ACTA ADRIATICA
INSTITUT ZA OCEANOGRAFIJU I RIBARSTVO — SPLIT
SFR JUGOSLAVIJA

Vol. XVIII, No. 8

SEDIMENT MOVEMENTS IN LEBANESE SUBMARINE CANYONS

POMICANJE SEDIMENATA U PODMORSKIM KANJONIMA LIBANONA

THOMAS GOEDICKE AND STEPHANIE SAGEBIEL

SPLIT 1976

SEDIMENT MOVEMENT IN LEBANESE SUBMARINE CANYONS

POMICANJE SEDIMENATA U PODMORSKIM KANJONIMA LIBANONA

Thomas Goedicke and Stephanie Sagebiel

American University of Beirut, Beirut, Lebanon

INTRODUCTION

In the course of investigation of the bathymetry of the upper continental shelf of the Eastern Mediterranean, a number of submarine canyons have been found crossing the shelves and the continental slopes of Lebanon, Cyprus and Rhodes (Goedicke, 1973; Goedicke and Sagebiel, 1973).

A number of canyons have been discovered on the continental slope offshore from the southern part of Lebanon (Carlisle, 1965) and recent surveys of the R/V *ATOLL II* have disclosed the presence of 8 canyons between Jounie Bay and the headland of Ras Chekka to the north. From south to north, these are the Adonis and Fidar canyons, offshore from the mouths of the Ibrahim and El Fidar Rivers respectively; Mouna, Feather and King canyons immediately north of the headland of Ras Amchit; and Batroun, Dibette and Koshka canyons between Batroun and Ras Chekka (Figure 1).

Three of the canyons on the central sector of the shelf have been investigated in detail. These are the Jounie Bay canyon in the approxiamte center of Jounie Bay, the St. George's Bay canyon in the approximate center of St. George's Bay and the Beirut canyon located off the north shore of the headland of Ras Beirut (Figures 2 and 3).

METHODS AND MATERIALS

Samples of bottom sediments from the three canyons were obtained by means of a cone dredge developed by the authors (Figure 4) and a small gravity corer. The research was carried out on board the research vessel *ATOLL II*. Locations of the fathometer traverses as well as of dredging and

