, p. 737–741.

Kovylin, V. M., 1964, A structural study of the Mediterranean sedimentary basin: Okeanologiya, v. 4, no. 1, p. 81–85.

Mellis, O., 1954, Volcanic ash-horizons in deep-sea sediments from the eastern Mediterranean: Deep-Sea Research, v. 2, no. 2, p. 89–92.

Moskalenko, V. N., 1965, Study of the sedimentary series of the Mediterranean Sea by seismic methods, *in* Formin, L. M., *Editor*, Basic features of the geological structure, of the hydrologic regime and biology of the Mediterranean Sea: Moscow, Science Publishing House, p. 34–41.

—— 1966, New data on the structure of the sedimentary strata and basement in the Levant Sea: Okeanologiya, v. 6, no. 6, p. 1030. Engl. trans. *in* Oceanology, v. 6, no. 6, p. 828–836.

Nekritz, R., 1963, Bottom sediment distribution in the Mediterranean Sea: USNOO IMR No. 0–55–63, 10 p.

Ninkovich, D., and Heezen, B. C., 1965, Santorini tephra: Colston Papers, v. 17, 17th Symposium Colston Research Soc. Proc., Bristol Univ., April 5–9, 1965: Toronto, Butterworth Co., p. 413–453.

Olausson, E., 1961, Studies of deep-sea cores, sediment cores from the Mediterranean Sea and the Red Sea: Swedish Deep-Sea Exped. Rept., 1947–1948, v. 8, no. 4, p. 335–391.

Ovchinnikov, I. M., and Fedoseev, A. F., 1965, The horizontal circulation of the water of the Mediterranean Sea during the summer and winter seasons: *in* Formin, L. M., *Editor*, Basic features of the geological structure, of the hydrological regime and biology of the Mediterranean Sea: Moscow, Science Publ. House, p. 107–118.

Parker, F. L., 1958, Eastern Mediterranean Foraminifera: Swedish Deep-Sea Exped. Rept., 1947–1948, v. 8, no. 2, p. 217–287.

Pettersson, H., 1957, The voyage of the ALBATROSS: Swed. Deep-Sea Exped. Rept., v. 1, p. 84.

Ryan, W. B. F., 1969, The floor of the Mediterranean. Part I: Structure and evolution, and Part II: The stratigraphy of the eastern Mediterranean: Ph.D. thesis, Columbia Univ., New York.

Ryan, W. B. F., Workum, F., and Hersey, J. B., 1965, Sediments on the Tyrrhenian abyssal plain: Geol. Soc. America Bull., v. 76, p. 1261–1282.

Ryan, W. B. F., Ewing, M., and Ewing, J., 1966, Diapirism in the sedimentary basins of the Mediterranean Sea (abs.): Am. Geophys. Union Trans., v. 47, no. 1, p. 120.

Ryan, W. B. F., Zarudzki, E. F. K., Ewing, M., and Thorndike, E. M., 1967, Deep water circulation in the Ionian Sea (abs.): Am. Geophys. Union Trans., v. 48, no. 1, p. 142–143.

Shukri, N. M., 1950, The mineralogy of some Nile sediments: Geol. Soc. London Quart. Jour., v. 105, p. 511–539; v. 106, p. 466–467.

