between mycelial and uredial forms. Uredospore bands 2 and 3 were close together, had lower mobilities than leaf band 2, were not observed in the infected leaf at any stage of infection, and were not destroyed by 5-minute heat treatments at 50°C.

Leaf band 3 was found in the supernatant but not in mitochondria of young uninoculated leaves. It faded as healthy leaves grew older but did not when healthy leaves were infected. It also was heat stable. The enhancement of band 3 during rusting indicates that the host cells were stimulated to continue its synthesis. In this way both host and parasite contributed to the enzymatic structure of the host-parasite complex.

Bean leaf band 4 was found in mitochondria as well as in supernatant from healthy plants, but was nearly absent from mitochondria in infected plants. The amount of malate dehydrogenase in mitochondria from healthy 22-day old leaves was four times that in the supernatant. The amount from rusted leaf cytoplasm was about the same as in healthy leaf cytoplasm.

Failure to detect band 4 in mitochondria from infected leaves indicates mitochondrial destruction during the course of disease development. Yet much of the metabolic capabilities of the tissue must have been retained as indicated by the resynthesis of band 3 in rusted leaves as well as starch synthesis around the pustules (*5*). Electron micrographs of rusted tissue (*6*) confirm the mitochondrial destruction and tissue disorganization in cells invaded by haustoria. If the work with black rot of sweet potatoes can serve as a model (*7*), band 3 originates by an enhanced protein synthesis in nearby, uninvaded host cells, whose mitochondria seem to be less stable than normal. Otherwise band 4 from these mitochondria should have been detected.

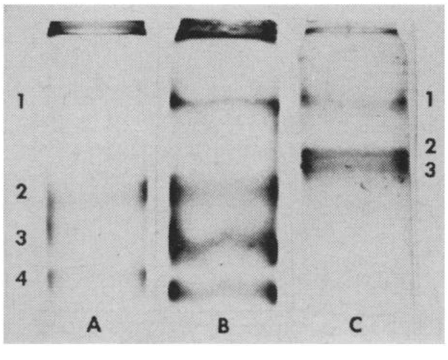

Fig. 1. Polyacrylamide gels stained for malate dehydrogenases from uninoculated 22-day-old bean leaves (*A*), bean leaves rusted 12 days (*B*), and bean rust uredospores (*C*).

These studies with malate dehydrogenase and other multiple enzyme systems in rusted leaves suggest that host-parasite interactions control enzyme synthesis in the infection complex. It appears that the host alters the number and form of the rust isozymes, while the fungus alters the rate of synthesis of enzymes by the host, enhancing some while repressing others (*8*).

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References and Notes

1. N. W. Pirie, *J. Agr. Eng. Res.* **6**, 142 (1961).
2. L. Ornstein and B. J. Davis, preprint by Distillation Products Industries (1959).
3. C. L. Markert and F. Møller, *Proc. Natl. Acad. Sci. U.S.* **45**, 753 (1959).
4. O. Lowry, in *Methods in Enzymology*, S. P. Colowick and N. O. Kaplan, Eds. (Academic Press, New York, 1957), vol. 5, p. 379.
5. M. Shaw and D. J. Samborski, *Can. J. Botany* **34**, 389 (1956).
6. R. T. Moore and J. H. McAlear, *Phytopathol. Z.* **42**, 297 (1961).
7. I. Uritani and M. A. Stahmann, *Plant Physiol.* **36**, 770 (1961).
8. Supported in part by grants from the Rockefeller Foundation and the Frasch Foundation. One of us (R.C.S.) was on leave from Boyce Thompson Institute for Plant Research, Inc., Yonkers, N.Y. Published with the approval of the director of the Wisconsin Agricultural Experiment Station.