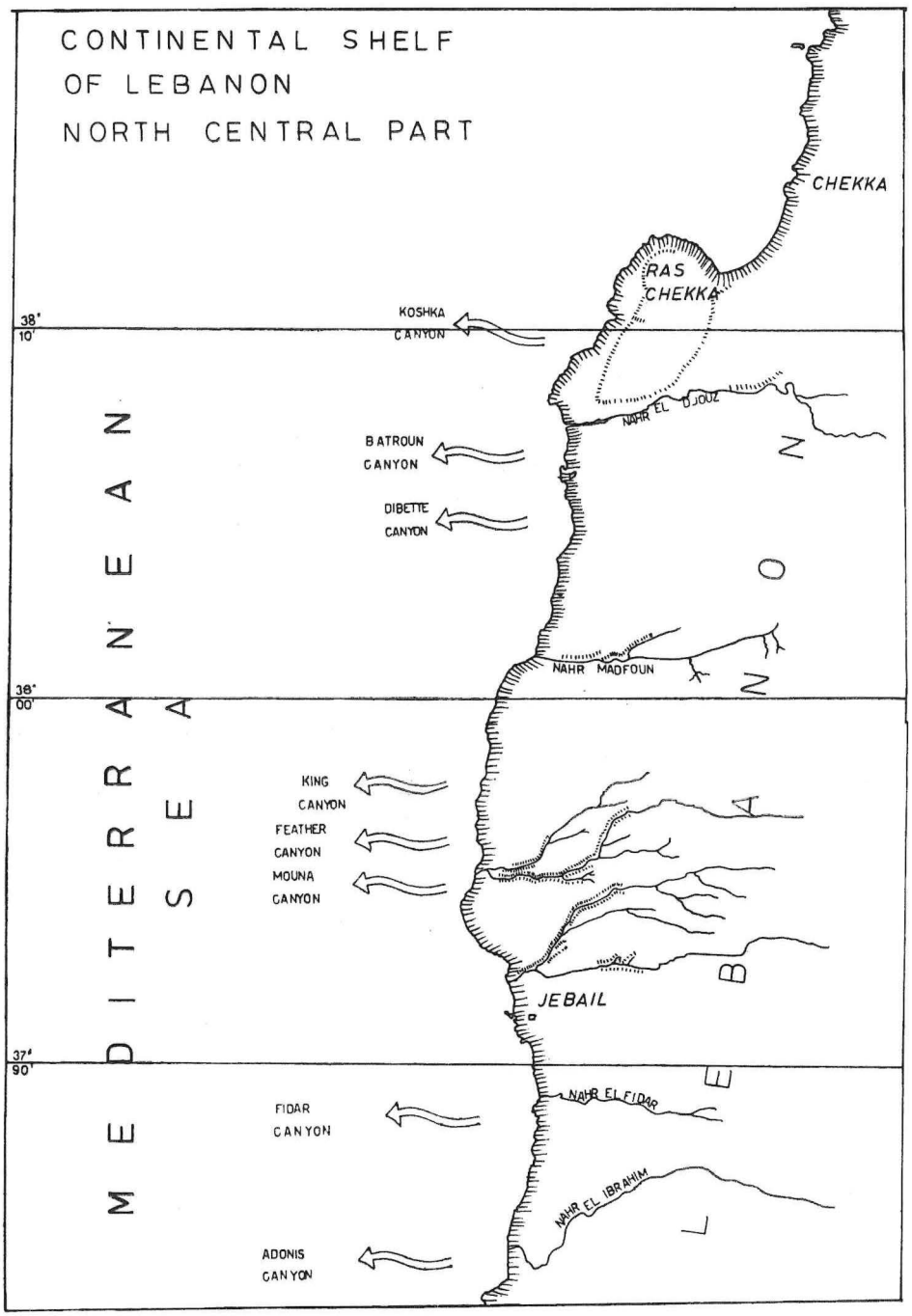

Fig. 1 — Location of submarine canyons on the north central portion of the continental shelf of Lebanon.

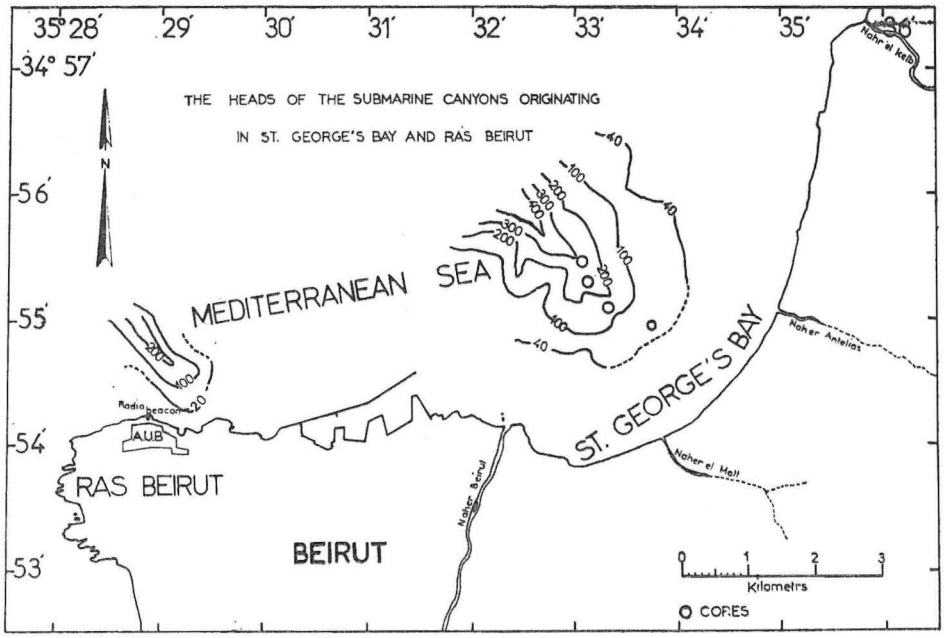

Fig. 2 — Location and bathymetry (contours in m) of Beirut and St. George's Bay submarine canyons.

coring stations were determined by means of sextant angles on prominent shore features. Details of the topography of the three canyons are shown on Figures 2 and 3 as are the locations of the core and dredge samples.

The dredge samples were washed to remove interstitial water, then dried and sieved. The fine fraction, less than 4 Ø, was analyzed by the pipette method. The size distribution curves were drawn from the results of the combined dry sieving and pipette analyses.

The core samples were X-rayed in the plastic core tubes at the X-ray Center of the American University Hospital. The core tubes were then split and the cores examined. Small samples were taken at intervals along the core and analyzed for grain size in the same manner as the dredge samples.

RESULTS

Jounie Bay Canyon

Figure 3 shows the submarine topography of Jounie Bay and the location of the core samples. The Jounie Bay canyon is aligned with a prominent land valley near the center of Jounie Bay and has a northern tributary which is roughly in line with a prominent fault and shear zone near Ras El Maameltein. Gravity cores were taken on the axis of the canyon at depths of 40, 200 and 230 m.

