Lucite container, was used. This apparatus was lowered by means of extended cables to various depths and locations within the basin. This method of detection plus the Na^{24} was used in an attempt to alleviate some of the sampling difficulties alluded to by other workers (*3*).

Figure 1 is an outline map of Stewart's Dark Lake showing the approximate extent of horizontal movement of the Na^{24}. The radioactivity was dispersed horizontally from the release point in a somewhat symmetrical pattern and was observed to have reached an average distance of 18 ± 3 m in all directions at the end of the first 24 hours. In one direction, a maximum horizontal movement of 22 m was observed during this period. This is a rate of horizontal movement, in this relatively static zone, which is several times greater than that found by other workers in similarly stable lake strata (*3*, *4*).

The radioactive material flowed along the bottom contour and continued to move toward the shore, reaching an average distance of 24 ± 3 m from the release point in 48 hours. Owing to the rapid decay of the Na^{24} and its dilution within the lake, however, accurate determination of the movement after the first day was difficult and became impossible by the third day. In addition, the background emanating from the bottom muds was highest near the shore, further hindering the accurate determination of the leading edge of the radioactivity.

Careful observations were made to determine whether the radioactivity was transported vertically within the lake. No appreciable vertical movement was observed above the release point, except shortly after the discharge, when high concentrations were found at the 4- and 6-m levels. This initial upward movement may have resulted from a density difference between the radioactive solution and the lake water at the release position. Also, a few small bubbles were seen to come to the surface as the bottle was broken, thus possibly transporting some radiosodium to higher levels. Further upward movement of the radioactivity, after this initial movement, was not observed above the release point. In addition, no vertical movement of the radioactive material was found at any other location in the lake.

The radioactivity was detectable in the lake for only 6 days, a fact which minimized any possible problems of radiation hazard to wildlife and other aquatic organisms.

There are at least two possible explanations for the rapid horizontal movement of the radiosodium; (i) physical transport as influenced by eddy diffusion, currents, internal seiches, and (ii) biological transport of the radionuclide to other parts of the lake (*5*).

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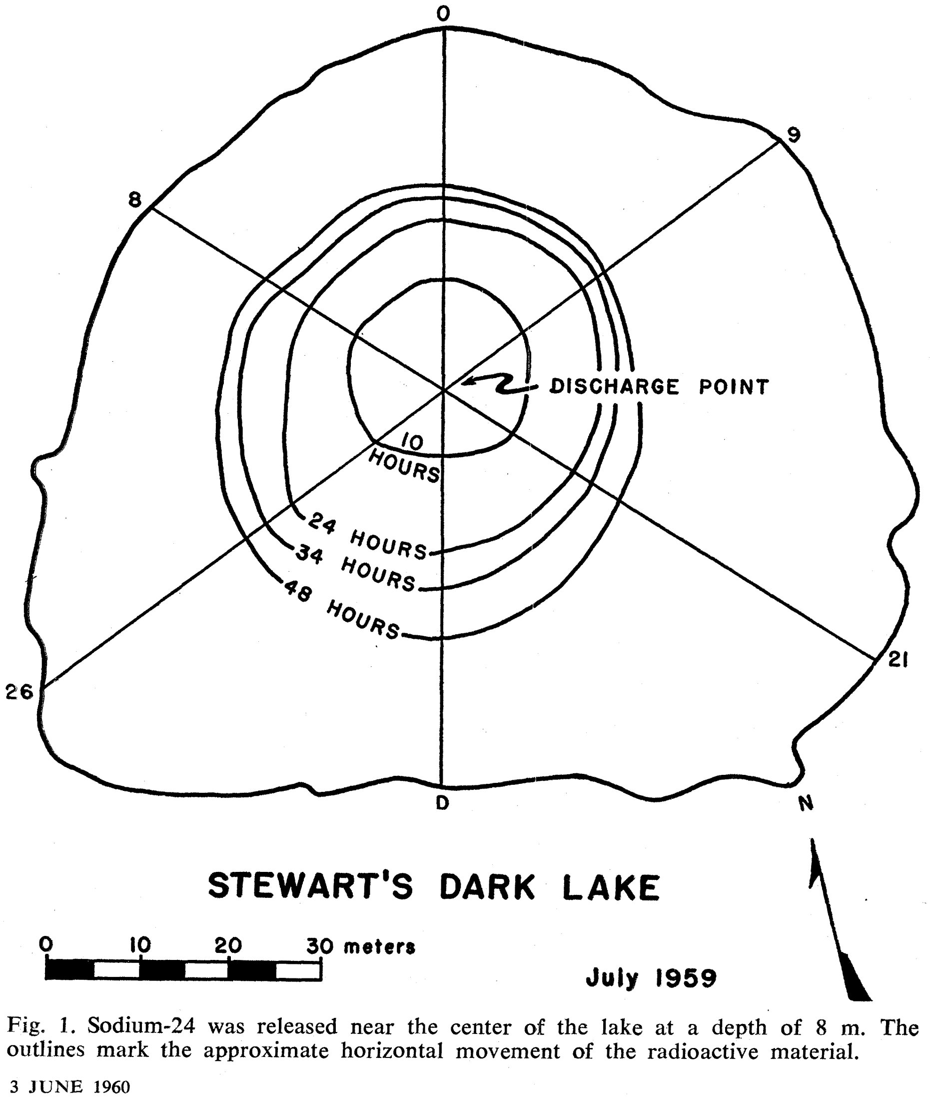