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Basalts Dredged from the Northeastern Pacific Ocean

Abstract. *Volcanic rocks dredged from seamounts, fault ridges, and other major geological features of the northeast Pacific Ocean include a wide variety of basalts. Most of these are vesicular, porphyritic types with near analogues in the Hawaiian and other oceanic islands. In addition, aluminous basalts and diabasic tholeiites impoverished in potassium also occur. There is no simple correlation of composition, degree of oxidation, vesiculation, or hydration of these basalts with texture, or depth of dredge site. Most samples appear to have been extruded at much shallower depths than those now pertaining at the dredge site. The distribution of these basalts suggests that the andesite line coincides with or lies on the continent side of the foot of the continental slope.*

During recent years expeditions of the Scripps Institution of Oceanography into the northeast Pacific Ocean have made about 150 dredge hauls from seamounts, pinnacles, submarine fault ridges, and irregular slopes. Seismic studies indicate that the thickness of crustal layer 3 (the "oceanic crust") at and near dredge sites ranges from 4.5 km to 6.4 km whereas the average thickness of layers 1, 2, and 3 in this region is 6.3 km (*1*). This typically deep ocean crustal structure continues to, or almost to, the foot of the continental slope as plotted in Fig. 1. Extended studies of heat flow from localities near the several dredge sites indicate a wide range of values from 0.1 to 5.8×10^{-6} cal cm^{-2} sec^{-1}, with a mean of about 1.4 (*2*). Some of the lower and higher values (0.1 and 5.8) occur respectively along the south and north sides of the Mendocino lineament, in the vicinity of samples 16 and 17 (Fig. 1).

Depths of dredged sites vary up to 4000 m. All of the igneous rocks from the dredge hauls in the Pacific Basin that appear to be indigenous (*3*) to the dredge sites are basalts, but these vary widely in composition. Petrographic and chemical studies indicate that alkali basalts, tholeiites, and high-alumina basalts are present in the northeast Pacific.

Studies of the original igneous rock types are hampered by extensive rock alteration and weathering. More than 90 percent of the rocks are encrusted with and variously replaced by hydrated manganese and iron oxides and weathered rinds. Many samples are veined and replaced by carbonates, phosphates, palagonite, chlorite, iddingsite, zeolites, and clay minerals.

Most of the recognizable igneous rocks from seamounts and pinnacles are porphyritic and vesicular basalts, with a glassy to microcrystalline groundmass. Flow banding and pillow structures are common. Several dredge hauls include fragments of glass and scoria. These forms and textures suggest that most of the rocks in the dredge hauls from seamounts are from the surficial parts of lava flows and cones.

Vesicles persist in basalt from the deepest dredge haul, at about 4000 m, and there is no uniform decrease in vesicles as a function of depth. Korzhinsky also reports vesicles in basalts dredged from depths of as much as 4885 m (*4*). It is probable, however, that

Table 1. Chemical composition of samples of basalts from the northeastern Pacific Ocean.

Oxide	PV 77	PV 71	PV 148	EM	PV 17	PV 37	PV 50
SiO_2	41.04	44.93	49.15	49.13	49.94	49.82	45.33
TiO_2	2.83	3.64	3.12	1.23	2.27	1.85	3.53
Al_2O_3	18.71	15.99	21.25	14.97	14.85	15.57	15.50
Fe_2O_3	4.43	4.11	3.82	3.28	2.17	3.13	1.81
FeO	6.59	6.15	1.65	5.72	8.07	6.58	10.64
MnO	0.21	0.30	0.27	0.16	0.22	0.11	0.23
MgO	7.92	7.51	2.09	7.68	6.42	5.82	6.77
CaO	10.99	9.38	9.97	12.68	11.92	12.83	8.50
Na_2O	2.43	3.82	4.14	2.37	2.70	3.24	4.30
K_2O	0.63	2.21	1.14	0.16	0.26	0.38	2.36
H_2O+	1.66	0.87	1.13	1.06	.63	.32	0.20
H_2O-	1.51	.29	1.20	1.25	.67	.22	.01
P_2O_5	0.98	.76	0.88	0.15	.18	.16	.73
Total	99.93	99.96	99.81	99.84	100.30	100.03	99.91

