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Radioiodine Levels in the U. S. Public Health Service Pasteurized Milk Network from 1963 to 1968 and their Relationship to Possible Sources

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Abstract. Meteorological analysis of the paths of nuclear clouds has been used to assign the source of radioiodine in the milk samples collected in the U. S. Public Health Service Pasteurized Milk Network (PMN). Most of the instances of elevated values between April 1963 and December 1968 are attributed to six atmospheric nuclear explosions in western China. Only one of five cratering events at the Nevada Test Site caused elevated values in the PMN milk. Two periods with relatively low concentrations of radioiodine in milk possess no apparent explanation. By selecting periods with no atmospheric or cratering events, it is argued that at most small amounts of radioiodine in the PMN can be attributed to accidental releases from underground nuclear tests in the United States during the period of analysis. Radioiodine from accidental releases, reactor tests, and cratering events has been detected in a local raw milk network surrounding the Nevada Test Site.

Accepted by Health Physics for publication

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Introduction

The potentially important sources of radioiodine (I^{131}) in milk are: (a) atmospheric nuclear tests, (b) nuclear cratering experiments, (c) unscheduled ventings from underground nuclear tests, (d) releases from fuel reprocessing plants and other installations. In 1963, Machta (1) attributed the origin of I^{131} in milk samples of the U. S. Public Health Service Pasteurized Milk Network (PMN) having $\geq$300 pCi/l (picocuries of I^{131} per liter of whole milk) to particular sources during the period September 1961 through 1962. The present report updates the original report for the following six-year period.

While radioiodine in milk has been measured because of its health implications, the primary purpose of this study is to account for the origin of I^{131} in PMN milk samples. For present purposes, the absolute values of the concentration are secondary to the assurance that the milk truly contains I^{131}. At least one PMN sample per week was routinely scheduled for analysis in each of about 60 milksheds; the sampling frequency increased to twice weekly when elevated concentrations were expected or found. A single sample each week may not reflect the highest level in milk.

The generally accepted limit of detection for iodine-131 analysis is 10 pCi/l. This level is based on the random deviation in the analysis and count statistics and is defined as that:

> "level of activity which results in a 100% error at the 95% confidence level."

However, if there are small quantities of unidentified isotopes present, such as naturally occurring radium-226, or unusual background fluctuations which are not accounted for in the analysis, a bias can be introduced in the results which will raise the minimum sensitivity. On this basis, a cut-off value of greater than 30 pCi/l was chosen as that representing a high level of confidence that iodine-131 was actually present (2).

Many states operate their own milk networks; their results will be examined for support of the PMN findings. Because of earlier controversy, special attention is devoted to the possible sources of radioiodine from various nuclear activities at the Nevada Test Site (NTS). A local network operated by the Public Health Service surrounding the test site provided data which bear on the interpretation of the PMN findings in terms of a Nevada source.

Origin of I^{131} in PMN milk.

As shown in figure 1, there are ten periods with I^{131} concentrations greater than 30 pCi/l in the PMN from April 1963 through December 1968. The period January through March 1963 is a continuation of the elevated values in the late 1962, almost certainly from the large scale atmospheric testing in late 1962. Table 1 shows these ten periods in chronological order together with the most likely source of radioiodine.

(a) Atmospheric events:

Six of the periods (1, 3, 5, 7, 8, and 9 in fig. 1) followed six of the eight atmospheric tests conducted at Lop Nor in weatern China (40°N, 90°E). These six nuclear tests were reported to have total yields ranging from less than 20 kilotons to a few hundred kilotons equivalent TNT (3). Nuclear explosions near the ground with yields in this range inject radioactivity mainly into the troposphere, the active weather layer of the atmosphere (4). The movements of the leading edges of these six nuclear clouds appear in Figures 2 through 7. The behavior of the clouds from the May 1965 and May 1966 tests has already been discussed by Machta (5) in connection with preferential thunderstorm scavenging in the mid-western United States. Two other atmospheric nuclear detonations were reported each having a total yield of about 3 megatons of equivalent TNT (6). Fallout of all bomb produced radioisotopes from the first megaton test of 17 June 1967 was virtually non-existent in ground level air or rainwater for months after the event. This may be due to the fact that an explosion with the yield of about 3 megatons will inject most of its radioactivity into the stratosphere. The second megaton test took place on 27 December 1968 so that its fallout, if any, would not occur in the period covered by this study.