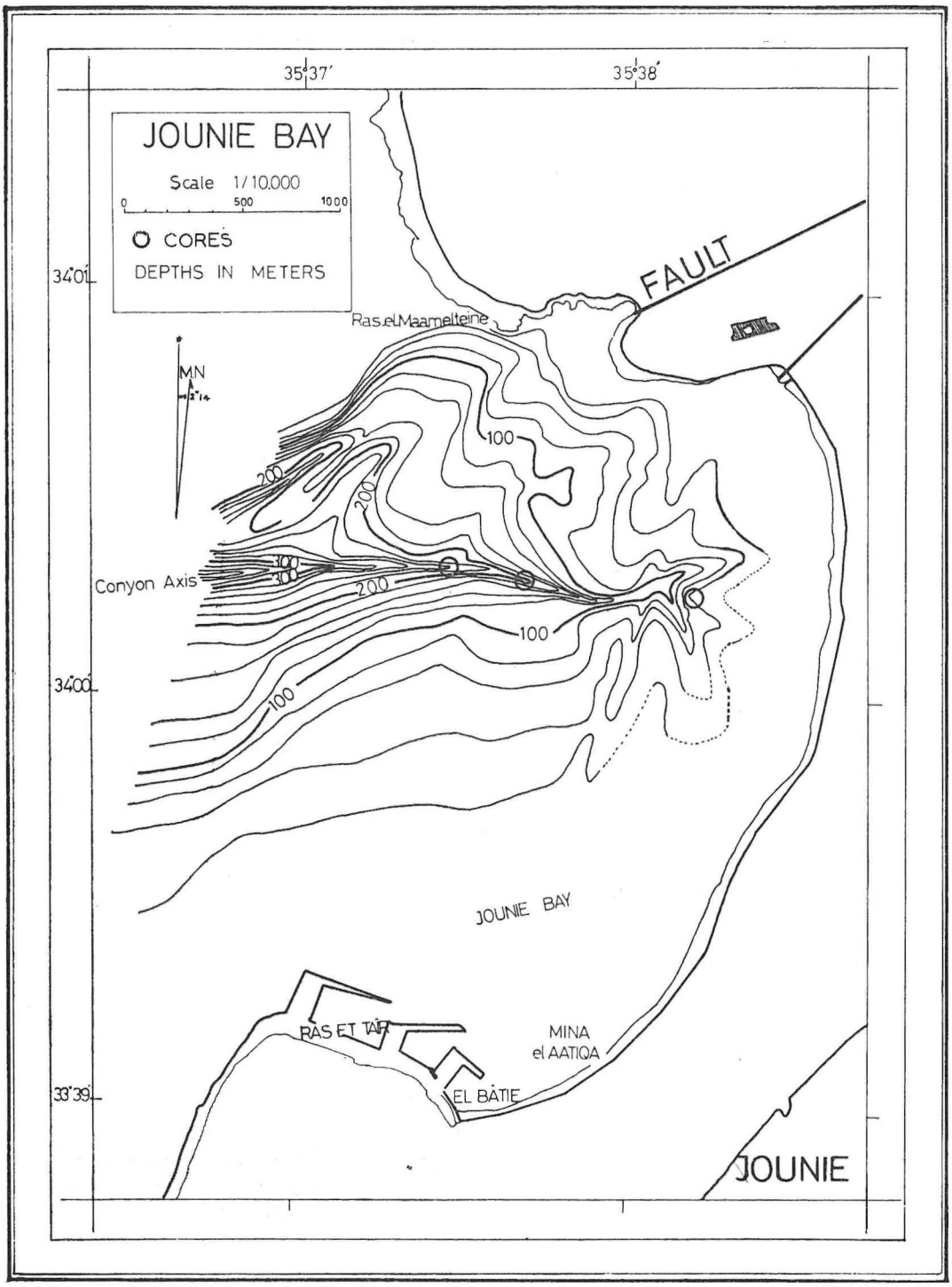

Fig. 3 — Location and bathymetry of Jounie Bay submarine canyon.

