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CURRENT RESEARCH FINDINGS ON RADIOACTIVE FALLOUT

I. INTRODUCTION

The radioactivity produced by the fission reaction, being due to a mixture of many different fission products, changes its characteristics continuously and rapidly following release by the bomb detonation. So, the conditions of firing are of extreme importance in determining the fallout effects. The intensity of radiation is enormously greater soon after the detonations, decreasing about tenfold for every sevenfold increase in age. Since the time required for ingestion into the body is long, ingestion is unlikely for the shorter-lived fission products and therefore the principal hazards for close-in fallout are radiation exposures by gamma radiation of the whole body and by beta radiation on the skin.

In the longer times, weeks and months after the explosion, the ingestive hazards begin to become

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important. The most serious of these is the high-yield fission product, radioactive strontium (Sr^{90}), which because of its own radiation and those of its short-lived daughter, yttrium-90 (Y^{90}), and because of its chemical similarity to the bone-building element, calcium, finds itself deposited in bone structure. Other radioactivities produced would be as bad if they spent as long a time in the body or if their radioactive lifetimes were long enough, or if they were produced in high-yield. Strontium has all of these characteristics. So, for the fission products which have survived the first weeks, the most important fallout constituent and the one most seriously to be considered is Sr^{90}. Neither radiostrontium nor its yttrium daughter emits gamma radiation, but only beta radiation. After the first year Cesium-137 (Cs^{137}), with a 33-year half-life, is the principal source of the residual gamma radiation, and any gamma radiation exposures due to fission products which are more than one year old are due very largely to radioactive cesium. In fact, old fallout can be thought of as a mixture of roughly equal radiation intensities in millicuries of radioactive Sr^{90} and radioactive Cs^{137}. The other isotopes either constitute no ingestive hazard or fail to emit gamma radiation in appreciable intensity. So, the hazards of world-wide fallout reduce themselves largely to the ingestive hazard of radioactive Sr^{90} and the external exposure from radioactive Cs^{137}.

The mechanism by which atomic weapon debris is disseminated leads to three kinds of fallout. First, the strictly <u>local fallout</u>, which is due to the return to earth of the larger particles in the fireball. These may have their origin in the dirt, the soil, or tower structures which are taken into the fireball and either wholly or partially vaporized. The fraction of the total which falls out locally depends very much upon the conditions of firing. The most serious factor is the degree of contact of the fireball with the surface; another is the nature of the surface. For example, soil appears to be much more effective than water in producing local fallout.

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Experience has shown that an atomic device exploded on the surface distributes about 80 percent of its fission products on the ground within a few hundred miles of the burst point. A somewhat larger percentage takes part in the close-in fallout from an underground burst, and a smaller percentage will be scavenged from a near-surface burst or tower shot.

The tower shot is, in a sense, a special case of a surface burst, since the material of the tower itself is mixed with the fission products in the fireball to a greater or lesser degree, depending on the yield. Experience with tower shots indicates that even in cases where the fireball does not touch the ground a few percent of the radioactive fission products come down as close-in fallout.

The fraction which takes part in the close-in fallout from a surface burst over deep ocean water appears to be somewhere between 20 and 50 percent. This is less than the fraction of close-in fallout occurring from a corresponding surface burst over land, due to the evaporation of many of the drops before they reach the ground. Presumably this fraction is also affected by the prevailing humidity and temperature structure of the atmosphere through which the drops must fall. As the depth of the water is decreased, the point is reached where the fireball extends downward to the bottom and picks up bottom material. In such shallow water one would expect a higher percentage of close-in fallout than in deep water. Experience in the Pacific indicates that such is indeed the case, and that in fact there would be very little difference in the fallout between a large-yield device in very shallow water and a true surface shot.1/

The second type of fallout is the material which, though not coarse enough to fall of its own weight in the first few hours, is, nevertheless, left in the lower layer of the atmosphere, known as the troposphere, where ordinary weather phenomena occur.

1/ "Close-In Fallout," W. W. Kellogg, R. R. Rapp, and S. M. Greenfield, P-822-AEC, March 12, 1956.

It is now well established that fallout particles are removed from this lower layer of the atmosphere in the first month or so; therefore, the tropospheric fallout stays airborne at most a matter of a month or two before being deposited. Of course, in this time, it will in general move great distances, possibly even clear around the earth; but, in general, it stays in the general latitude in which the explosion occurred. So, the second type of fallout, the tropospheric world-wide fallout, produces a band of radioactivity in the general latitude of the firing site. The fraction of the fallout which falls in this category depends mainly on the bomb yield and the conditions of firing. A bomb which is fired on the ground produces a maximum of local fallout, naturally leaving less for the world-wide fallout of either the tropospheric or stratospheric variety. The bomb yield determines the division of the world-wide fallout between the two kinds of world-wide fallout. A general rough rule is that a one megaton bomb will produce clouds which push into the higher layer of the atmosphere, the stratosphere, before disseminating and that the clouds from bombs of less than one megaton will tend to stay mainly in the tropopshere. Thus, we see that a 500 kiloton weapon fired so its fireball did not touch the ground would be expected to put the major part of its radioactivity in a band stretching clear around the world in the general latitude of the firing site. The distribution of the activity would be world-wide and would be completed within the first month or two. Similarly, the same bomb fired in contact with the earth with ordinary soil would have a large fraction--something like 80 percent--of its fallout deposited within the first few hours within a few hundred miles of the test site and the rest of the material would be spread in the tropospheric world-wide fallout pattern in a band around the earth in the same general latitude.

The third type of fallout is the stratospheric world-wide fallout. Weapons of yields of one megaton and greater thrust their radioactive clouds into the stratosphere, and the material which does not fall of its own weight within the first few hours is then very largely borne in the stratosphere for great lengths of time. An average time seems to be about 10 years or somewhat less. They produce a small amount of tropospheric world fallout also, presumably due to a small

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fraction of particulate matter which is of just the right size to descend in a matter of weeks. The division into the two types, the local and the stratospheric world-wide, is very sharp and marked, however, and to a very considerable approximation one can say that the megaton weapons yield the bulk of their fallout in these two categories. A weapon involving one megaton of fission would if fired in the air place most of its radioactivity in the stratosphere, and this in contrast to the tropospheric fallout appears to be widely distributed latitudinally and does not descend through the tropopause into the troposphere until months and years--an average time of about 10 years--have elapsed. The resultant pattern of fallout appears to be essentially an approximately uniform world-wide distribution. The long time spent in the stratosphere is probably due to the absence of such scavenging agents as rain or snow, so the particles either must fall-out of their own weight or diffuse downward by slight eddy motion, either of these processes being of their very nature slow. After passing through the tropopause into the troposphere they will be rained out rather quickly in a matter of days or weeks. Because of the long residence time in the air, this type of fallout is particularly harmless as a gamma ray hazard, since only the Cs^{137} is left. The amount of Cs^{137} is about the same in millicuries as the Sr^{90}, so one megaton of fission thus distributed throughout the stratosphere would yield about $\frac{1}{2}$ mc/mi^2 of either Sr^{90} or Cs^{137}. Just as in the case of Sr^{90}, the rate of deposition of about 10 percent of the reservoir per year corresponds to a stratospheric fallout rate of Cs^{137} of 0.05 mc/mi^2/yr in the beginning. This rate decreases to half, or 0.025 mc/mi^2/yr, at about 7 years as the stratospheric reservoir becomes depleted.

After the Castle test series was completed there were about 24 megatons of fission products in the stratosphere, corresponding to about 12 mc/mi^2 of Sr^{90} on the average and about the same amount of Cs^{137}. The subsequent stratospheric world-wide fallout rate appears to have been a little over 1 mc/mi^2/yr all over the world. In addition, of course, local fallout and

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tropospheric latitudinally localized world-wide fallout have occurred from subsequent weapons tests by the Russians and the Redwing series completed last summer at the Eniwetok Proving Grounds.

II. RESEARCH FINDINGS

A. Amount of Fallout and Expected Sr^{90} Body Burden from Weapons Fired to Date.

Since our last report,[2/] further data on the actual magnitude of fallout in various places in the world and in various selected spots in the food chain have become available. We shall summarize the results. Some human bone now contains radioactive strontium at levels of about 1/1000 of maximum permissible concentration (0.001 MPC; the MPC is 1 microcurie of Sr^{90} for the standard man and proportionally less for children and is the maximum permissible concentration) in the northern latitudes where the bombs have been fired and the world-wide tropospheric fallout has occurred. There is evidence in the data on human material that age is a factor, e.g., older people having had their calcium deposited prior to the weapons tests show lower concentrations, though in some instances exceptions to this rule are to be found. Lower levels are found in the Southern Hemisphere where the major contamination is due solely to the world-wide stratospheric fallout which in the northern latitudes of 10°N to 50°N is generally less than one-half or one-quarter of the total fallout. The deposition in the human body seems roughly to parallel the levels of the total fallout. More data are necessary to fully validate this point.

At the end of 1955, the total deposition in the upper midwest of the United States was some 13 mc/mi^2 of Sr^{90}. In the spring of 1956, this total rose to about 16 mc/mi^2.

2/ "Radioactive Strontium Fallout," W. F. Libby, Proc. Nat. Acad. Sci., 42, 365 (1956).

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Between May 5 and mid-July of this year, Operation Redwing was conducted at the Eniwetok Proving Grounds in the Pacific. Particular attention was paid to the fallout problem in this Operation and a major effort was made to produce a megaton-range weapon with an inherently smaller amount of fallout for a given energy release. This effort was successful. In addition, considerable attention was paid to operational factors which would minimize world-wide fallout. Thus, the total deposition in the stratosphere during this Operation was held to a figure very considerably less than that present in the stratosphere before the Operation. In fact, we estimate at the present time that the total stratospheric reservoir, counting all sources, is about the same as it was two years ago, i.e., that 12 mc/mi^2 of Sr^{90} or the equivalent of 24 megatons of fission products calculated as a uniform world-wide distribution. During the past two years the additional depositions in the stratosphere have amounted to about 6 megatons equivalent of fission products total or 3 mc/mi^2 of Sr^{90} or Cs^{137}. This appears to have compensated approximately for the 10 percent per year of fallout and the 2.5 percent per year of radioactive decay. In other words, the testing by all countries seems to have restored the stratospheric reservoir to approximately the 24 megaton value of two years ago.