Thirteen atmospheric nuclear tests have been conducted by the Republic of France in the South Pacific near Muraroa (22°S, 140°W), (7, 8). Unfortunately, the sparsity of weather data over the equatorial oceans prevents the construction of reliable meteorological trajectories of the clouds from these tests. Iodine-131 concentrations in excess of 30 pCi/l occurred during period 10 following tests in the South Pacific. One milk sample, 32 pCi/l, in the Canal Zone in the last week of August 1968 probably derived its I^{131} from these tests. Other short-lived radioactivity was found in air during the same period at stations in South America and the tropics, which fits a pattern expected of a South Pacific source (9).

(b) Cratering events:

Five cratering tests conducted as part of the U. S. Atomic Energy Commission Plowshare Program for the peaceful application of nuclear explosives took place between 1963 and 1968. Although some radioactivity was detected in the atmosphere following each test, only the Palanquin event of 14 April 1965 resulted in elevated I^{131} levels in the PMN milk (Period 2). The meteorological trajectory for this event is shown in figure 8. Only Helena, Montana, reported detectable levels of I^{131} in milk.

Radioiodine must pass from the atmosphere through crops, cows, dairy transport, storage and pasteurization before its radioactivity is measured in milk in the PHS laboratories. These delays involve only a few days but may, in rare cases, take up to five days for the PMN. Further, only one sample per week is routinely collected from each milkshed. Thus, the delays and periodic sampling can result in time differences between nuclear cloud arrival and first milk contamination in Table 1 of up to a week and a half. The longest time difference, eleven days, was found in period 2. As discussed in the next paragraph, the explanation involves another factor, the weather.

During the colder half of the year in northern milksheds, herds are fed stored hay so that the cows have little opportunity to obtain radioiodine even if fallout were present (10). A specific instance in which this was observed took place at Helena, Montana, which according to Weather Bureau records, was snow-covered on April 16, 1965, the date of fallout deposition from the Palanquin cratering event, until a thaw a few days later. This probable delay in exposure of the cattle to the deposited radioiodine may help to account for the eleven day delay between deposition and first milk contamination.

There were four other cratering tests at the NTS between 1963 and 1968, none of which elevated the PMN milk radioiodine. These tests were intentionally conducted during the colder half of the year with wind blowing towards the north to take advantage of the fact that dairy cattle were on dry feed; the absence of I^{131} in milk does not preclude its deposition.

(c) Underground tests:

The contribution of radioiodine from underground nuclear tests at the Nevada Test Site (NTS) in PMN milk since September 1961 has been questioned

(11 through 20). Underground tests at the NTS must always be viewed as a potential source of radioiodine for milk within the U. S. because of its proximity compared with any proving ground outside the continental U. S. Further, the radioactivity from underground tests at NTS may often be released near the ground so that direct contact with the crops and scavenging by precipitating clouds is easier than for nuclear clouds aloft. Finally, since I^{131} is gaseous, atmospheric contamination from underground tests may be postulated even when particulates fail to escape.

Questions about the source of radioiodine have been raised for the period in 1961 and 1962 when both atmospheric and underground tests were being conducted. Over five and one half years have elapsed since the I^{131} fallout from the 1961-62 atmospheric nuclear test stopped and there are now intervals with frequent underground but no atmospheric nuclear tests. Inspection of Fig. 1 reveals nine such intervals which are listed in Table 2b, during which 5 cratering and 13 contained underground tests were reported to have taken place within the United States. In addition, ~~11~~ 12 underground tests were reported to have vented. The term "vented" is used to mean that radioactivity was detected off the Nevada Test Site. Excluding the interval after the Palanquin cratering event of 14 April 1965 and the unexplained November-December 1965 episode in southeastern United States (to be discussed later), no I^{131} concentration in milk of the PMN exceeded 30 pCi/l.

Because of the cattle feeding practices during cold weather, a better measure of the lack of radioiodine in milk following underground tests in the absence of atmospheric nuclear tests or the Palanquin event may be obtained from the warm seasons, May through October. Examination of these warm season PMN milk concentrations also shows that no milk sample contained over 30 pCi/l despite 64 reported underground tests of which three were reported to have vented (Table 2c).

