Reports

Modern Graywacke-Type Sands

Abstract. *A preliminary study of more than 100 deep-sea cores from abyssal plains has revealed two examples of recent muddy sands of the graywacke type which, together with the microcrystalline matrix, form a bimodal-size distribution sands have a well-sorted framework of quartz, feldspar, and rock fragments which, together with the microcrystalline matrix, form a bimodal-size distribution that is also typical of ancient graywackes. The matrix is considered to be primary.*

Those characteristics of graywacke which might be recognized in a modern sediment are ". . . (1) a varied assemblage of unstable materials (25 percent or more) including both feldspar grains and sand-sized rock fragments, and (2) interstitial matrix (15 percent or more) . . ." (*1*). It is around the origin of the matrix that the graywacke debate has raged for over 100 years (*2*).

Recently, Shepard (*3*), noting the apparent absence of modern graywackes in the deep sea, concluded that deep-sea sands ". . . are being transported in a form that prevents the incorporation of coarse sand in a muddy matrix." Cummins (*4*), supporting a postdepositional origin for graywacke matrix, stated ". . . a major difficulty with any hypothesis involving a detrital [primary] origin for the characteristic graywacke matrix is the failure to find a modern sediment of graywacke type."

An investigation of over 200 thin sections of deep-sea sands from 118 piston cores taken on abyssal plains in the Atlantic, Pacific, Caribbean, and Mediterranean and now in the collection of the Lamont Geological Observatory has revealed modern graywacke-type sands in two cores (Table 1).

Relatively clean sands of the subgraywacke or subarkose-type (*1*) were found in all cores studied. These clean sands are moderately poorly sorted and exhibit a distinct preferred orientation subparallel to the bedding plane. Matrix percentages calculated by point counting (*5*), range between 5 and 13 percent for the cleaner subgraywacke-type sands and between 22 and 44 percent for the muddy graywacke-type sands. The framework grains of the muddy sands "float" in a matrix, whereas the grains of the cleaner sands are nearly always in contact with one another (Fig. 1). Primary structures such as graded bedding, cross laminations, parallel laminations, and convolute laminations are commonly found in the cleaner sands. Parallel laminations are found in the upper portion of the thick muddy sand in core V 16-212 (Fig. 2).

The shapes of the grains in the muddy sand are variable and range from very angular to well-rounded. There is no significant difference in grain shape between any of the samples. The quartz is well-rounded to angular and the rock fragments are well-rounded to subrounded.

Measurements of grain orientation in all of the elongate framework grains (quartz, feldspar, and rock fragments) in the three thin sections from "graywacke" core V 16-212 indicate an imperfect preferred orientation inclined approximately 10 degrees to the bedding plane. There is no definite preferred orientation of elongate grains in "graywacke" core V 7-55.

Although these sands of the graywacke type have a complete size gradation from lutite to sand, the upper limit for matrix was placed at 0.02 mm (*1*). Approximate size distributions of the muddy sands were determined with the aid of a microprojector by measuring the long axis of at least 400 grains from randomly selected fields of each thin section. Number percentages were calculated and converted to weight percentages by multiplying the number percent in each Udden class by the cube of the mean size of each class and recalculating this product to 100 percent (*6*).

Table 1. The percentage composition of deep-sea sands calculated by point counting of thin sections. The characteristic low percentages for the matrix and high percentages for the pore spaces of subarkose and subgraywacke-type sands may be compared with the high values for the matrix and low values for pore spaces in the graywacke-type sands.

Component	Mid-Ocean Canyon			Sohm Abyssal Plain		
	Graywacke, core V 16-212 (lat. 38°36′N; long. 58°55′W); water depth, 5227 m			Subarkose, core V 7-42 (lat. 38°55′N; long. 57°08′W); water depth, 5261 m	Subgraywacke, core V 7-48 (lat. 37°58′N; long. 50°53′W); water depth, 5421 m	Graywacke, core V 7-55 (lat. 37°29′N; long. 54°53′W); water depth, 5394 m
	120 cm*	180 cm	330 cm	135 cm	350 cm	355 cm
Quartz	45	42	30	40	41	28
Feldspar	3	6	3	4	7	5
Rock fragments	8	9	19	1	8	12
Matrix	26	30	22	13	11	44
Pore space	11	5	17	34	24	4
Shell fragments	5	4	3	6	4	4
Glauconite	1	3	1	1	1	1
Minor constituents	1	1	5	1	4	2
Total counts	453	407	396	300	306	826
Median size (mm)	0.5	0.5	1.6	0.2	0.2	1.4

* Depth in core.