Location of samples:
PV 77, 24°36′N, 117°3′W, top of Crest Seamount, depth 670 m.
PV 71, 27°42′N, 119°17′W, top of unnamed seamount, depth 940 m.
PV 148, 29°31′N, 117°17′W, top of elongate bank, depth 880 m.
EM, 28°59′N, 117°30′W, experimental Mohole drilled on flat sea floor. Depth of water 3566 m, depth of basalt below sediment-water interface, 180 m (*5*).
PV 17, 40°23′N, 127°59′W, top of Mendocino Ridge, depth 1260 m.
PV 37, 47° 5′N, 130°45′W, top of Cobb Seamount, depth 125 m.
PV 50, 53°15′N, 136°46′W, Hodgkins Bank Pinnacles, depth 85 m.

these are not the depths at which many of the vesicular basalts were extruded. Some studies suggest that many of the seamounts were truncated by wave erosion at or near sea level, and that they, and the sea floor upon which they rest, have subsequently sunk to progressively greater depths (*5*). Also some of the basalt may possibly be scree that has migrated many meters down the slopes of seamounts before it was collected.

Phenocrysts of olivine, pyroxene, plagioclase, and opaque minerals are common in many of the basalts. In most samples, plagioclase is the phase most resistant to weathering and alteration, followed in order of decreasing resistance by pyroxenes and finally olivine. None of the olivine is completely fresh and much of it is largely altered to iddingsite, chlorite, and iron oxides.

Most basalts dredged from tops and flanks of seamounts are alkali basalts with subordinate tholeiites and highly aluminous types. Most of the basalts dredged from the sea floor per se are tholeiites.

Basalts dredged from the Mendocino Ridge and the Gordo Escarpment (*6*) and from other scattered ridges are more equigranular, have diabasic to gabbroic textures, and are predominantly tholeiitic in composition. Many of these rocks are probably from mafic intrusives or from the medial parts of basaltic flows. Several of the samples from the Mendocino Ridge and the Gordo Escarpment are sheared and highly fractured with striae on the fracture surfaces. These rocks appear to be fault breccia and seem to constitute direct evidence that faulting has occurred along these lineaments (*6*).

To date we have found no evidence of albitization or spilitization of the basalts dredged from the Pacific. These observations are consistent with Korzhinsky's conclusion that spilites are not developed through the interaction of basaltic lava and sea water, at least to depths of 5000 m (*3*).

Chemical and modal analyses of six basalts which are little altered and representative of the more diverse types are grouped in Tables 1 and 2. All analyses were made by the authors. Latitude and longitude, and depth of the dredge site, are given in Table 1. Locations are plotted in Fig. 1. Table 1 also includes an analysis of the basalt drilled in the experimental Mohole (Guadalupe site) located 150 miles west of Baja California (*7*).

Table 2. Modal analyses of basalts from the northeastern Pacific Ocean (percentages).

Mineral	PV 77	PV 71	PV 148	EM	PV 17	PV 37	PV 50
Groundmass	25.8		40.8			15	
Glass*	2.0	55.4				tr†	52.6
Plagioclase	34.8	9.0	32.7	41	32.4	23	10.0
Pyroxene	3.4	4.6	1.0	49	60.0	50	3.0
Olivine	6.4	5.2		1			4.1
Opaque	4.8	1.1	3.0	5	5.8	tr†	2.1
Vesicles	18.4	23.6	21.0	tr†	1.0	11	28.0
Others‡	4.4	1.1	1.5	3	0.8	1	0.2

* Includes crystallites. † Trace. ‡ Palagonite, chlorite, carbonate, zeolites, iron oxides, and rare apatite.

Sample 77, from the Crest Seamount, is an angular fragment of vesicular porphyritic basalt, 10 inches across. The surface of the fragment is incipiently altered by, and partially coated with, a thin film of iron oxides. The interior is light gray, mottled with large white phenocrysts of plagioclase and dark gray to brown phenocrysts of olivine and pyroxene. The vesicles are rounded, uniformly distributed, and constitute about 30 percent of the rock. Many vesicles contain thin rims of iron oxide and other microcrystalline alteration products. Much of the fine-grained olivine is altered to iddingsite and limonite. Some grains of olivine are deeply embayed; a few have scattered inclusions of picotite. The phenocrysts of olivine, pyroxene (titanoaugite), plagioclase (anorthite, 76 percent), and opaque oxides are stubby subhedral to euhedral and range in size to 4 mm.