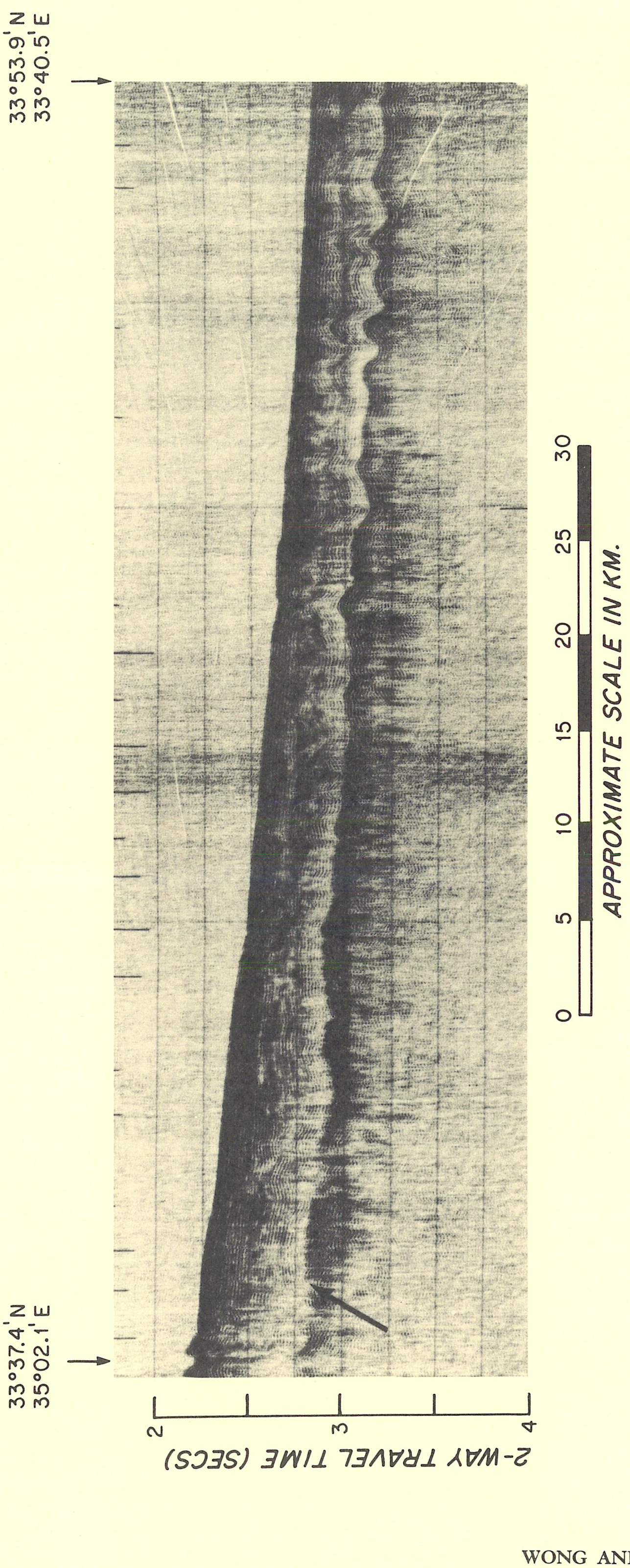
Yelnikov, I. N., 1966, Seismic reflection surveys in the Mediterranean between Crete and Africa: Akad. Nauk SSSR Inst. Okeanologii Trudy, v. 5.

Yemelyanov, Ye M., 1961, New data on Mediterranean sea deposits: Akad. Nauk SSSR Doklady, v. 137, no. 6, p. 1437–1440. Engl. trans. *in* Doklady, Acad. Sci. USSR, v. 137. p. 432–434.

MANUSCRIPT RECEIVED BY THE SOCIETY APRIL 4, 1969

WOODS HOLE OCEANOGRAPHIC INSTITUTION CONTRIBUTION NO. 2299

A TYPICAL CONTINUOUS SEISMIC PROFILE



A typical continuous seismic profile. Arrow indicates the distinct reflecting horizon referred to in the text.

DISTRIBUTION LIST
4029

Office of Naval Research
Department of the Navy
Attn: Code 480 1
480 D 1
460 1
466 5
468 1
414 1
Washington, D. C. 20360

Chief of Naval Operations
Department of the Navy
Attn: OP 07 1
71 1
95 1
Washington, D. C. 20350

Director
Office of Naval Research 1
Branch Office
495 Summer Street
Boston, Massachusetts 02210

Director
Office of Naval Research 1
Branch Office
New York Area Office
207 West 24th Street
New York, New York 10011

Director, Naval Research Laboratory
Attn: Library, Code 2029 (ONRL)
Washington, D. C. 20390 1

Commander
Naval Ship Systems Command
Department of the Navy
Attn: SHIPS 03 1
1622C1 1
Washington, D.C. 20360

Commander
Naval Air Systems Command 1
Department of the Navy
Attn: AIR 370E
Washington, D.C. 20360

Chief of Naval Material 1
Department of the Navy
Attn: DCNM/DND (Development)
Washington, D.C. 20360

Assistant Secretary of the Navy 1
For Research and Development
Department of the Navy
Washington D.C.

