3. W. J. H. Nauta, *J. Comp. Neurol.* **104**, 247 (1956); *Brain* **81**, 319 (1958); ——— and H. G. J. M. Kuypers, *Reticular Formation of the Brain* (Little, Brown, Boston, 1958).
4. E. E. King, R. Naquet, H. W. Magoun, *J. Pharmacol. Exptl. Therap.* **119**, 48 (1957).
5. This research was supported by U.S. Public Health Service grant No. M-1918 and the Wallace C. and Clara A. Abbott Memorial Fund of the University of Chicago.

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Geochemistry of Graywackes and Shales

Abstract. Sixty-nine graywackes and 33 shales were analyzed spectrographically for 14 minor elements to illustrate the variation of composition within a graywacke bed, between beds in one section, between sections, and between formations. Analyses of several fractions of a graywacke indicate what each contributes chemically to the rock.

Some interesting features regarding the geochemistry of graywackes and shales are shown by 28 Normanskill-formation graywackes, 24 Quebec-group graywackes, 17 miscellaneous graywackes, and 33 shales analyzed spectrochemically for boron, barium, cobalt, copper, chromium, gallium, magnesium, manganese, nickel, scandium, strontium, titanium, vanadium, and zirconium (*1*) (see Table 1).

Turbidite graywackes result from deposition by turbidity flows which form when oversteepening of the continental shelf results in large-scale slumping of shelf or deltaic sediments. It might be expected that as these flows sweep down the gentle continental slope, the largest and heaviest mineral grains, which are often those showing relatively high concentrations of minor and trace elements, would be dropped first, and that the finer clay particles would be the last to settle. Therefore, a considerable difference in composition between the bottom and the top of a bed might be expected.

The analyses show no statistically valid difference in composition between the top and bottom of a graywacke bed except for zirconium, which is always found in relatively high concentrations at the base. Such homogeneity results from the counterbalancing effect of elements contained in both the heavy mineral fraction and in the clay matrix. For example, the amount of boron present in a few grains of tourmaline at the base of a bed is counterbalanced by the smaller amount present in a large amount of clay near the top. Less zirconium is found in the clay matrix than in the heavy mineral fraction because of the absence of naturally occurring soluble zirconium compounds; thus, for zirconium, there is no counterbalancing effect.

There is little variation in average composition between graywacke formations, an indication that graywacke sediments are, in general, similar. Graywacke sediments are mechanical mixtures of most of the common rock types, derived from large areas of the continent and distributed to the ocean by the larger rivers.

Between stratigraphic sections in one formation and between beds in one section there are great differences which reflect the position of the section with respect to the shelf area and the position of the bed with respect to the source, since turbidity currents are inhomogeneous both laterally and vertically. The composition of a bed as a whole may change without any accompanying change in the compositional differences between the top and bottom, except for zirconium.

Normanskill graywackes contain seven major constituents—quartz, feldspar, clay matrix, carbonate cement, heavy minerals, clay rock fragments, and carbonate rock fragments. By separating several fractions and analyzing them separately, the contribution of each fraction to the rock can be obtained. Feldspars add a considerable amount of barium but very little strontium. Carbonate cement contributes magnesium, manganese, strontium, and barium, the strontium arising from the redistribution of aragonite and radiolarian skeletal material by percolating intrastratal fluids. Heavy minerals are very rich in zirconium (over 10,000 parts per million) and contain much barium, cobalt, chromium, copper, nickel, scandium, titanium, vanadium, and silver but no detectable gold. The clay matrix adds considerable amounts of hydrolyzate elements such as boron, barium, cobalt, chromium, copper, gallium, nickel, titanium, and vanadium, but the levels of zirconium, manganese, magnesium, and strontium are very low.

A correlation of mineral composition, determined by detailed point-counting of thin sections, and chemical composition was attempted, but only gross correlations are visible—for example, graywackes rich in clay matrix tend to be richer in boron. The interplay of analytical and point-counting errors and the small range of mineral composition of the graywackes tend to obscure detailed correlations.