The latitudinal tropospheric world-wide fallout, which is maximized by weapons of high-yield which do not puncture into the stratosphere, is increasing. Several such weapons have been air fired abroad in the last months. This material, for the reasons explained above, descends rather rapidly but all the way around the world in the same general latitude as the firing site. Thus, though it is difficult to estimate, it appears that this amounts to perhaps 5 additional mc/mi^2 of Sr^{90} and Cs^{137} in the U.S. Adding to this about ½ mc/mi^2 for the world-wide tropospheric fallout from the Redwing Operation and 1 mc/mi^2 for stratospheric fallout, we would estimate at present that a total of about 22 mc/mi^2 of Sr^{90} is to be found in the soils of the midwestern U.S., and that perhaps 15 to 17 mc/mi^2 is the total to be expected for similar latitudes elsewhere in the world, the difference being due to our proximity to our own weapons testing

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site in Nevada. These 22 mc/mi^2 of Sr^{90} in the soil of the U.S. amount to about 0.040 MPC units in the top two inches of soil where most of the fallout is absorbed.

As of the present time, considering the latest human bone and milkshed data, both domestic and foreign, together with the total fallout figures for corresponding periods, we find that the level of somewhat less than 0.001 MPC units now found in the bones of young children is to be compared with a total Sr^{90} fallout in the soil of about 12 times higher concentration. Additionally, laboratory data have shown that there is a three-fold discrimination against strontium as compared to calcium in the assimilation by plants from the soil, and that a further factor of about eight-fold of discrimination against strontium relative to calcium in the excretion of strontium in milk as compared to the cow feed exists. Earlier[2/], it seemed reasonable to conclude that the human body burden of Sr^{90} might well be as high as 70 percent of the concentration in the top soil on which people live. The further evidence just cited seems to indicate that this figure is much too high and possibly should be reduced to about 10 percent. A strict application of the two discrimination factors described would give 4 percent. Leaf retention of fallout which bypasses the soil causes the figure to be higher. Therefore, at the moment, we would expect that the body burden for children born now in America eventually would amount to between 0.004 MPC units, corresponding to 10 percent of the top soil concentration and possibly a figure two or three times higher. The stratospheric deposition would be expected to continue at the expected rate which at the present is about 1.2 mc/yr, so that some 15 years from now, in the early 1970's, a maximum additional total stratospheric fallout of about 6 mc/mi^2 will have occurred. In the meantime, the present 22 mc/mi^2 would have been reduced to 15 by radioactive decay, just about compensating for the stratospheric deposition. Thus, the conclusion that the body burden in the U.S. from weapons fired to date would be about 0.004 MPC units, or possibly as high as 0.010 MPC units, seems justified. This level probably will not

2/ "Radioactive Strontium Fallout," W. F. Libby, Proc. Nat. Acad. Sci., 42, 365 (1956).

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be exceeded in other countries unless particular factors of environment intervene since the U. S. probably has the highest total fallout in the world. It seems very unlikely, however, that environmental factors could increase the level over the U. S. by more than a factor of 2 or 3.

B. Effect of Rainfall.

As mentioned earlier, there is excellent reason to suppose that the deposition from the troposphere on the earth's surface is best accomplished by rain. By rain is meant not heavy rain but anything which involves the settling of water droplets. This might include fog or mist. The suggestion has been made3/ that the small size of the stratospheric fallout particles gives them a very high mobility due to molecular motion since, in fact, they probably are almost molecular in dimensions. This high mobility of the particles makes it probable that direct contact of the fallout particles with water droplets will occur. One imagines on this theory that the tiny particles pass through the tropopause from the stratosphere, and then meet water droplets in a cloud or mist or rain in the course of their rapid random motion due to collisions with the air molecules. So, rather than the classical Langmuir mechanism of the rain sweeping out the air through which it falls by colliding with the particles themselves, the particles probably collide with the water droplets either before or during the rainstorm, probably most importantly before. It is clear from this mechanism that fog and mist may very well be very effective and that a cloud probably gathers a considerable fraction of the fallout from the air in its bulk.

In any case, some experimental evidence has been found for the effect of rainfall on fallout by studying three particularly arid regions--the Imperial Valley in California at the town of Brawley, and the

3/ Stanley Greenfield, Rand Corporation.

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western coast of South America at Antofagasta, Chile and Lima, Peru. The soil in Brawley was sampled in January of this year and found to contain less than 0.6 mc/mi^2 of Sr^{90}. In order to realize the significance of this number, one should recall that we would have expected about 13 mc/mi^2 as an average figure for the U. S. It is true that a considerable part of this is from the Nevada tests--the depositions of which occur mainly in an easterly direction and might well miss southern California--but it certainly seems that at least 8 mc/mi^2 would have been expected in the Imperial Valley under normal conditions such as prevailing elsewhere in the United States and in Europe and Asia. Thus, the observed fallout is not over a few percent of that expected normally.

In addition to the soil samples, tests were made on the vegetation grown at Brawley, California, as well. As expected, it was found that the level was lower. Lettuce samples collected from this region at the same time as the soil samples showed 0.0004 MPC; broccoli, 0.00025 MPC; green peas, 0.00134 MPC; alfalfa, 0.0021 MPC. These values all are much lower than for the midwestern U. S. (Shown in Table 2, attached).

The rainfall data for Brawley are as follows: In 1955, the rainfall totaled 1.70 inches, 1.3 inches having occurred in January of that year, and 9 months having had no registered rainfall at all. In 1953, the annual total rainfall was only a trace, this trace having occurred in February.

At Antofagasta, Chile, where it has never been known to rain, except possibly on one occasion, we find 0.02 mc/mi^2 of Sr^{90} in January, 1956, when the general deposition for this latitude was apparently a little over 2 mc/mi^2. In other words, about 1% of the fallout expected was found and 0.02 is hardly larger than the experimental error of measurement.

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In Lima, Peru, the total fallout of Sr^{90} in January, 1956, was 0.7 mc/mi^2. The annual precipitation in Lima averages only 1.89 inches, though there is a considerable amount of ground fog and mist.

It seems clear from these results and the reasonableness of the mechanism of deposition advanced by Mr. Greenfield that there is valid reason to believe that world-wide fallout is small in the absence of precipitation. Also, it is clear from this mechanism that the fallout should not be strictly proportional to total rainfall. Frequent light rains or mists would be expected to be more efficient than occasional heavy rains. So, the importance of rain is only to be revealed by a study of desert areas and a careful investigation of the scavenging mechanism itself. This work may well prove to be of considerable importance in meteorology, as well as to fallout studies. One should note that the local fallout due to larger particles which descend in the first hours probably does not need rain to precipitate it and occurs in the absence of the precipitation of moisture, although rain may well be able to increase even this fallout.

The importance of precipitation as a scavenging mechanism raises the possibility that different regions will be subjected to varying intensities of fallout, depending upon the weather conditions. It will be important to test whether this is so and whether it is a major effect in populated areas. We have evidence showing that extreme aridity greatly reduces the long-range or world-wide fallout as explained above. The evidence to date does not indicate that it is a major effect for normal climates in the sense that it does not appear to amount to more than a factor of 2. Regions in which people live normally have enough precipitation so that differences in precipitation appear not to affect the fallout by more than such a factor. Careful study of the data appended and

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the previously released data 2/ 4/ 5/ have failed to reveal any more serious deviation. To summarize, desert regions with little or no precipitation, or with only very minimum precipitation, apparently have minimum long-range, world-wide fallout, but other regions do not show that the fallout is proportional to the total precipitation, nor should it be expected to be so, but detailed conditions related to frequency of precipitation might well be important. The data to date do not reveal deviations from the general average by more than about a factor of 2 and, in fact, they seem to indicate a smaller deviation than this. There is some evidence that certain areas have had more fallout than one might expect on the model described above and on previous occasions. In particular, there are reports that certain areas in England show higher levels, but the deviations appear to be considerably less than two-fold.

More important, probably, than the variations in total fallout due to weather conditions is the effect of calcium in the soil in reducing the rate of assimilation of radioactive strontium by plants. The plants assimilate strontium because it is chemically similar to calcium and, since their appetite for calcium is limited, a larger calcium content in the soil dilutes the strontium so that a smaller fraction is assimilated. This effect might amount to a factor of five in the human body assimilation of radio-strontium in regions with very low calcium content in the top soil.

2/ "Radioactive Strontium Fallout," W. F. Libby, Proc. Nat. Acad. Sci., 42, 365 (1956).
4/ "Summary of Analytical Results from the HASL Strontium Program to June 1956," John H. Harley, Edward P. Hardy, Jr., George A. Welford, Ira B. Whitney, and Merril Eisenbud, NYO-4751, August 31, 1956.
5/ Project Sunshine Bulletins Nos. 11 and 12, The Enrico Fermi Institute for Nuclear Studies, The University of Chicago, Dec. 1, 1955 and Aug. 1, 1956.

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C. Direct Measurement of the Stratospheric Fallout Content.

Direct measurement by means of high-flying balloons has shown that the stratosphere does indeed have about the fallout anticipated in it.6/

In addition, it has been found in these measurements that the radiocesium, Cs^{137}, occurs at about the same level as Sr^{90} in millicurie units indicating there has been no serious fractionation of the two fission products by the fallout mechanism. It further points out that the sampling of the stratosphere is a practical matter and that measurements can be made of the stratospheric content of radioactive fallout. Such data should greatly assist the whole study of fallout.

D. Radiocesium Assays for the Biosphere.

Recently a technique for measuring Cs^{137} in biosphere samples, particularly in human bodies, has been developed by Mr. L. D. Marinelli of the Argonne National Laboratory7/. It has been found that about four-millionths of one millicurie is present in an average adult. This corresponds rather well to the expected amount considering the short residence time of radiocesium in the body, which is about 3 months, and the expected precipitation rate, which is taken to be equal as a first approximation, to that of radiostrontium. The radiocesium, of course, constitutes no hazard, amounting in radiation dosage to a small fraction of the amount present in the blood in the form of that received from the ordinary potassium present in the body. Potassium is naturally radioactive. It is interesting further evidence, however,

6/ "General Mills High Altitude Balloon Filter Samples," Memorandum by A. P. Hardy and S. Tarras, New York Operations Office, July 2, 1956.
7/ "Gamma-Ray Activity of Contemporary Man," Science, 124, 122, July 20, 1956.

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that the general model of fallout set forth is consistent with the data and essentially correct.

III. PLANS

It is clear that the peoples of the world are extremely interested in radioactive fallout because of the bearing that the new phenomenology of the nuclear age has on everyone's life. For this reason, we must understand radioactive fallout in all its intricacies. It is to be hoped that the study will be a cooperative, international one. The United Nations Scientific Committee on Effects of Atomic Radiation offers an ideal forum for the discussion and consideration of the problem. From these deliberations will come further suggestions, ideas, appraisals and statement of the problem. The methods developed in this country for measurement and all the data collected are available to everyone. It is our hope and intention that this problem, like others of the atomic age, will come to be generally understood.