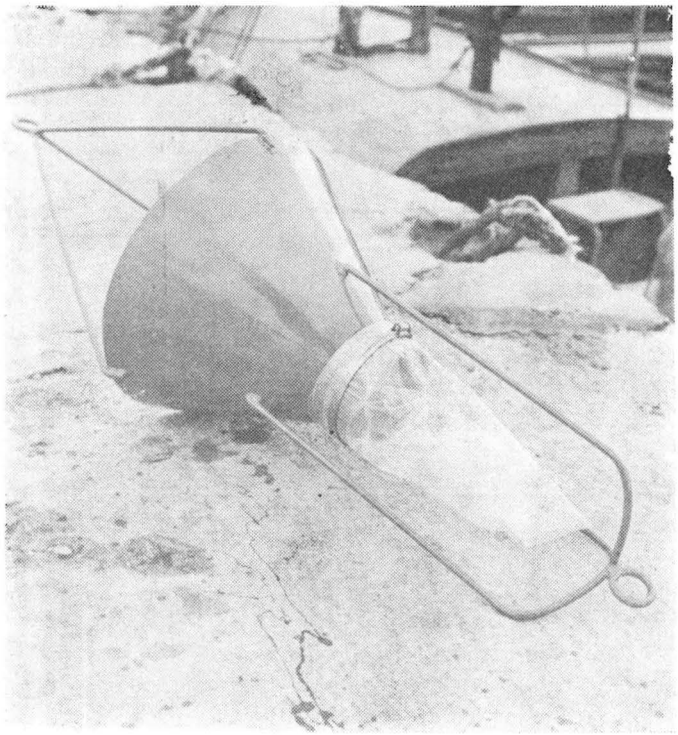

Fig. 4 — Cone dredge developed by the authors.

Radiographs of the core from 40 m depth in Jounie Bay canyon and another core from a depth of 60 m near the head of the Adonis Canyon are shown in Figure 5. Both cores showed mottled sediments and the core from Adonis Canyon showed cross-bedding and slump structures at a depth of 22 cm below the bottom.

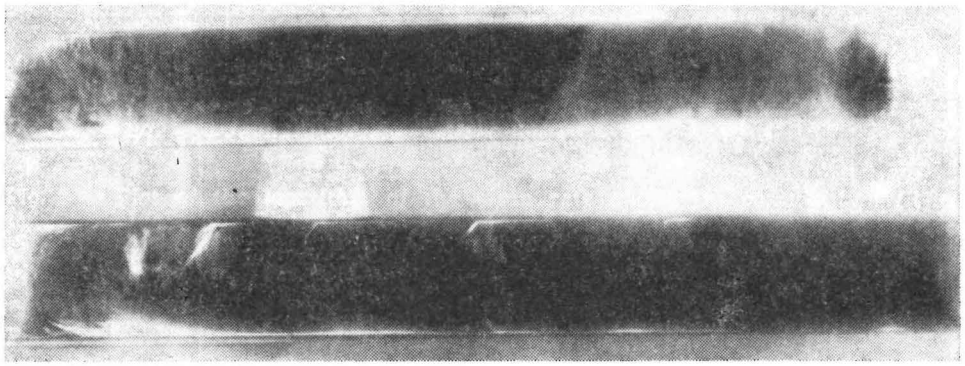

Fig. 5 — Radiograph to two cores from submarine canyons. Core at the top from Jounie Bay at a depth of 40 m; core at the bottom from Adonis canyon at a depth of 40 m.

The core from Jounie Bay canyon, taken at a depth of 200 m, was 37 cm long and well stratified (Figure 6). The top 15.4 cm of the core consisted of brown clay. Below this there was a layer of grayish green clay to a depth of 19.4 cm followed by brown clay, to a depth of 20.6 cm. Between the depths of 20.6 and 27.3 cm there was a layer of sand grading to greenish clay. From a depth of 31.0 cm to a depth of 33.6 cm there was a layer of sand and clay and the bottom of the core from 33.6 to 37.6 cm consisted of sand. Granulometric characteristics of sediment samples taken from the bottom, center and top of the 200 m core and another core from a depth of 230 m are given in Table 1.

Table 1. Granulometric characteristics of the sediment of gravity cores from along the axis of Jounie Bay canyon.