The effect of provenance is shown by the Normanskill formation (island-arc-derived) and the Quebec group (shield-derived) graywackes. Turbidites originating from the relatively more basic island arc environment show higher concentrations of the elements which are usually found in relatively high concentrations in basic rocks, while shield-derived graywackes are richer in elements such as zirconium, which are associated with acidic rocks.

No striking difference between the composition of graywackes and the average crustal rock is evident.

If each pair of elements is statistically treated to show the degree of correlation or interdependency of the concentration between the two, a great number of correlations are evident even at the 1-percent level of significance. This is largely the result of the presence of seven major constituents which form these graywackes. For example, graywackes rich in manganese tend to show high concentrations of strontium also, thus reflecting the quantity of cementing material in which these two elements are contained.

Analyses of 33 shales from formations of Ordovician, Devonian, and Cretaceous age show an increase in the boron content toward the present, suggesting that boron was added to the oceans by volcanism rather than by the condensation of volatile boron trichloride from a protoatmosphere.

Table 1. Results of spectrographic analysis of samples of graywackes and shales for 14 elements. All concentrations are given in parts per million except those for magnesium, which are given in percentages.

Sample	Concentration													
	B	Ba	Co	Cr	Cu	Ga	Mg	Mn	Ni	Sc	Sr	Ti	V	Zr
Quebec-group graywackes	70	220	15	88	9	10	.82	540	27	5	110	8500	43	810
Normanskill graywackes	35	380	22	140	33	14	1.2	600	43	8	260	5100	67	400
Kiskatom graywackes	120	530	28	250		6	1.9	850	77	11	120	11000	88	440
Rennselaer graywackes	32	750	14	130	14	9	1.5	750	25	8	190	6300	48	460
Miscellaneous graywackes (N = 9)	42	430	20	120	5	9	3.2	470	39	8	150	4500	52	260
Normanskill shale	130	360	32	87	37	20	2.4	400	58	15	150	7000	79	230
Miscellaneous shales (N = 33)	220	520	22	110	58	13	1.6	180	64	12	150	6000	150	340

Pelagic shales show striking differences from shales associated with graywackes in that the slowly accumulating pelagic shales are thinner-bedded, more fissile when compacted, and flaky when weathering. In addition, they tend to be richer in boron, barium, chromium, copper, nickel and vanadium, elements typical of hydrolyzate environments. These elements are removed from the sea in greater quantities because of the slower deposition of pelagic shales, which show a much lower content of magnesium, manganese, and cobalt than shales associated with graywackes. The latter are thicker-bedded, slabby, and more compact, and they contain less organic material. The differences are a result, largely, of the rate of deposition; shales associated with graywackes represent the tail of a turbidity flow.

Graywackes are intermediate in composition between shales on the one hand and sandstones on the other.

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Note

1. The samples were collected by G. V. Middleton, who also determined the mineral composition by point-counting.

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Autonomy of Cytoplasmic Male Sterility in Grafted Scions of Tobacco

Abstract. Negative results were obtained in experiments designed to detect graft transmission to progeny of cytoplasmic male sterility in tobacco, contrary to positive results reported by Frankel in petunia. Attempts to show graft transmission of male fertility also failed. Evidently transmission of cytoplasmic male sterility through a graft union with a fertile individual is not an easily repeatable or else is not a general phenomenon in plants.

Frankel (*1*) has reported graft-induced transmission to progeny of cytoplasmic male sterility in certain cultures of petunia. Because of the considerable theoretical and practical interest attaching to such a demonstration, we have attempted to repeat the work by using cultures of cytoplasmic male sterile tobacco. Although these results are entirely negative, a published note seems desirable to indicate that graft transmission of cytoplasmic determination of male sterility is not a general or easily repeatable phenomenon in plants. The grafting experience of other workers (*2*) with cytoplasmic male sterility in petunias has also failed to demonstrate graft-induction or graft transmission of sterility.