During the periods of I^{131} fallout from atmospheric tests in 1963-68 there were also 30 reported underground tests in the United States, four of which were reported to have vented. There remains the possibility that these underground tests contributed I^{131} to the PMN milk which may have been masked by atmospheric testing. It is unlikely, however, that underground tests will produce I^{131} in PMN milk only when there are atmospheric tests.

(d) Unexplained Episodes:

Figure 1 reveals two other isolated periods (4 and 6) of slightly elevated isolated radioiodine concentrations in the PMN that have not been previously discussed. From November 30 to December 8, 1965, eleven milksheds in the southeastern U. S. (Baltimore, Md. to Tampa, Fla. to Little Rock, Ark.) reported concentrations between 14 and 36 pCi/l. Reanalysis of the gamma spectra for the detectable values during the November 30 - December 8, 1965 period confirmed the presence of radioiodine as originally reported. The Savannah River and Oak Ridge Atomic Energy Commission installations lie in this area and mere proximity suggests them as possible sources. However, neither their local monitoring results nor reported I^{131} releases, if any, implicate either plant. The other period, July 1966, followed the South Pacific atmospheric tests. A value of 60 pCi/l was observed at Palmer, Alaska, on July 19, 1966. But it is deemed unlikely that an Alaskan milkshed would be contaminated by a source at 22°S. There is, however, no independent evidence for accepting or rejecting southern hemisphere nuclear tests for the several elevated I^{131} milk concentrations in 1966.

In addition to the two unexplained periods in November-December 1965 and July 1966, there are others during which the radioiodine concentrations exceeded 10 pCi/l but failed to reach 30 pCi/l, most lying close to the lower value. These concentrations do not, of course, appear on Fig. 1. In all of these latter cases the geographical and temporal distribution of milksheds appears to be almost random. These relatively few concentrations above 10 pCi/l might be expected as statistical fluctuations because of the routine handling and analysis of the many thousands of samples.

Comparison of PMN with State milk network

In addition to the PMN, about 40 states monitor I^{131} in milk. In 1963 only 11 states reported to the PHS, which publishes their results in the Radiological Health Data and Reports (21). By 1968 the number of states reporting had increased to fifteen. Many of the state networks collect and analyze milk samples on a monthly basis while some collect more frequently. Neill and Snavely (22) summarized the criteria used by the states in their milk sampling programs.

The state results almost always confirm the presence of I^{131} in milk when the radioisotope appears in the PMN, sometimes higher and sometimes lower than the PMN concentration. During the periods with no I^{131} in PMN milk, the state findings also confirm the absence of radioiodine in milk in the United States, with two minor exceptions. On September 12, 1966, Tulsa, Oklahoma, reported 45 pCi/l but four other milksheds in Oklahoma had values below 8 pCi/l. Del Norte, California listed a mean monthly value of 40 pCi/l for March 1967. Again, other California milksheds were much lower. These elevated values in the state networks are not accounted for. The general lack of I^{131} in milk samples collected by the states is not a conclusive verification of its absence in the PMN because of infrequent sampling, limited reporting, and the monthly averaging.

Comparison of PMN with SWRHL milk network:

The Southwest Radiological Health Laboratory of the U. S. Public Health Service (SWRHL) operates a milk sampling network which surrounds the Nevada Test Site. Milk is routinely sampled each month from dairy farms and individual family cows in Nevada, western Utah and eastern California. In the event of a release of airborne radioactivity from the testing activities at the NTS some 155 producing dairies in 11 western states can be alerted by telephone to collect milk samples. The SWRHL conducts a continuous survey of off-site milk sampling locations.

A summary of I^{131} findings in milk in the SWRHL network appears in Table 3 for nuclear rocket tests, cratering tests, and unscheduled venting from underground tests.

Levels of radioiodine in the SWRHL milk network following the reactor tests in Jackass Flats of the NTS show a peak value of 240 pCi/l. The farthest farm from the test site with a concentration in excess of 30 pCi/l (from a test on February 23, 1967) was located at a distance of 250 miles. There was no detectable I^{131} in the SWRHL milk network for about half of the reactor events.