Core Depth (m)	Depth Below Sediment Surface (cm)	Median Diameter (∅)	Mean Diameter (∅)	Kortosis	Skewness	Sorting (∅)
200	Top	4.70	4.70	1.11	0.040	1.150
200	Center	4.25	4.75	0.98	0.620	1.245
200	Bottom	4.25	4.75	1.00	0.600	1.245
230	3	3.45	4.12	0.283	0.971	2.481
230	34	4.05	4.25	0.995	0.209	1.307

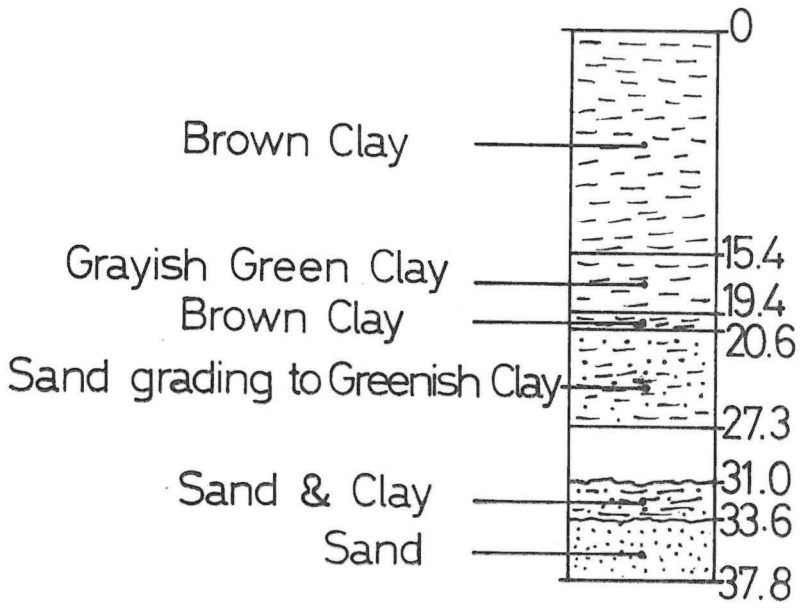

Fig. 6 — Layering of sediment (cm) of a core from a depth of 200 m in Jounie Bay canyon.

Figure 7 shows a photograph of the lower portion of the core from 200 m depth. It clearly shows fine interbedding of sandy layers with clay layers indicative of slumping of sediments along the axis of the canyon as well as a high angle of inclination of layers as compared to the axis of the core.

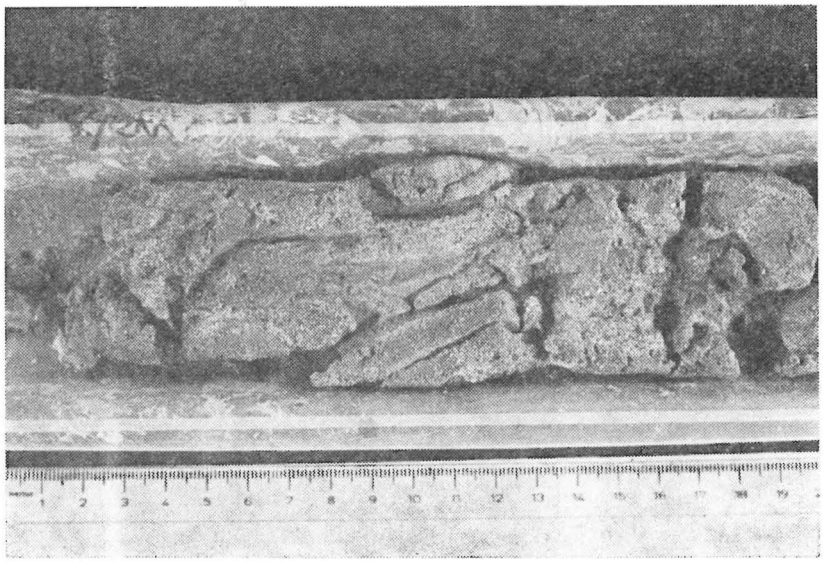

Fig. 7 — Photograph of lower portion of a core from a depth of 200 m in Jounie Bay canyon.

Involute interbedding of sandy layers with clay has been observed in many cores from continental shelves and shopes and was produced artificially in the laboratory (Reinick and Singh, 1973). It is generally accepted as evidence of penecontemporaneous deformation of sediments. In the case of the present cores, it is taken as an indication of down-canyon movement of sediments together with the discovery of land plants and roots in dredge samples from over 400 m depths along the axis of the canyon.

The stratigraphy of the core taken from a depth of 230 m along the axis of the Jounie Bay canyon is shown in Figure 8. This core had a total length of 42 cm and consisted mainly of fine sand and clay. The upper 8 cm of the core, however, consisted of coarse sand with some clay and showed an irregular inclined contact with the underlying fine sand and clay. A photograph of the core is shown in Figure 9 and a detailed section of the contact in Figure 10. The irregularity of the contact and the difference in grain size are clearly visible. Some clay particles are seen interbedded with the lowest layer of sand. It is believed that the slump or turbidity current which transported the sand to a depth of 230 m disturbed the uppermost, partly consolidated clay, and rolled irregular clay balls were incorporated in the sand layer.