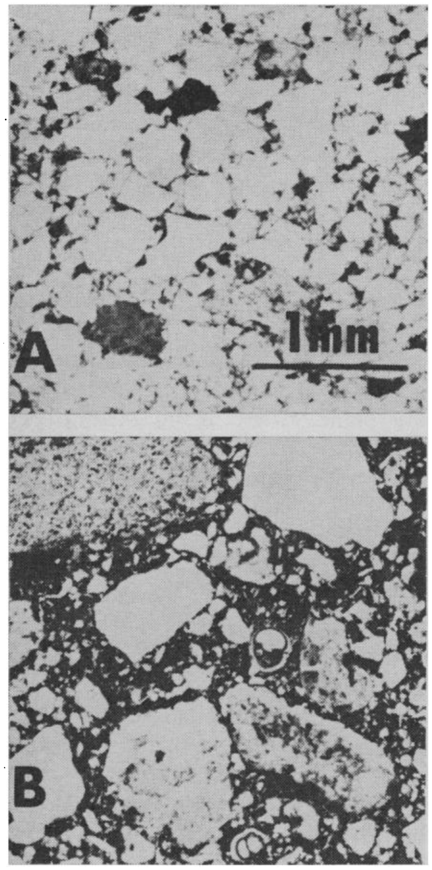

Fig. 1. Photograph of a thin section through (*A*) core V 7-42 (135 cm), subarkose-type sand; and (*B*) core V 7-55 (355 cm), graywacke-type sand (× 25). Light-colored grains are quartz and feldspar. Note abundant dark-colored interstitial matrix in *B*. The thin sections are obtained from portions of cores that have been impregnated with epoxy resins, sliced, mounted on glass, and ground to the standard thickness of 30 μ.

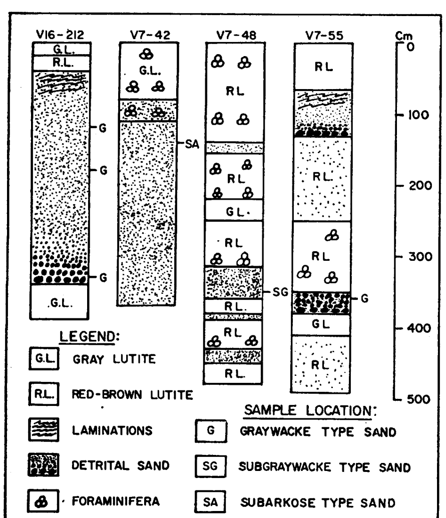

Fig. 2. Graphic descriptions of four sediment cores from the Sohm Abyssal Plain. Cores V 16-212 and V 7-55 contain graywacke-type sands. Cores V 7-42 and V 7-48 contain subarkose and subgraywacke-type sands that are typical of most abyssal plain sands studied.

The framework grains of the two graywacke-type sands are well sorted. There were no grains larger than 2 mm and 88 percent of each distribution falls within two classes (2.0-1.0 mm and 1.0-0.5 mm). The fine admixtures decrease rapidly to less than 0.02 percent between 0.06 mm and 0.03 mm. As the fine matrix (<0.02 mm) makes up at least 20 percent of the sample volume (Table 1), it is apparent that this sediment is strongly bimodal and that the fine fraction forms a secondary mode in the original material. Similar bimodal distributions are typical of ancient graywackes (see *6*).

Although minor postdepositional changes may have occurred, it is concluded that this fine matrix is a primary feature of the sediment and that both were deposited simultaneously. The emplacement of matrix by burrowers has been suggested as a mechanism to produce graywackes from clean sands (*7*); however, the clean sands of the abyssal plains are found to depths several times the maximum depth reached by burrowers.