Sample 71 is a bomb-shaped fragment of vesicular porphyritic basalt. The surface of the fragment is thickly encrusted with hydrated manganese oxides, and veinlets of manganese also cut the interior of the sample. The interior of the rock is dark gray to black, with vesicles and tubules as much as 6 cm in length. In thin section the rock consists of zoned plagioclase (approximately 68 percent anorthite), augite, and olivine set in a matrix of brownish glass and scattered crystallites. Most of the augite phenocrysts are zoned and contain inclusions of glass. Some of the larger olivines are embayed in a complex manner and partially resorbed.

The basalt PV 148 is an angular fragment, gray and porphyritic, 8 inches across, with a thin surface coating of hydrated iron and manganese oxides. The interior is massive to highly vesicular; the vesicles range in size up to 3 mm. In thin section the rock consists of abundant plagioclase (58 percent anorthite) and rare, large, deeply embayed pyroxenes set in a microcrystalline groundmass.

Sample EM is basalt from the experimental Mohole (*7*). It is a fine-grained basalt with rare vesicles as much as 0.5 mm in diameter. In thin section the rock consists of subradiating laths of plagioclase, pyroxene, and rare olivine, set in a finer-grained matrix of these minerals, opaque minerals, and alteration products.

Sample PV 17 is an angular fragment 6 inches across with vesicles abundant in the rounded, marginal parts of the sample. The vesicles are elongate and aligned parallel to flow surfaces and the specimen appears to be part of a large pillow. The surface is encrusted with a thin coating of hydrated iron and manganese oxides. In thin section the texture is diabasic with abundant, subradiating laths of plagioclase intergrown with, and partly enveloped by, pyroxene. Some vesicles appear to be filled with microcrystalline to glassy basalt rich in opaque minerals and rare opal.

Sample PV 37 is a fragment of pillow basalt about 10 inches across. The pillowed structure is accentuated by internal flow banding. Abundant vesicles appear in a zone 3 cm wide in the outer part of the pillow. The interior of the pillow is fine-grained, gray, vesicular basalt. In thin section the rock has a fine subophitic texture which merges from place to place into a felted aggregate of pyroxene, plagioclase, and opaque minerals.

Sample PV 50 is a fragment of scoriaceous basalt approximately 8 inches across. The surface of the rock is essentially unaltered. The interior is dark gray to black with vesicles and tubules as much as 3 cm in diameter and 5 cm long. In thin section the rock is porphyritic with phenocrysts of plagioclase, pyroxene, and olivine set in a glassy to microcrystalline groundmass.

Most of these basalts have at least approximate analogues in the Hawaiian and other oceanic islands. There are, however, some interesting differences. Samples PV 77 and PV 148 are both more aluminous than most oceanic basalts. Indeed Kuno and others (*8*) have suggested that high alumina basaltic magmas are confined to orogenic belts marginal to oceanic basins. It is possible that the high content of Al_2O_3 of sample PV 148 reflects the preferential concentration of plagioclase crystals into this part of an initially less aluminous magma, but this interpretation is not plausible for sample PV 77; for in this sample the microcrystalline to glassy groundmass and the pyroxene are both alumina rich, containing respectively 18 and 7 percent Al_2O_3 by weight. We have found other microcrystalline to glassy basalts which contain in excess of 16 percent Al_2O_3 by weight and high-alumina basalts may be common in the northeast Pacific Ocean.