Fig. 1. Sodium-24 was released near the center of the lake at a depth of 8 m. The outlines mark the approximate horizontal movement of the radioactive material.

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5. This work was supported by a grant from the U.S. Atomic Energy Commission, contract No. AT(11-1)-64, project No. 12. We gratefully acknowledge Drs. John E. Willard and John W. Anderegg for their counsel and technical assistance; John J. Peterka for his aid in the field; and Duncan J. Stewart for the generous use of his facilities and property.

22 January 1960

Continuity of Mid-Oceanic Ridge and Rift Valley in the Southwestern Indian Ocean Confirmed

Abstract. The existence of a continuous, rifted, mid-oceanic ridge in the southwestern Indian Ocean, previously predicted by us, has been confirmed by soundings taken by the research vessel *Vema* during the expedition now in progress.

An important objective of the present world cruise of the *Vema* (*Vema* cruise No. 16, 1 October 1959 to 1 August 1960) is the examination of the Mid-Oceanic Ridge. The outstanding questions are (i) whether the ridge is continuous, as has been inferred from topographic and seismicity data (*1*, *2*) and (ii) whether the median rift, which has been shown to coincide with the epicenter belt along the Mid-Atlantic Ridge (*3*), follows the epicenter belt along the entire ridge system. The scarcity of soundings in the southern Indian Ocean has made this a critical area for checking the prediction that the mid-oceanic epicenter belt is a guide to the continuation of the median rift valley through unsounded areas.

Table 1. Principal topographical data obtained on six crossings of the mid-oceanic epicenter belt in the southern Indian Ocean and on three crossings in the Atlantic Ocean.

Crossing No.	Latitude and longitude	Depth (fathoms)			Width (mi)	
		Valley		Highest point on profile	Bottom	Top
		Top	Bottom			
1*	16°35′N, 46°25′W	1180	2600	1140	5	18
2	7°50′N, 38°55′W	1850	3120	1580	4	14
3	18°40′S, 12°50′W	1360	1940	970	5	18
4	47°20′S, 31°47′E	1540	2635	680	1	20
5	39°30′S, 45°00′E	1140	1990	820	5	20
6	37°56′S, 49°08′E	880	2040	750	5	17
7	33°46′S, 56°07′E	1050	2000	655	1	15
8	28°49′S, 61°52′E	1860	2760	1115	1	12
9	30°27′S, 76°26′E	1550	2100	1130	½	4

* Same location as 1938 *Meteor* crossing (*8*).