Fallout is normally considered an aspect of atomic warfare and nuclear armament. There is some similarity, however, between the weapons fallout and the hazard from a reactor accident, in which radioactive products would be disseminated over a limited area, but never reach the stratosphere or undergo anything like the world-wide tropospheric dissemination. As it has so often been observed in the past, so it is again true in this instance, that a new fact of nature is likely to have its beneficent as well as its somber and frightening aspects. As we learn about the way the world-wide fallout particle, probably as tiny as a virus molecule, wends its way from the stratosphere through the tropopause into the troposphere and, within a few weeks, collides with a water droplet and thus is brought to the earth's surface by rain, we shall learn more about the circulation of the atmosphere, about the way in which rain is formed, and about the questions which will naturally arise more

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and more frequently as the world's population increases world-wide pollution of the atmosphere not only with fission products but with the other by-products of our new technological age.

TABLE 1

BIOSPHERE Sr^{90} ASSAY

WISCONSIN MILKSHED -- SEPTEMBER 30, 1955
(0.001 MPC Units unless otherwise stated)

FARM	SOIL 0"-2"	SOIL 2"-6"	TOTAL Sr^{90} (mc/mi^2) 1955 Value	TOTAL Sr^{90} (mc/mi^2) 1953 Value	ALFALFA 1955 Value	ALFALFA 1953 Value
Holcomb, Wisconsin	26.7 ± 1.0	3.8 ± .14	14.8	5.1	19.2 ± 1.0	8.3
Premo, Wisconsin *	15.0 ± 0.5 (0"-6")		10.6	3.8	25.5 ± 1.3	4.1
Kurpeski, Illinois *	12.2 ± 0.4 (0"-6.5")		10.4	4.0	7.05 ± .33	7.4
Austin, Illinois	49.9 ± 1.3	9.6 ± 0.4	16.5	4.7	38.0 ± 2.0	5.0
McKee, Illinois	9.8 ± 0.4	0.99 ± .04	10.6	6.3	30.5 ± 1.7	14.8
Van Winkle, Illinois	65.1 ± 2.6	10.0 ± 0.4	9.4	3.8	5.76 ± 0.29	5.0
Carver, Illinois	64.5 ± 1.3	14.0 ± 0.7	8.9	3.3	2.73 ± 0.18	2.3
	Average Sr^{90} (mc/mi^2)		12.0	4.5		

* Had been plowed to 6" depth.

TABLE 2

1955 DOMESTIC SOIL SAMPLES

Location	Lab No.	Date Sample Taken	Depth of Sample (Inches)	Ca Extracted (Electro-dialysis or NH_4Ac)	Calc. Ca. (Gm/Ft^2)	Sr^{90} Content (0.001 MPC)	Total Sr^{90} (Mc/Mi^2)	
Winnebago Co., Ill., Swanson Farm, Site #3, Carrington silt loam.	551503	9/30/55	0-8"	NH_4Ac	82.8	6.83 ± .08	9.8	
Rock Co., Wis., Holcomb Farm, Site #4, Carrington silt loam.	551500	"	0-2"	"	15.0	26.7 ± 1.0	11.4	} 14.8
Rock Co., Wis., Holcomb Farm, Site #4, Carrington silt loam.	551501	"	2-6"	"	31.8	3.81 ± .14	3.4	}
Columbia Co., Wis., Premo Farm, Site #6, Miami silt loam.	551502	"	0-6"	"	25.5	15.0 ± 0.5	10.6	
McHenry Co., Ill., Kurpeski Farm, Site #7.	551496	"	0-6.5"	"	30.9	12.2 ± 0.4	10.4	
McHenry Co., Ill., Austin Farm, Site #8, Miami silt loam.	551504	"	0-2"	"	6.98	49.9 ± 1.3	12.0	} 16.5
McHenry Co., Ill., Austin Farm, Site #8, Miami silt loam.	551505	"	2-6"		7.8	9.6 ± 0.4	4.5	}
McHenry Co., Ill., McKee Farm, Site #9, Drummer silt-clay loam.	551448	"	0-2"	"	31.2	9.8 ± 0.4	8.5	} 10.6
McHenry Co., Ill., McKee Farm, Site #9, Drummer silt-clay loam.	551499	"	2-6"	"	78.4	0.99 ± .04	2.1	}

TABLE 2 - Continued

Location	Lab No.	Date Sample Taken	Depth of Sample (Inches)	Ca Extracted (Electrodialysis or NH_4Ac	Calc. Ca (Gm/ Ft^2)	Sr^{90} Content (0.001 MPC)	Total Sr^{90} (Mc/Mi^2)	
Will Co., Ill., Van Winkle Farm, Site #11, Plainfield sand.	551508	9/30/55	0-2"	NH_4Ac	4.4	65.1 ± 2.6	8.0	9.4
Will Co., Ill., Van Winkle Farm, Site #11, Plainfield sand.	551509	"	2-6"	"	5.1	10.0 ± 0.4	1.4	
Will Co., Ill., Carver Farm, Site #12, Plainfield sand.	551510	"	0-2"	"	3.7	64.5 ± 1.3	6.7	8.9
Will Co., Ill., Carver Farm, Site #12, Plainfield sand.	551511	"	2-6"	"	5.6	14.0 ± 0.7	2.2	
Brawley, Calif. (In Imperial Valley). Annual rainfall = 2.57 inches	56316	1/5/56	0-6"	Electro-dialysis	54.9	≤ 0.4	≤ 0.6	

TABLE 3

Sr^{90} CONTENT OF FOREIGN SOILS AFTER CASTLE

Lat./Long.	Location	Lab.No.	Date Sample Taken	Depth of Sample (Inches)	0.001 MPC Units	Calc. Exch. Ca. (gm/ft²)	Total Sr^{90} (mc/mi²)
33°N/36°E	Damascus, Syria	55590	2/55	0-4	1.40 ± .10	62.8	2.5
49°N/2°E	Paris, France	55614	2/55	0-4	0.69 ± .05	66.2	1.3
36°N/139°E	Tokyo, Japan	55643	2/55	0-4	3.74 ± .34	20.3	2.1
36°N/139°E	Tokyo, Japan	55644	2/55	0-4	5.86 ± .29	18.9	3.1
0°/27°W	Dakar, French W. Africa	55645	2/55	0-4	3.71 ± .14	4.4	0.45
0°/27°W	Dakar, French W. Africa	55646	2/55	0-4	9.31 ± .74	1.3	0.34
36°N/2°E	Algiers, Algeria	55647	2/55	0-4	1.20 ± .08	60.0	2.0
36°N/2°E	Algiers, Algeria	55648	2/55	0-4	2.90 ± .20	53.8	4.4
25°S/57°W	Asuncion, Paraguay	56450	1/56	0-6	11.3 ± .75	6.1	1.9
22°S/46°W	Sao Paulo, Brazil	56448	1/56	0-6	3.04 ± .27	21.0	1.8
30°S/30°E	Durban, Natal S. Africa	55777	2/55	0-4	4.43 ± .19	12.6	1.6
30°S/30°E	Durban, Natal S. Africa	55778	2/55	0-4	15.0 ± .08	3.3	1.4
12°N/45°E	Aden, Saudi Arabia	55787	2/55	0-4	0.69 ± .09	> 12.5 < 107.2	> 0.24) < 2.1)
33°N/40°E	Ankara, Turkey	55878	2/55	0-4	1.9	51.6	2.7
34°N/36°E	Beirut, Lebanon	55591	2/55	0-4	3.2	52.6	4.6
34°N/36°E	Terbol, Lebanon	55592	2/55	0-4	1.8	46.7	2.4
24°S/70°W	Antofagasta, Chile	56447	1/56	0-½	0.44 ± .04	1.7	0.02
12°S/80°W	Lima, Peru	56456	1/56	0-6	0.60 ± .04	42.7	0.7
30°S/115°E	Perth, Australia	55839	2/55	0-4	14.7 ± 1.1	2.8	1.1