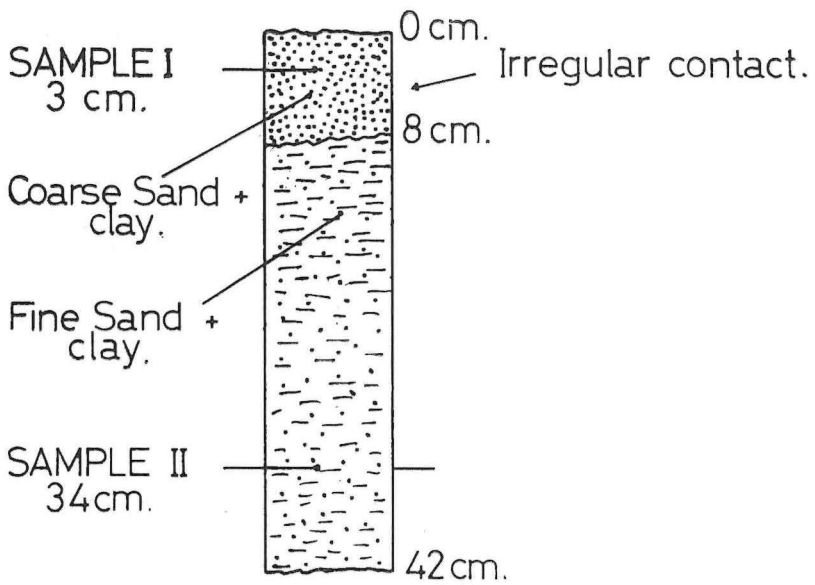

Fig. 8 — Layering of sediment of a core from a depth of 230 m in Jounie Bay canyon.

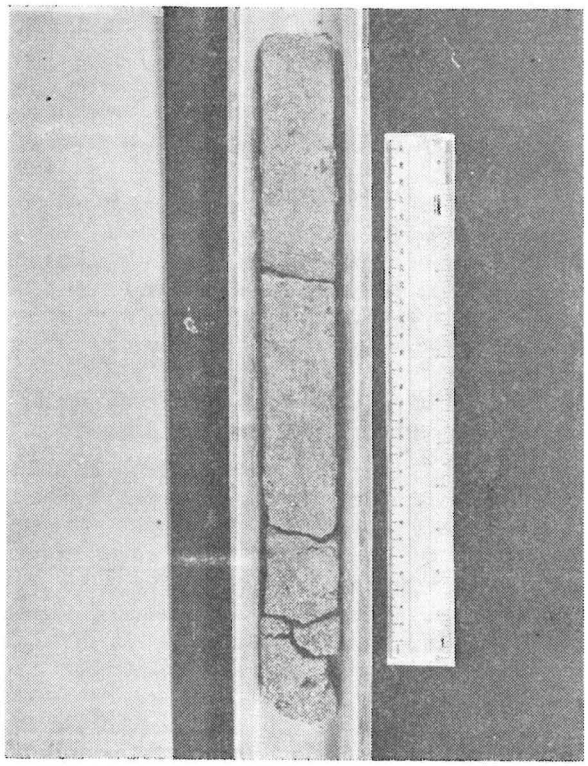

Fig. 9 — Photograph of a core from a depth of 230 m in Jounie Bay canyon.

Table 1 gives the granulometry of sediment samples taken at a depth of 3 cm and 34 cm respectively in the core obtained from the depth of 230 m. The sample from the top is very poorly sorted and fine skewed. It is a bimodal sediment with modes at 2.5 to 3.0 ∅ and at 7.0 and 8.0 ∅. The sample from a depth of 34 cm in the core is poorly sorted and fine skewed with modes at 3.0 to 3.5 ∅. It is classified as mesokurtic.

Both the cores from 200 m and 230 m showed poorly sorted sediments and interbedding of coarse and fine layers characteristic of sediment slumping or turbidity current deposition. The coarse sand layer near the top of the core from a depth of 230 m also included shell fragments of clearly shallow water origin.