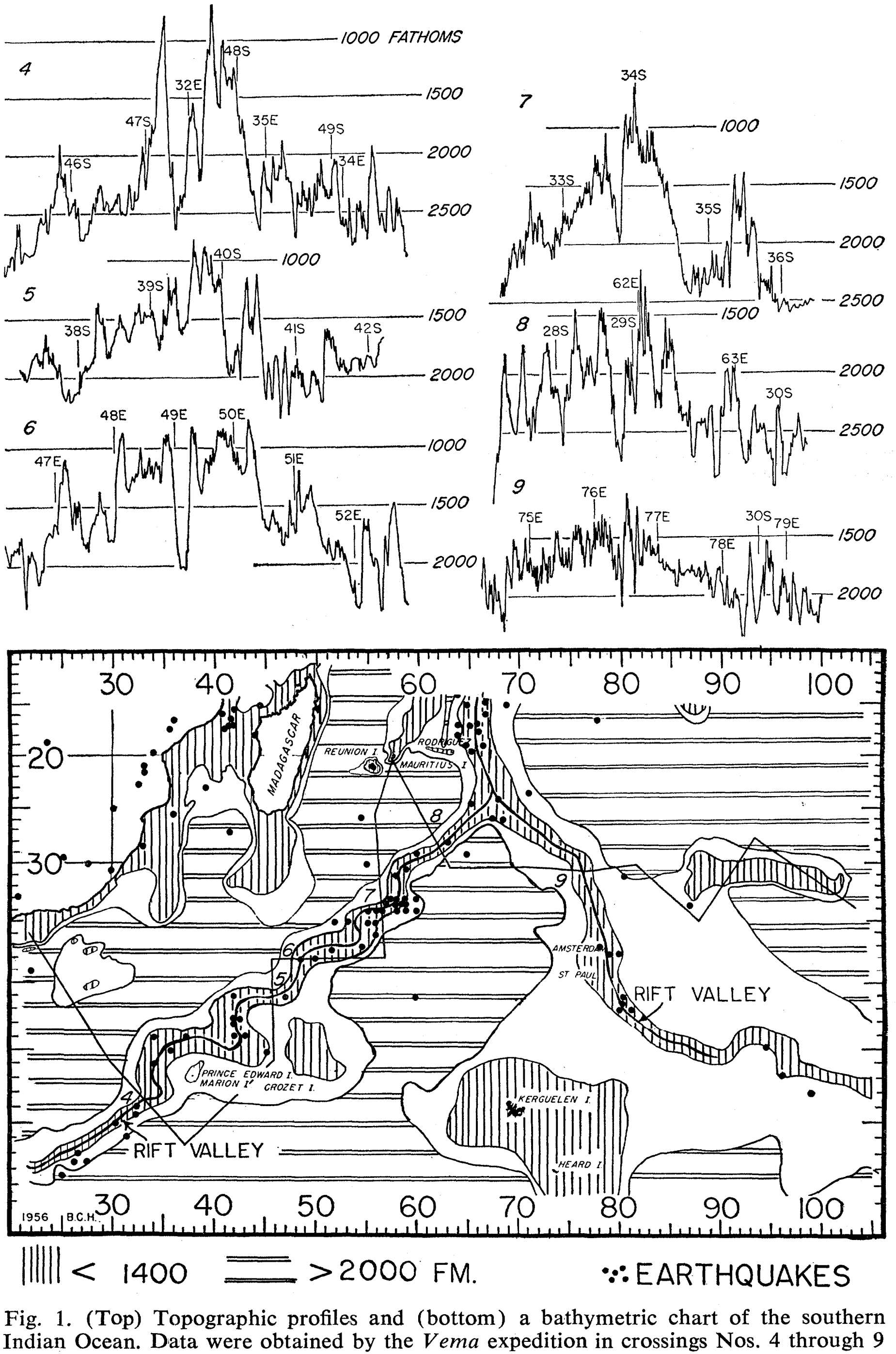

Fig. 1. (Top) Topographic profiles and (bottom) a bathymetric chart of the southern Indian Ocean. Data were obtained by the *Vema* expedition in crossings Nos. 4 through 9 of the mid-oceanic epicenter belt. Vertical exaggeration of profiles 100:1, depths in fathoms at sounding velocity of 800 fathom/sec.

During *Vema* cruise 16, six crossings of the mid-oceanic epicenter belt have been made in the southern Indian Ocean (Fig. 1) and three in the Atlantic Ocean. The principal facts about the topography that was found on these crossings, taken from preliminary readings and radio reports, are listed in Table 1.