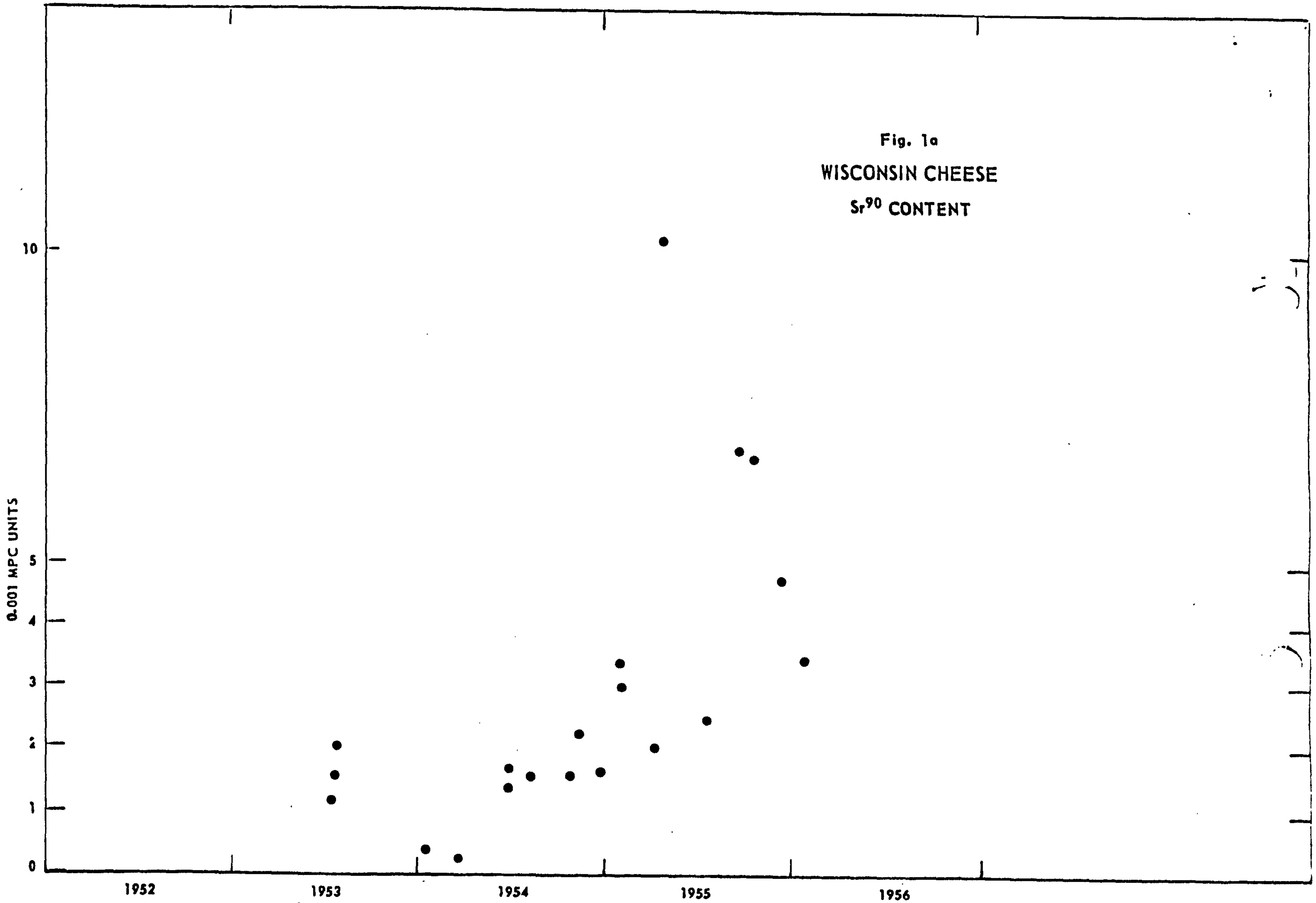


Fig. 1a
WISCONSIN CHEESE
Sr90 CONTENT
10
5
4
3
2
1
0
0.001 MPC UNITS
1952
1953
1954
1955
1956

14

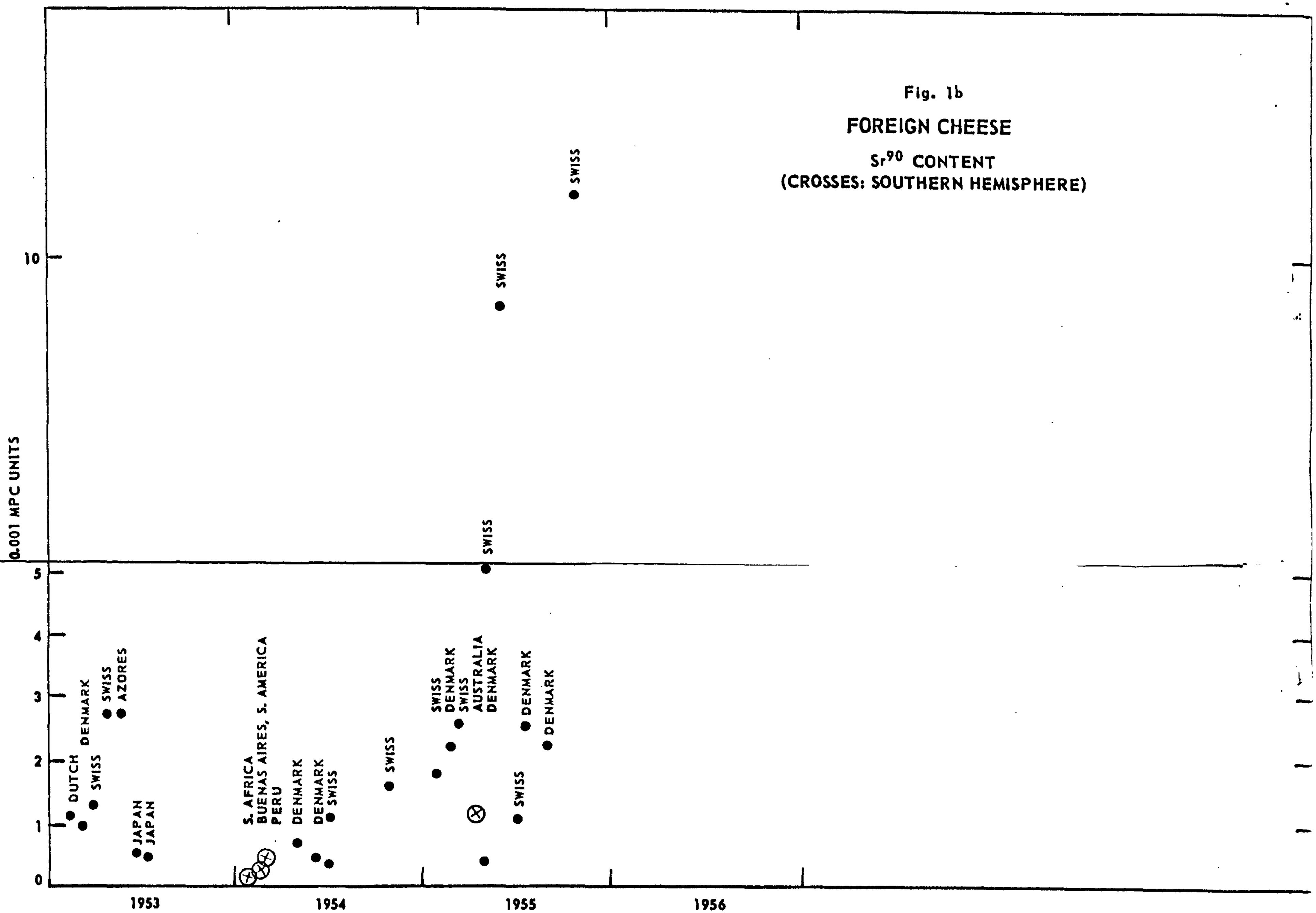


Fig. 1b

FOREIGN CHEESE

Sr^{90} CONTENT

(CROSSES: SOUTHERN HEMISPHERE)