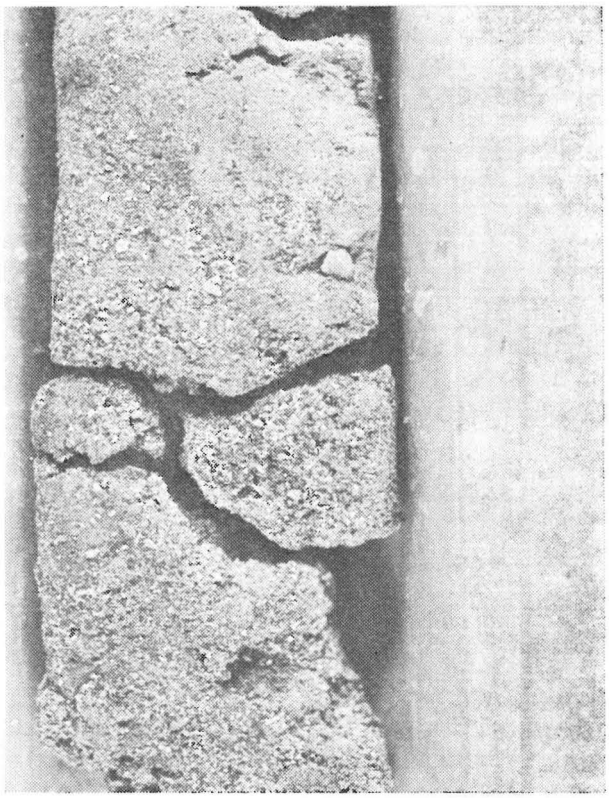

Fig. 10 — Photograph of upper section of a core from a depth of 230 m in Jounie Bay canyon showing irregular contact indicative of slumping and shell fragments in the upper central portion of the coarse sediment.

St. George's Bay Canyon

Four short gravity core samples were obtained from the axis of St. George's Bay canyon. These were taken at depths of 45, 153, 240 and 284 m. The sediments in these cores consisted of clayey silt to silty clay with fine intercalated sandy layers. Cross laminations and gradations in grain size are

clearly visible on radiographs of the cores (Goedicke, 1973). Intercalated organic matter is also observed. All these sedimentary structures are well known from other submarine canyon deposits and have been termed »flexo--turbidites». They are considered as evidence of periodic slumping of shallow water sediments along the axis of the canyons (Bourcart, 1964; Reineck and Singh, 1973). It appears to be clear that the same type of process operates in the submarine canyons of the Lebanese continental shelf. Further evidence to support this theory comes from a core taken at a depth of 284 m along the axis of the St. George's Bay canyon. Over half of the core was found to consist of matted sea grass interbedded with sand, silt and some shell fragments (Goedicke, 1973). The entire section of the core was black in color and had a strong hydrogen sulfide odor. The color disappeared in a matter of 8 to 12 hours on exposure of the core to air. Similar conditions were found for a fine silt layer near the lower end of the core from 230 m depth in the Jounie Bay canyon. Dredge samples of silt and mud from the shallow areas of both bays were black in color and high in organic content, indicative of anaerobic conditions on the bottom. Presence of similar sediment layers intercalated with sand layers in cores from the submarine canyons suggests down-canyon movement of these black silts.

Table 2 shows the organic content in total mg protein per g of sediment for two cores taken along the axis of the Jounie Bay submarine canyon. The presence of a high value of 10.5 mg protein/g of sediment at a depth of 30 cm below the surface suggests that some of the fine grained shallow water sediments from Jounie Bay deposited under anaerobic conditions have found their way down the axis of the canyon and have been covered by later sediment slumps from the sides of the canyon where anaerobic conditions do not occur.

Table 2. Organic content (mg protein/g sediment) of sediment samples from gravity cores from depths of 157 m and 200 m along the axis of the Jounie Bay canyon.

Core Depth (m)	Depth Below Sediment Surface (cm)	mg Protein/g
157	Surface	7.9
157	20	9.2
157	30	10.5
157	40	7.6
157	45	6.4
200	Surface	9.7
200	10	6.8
200	20	4.65
200	30	5.9

DISCUSSION

Core and dredge samples of the sediment taken from the axes of three submarine canyons in the vicinity of Beirut show slumping, graded bedding and interbedding of coarse and fine sediments. Shallow water sea grass and

shells were present at depths in excess of 200 m along the axes of the canyons.

All of these sedimentary structures are known to be characteristic of flexoturbidites and indicate periodic sediment movement into and along the axes of the submarine canyons. Such movement has been observed in canyons on the west coast of the United States and on the Mediterranean south coast of France. In the latter case, the canyons of the Gulf of Lyons were eroded subaerally during the upper Miocene and filled with sediments during the Pliocene (Bourcart, 1964). Preliminary investigations of the canyons on the continental shelves of Lebanon, Cyprus and Rhodes have suggested a similar origin (Goedicke, 1973; Goedicke and Sagebiel, 1973).