Director
Naval Research Laboratory 2
Attn: Code 2021
Washington, D. C. 20390

Commander
U. S. Naval Oceanographic Office
Washington, D. C. 20390
Attn: Code 037-B 1
Code 1640 1

Chief Scientist 1
Naval Research Laboratory
Underwater Sound Reference Div.
P.O. Box 8337
Orlando, Florida 32806

Commanding Officer and Director
Navy Electronics Laboratory
Attn: Code 3060C 1
Code 3102 1
San Diego, California 92152

Commanding Officer
Naval Ordnance Laboratory 1
White Oak, Maryland 20910

Commanding Officer and Director
Naval Underwater Weapons Research 1
and Engineering Station
Newport, Rhode Island 02844

Commanding Officer and Director 1
Naval Civil Engineering Laboratory
Port Hueneme, California 93401

Commanding Officer
Navy Air Development Center 1
Attn: NADC Library
Johnsville, Pennsylvania 18974

Superintendent 1
U.S. Naval Academy
Annapolis, Maryland 21402

Office of Naval Research
Project Officer 1
U.S. Sofar Station
APO 856
New York, New York 09856

Commanding Officer and Director 1
Naval Underwater Sound Laboratory
Fort Trumbull
New London, Connecticut 06321

Commanding Officer and Director
Navy Mine Defense Laboratory 1
Panama City, Florida 32402

Office Chief of Research and
Development 1
Department of the Army
Washington, D.C. 20310

U.S. Army Beach Erosion Board 1
5201 Little Falls Rd., N.W.
Washington, D.C. 20016

Defense Documentation Center 20
Cameron Station
Alexandria, Virginia 22314

National Academy of Sciences
National Research Council
2101 Constitution Ave., N.W.
Attn: Committee on Undersea
Warfare 1
Committee on Oceanography 1
Washington, D.C. 20418

ESSA
U.S. Department of Commerce
Attn: Institute of Oceanography 1
Institute of Atmospheric
Sciences 1
Washington, D.C. 20235

Geological Division
Marine Geology Unit 1
U.S. Geological Survey
Washington, D.C. 20240

U.S. Geological Survey 1
Marine Geology and Hydrology
345 Middlefield Road
Attn: Dr. Rusnak
Menlo Park, California 94025

Director
Oceanography Museum of
Natural History 1
Smithsonian Institution
Washington, D.C. 20560

Mr. Theodore V. Ryan 1
Director
Pacific Oceanographic Research Laboratory
1801 Fairview Avenue East
Seattle, Washington 98102

Commander
Naval Ordnance Test Station 1
Attn: Technical Library
China Lake, California 93557

Naval Ordnance Test Station
Pasadena Annex 1
3202 East Foothill Blvd.
Attn: Library
Pasadena, California 91107

Naval Post Graduate School
Attn: Librarian 1
Dept. of Meteorology and
Oceanography 2
Monterey, California 93940

Naval Applied Science Laboratory
Naval Base 1
Attn: Technical Library
Code 222
Brooklyn, New York 11251

Advanced Research Projects Agencies 1
Attn: Nuclear Test Detection Office
Washington, D.C. 20301

Director
Scripps Institution of Oceanography 1
La Jolla, California 92037

Ordnance Research Laboratory 1
Pennsylvania State University
University Park, Penn. 16801

Director
Marine Physical Laboratory 1
Scripps Institution of Oceano-
graphy
San Diego, California 92152

Director
Marine Laboratory
University of Miami
#1 Rickenbacker Causeway 1
Miami, Florida 33149

Director
Department of Oceanography
and Meteorology 1
Texas A & M University
College Station, Texas 77843

Head, Department of Oceanography 1
Oregon State University
Corvallis, Oregon 97331

Director
Arctic Research Laboratory 1
Point Barrow, Alaska 99723

Head, Department of Oceanography
University of Washington 1
Seattle, Washington 98105

Geophysical Institute of the
University of Alaska 1
College, Alaska 99735

Applied Physics Laboratory
University of Washington 1
1013 NE Fortieth Street
Seattle, Washington 98105

Department of Geodesy and
Geophysics 1
Cambridge University
Cambridge, England

Director
Institute of Geophysics 1
University of Hawaii
Honolulu, Hawaii 96825

Director
Applied Research Laboratories 1
University of Texas
Austin, Texas 78712

Bell Telephone Laboratories, Inc.
Attn: Dr. John Mayo, Div. 54
Whippany, New Jersey 07981 1