Four of the five cratering events resulted in readily detectable concentrations of radioiodine in the SWRHL network. The Sulky cratering event created a mound rather than a conventional crater and only very small amounts of radioactivity were released to the atmosphere. Thus, it is not surprising that no detectable amounts of radioiodine could be found in milk. Iodine-131 from the Palanquin cratering event provided the highest milk concentrations of any NTS event and, as noted earlier, its I^{131} appeared in the PMN milk at Helena, Montana as well. The SWRHL collected milk samples from 154 locations in the western U. S. for this event with extensive sampling concentrated in seven states. The farthest distance of I^{131} in milk >30 pCi/l was found at Miles City, Montana, approximately 900 miles from the test site. The date of this sample preceded that found at Helena in the PMN from the same event.

~~Eleven~~ Twelve of the ~~fifteen~~ sixteen unscheduled releases of radioactivity from underground tests at the NTS produced no detectable I^{131} in the local NTS milk samples. The Pin Stripe event on April 25, 1966, resulted in a milk concentration of 4,800 pCi/l at a distance of 60 miles. Concentrations decreased to 70 pCi/l in a sample obtained at 550 miles. Aside from Pin Stripe, the highest concentration of I^{131} in the SWRHL milk network from an unscheduled release of radioactivity from an underground test (130 pCi/l) occurred from the June 16, 1965 event. Actually, at this time, fallout from a Lop Nor nuclear test deposited radioactivity over the United States and the assignment of the origin of the radioiodine in milk is ambiguous (23). The same confusion on the source of radioiodine in milk existed a year later for the June 8, 1966 rocket test (24).

Why did the PMN not reflect the presence of radioiodine when it was seen in the local SWRHL network? The probable explanations are both meteorological and non-meteorological. In the latter category one notes that the PMN composites milk from farms dispersed over hundreds to thousands of square miles. Milk from farms with detectable concentrations of I^{131} can be diluted by milk from other farms in the milkshed with no radioiodine, the composite I^{131} being too small to detect. This contrasts with the SWRHL network where, for the most part, individual farms or dairies are sampled. The clouds from some of the atmospheric releases in Table 3 moved northward in the cold half of the year when cows were not on pasture. But probably more important are the several meteorological reasons. A cloud of radioiodine dilutes as it moves downwind of its source due to both horizontal and vertical turbulent mixing and to removal processes. The dilution caused by atmospheric diffusion, on the average, decreases the peak concentration in the cloud at the rate of roughly the square of time. The peak concentration at 5 hours would therefore be reduced by a factor of 25 one day later. The rate of loss due to uptake of I^{131} by the soil and vegetation is unknown. Precipitation scavenging is effective whenever it rains or snows. It is believed that this removal process was particularly effective for the Palanquin cloud which was snowed out while moving over Idaho and Montana. Finally, the PMN milksheds cover only small areas of the United States. Could a cloud of radioiodine have passed through the country missing every PMN milkshed? Such a passage is possible but is highly unlikely. However, the first PMN milkshed that the debris will pass through outside the State of Nevada lies from 300 to 600 miles from the NTS, depending on direction of cloud travel. The answer to the question heading this paragraph therefore is that the concentration of radioiodine in most cases is probably too low to cause an elevated milk concentration by the time the radioiodine cloud reaches the PMN.

Summary and Conclusions

Six atmospheric tests conducted in Western China provided the source of radioiodine for the majority of cases of elevated concentrations of I^{131} in PMN milk in the United States from April 1963 to December 1968. Atmospheric tests in the South Pacific probably accounted for only one elevated value, in the Canal Zone.

During periods without I^{131} fallout from atmospheric tests, 131 contained underground and 5 cratering tests were reported in the U. S. almost all at the NTS. In addition, 12 underground tests were reported to have vented. During the same period no PMN milk samples contained I^{131} greater than 30 pCi/l except for the period following the Palanquin cratering event and the unexplained episode in the southeastern U. S. The evidence since 1963 strongly suggests that nuclear cratering events conducted in the cold season with wind blowing toward the north did not contribute significantly to elevated radioiodine in the PMN milk.