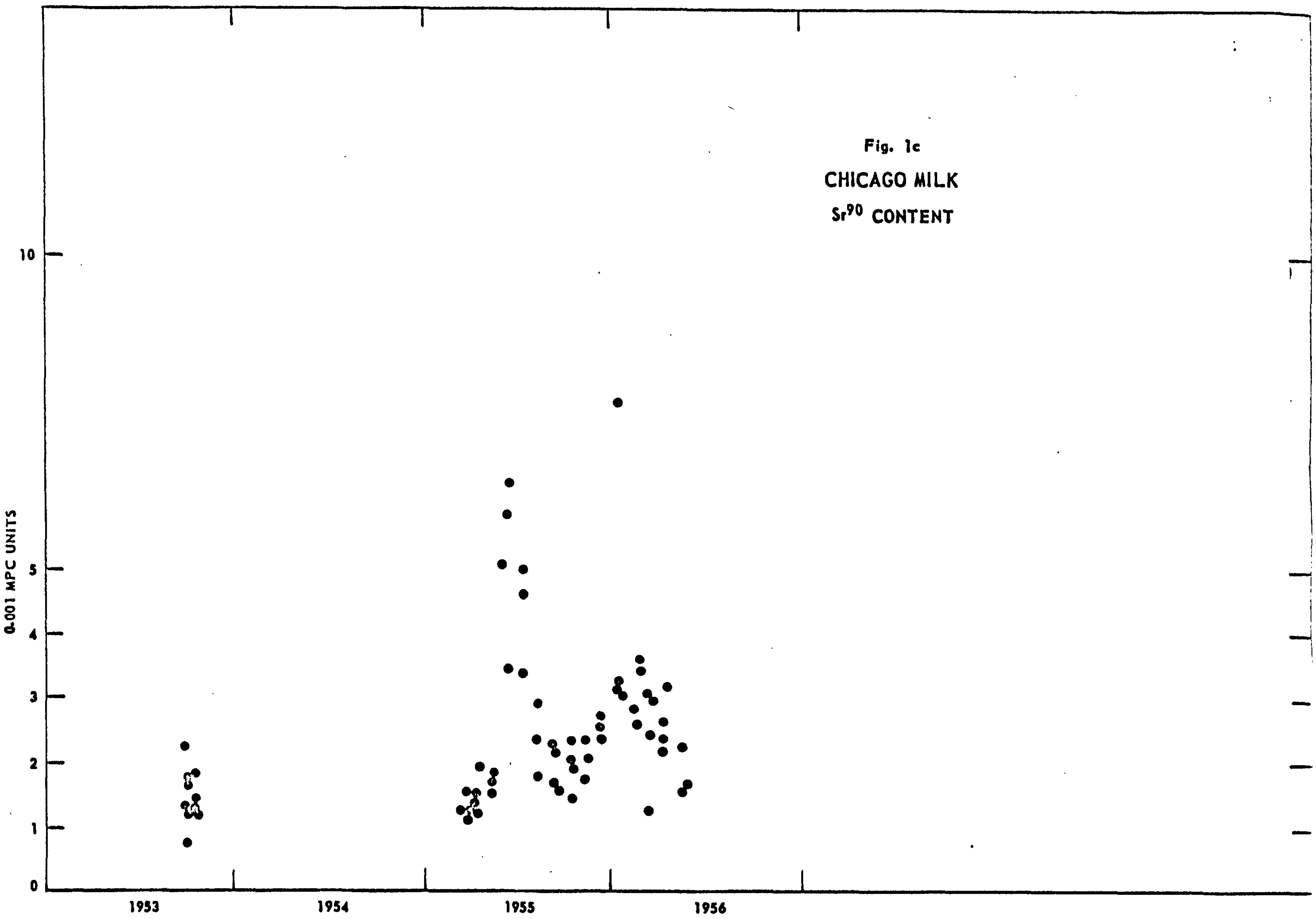


Fig. 1c
CHICAGO MILK
Sr90 CONTENT
0.001 MPC UNITS
10
5
4
3
2
1
0
1953
1954
1955
1956

142

143

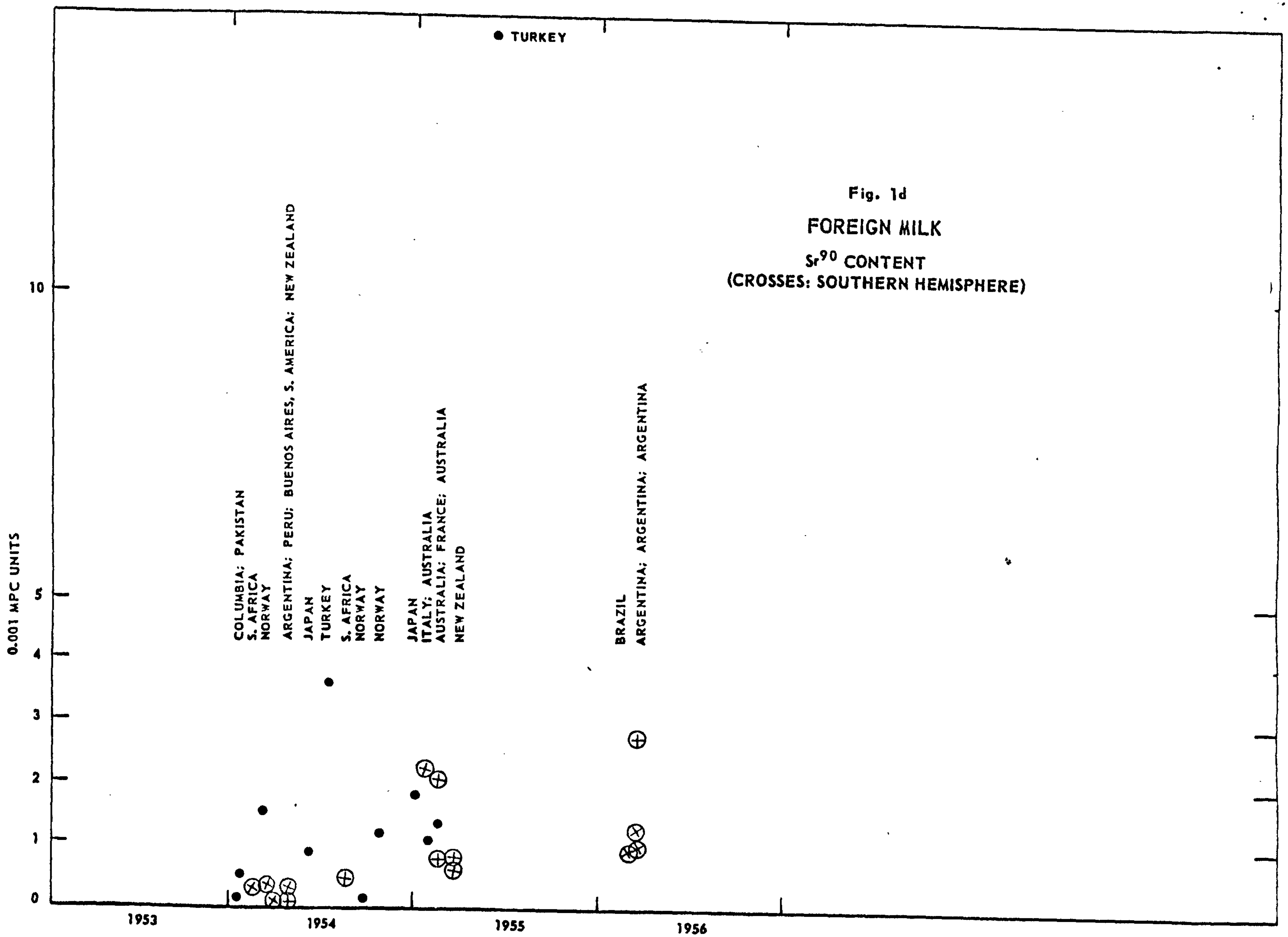
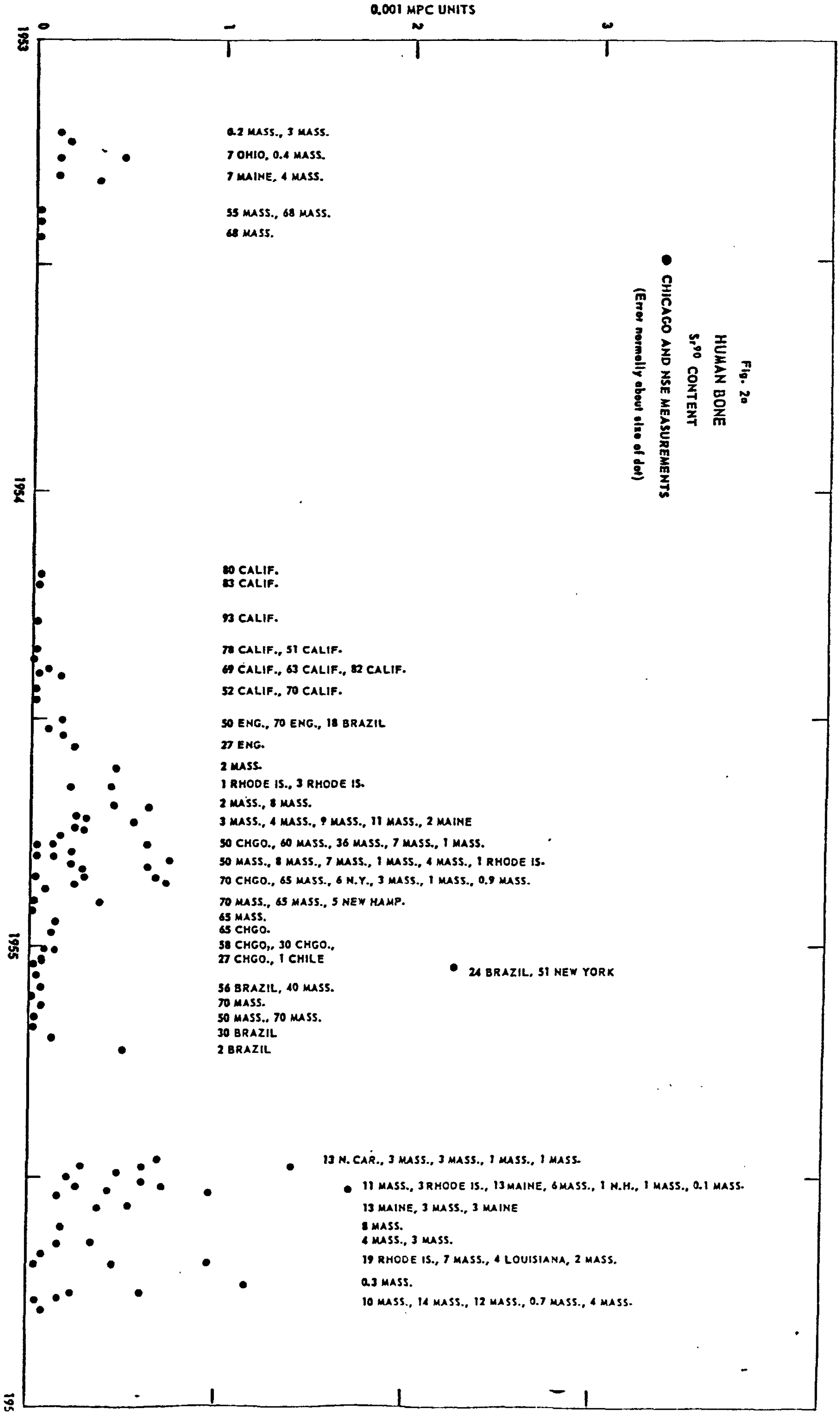


Fig. 1d

FOREIGN MILK

Sr^{90} CONTENT

(CROSSES: SOUTHERN HEMISPHERE)


0.001 MPC UNITS
0
1
2
3
1953
1954
1955
195
Fig. 2a
HUMAN BONE
Sr90 CONTENT
● CHICAGO AND NSE MEASUREMENTS
(Error normally about size of dot)
0.2 MASS., 3 MASS.
7 OHIO, 0.4 MASS.
7 MAINE, 4 MASS.
55 MASS., 68 MASS.
68 MASS.
80 CALIF.
83 CALIF.
93 CALIF.
78 CALIF., 51 CALIF.
69 CALIF., 63 CALIF., 82 CALIF.
52 CALIF., 70 CALIF.
50 ENG., 70 ENG., 18 BRAZIL
27 ENG.
2 MASS.
1 RHODE IS., 3 RHODE IS.
2 MASS., 8 MASS.
3 MASS., 4 MASS., 9 MASS., 11 MASS., 2 MAINE
50 CHGO., 60 MASS., 36 MASS., 7 MASS., 1 MASS.
50 MASS., 8 MASS., 7 MASS., 1 MASS., 4 MASS., 1 RHODE IS.
70 CHGO., 65 MASS., 6 N.Y., 3 MASS., 1 MASS., 0.9 MASS.
70 MASS., 65 MASS., 5 NEW HAMP.
65 MASS.
65 CHGO.
58 CHGO., 30 CHGO.,
27 CHGO., 1 CHILE
24 BRAZIL, 51 NEW YORK
56 BRAZIL, 40 MASS.
70 MASS.
50 MASS., 70 MASS.
30 BRAZIL
2 BRAZIL
13 N. CAR., 3 MASS., 3 MASS., 1 MASS., 1 MASS.
11 MASS., 3 RHODE IS., 13 MAINE, 6 MASS., 1 N.H., 1 MASS., 0.1 MASS.
13 MAINE, 3 MASS., 3 MAINE
8 MASS.
4 MASS., 3 MASS.
19 RHODE IS., 7 MASS., 4 LOUISIANA, 2 MASS.
0.3 MASS.
10 MASS., 14 MASS., 12 MASS., 0.7 MASS., 4 MASS.