Although graywacke may be produced by later filling of the pore spaces of subgraywacke-type sediment during diagenesis, the occurrence of primary, modern deep-sea sands of the graywacke type indicates that postdepositional alteration is not always necessary. The predominance of the clean "subgraywacke-type" sands over muddy "graywacke-type" modern sediments in the deep sea, however, suggests that postdepositional alteration is an important factor in graywacke genesis.

CHARLES D. HOLLISTER
BRUCE C. HEEZEN
Lamont Geological Observatory, Palisades, New York

References and Notes

1. F. J. Pettijohn, *Sedimentary Rocks* (Harper, New York, ed. 2, 1957).
2. E. B. Bailey, *Geol. Mag.* **67**, 77 (1930).
3. F. P. Shepard, in *Deltaic and Shallow Marine Deposits*, L. M. J. U. Van Straaten, Ed. (Elsevier, New York, 1964), pp. 1-25.
4. W. A. Cummins, *Liverpool Manchester Geol. J.* **3**, 51 (1963).
5. F. Chayes, *Am. Mineralogist* **36**, 704 (1951).
6. E. F. McBride, *J. Sediment. Petrol.* **32**, 1, 39 (1962).
7. J. R. Curray, in *Recent Sediments, Northwest Gulf of Mexico*, F. P. Shepard *et al.*, Eds. (American Association of Petroleum Geologists, Tulsa, Oklahoma, 1960), pp. 265-266.

8. This report is Lamont Geological Observatory Contribution No. 754 and was supported by the U.S. Navy Office of Naval Research. Reproduction of this report in whole or in part is permitted for any purpose of the United States Government. We benefited from discussions with K. O. Emery, F. J. Pettijohn, J. Schlee, and R. Siever.

31 August 1964

Variations of Nitrogen-15 Abundance in Soils

Abstract. *A survey of the isotopic composition of soil nitrogen has shown that there is variation in the abundance of nitrogen-15 in soils and in different forms of soil nitrogen. The variation detected is small, but it cannot be attributed to analytical errors and should be considered in studies of nitrogen transformation in soils when nitrogen-15 is used as a tracer.*

Variations in the relative abundance of nitrogen isotopes in the atmosphere and in natural materials such as peat, coal, oil, rain, rocks, minerals, and leaves have been reported (*1*). No survey of variation in nitrogen isotopic abundance in soils appears to have been made, but there is evidence to indicate that variation does occur (*2*).

The isotopic abundance of the nitrogen in different soils and in various forms of soil nitrogen has been studied by analysis of the nitrogen isotope-ratio of a wide variety of soil samples, including samples from virgin and ad-

Table 1. The N^{15}-content (ΔN^{15}) of the nitrogen in soils.

Soil type*	Sample depth (cm)	Total N (%)	ΔN^{15}
Edina SiL (V)	0–15	0.30	+2
Edina SiL (C)	0–15	.17	+1
Grundy SiCL (V)	0–15	.35	+16
Grundy SiCL (C)	0–15	.20	+10
Hayden SiL (V)	0–15	.28	+2
Hayden SiL (C)	0–15	.16	+7
Sable SiCL (N)	0–15	.21	+11
Sable SiCL (N)	15–30	.20	+12
Sable SiCL (N)	30–45	.14	+14
Sable SiCL (T)	0–15	.24	+4
Sable SiCL (T)	15–30	.21	+11
Sable SiCL (T)	30–45	.13	+16
Cisne SiL (N)	0–15	.11	+3
Cisne SiL (N)	15–30	.09	+6
Cisne SiL (N)	30–45	.06	+5
Cisne SiL (T)	0–15	.15	+3
Cisne SiL (T)	15–30	.11	+7
Cisne SiL (T)	30–45	.07	+5
Fargo SiC	0–15	.30	−1
Harpster SiL	0–15	.36	0
Sceptre C	0–15	.32	+1
Naicam SL	0–15	.30	+2
Clinton SiL	0–15	.18	+4
Houston SiC	0–15	.19	+8
Promise C	45–75	.09	+17

* SiL, silt loam; SiCL, silty clay loam; SiC, silty clay; C, clay; SL, sandy loam; V, virgin soil; C, cultivated soil; N, soil receiving no residue or fertilizer treatments in long-term rotation experiment; T, soil receiving periodic treatments of residue, lime, phosphorus, and potassium in long-term rotation experiment.