Basalt sample PV 77 also contains nepheline in the norm and lies in the compositional overlap between the low-alkali "alkali basalts" and the nepheline basalts of Hawaii, as defined on the basis of alkalis and silica by Macdonald and Katsura (*9*). The basalts PV 50 and PV 71 lie on the high-alkali side of the alkali-silica field of Hawaiian alkali basalts, although they contain less silica than the typical hawaiites (*9*). Samples PV 17 and PV 37 are characteristic of a group of high-silica, low-potassium tholeiites dredged from the northeast Pacific. Ex-

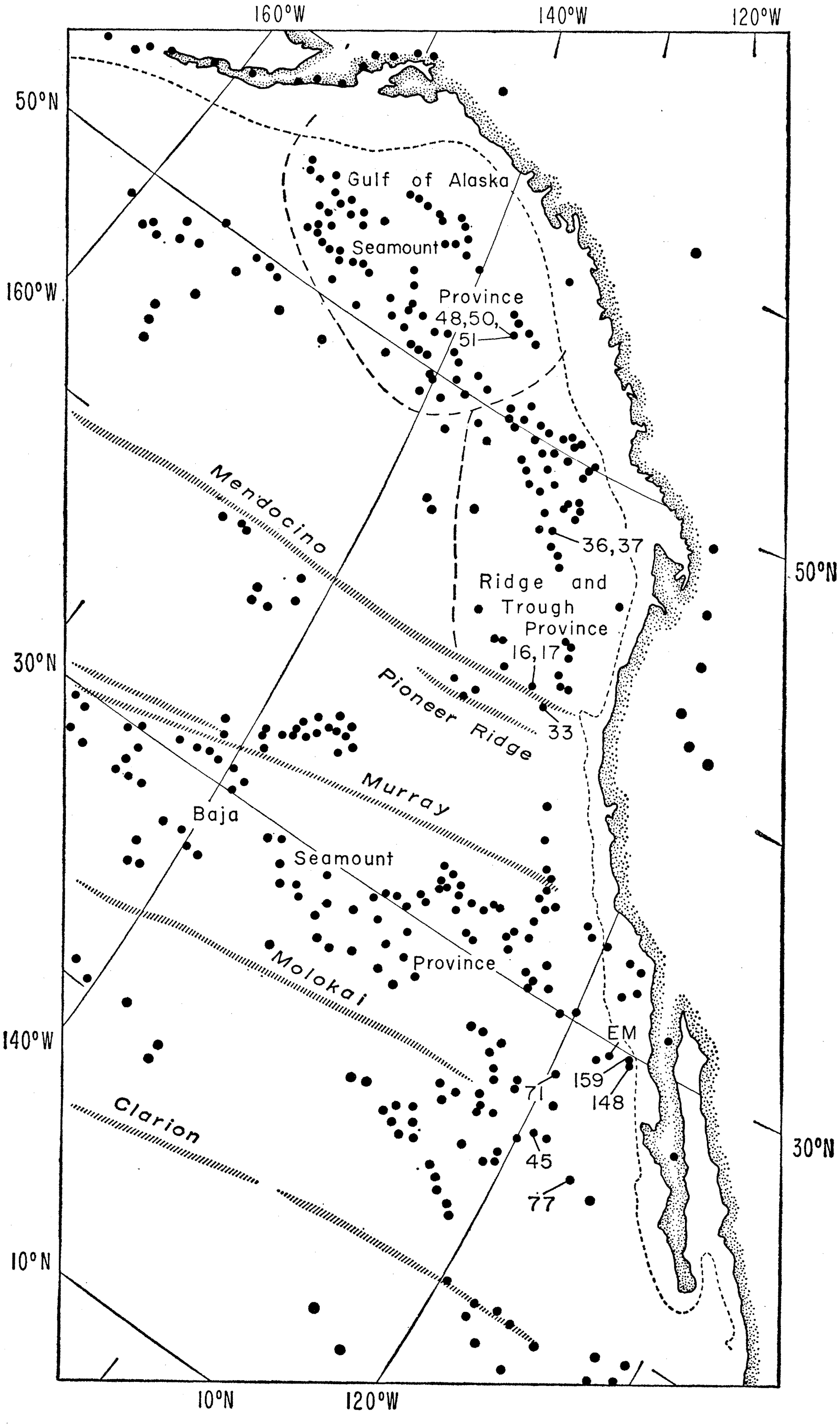

Fig. 1. Sketch map of the northeast Pacific Ocean showing the major topographic and structural lineaments and known volcanic seamounts (black dots). The black dots on land represent recent and active volcanoes. The dashed line offshore represents the foot of the continental slope and the eastward extent of typical ocean crustal structure.