The limited data from state networks measuring radioiodine in milk confirm the presence or absence of I^{131} in PMN milk with minor exceptions. However, a local Public Health Service network surrounding the NTS showed radioiodine in milk following 13 of 25 rocket tests, four of five cratering tests, and four of sixteen unscheduled ventings from underground tests. Only after one cratering test, Palanquin, did the PMN also contain I^{131} in milk. It is suggested that atmospheric mixing and removal processes dilute the radioactive clouds. These as well as non-meteorological factors account for the absence of PMN contamination when the local PHS network revealed elevated radioiodine.

Acknowledgment. The authors gratefully acknowledge support by the Fallout Studies Branch, Division of Biology and Medicine, U. S. Atomic Energy Commission. The assistance of the Office of Criteria and Standards, Division of Environmental Radiation, and the Southwestern Radiological Health Laboratory of the Bureau of Radiological Health, Public Health Service, Department of Health, Education and Welfare is appreciated. Finally, we should like to thank our colleague, Robert List, for his invaluable aid in preparing this paper.

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Table 1. Cases of I-131 >30 pCi/l of milk in PHS Pasteurized Milk Network

(April 1963 through December 1968)

Period (See fig. 1)	Period of Milk Contamination Begin	End	First Contaminated Milk Milkshed	I-131 (pC/l)	Highest Contaminated Milk Milkshed	Date	I-131 (pCi/l)	Nuclear Cloud Arrival Date from Meteorological Trajectories	Probable Source
1	10/26/64	11/2/64	Albuquerque, N.M.	60	Albuquerque, N.M.	10/24/64	60	10/20/64	Lop Nor Atmospheric test
2	4/27/65	4/27/65	Helena, Mont.	80	Helena, Mont.	4/27/65	80	4/16/64	NTS Cratering event
3	5/25/65	6/22/65	Minneapolis, Minn.	90	Kansas City, Mo.	5/28/65	220	5/19/65	Lop Nor Atmospheric test
4	12/1/65	12/1/65	Chattanooga, Tenn.	36	Chattanooga, Tenn.	12/1/65	36	--	Unknown
5	5/20/66	6/24/66	Kansas City, Mo.	80	Little Rock, Ark.	5/24/66	392	5/13/66	Lop Nor Atmospheric test
6	7/19/66	7/19/66	Palmer, Alaska	60	Palmer, Alaska	7/19/66	60	--	Unknown
7	11/10/66	11/16/66	Kansas City, Mo.	37	Kansas City Mo. Austin, Tex.	11/10/66 11/16/66	37 37	11/2/66	Lop Nor Atmospheric test
8	1/6/67	1/16/67	Portland, Ore.	74	Charlestown, S.C.	1/10/67	212	12/31/66	Lop Nor Atmospheric test
9	1/4/68	1/4/68	Charlotte, N.C.	36	Charlotte, N.C.	1/4/68	36	12/28/67	Lop Nor Atmospheric test
10	8/26/68	8/26/68	Canal Zone, Panama	32	Canal Zone, Panama	8/26/68	32	Unknown	S. Pacific Atmospheric test

1965

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Table 2. Number of reported underground and cratering events in the United States (April 1963 - December 1968).

a. Total number of events

Non-vented underground -	~~158~~ 157*
Vented underground------	~~15~~ 16
Cratering events--------	5

b. Number of events during periods of non-atmospheric testing

	Non-vented Underground	Vented Underground	Cratering
Apr. 1963 - Oct. 16, 1964	39	3	0
Nov. 2, 1964 - May 14, 1965	13	3	2
June 22, 1965 - May 9, 1966	27	2	0
July 19, 1966 - Sept. 11, 1966	2	0	0
Nov. 16, 1966 - Dec. 27, 1966	3	0	0
Jan. 16, 1967 - June 5, 1967	12	1	0
July 2, 1967 - Dec. 24, 1967	11	1	0
Jan. 4, 1968 - July 7, 1968	~~15~~ 14	2	2
Sept. 8, 1968 - Dec. 27, 1968	10	0	1
TOTAL:	~~132~~ 131	~~11~~ 12	5

c. Number of events during period May through October excluding atmospheric tests.