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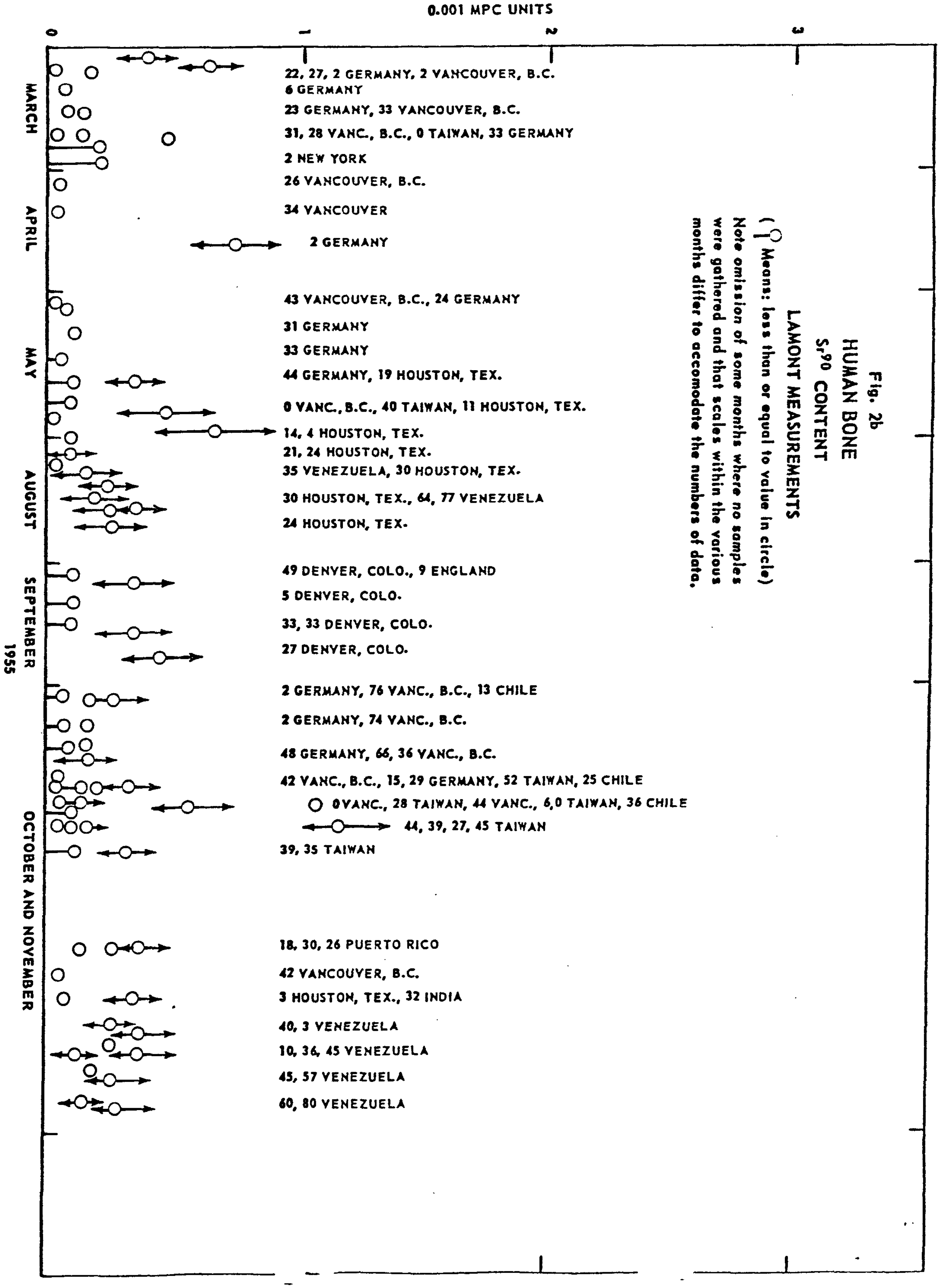


Fig. 2b
HUMAN BONE
S_r^{90} CONTENT
LAMONT MEASUREMENTS
(○| Means: less than or equal to value in circle)
Note omission of some months where no samples were gathered and that scales within the various months differ to accomodate the numbers of data.

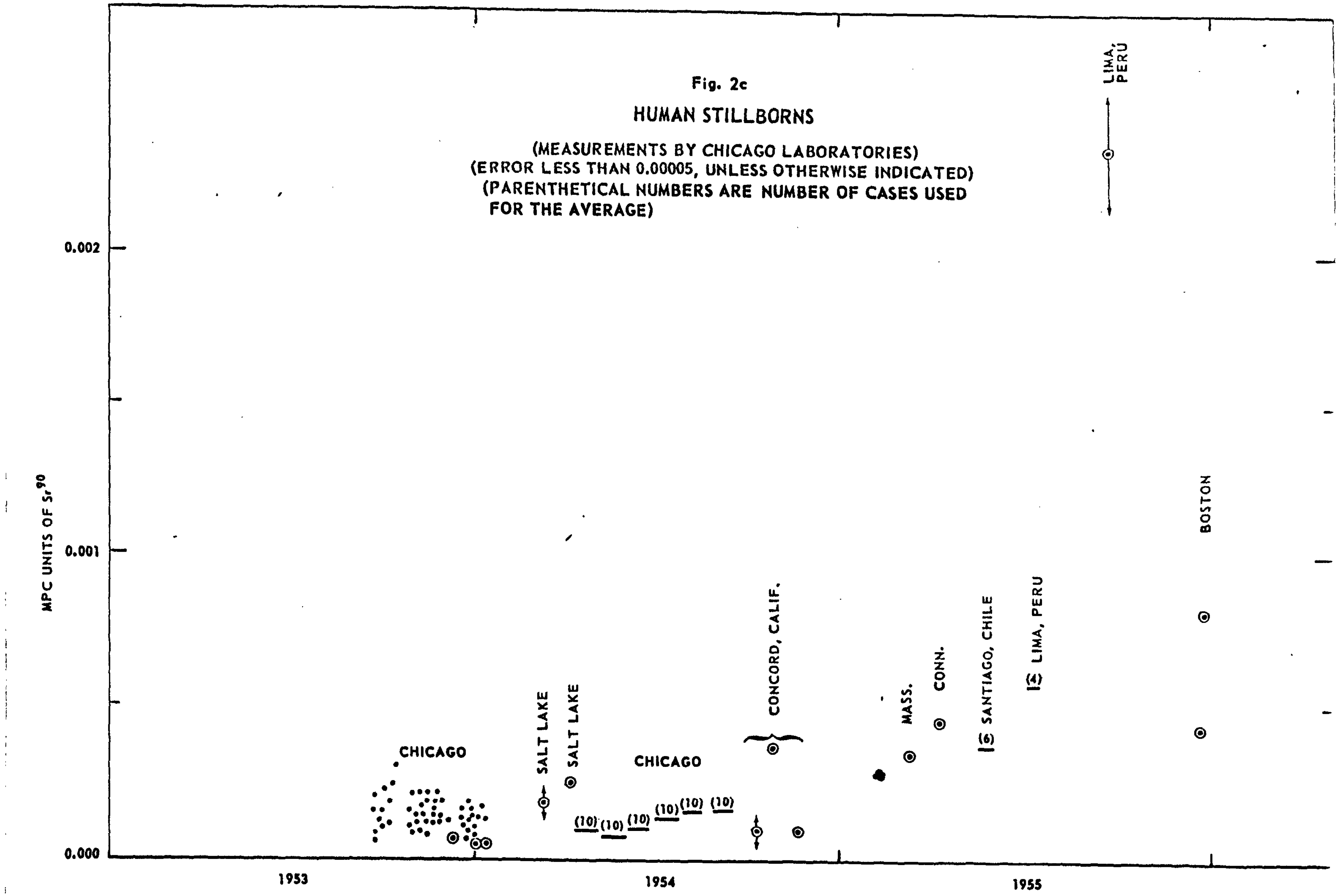


Fig. 2c
HUMAN STILLBORNS
(MEASUREMENTS BY CHICAGO LABORATORIES)
(ERROR LESS THAN 0.00005, UNLESS OTHERWISE INDICATED)
(PARENTHETICAL NUMBERS ARE NUMBER OF CASES USED FOR THE AVERAGE)

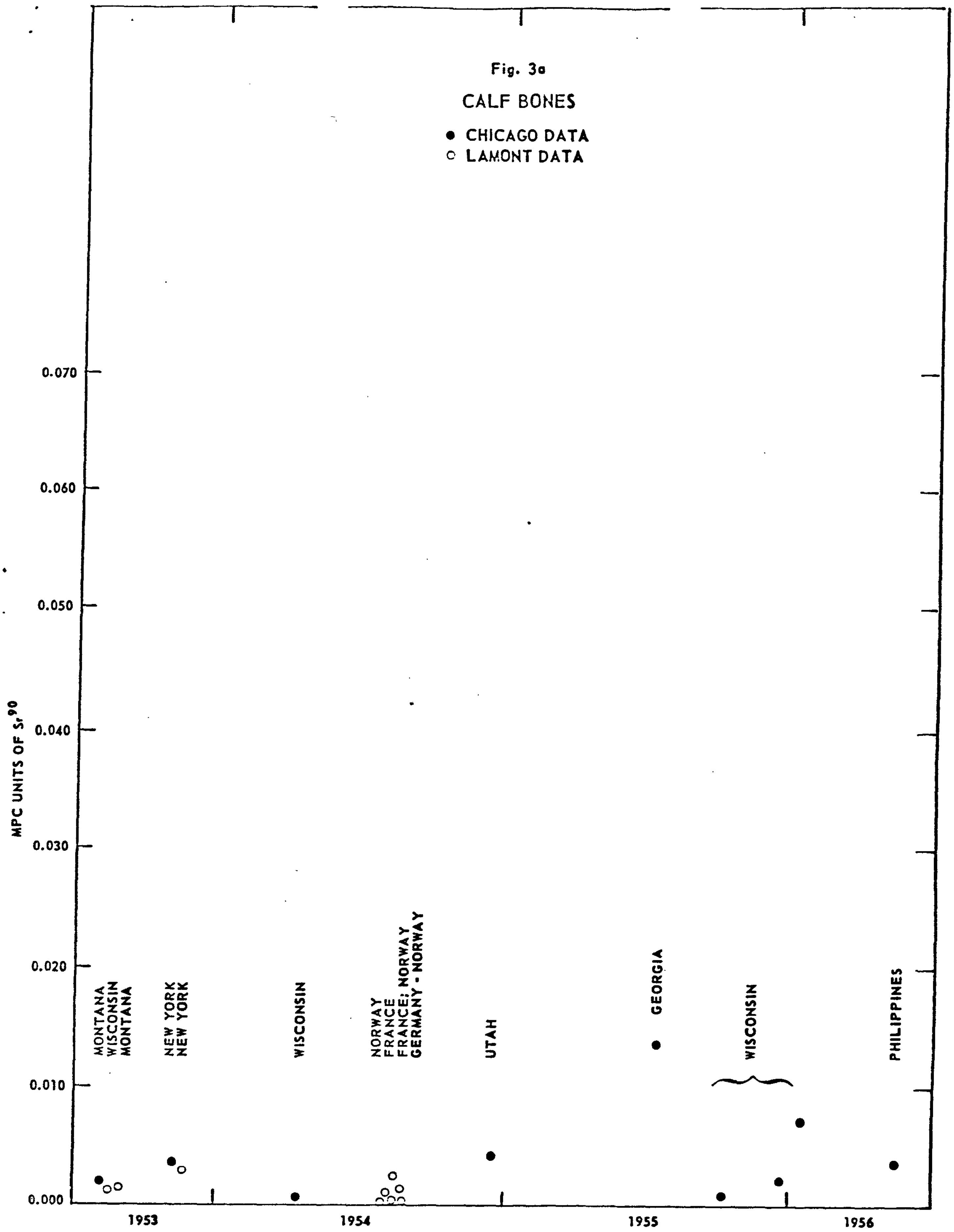


Fig. 3a
CALF BONES
● CHICAGO DATA
○ LAMONT DATA
MPC UNITS OF Sr90
0.070
0.060
0.050
0.040
0.030
0.020
0.010
0.000
MONTANA
WISCONSIN
MONTANA
NEW YORK
NEW YORK
WISCONSIN
NORWAY
FRANCE
FRANCE; NORWAY
GERMANY - NORWAY
UTAH
GEORGIA
WISCONSIN
PHILIPPINES
1953
1954
1955
1956