The very pronounced periodicity of the climatological pattern of Lebanon with its long period of drought during the summer, heavy rains with considerable runoff and erosion during the winter interspersed with periods of violent storms and high storm waves and swell along the Lebanese coast may have a marked effect on continental shelf sedimentation. Sediment movement including sand falls in submarine canyons have been observed to be connected with storm waves (Shepard and Dill, 1966). It is suggested that rhythmic sediment movement and sedimentation in the submarine canyons on the continental shelf of Lebanon are connected with the mobilization of upper continental shelf sediments by high long period winter storm waves leading to slumping and perhaps turbidity currents along the axes of the canyons. Verification of this hypothesis will have to await the acquisition of more data, including long cores and current measurements in the canyons.

SUMMARY

Three of the seven submarine canyons discovered during recent surveys on the continental shelf of Lebanon have been investigated in detail. Dredge and core samples were collected in Jounie Bay, St. George's Bay and Beirut submarine canyons and analyzed for organic content, stratification and grain size. Core and dredge samples from Jounie Bay and St. George's Bay showed evidence of anaerobic conditions in sea floor sediments. These conditions exist to a sediment depth of 45 cm as shown by analysis of cores taken along the axes of the submarine canyons. Organic matter, land plants and shallow-water organisms occurred to depths of at least 450 m. Some cores showed irregular inclined contacts between fine grained sediments and overlying coarse grained layers; other cores showed alternating sand, silt and clay. These features are evidence of sediment movement downslope along canyon axes. This movement is probably seasonal reaching a maximum during the winter months when heavy swells due to offshore storms in the Eastern Mediterranean create conditions of strong surf and consequent agitation of nearshore sediments in the bays surrounding the heads of the submarine canyons.

ACKNOWLEDGEMENTS

The field work aboard the research vessel *ATOLL II* furnished by the Inner Space Research Foundation was performed by Miss S. Sagebiel of the Department of Biology, and M. Michel Majdalana, and Mr. E. R. Evaneshen of the Department of Geology, American University of Beirut. Professor I. Kafescioglu photographed the core samples, Mr. S. Frangie took he radiographs and Miss Mary Jo Ferro analyzed the samples for organic content. Mr. Besharah Darghawth supervised analysis of the samples. Miss I. de Gheiking prepared all illustrations and assisted the field work.

REFERENCES

Bourcart, J. 1964. Les sables profonds de la Mediterranee occidentale. Develop. Sedimentol., pp. 148—155.

Carlisle, D. H. 1965. A continuous seismic profiling survey off the coast of Lebanon. M. Sc. Thesis, Massachusetts Inst. Technology.

Goedicke, T. 1973. Submarine canyons on the central continental shelf of Lebanon. In: The Mediterranean Sea: A Natural Sedimentation Laboratory, Ed. by. D. J. Stanley. Dowden, Hutchinson Ross, Stroudsburg, Penn., 800 p.

Goedicke, T. and S. Sagebiel. 1973. Submarine canyons of the Eastern Mediterranean. Bull. Geol. Soc. Greece, *10* (1), p. 18.

Reineck, H. E. and I. B. Singh. 1973. Depositional sedimentary environments. Springer Verlag, Berlin.

Shepard, F. P. and R. F. Dill. 1966. Submarine canyons and other sea valleys. Rand McNally, New York.

POMICANJE SEDIMENATA U PODMORSKIM KANJONIMA LIBANONA

Thomas Goedicke i Stephanie Sagebiel

Američki univerzitet u Beirutu, Beirut, Libanon

KRATAK SADRŽAJ

Detaljno su istraživana tri od sedam nedavno otkrivena podmorska kanjona u kontinentalnoj podini (šelfu) Libanona. Uzorci iz dredže i sonde su prikupljani u zaljevu Jounie, St. George i kod Beiruta. U zaljevu Jounie i St. George u sedimentima tla do dubine 45 cm nađeni su anaerobni uslovi. Organska materija, kopnene biljke i organizmi plitkih voda su nađeni do dubina mora od najmanje 450 m. Neki uzorci su pokazali nepravilno slojanje između slojeva finih i krupnijih sedimenata, dok drugi uzorci pokazuju naizmjenično pjesak, mulj i glinaste taloge. Ovo ukazuje na kretanje sedimenata prema dolje uzduž osovine kanjona. Ovakvo gibanje ima vjerojatno sezonski karakter s maksimumom u zimskim mjesecima. Tada snažne oluje u istočnom Mediteranu uslovljuju jako udaranje valova o obalu i gibanje obalnih sedimenata u zaljevima gdje su smješteni ulazi u podmorske kanjone.