cept for their remarkably low potassium content, these basalts are very similar to typical tholeiites from Hawaii and from many other areas (*9, 10*).

The basalt PV 17 is texturally and compositionally similar to the basalt cored from the experimental Mohole (Tables 1 and 2). The experimental Mohole basalt (sample EM) contains 0.16 percent K_2O, and PV 17, 0.26 percent K_2O. There are no obvious signs of leaching or extensive alteration of these basalts that might induce a secondary loss of potassium. It is probable that the low potassium content of these basalts is a primary feature. Basalts from both of these sites tend to be uniformly crystalline, medium-grained, and have a diabasic texture.

Other compositional features of interest in the basalts analyzed to date are the wide range and occasional high values of Ti, P, H_2O, and the ratio of Fe_2O_3 to FeO. Numerous workers have attempted to relate the degree of hydration and oxidation of basalts to subaerial or subaqueous extrusion and to textural features (*11*). These relations are bound to be complicated by nonequilibrium processes and products. Hence, generalizations are dangerous. Extreme hydration and oxidation of fine-grained and glassy submarine basalts from the dredge hauls are common and widespread, presumably both as a primary feature and as a function of aging and weathering. There is no obvious, simple correlation between texture and degree of oxidation and hydration in the least weathered basalts as is frequently suggested (*11*). It seems probable, however, that most fine-grained and glassy submarine basalts become increasingly hydrated and oxidized within a few thousand or tens of thousands of years after their extrusion. We are separating plagioclases and pyroxenes from these basalts for age dating in an effort to clarify some of these problems.

The glassy to distinctly porphyritic nature of many samples permits the complete separation of phenocrysts and groundmass. Analyses of the separates permits studies of the partitioning of elements between the coexisting phases, the course of crystallization, magmatic differentiation, as well as age studies. In many of the basalts, olivine, plagioclase, pyroxene, and iron oxides appear to precipitate within a relatively short temperature interval (*11*). This is indicated by the fact that all four phases appear in basalts of appropriate composition that contain more than 85 percent glass and crystallites. Other basalts deviate from this pattern. The most striking example is the aluminous basalt PV 148. Therein, the plagioclase phenocrysts form up to 45 percent of the rock and the remainder consists of microcrystalline groundmass and glass. Very possibly sample PV 148 is an example of a crystal accumulate in which plagioclase has been locally concentrated.

The optical properties, brownish-pink color, and chemical composition of pyroxene in the alkali basalts indicate that subcalcic augite and titanoaugites predominate. The augite in sample PV 77 contains 2.5 percent TiO_2, 7 percent Al_2O_3, and 22 percent CaO. The olivine is 65 percent forsterite. Compared to the total rock, the groundmass of sample PV 77 is enriched in alkalis, especially Na, as well as Fe and has a higher ratio of Fe_2O_3 to FeO. In contrast, it is slightly impoverished in silica. Hence, the trend in the composition of the liquid with increasing crystallization was toward an even more alkalic basalt (*12*).