	Non-vented Underground	Vented Underground	Cratering
May 1 - Oct. 31, 1963	13	1	0
May 1 - Oct. 16, 1964	14	0	0
May 1 - May 14, 1965	2	1	0
June 22 - Oct. 31, 1965	7	0	0
May 1 - May 9, 1966	3	0	0
July 19 - Sept. 11, 1966	2	0	0
May 1 - June 5, 1967	4	0	0
July 2 - Oct. 31, 1967	8	1	0
May 1 - July 7, 1968	4	0	0
Sept. 8 - Oct. 31, 1968	4	0	0
TOTAL:	61	3	0

* Includes two joint US-UK events.

Table 3. Iodine-131 in the PHS Southwestern Radiological Health Laboratory milk network surrounding the Nevada Test Site (25).

a. Reactor tests:

Date	Location receiving Max I-131 in milk Distance (miles)	(pCi/l)	Farthest location receiving 30 pCi/l Distance (miles)	(pCi/l)
1964				
May 13	90	140	220	40
Aug 28	150	20	-	-
Sept 10	80	40	80	40
Sept 24	-	ND(1)	-	-
Oct 15	-	ND	-	-
1965				
Jan 12	-	ND	-	-
Apr 23	-	ND	-	-
May 20	80	90	80	90
May 28	30	70	30	70
June 25	130	180	130	180
1966				
Feb 3	-	ND	-	-
Feb 11	-	ND	-	-
Mar 3	-	ND	-	-
Mar 16	-	ND	-	-
Mar 25	100	140	115	40
June 8	30	50	30	50
June 23	170	240	200	50
1967				
Feb 10	-	ND	-	-
Feb 23	180	60	250	40
Dec 15	30	90	30	90
1968				
June 8	-	ND	-	-
June 26	80	30	-	-
July 18	140	90	140	90
Nov 21	-	ND	-	-
Dec 4	-	ND	-	-

b. Cratering Experiments:

Date	Test	Location receiving Max I-131 in milk Distance (miles)	(pCi/l)	Farthest Location receiving >30 pCi/l Distance (miles)	(pCi/l)
1964					
Dec 18	Sulky	-	ND	-	-
1965					
Apr 14	Palanquin	135	11,000	900	60
1968					
Jan 26	Cabriolet	275	630	285	40
Mar 12	Buggy I	300	550	320	40
Dec 8	Schooner	250	100	250	100

c. Unscheduled Ventings

Date	Test	Location receiving Max I-131 in milk Distance (miles)	(pCi/l)	Farthest Location receiving >30 pCi/l Distance (miles)	(pCi/l)
1963					
June 5	Yuba	-	ND (2)	-	-
Dec 12	Eagle	-	ND	-	-
1964					
Mar 13	Pike	300	80	300	80
Dec 16	Parrot	-	ND	-	-
1965					
Feb 12	Alpaca	-	ND	-	-
May 7	Tee	-	ND (2)	-	-
June 16	Diluted Water	130	130	280	60
1966					
Mar 5	Red Hot	-	ND	-	-
Apr 25	Pin Stripe	60	4800	550	70
June 15	Double Play	-	ND	-	-
Sept 12	Derringer	-	ND	-	-
1967					
Jan 19	Nash	-	ND	-	-
June 29	Umber	-	ND	-	-
Aug 31	Door Mist	-	ND	-	-
1968					
Jan 18	Hupmobile	30	30	-	-
Mar 25	Milkshake	—	ND	—	—

(1) ND indicates I-131 in milk was not detected.

(2) No milk samples were collected for this event. Radioactivity above background levels was not detected in the off-site area by air samples.

Caption for Figures

Fig. 1 The highest individual milk concentration (>30 pCi/l) of I^{131} for each week reported in the U.S. Public Health Service Pasteurized Milk Network and the announced nuclear detonations. The hatched bars indicate the highest concentrations were outside the contiguous 48 states. Asterisk indicates joint US-UK underground test.

Fig. 2. The successive areas covered by the leading edge in the upper troposphere from the announced atmospheric nuclear detonation near Lop Nor, western China, on October 16, 1964 determined by meteorological trajectories.