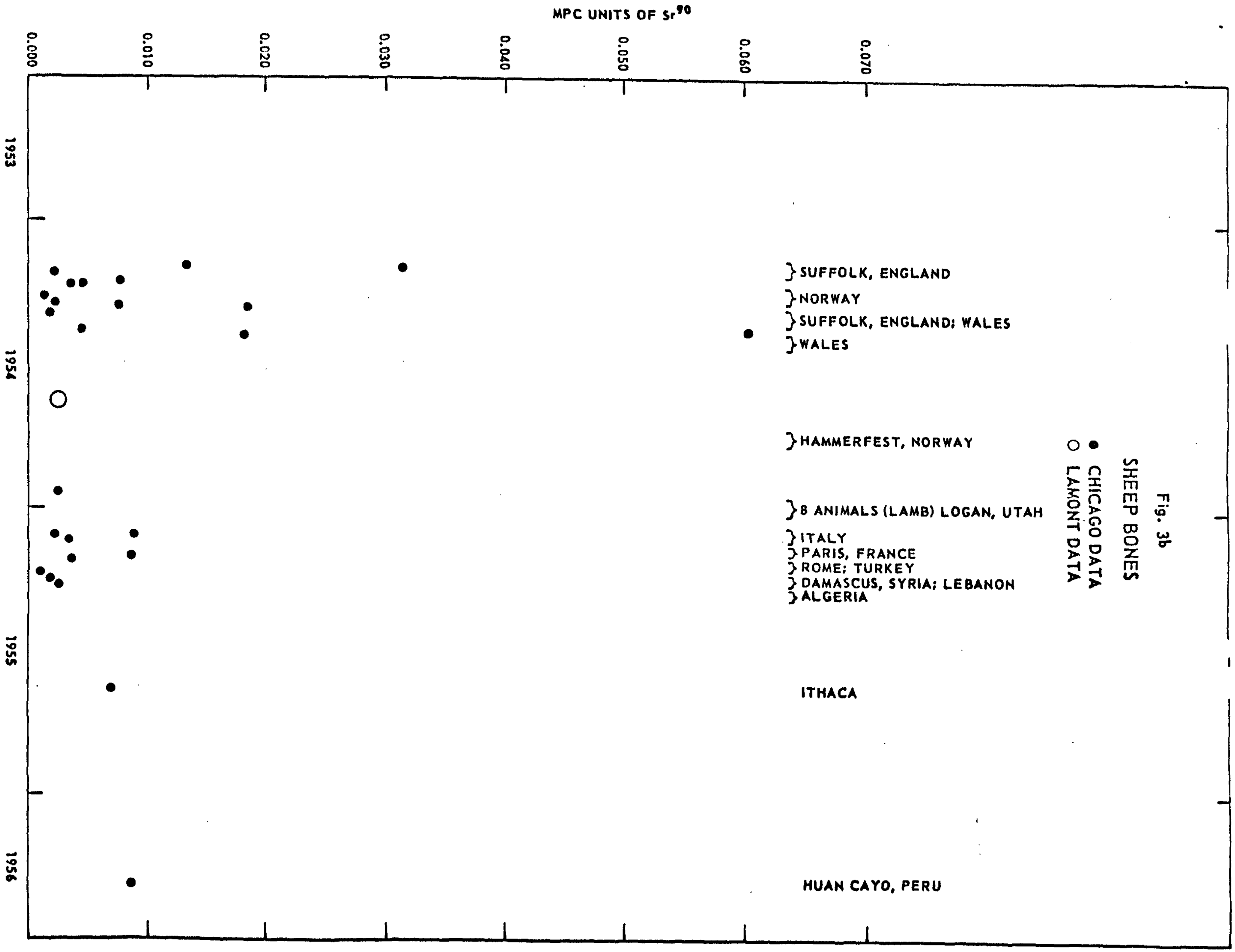


Fig. 3b
SHEEP BONES

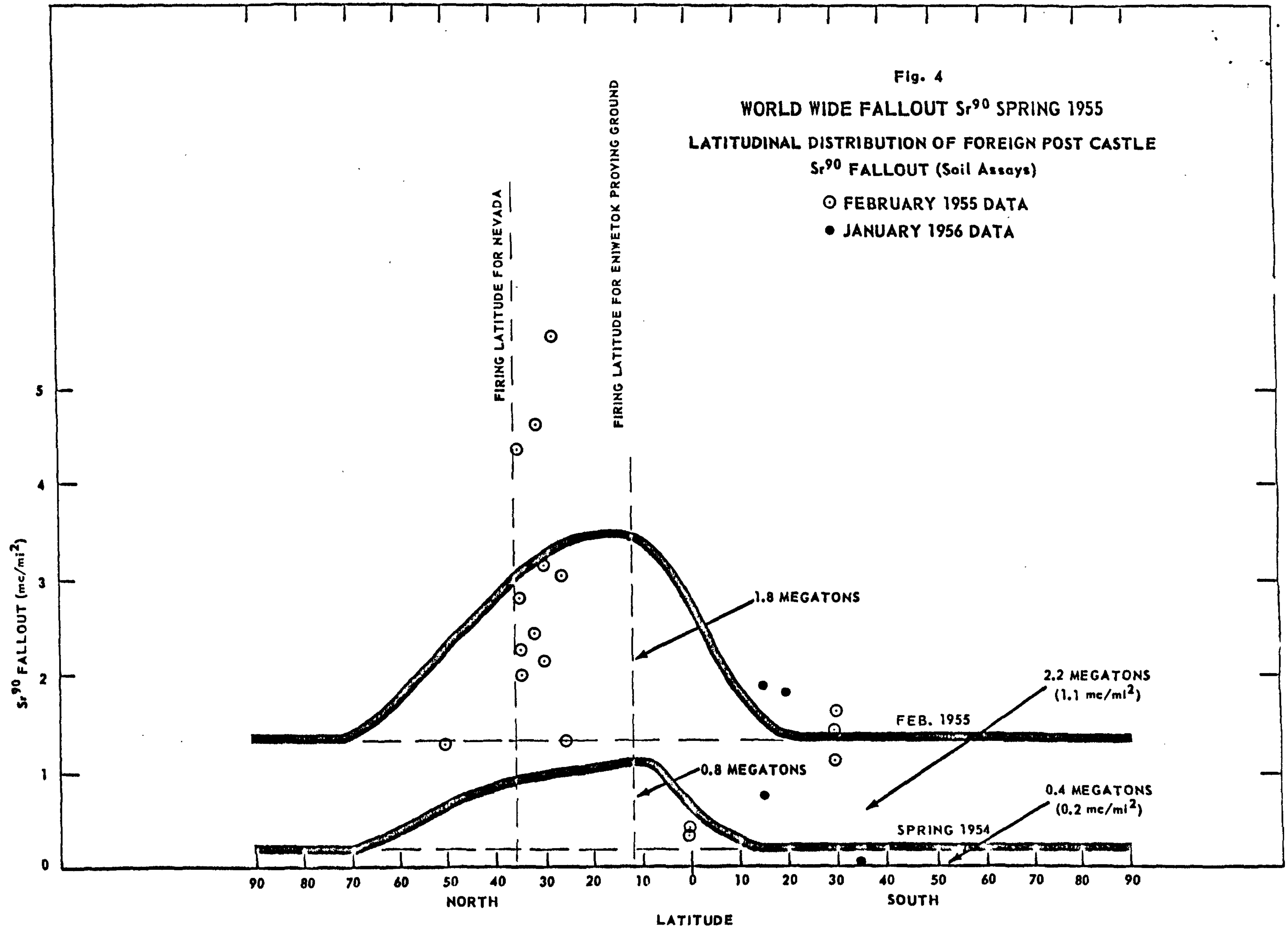


Fig. 4
WORLD WIDE FALLOUT Sr^{90} SPRING 1955
LATITUDINAL DISTRIBUTION OF FOREIGN POST CASTLE
Sr^{90} FALLOUT (Soil Assays)
⊙ FEBRUARY 1955 DATA
● JANUARY 1956 DATA
FIRING LATITUDE FOR NEVADA
FIRING LATITUDE FOR ENIWETOK PROVING GROUND
1.8 MEGATONS
2.2 MEGATONS
(1.1 mc/mi²)
FEB. 1955
0.8 MEGATONS
0.4 MEGATONS
(0.2 mc/mi²)
SPRING 1954
Sr^{90} FALLOUT (mc/mi²)
0
1
2
3
4
5
90 80 70 60 50 40 30 20 10 0 10 20 30 40 50 60 70 80 90
NORTH
SOUTH
LATITUDE