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References and Notes

1. G. G. Shor, Jr., *Bull. Seismol, Soc. Am.* **52**, 37 (1962); R. W. Raitt, *Bull. Geol. Soc. Am.* **67**, 1623 (1956); A. Milne, "Pacific Naval Lab. Rept. 60–10" (1960), unpublished; R. W. Raitt and G. G. Shor, Jr., personal communication.
2. R. P. Von Herzen and S. Uyeda, *Contribs. Scripps Inst. Oceanogr.*, new ser., Marine Geophys. Lab., U-44 (1962); T. D. Foster, *J. Geophys. Research.* **67**, 2991 (1962); R. P. Von Herzen, personal communication.
3. Tests of the indigenous nature of the samples include the reported hang-up of the dredge at the site; the abundance of angular fragments, pillows, and glass with freshly broken edges; and the uniformity of basaltic composition of the fragments.
4. D. S. Korzhinsky, *Izv. Akad. Nauk S.S.S.R., Ser. Geol.* No. 9, 12 (1962).
5. H. H. Hess, *Am. J. Sci.* **244**, 772 (1946); H. W. Menard and R. S. Dietz, *Bull. Geol. Soc. Am.* **62**, 1263 (1951); E. L. Hamilton, *Geol. Soc. Am. Memoir* **64** (1956).
6. H. W. Menard, *Bull. Geol. Soc. Am.* **70**, 1491 (1959); V. Vacquier, in *Continental Drift*, S. K. Runcorn, Ed. (Academic Press, New York, 1962), vol. 3, p. 135; V. Vacquier, A. D. Raff, R. E. Warren, *Bull. Geol. Soc. Am.* **72**, 1251 (1961).
7. C. G. Engel and A. E. J. Engel, *Bull. Am. Assoc. Petrol. Geol.* **45**, 1799 (1961).
8. H. K. Kuno, *J. Petrology* **1**, 121 (1960).
9. G. A. Macdonald and T. Katsura, in *The Crust of the Pacific Basin*, Am. Geophys. Union Monograph No. 6 (1962), p. 187; H. A. Powers, *Geochim. Cosmochim. Acta* **7**, 77 (1955); H. K. Kuno, C. I. Yamasaki, K. Nagashima, *Japan. J. Geol. Geograph.* **28**, 179 (1957).
10. F. J. Turner and J. Verhoogen, *Igneous and Metamorphic Petrology* (McGraw-Hill, New York, 1960), p. 203.
11. H. S. Washington, *Am. J. Sci., 4th Ser.* **50**, 446 (1920); J. D. H. Wiseman, "The John Murray Expedition, 1933–34," *Publ. Brit. Mus. Geol. and Mineral Invest.* **3**, 1 (1940); G. C. Kennedy, *Am. J. Sci.* **246**, 529 (1948); H. S. Yoder and C. E. Tilley, *J. Petrology* **3**, 342 (1962).
12. Publication authorized by the director, U.S. Geological Survey.

13 May 1963

Reversal of Thyroxine-Induced Hypermetabolism by Puromycin

Abstract. *Previous studies have demonstrated that in addition to its effects on metabolic rate, thyroxine stimulates protein biosynthesis. The administration of puromycin, a drug which blocks protein synthesis and, therefore, the thyroxine effect on protein synthesis, acutely reverses the hypermetabolism induced in rats by prior administration of thyroxine and restores the oxygen consumption of the thyrotoxic rats to the euthyroid level. The results suggest that a larger fraction of the total body basal oxygen consumption in hyperthyroidism is related to the process of protein synthesis than in the euthyroid state and that the calorigenic effect of thyroxine is secondary to its effect on protein synthesis.*

Previous studies in this laboratory have demonstrated that L-thyroxine administered either in vivo or in vitro stimulates the rate of amino acid incorporation into microsomal protein in cell-free rat liver homogenates (*1, 2*). More recently it has been found that hyperthyroidism induced by L-thyroxine administration results in increased amino acid incorporation into protein in the liver, kidney, and heart in the intact animal (*3*), but has no effect on incorporation in the brain, testis, and spleen, all organs in which oxygen consumption is also unaffected in hyperthyroidism (*4*).

In their initial report of the thyroxine effect on amino acid incorporation into protein, Sokoloff and Kaufman (*1*) suggested that the "acceleration of metabolic rate characteristic of thyroxine action may be secondary to the stimulation of energy-requiring reactions such as protein synthesis." The results of the present studies offer support for this possibility. Administration