The question of continuity of the ridge in the southwest Indian Ocean is of particular interest. The belt of earthquake epicenters, which follows the crest of the Mid-Atlantic Ridge throughout its length, continues without interruption past Prince Edward Island, through Rodriguez Island, and into the Gulf of Aden (*4*). Almost all published bathymetric charts (*5*) fail to show a corresponding ridge. Although a segment trending northeast from Prince Edward Island has been recognized, a major gap is generally shown between Prince Edward Island and the Mid-Atlantic Ridge. However, crossing No. 4 found the ridge fully developed, as had been predicted by Ewing and Heezen (*1*). Crossings Nos. 5 and 6 likewise found the ridge fully developed, as would be generally expected.

Southwest of Rodriguez Island the epicenter belt is continuous, but soundings are rare and no ridge has generally been shown over a span of about 1000 miles (*5*). The track of *Vema* was chosen to explore this region. Crossings Nos. 7 and 8 in this region may be taken as strong evidence for the continuity of the ridge from Prince Edward Island to Rodriguez Island.

Near Rodriguez Island, the epicenter belt branches; the southeastern branch continues through Amsterdam and St. Paul islands toward the Pacific Ocean. Crossing No. 9 verified the existence of a corresponding ridge near latitude 30°S. The three Atlantic crossings only confirmed our previous knowledge of the continuity and position of the Mid-Oceanic Ridge.

All nine crossings also give evidence about the median rift. As shown in Table 1, a deep narrow valley exists, coinciding exactly with the belt of epicenters. The dimensions of the valley on all crossings are closely comparable with those given for the Rift Valley in the North Atlantic (*3*).

Thus, the Mid-Oceanic Ridge and the Rift Valley have the same characteristics in the Indian Ocean as those described for the Atlantic. Apparently the form of the ridge changes before Easter Island is reached (*6*), and it is of interest to find how far the characteristics found in the Atlantic and Indian oceans continue (*7*).

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7. We are indebted to R. Gerard and C. Fray, successively chief scientists of *Vema*, to H. C. Kohler, master of *Vema*, and to M. Tharp for their assistance. This report is Lamont Geological Observatory (Columbia University) contribution No. 415.
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23 February 1960

Succinylcholine and Muscle Excitability

Abstract. Succinylcholine lowers the resting membrane potential taken with microelectrodes similarly in nerve-scarce and innervated portions of frog sartorius muscle. Twitches to electrical excitation of the nerve-scarce pelvic end of the muscle are also rapidly reduced. The results indicate that succinylcholine probably acts generally on the muscle membrance to diminish excitability.

It is generally believed that the class of neuromuscular blocking agents known as "depolarizing blockers" act by lowering the membrane potential in the end-plate region, thereby making neuromuscular transmission ineffective (*1*). Another theory of action is that these agents decrease the sensitivity of the end-plate region to transmitter agent (*2*). Recently we found, with a microelectrode technique, that some of these agents (acetylcholine and choline) diminish the resting membrane potential, generally to the same degree, everywhere in the isolated frog sartorius muscle membrane. The potential fell to the same extent in and out of the end-plate region, and the effect was prevented by pretreating with curare (*3*). Decamethonium and other agents in this group also caused a generalized fall (*4*). Inexcitability to direct electrical and mechanical stimulation of the muscle was roughly correlated with the mean degree of membrane potential diminution and the amount of blocking agent added to the bath. The hypothesis was advanced that a generalized action of these agents and of curare occurs everywhere on the membrane of the muscle.

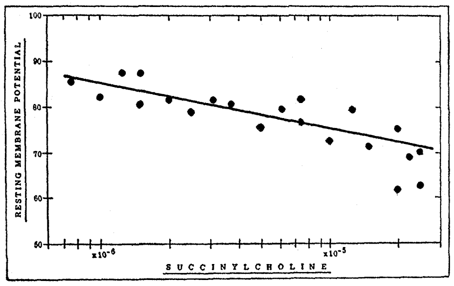

Fig. 1. Resting membrane potential and succinylcholine. Each point represents the mean resting membrane potentials of 50 to 55 fibers, taken with microelectrodes from frog sartorius muscles after adding succinylcholine in concentrations (gm/cm^3) shown on the abscissa. Resting membrane potential is shown on the ordinate.