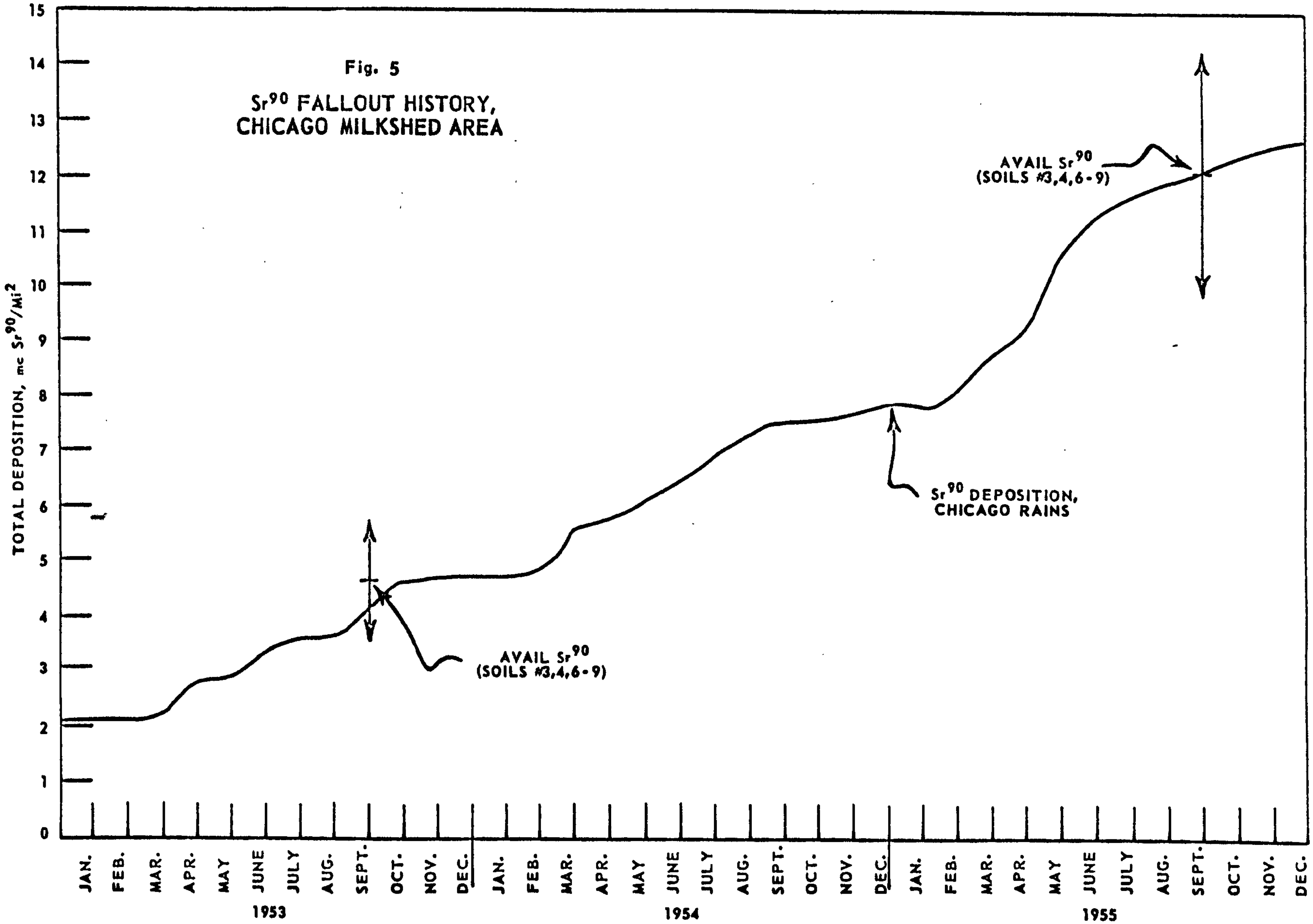


Fig. 5
Sr90 FALLOUT HISTORY,
CHICAGO MILKSHED AREA
AVAIL Sr90
(SOILS #3,4,6-9)
Sr90 DEPOSITION,
CHICAGO RAINS
AVAIL Sr90
(SOILS #3,4,6-9)
TOTAL DEPOSITION, mc Sr90/Mi2
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
JAN. FEB. MAR. APR. MAY JUNE JULY AUG. SEPT. OCT. NOV. DEC.
1953
1954
1955

152

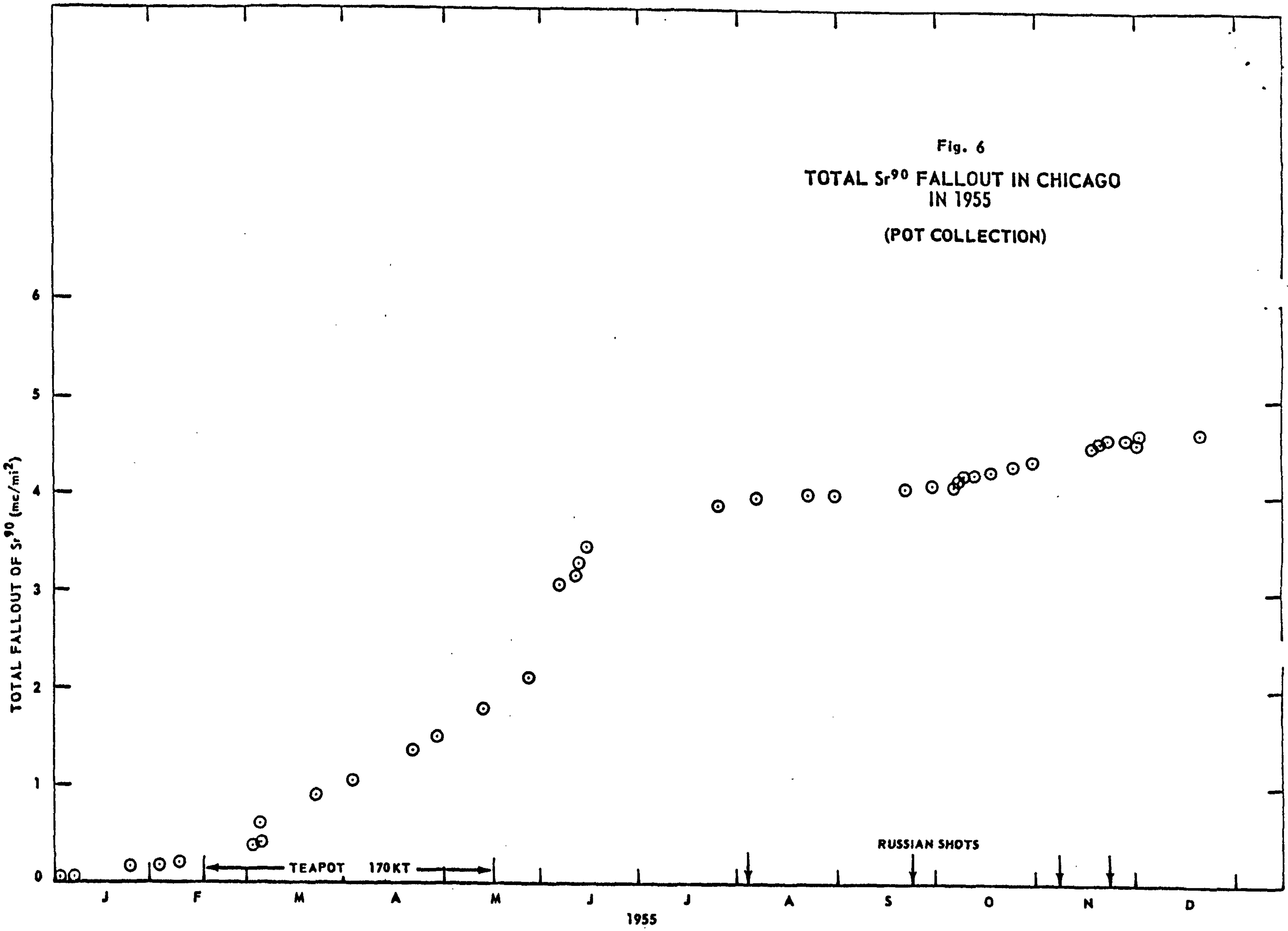
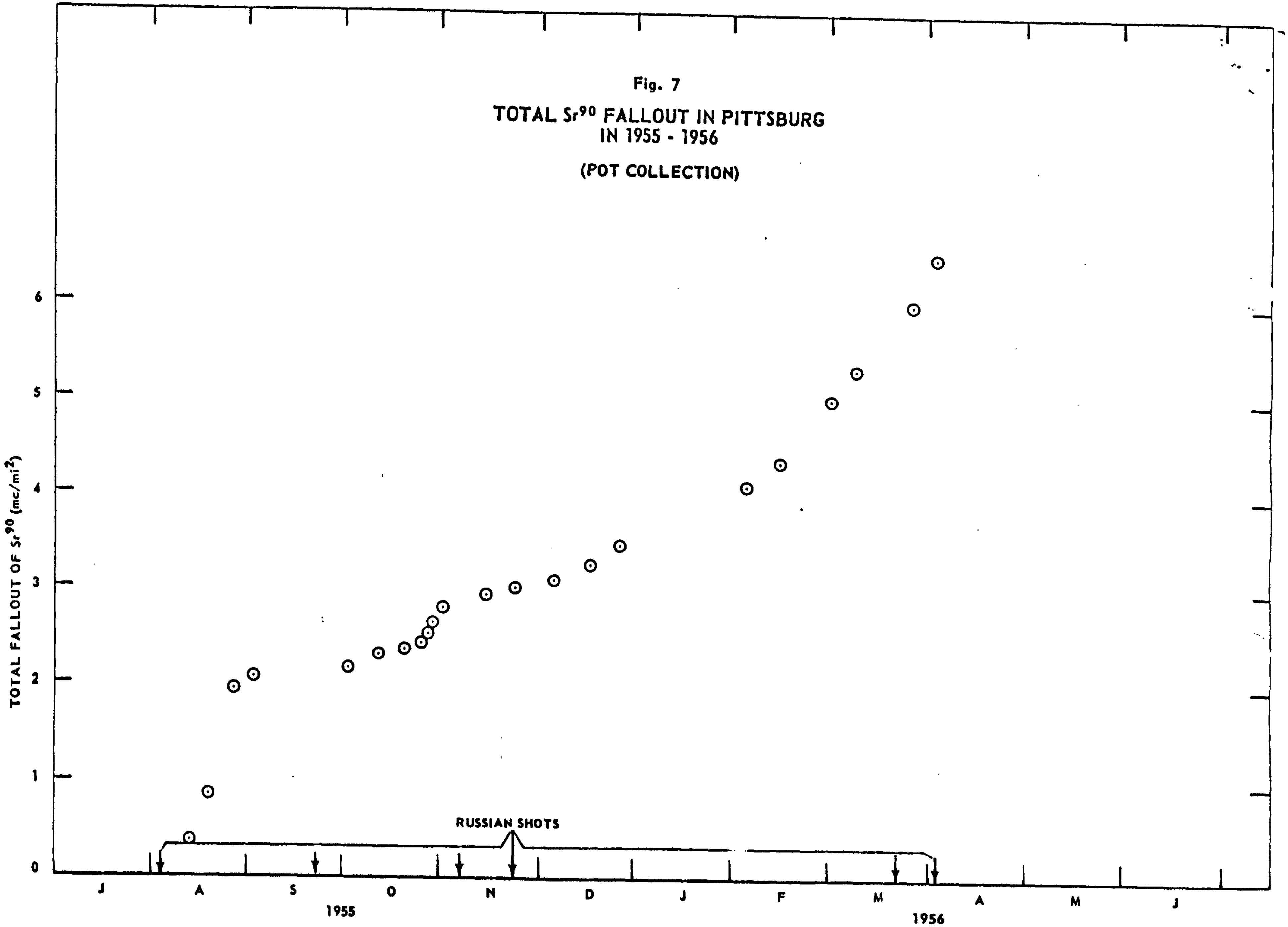


Fig. 6
TOTAL Sr90 FALLOUT IN CHICAGO IN 1955
(POT COLLECTION)
TOTAL FALLOUT OF Sr90 (mc/mi2)
0
1
2
3
4
5
6
TEAPOT 170KT
RUSSIAN SHOTS
J
F
M
A
M
J
J
A
S
O
N
D
1955

Fig. 7

TOTAL Sr^{90} FALLOUT IN PITTSBURG IN 1955 - 1956

(POT COLLECTION)



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