The male sterile tobacco material used in these experiments was derived by pedigree culture from a type selected by Clayton (*3*) after an interspecific cross between *Nicotiana debneyi* as female and *N. tabacum*. Subsequent backcrosses to tobacco reinstated the tobacco genome. The male sterility and split-blossom characters were consistently maintained in recurrent backcrosses, and therefore, by inference, are associated with an autonomous cytoplasmic system, presumably contributed by *N. debneyi*. The behavior shown in repeated crosses is illustrated in Table 1 by cultures 1, 2, and 3. The recurrent fertile parent was an inbred line of Connecticut broadleaf cigar tobacco. The male-sterile family represented by culture 3 was the product of the 14th backcross to tobacco following the original cross with *N. debneyi*.

Table 1. Progeny obtained from grafted and control parents possessing cytoplasmic male sterility or fertility in *Nicotiana tabacum*.

Culture	Family	Parents		Progeny	
		Mating*	Pedigree	Fertile	Sterile
1	5685	U.S. × U.F.	55322-1 × 55 Kup.	0	20
2	5768	U.S. × U.F.	5685-22 × 569-9	0	16
3	5842	U.S. × U.F.	5768-3 × 577-2	0	19
4	S5863	S/F × U.F.	5768-3/577-2 × 577-1	0	55
5	S5859	U.F. Self	5710-3 Self	59	0
6	S5860	F/F Self	5710-4/577-4 Self	57	0
7	S5858	F/S Self	5710-2/5768-1 Self	48	0
8	S5861	F/S × U.F.	5710-2/5768-1 × 5710-3	51	0
9	S5862	U.F. × F/S	5710-3 × 5710-2/5768-1	54	0

* F, male fertile; S, male sterile; U.F., ungrafted fertile; U.S., ungrafted sterile. Graft type is shown as scion/stock. The scion was always used as parent.

Four families of plants were employed in the reciprocal grafting experiments in 1957. These included a male-sterile and a male-fertile broadleaf tobacco (families 5768 and 577), and a male-sterile and a male-fertile Havana seed tobacco (families 5767 and 5710). The ten whip grafts made in the field during the week of 17 Aug. 1957 comprised three sterile on fertile, three fertile on sterile, two fertile on fertile, and two sterile on sterile. These grafts were readily established, and the material was transplanted to the greenhouse in September along with two ungrafted fertiles and two ungrafted steriles.

Self-pollinations and intercrosses of a large number of types are possible if these five sterile and five fertile scions, five sterile and five fertile stocks, and the four ungrafted fertile and sterile controls are employed as parents. Fifty-three of the more significant of these pollination types were made during the period from September 1957 to February 1958, and seed was successfully harvested.

The sterile scions remained sterile and the fertile scions remained fertile in phenotype, irrespective of the stock type to which they were grafted, throughout the period of more than 6 months during which they were observed. This autonomy of scion phenotype is in agreement with the observations of Frankel on petunia grafts (*1*). However, Frankel's tests were interpreted to indicate that the "grafting induced changes in the fertile scion that resulted in the appearance of cytoplasmic sterility in its progeny."

The progeny results for our tobacco material are shown in Table 1 for seven critical pollinations grown as seven families (cultures 3 to 9) in the summer of 1958. Seed from the additional pollinations is still available, but loses much of its interest in the absence of a positive transmission effect. Culture 4, in comparison with 3, shows that male *fertility* is not transmitted from stock through scion to progeny. Culture 6 indicates that the grafting process itself has not induced detected male *sterility*. Cultures 7, 8, and 9, in comparison with cultures 5 and 6, give no indication of any influence of the cytoplasmic male sterile stock on the progeny obtained from the fertile scion. Rather, these data concur in the indication of autonomous control of cytoplasmic male sterility or fertility in these grafted scions of tobacco.

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References and Notes

1. R. Frankel, *Science* **124**, 684 (1956).
2. H. L. Everett, Department of Plant Breeding, Cornell University, Ithaca, N.Y., personal communication.
3. E. E. Clayton, *J. Heredity* **41**, 171 (1950).

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