Attention was turned to other agents classified as depolarizing blocking drugs; the effect of succinylcholine is of particular interest. Single fibres were sampled at different sites along the length of frog sartorius muscles by the Ling-Gerard microelectrode technique as previously described (*3*). Each point in Fig. 1 represents the mean of approximately 50 to 55 fibers for a given muscle determined after adding different concentrations of succinylcholine. Lower mean membrane potentials were found with increased amounts of this agent. Pretreatment with curare prevented the fall in membrane potential caused by succinylcholine.

The effect of succinylcholine on the isotonic-twitch response is shown in Fig. 2. For these experiments, frog sartorius muscles were clamped and directly stimulated maximally at the pelvic nerve-scarce region with 5-msec pulses at 15 second intervals. Adequate controls showed that current did not spread to nerve endings outside the pelvic nerve-scarce region.

When succinylcholine was added to make a final concentration of 5×10^{-6} gm/cm^3 (Fig. 2*A*) or 20×10^{-6} (Fig. 2*B*), the mechanical twitch response to direct electrical stimulation showed a characteristic diminution. The decrease appeared after a latency which was shorter with higher concentrations of succinylcholine (compare *A* and *B*, Fig. 2). A contracture seen as a rise in base line just after adding succinylcholine (Fig. 2*B*) was related to the amount of drug added. An occasional twitch larger than normal was also common at this time (Fig. 2*A*). The amplitude dropped, reaching a "plateau" of smaller twitch response heights which was not directly related to the concentration of the agent added. After pretreatment with curare (6×10^{-6}), succinylcholine action was blocked (Fig. 2*C*).

Relatively small drops in membrane resting potentials were found with amounts of succinylcholine which were effective in diminishing direct excitability. This suggested that succinylcholine does not produce its block of excitability by simply lowering resting membrane potential. Jenerick and Gerard had shown that the sartorius muscle membrane could support an action potential until the resting membrane potential was lowered by KCl to a critical level of 52 to 57 mv (*5*). The inference drawn of an excitation block applies as well to similar data obtained with acetylcholine, choline, and decamethonium, where membrane potential falls were reported (*3*), but usually above the critical level of 52 to 57 mv.

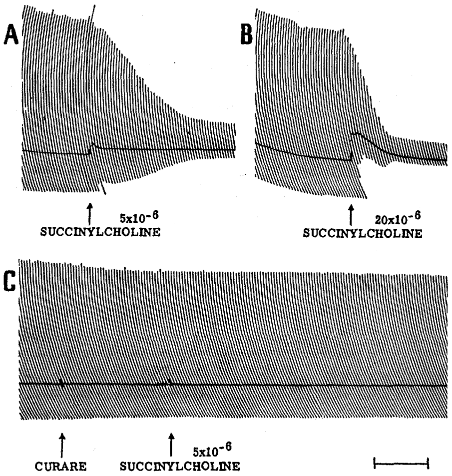

Fig. 2. Twitch responses and succinylcholine. Twitch heights to maximal direct stimulation at the relatively nerve-scarce pelvic end of isolated frog sartorius muscle are shown. Stimulation every 15 sec with 5-msec pulses. *A*, after 5×10^{-6} (gm/cm^3) succinylcholine; *B*, 20×10^{-6}; *C*, curare 6×10^{-6} added and then 5×10^{-6} succinylcholine ineffective. Bar represents 5 min.

A much greater degree of depolarization in the end-plate region, which, from Burns and Paton's work with external electrodes (*1*), was to be expected with microelectrode recordings, was not found for succinylcholine, acetylcholine, choline, or decamethonium. Nor does the theory of Thesleff that these depolarizing blocking agents decrease the sensitivity of the end-plate regions (*2*) indicate that a conduction block to direct muscular excitation would be expected.

Our findings suggest that the excitation mechanism of the membrane is interfered with or the membrane-contractile link (*6*) is blocked. The lowering of membrane potential is probably a coincident phenomenon with a generalized membrane action of succinylcholine on the muscle fiber (*7*).

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