U.S. Naval Schools, Mine Warfare
U.S. Naval Base 1
Charleston, South Carolina 29408

Hawaii Technical Information Center
567 South King Street
Honolulu, Hawaii 96813 1

National Institute of Oceanography
Wormley, Godalming
Surrey, England
Attn: Librarian 1

Woods Hole Oceanographic Institution
Reference No. 70-5

THICKNESS OF UNCONSOLIDATED SEDIMENTS IN THE EASTERN MEDITERRANEAN SEA by How-Kin Wong and Edward F. K. Zarudski. Reprinted from Geological Society of America Bulletin, v. 80, p. 2611-2614, 2 figs., 1 pl., December 1969". Contract Nonr-4029(00); NR 260-101, with the National Science Foundation Grants GP-2730 and GA-283.

The unconsolidated sedimentary layer in the eastern Mediterranean Sea becomes more variable in thickness toward the east. The distribution pattern suggests that the primary sources of sediment in Cenozoic times have been the Nile River, elevated areas of Cyrenaica, the Taurus, and the Apennines.

1. Eastern Mediterranean Sea
2. Unconsolidated Sediments
3. Thickness

I. Wong, How-Kin
II. Zarudzki, Edward F. K.

Unclassified

Woods Hole Oceanographic Institution
Reference No. 70-5

THICKNESS OF UNCONSOLIDATED SEDIMENTS IN THE EASTERN MEDITERRANEAN SEA by How-Kin Wong and Edward F. K. Zarudski. Reprinted from Geological Society of America Bulletin, v. 80, p. 2611-2614, 2 figs., 1 pl., December 1969". Contract Nonr-4029(00); NR 260-101, with the National Science Foundation Grants GP-2730 and GA-283.

The unconsolidated sedimentary layer in the eastern Mediterranean Sea becomes more variable in thickness toward the east. The distribution pattern suggests that the primary sources of sediment in Cenozoic times have been the Nile River, elevated areas of Cyrenaica, the Taurus, and the Apennines.

1. Eastern Mediterranean Sea
2. Unconsolidated Sediments
3. Thickness

I. Wong, How-Kin
II. Zarudzki, Edward F. K.

Unclassified

Woods Hole Oceanographic Institution
Reference No. 70-5

THICKNESS OF UNCONSOLIDATED SEDIMENTS IN THE EASTERN MEDITERRANEAN SEA by How-Kin Wong and Edward F. K. Zarudski. Reprinted from Geological Society of America Bulletin, v. 80, p. 2611-2614, 2 figs., 1 pl., December 1969". Contract Nonr-4029(00); NR 260-101, with the National Science Foundation Grants GP-2730 and GA-283.

The unconsolidated sedimentary layer in the eastern Mediterranean Sea becomes more variable in thickness toward the east. The distribution pattern suggests that the primary sources of sediment in Cenozoic times have been the Nile River, elevated areas of Cyrenaica, the Taurus, and the Apennines.

1. Eastern Mediterranean Sea
2. Unconsolidated Sediments
3. Thickness

I. Wong, How-Kin
II. Zarudzki, Edward F. K.

Unclassified

Woods Hole Oceanographic Institution
Reference No. 70-5

THICKNESS OF UNCONSOLIDATED SEDIMENTS IN THE EASTERN MEDITERRANEAN SEA by How-Kin Wong and Edward F. K. Zarudski. Reprinted from Geological Society of America Bulletin, v. 80, p. 2611-2614, 2 figs., 1 pl., December 1969". Contract Nonr-4029(00); NR 260-101, with the National Science Foundation Grants GP-2730 and GA-283.

The unconsolidated sedimentary layer in the eastern Mediterranean Sea becomes more variable in thickness toward the east. The distribution pattern suggests that the primary sources of sediment in Cenozoic times have been the Nile River, elevated areas of Cyrenaica, the Taurus, and the Apennines.

1. Eastern Mediterranean Sea
2. Unconsolidated Sediments
3. Thickness

I. Wong, How-Kin
II. Zarudzki, Edward F. K.

Unclassified