Fig. 3. The successive areas covered by the leading edge in the upper troposphere from the announced atmospheric nuclear detonation near Lop Nor, western China, on May 14, 1965 determined by meteorological trajectories.

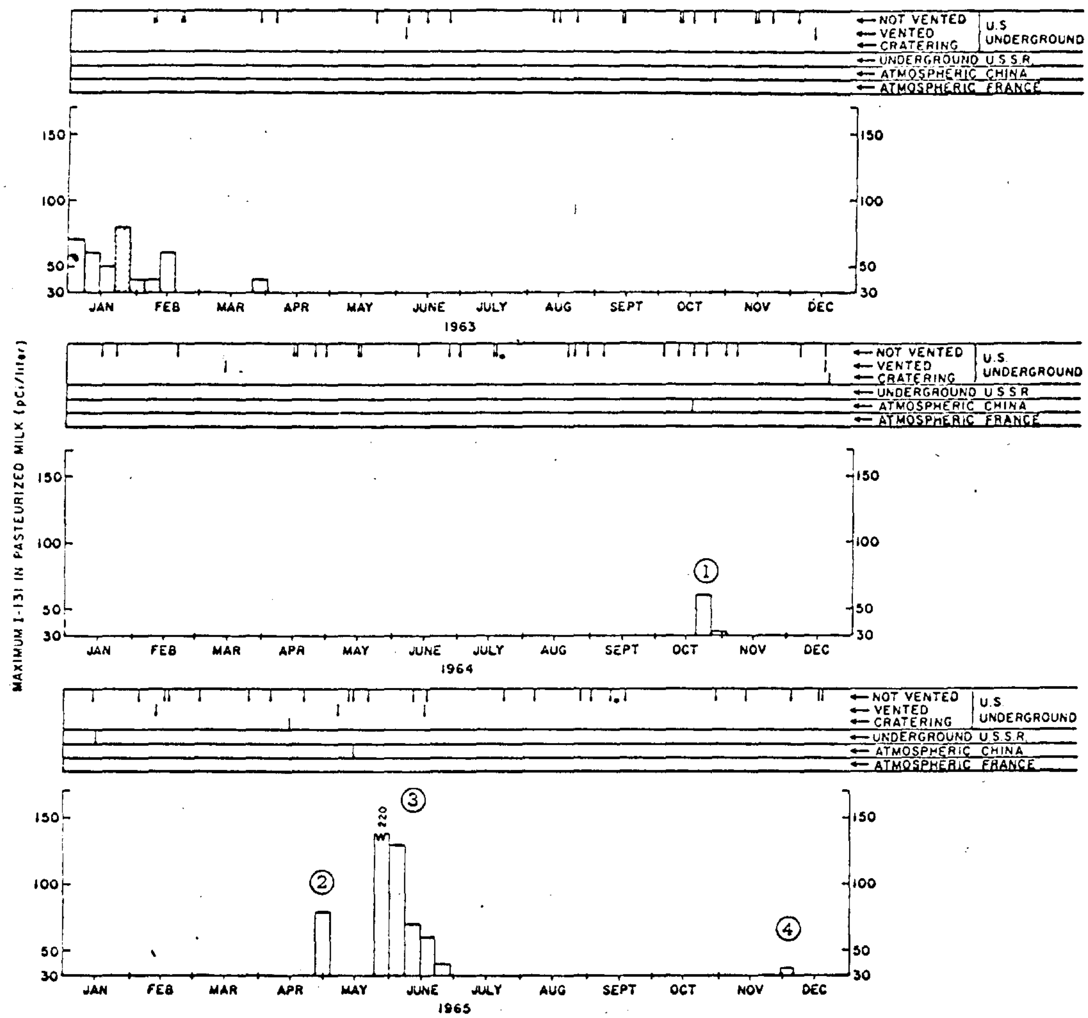
Fig. 4. The successive areas covered by the leading edge in the upper troposphere from the announced atmospheric nuclear detonation near Lop Nor, western China, on May 9, 1966 determined by meteorological trajectories.

Fig. 5. The successive areas covered by the leading edge in the upper troposphere from the announced atmospheric nuclear detonation near Lop Nor, western China, on October 27, 1966 determined by meteorological trajectories.

Fig. 6. The successive areas covered by the leading edge in the upper troposphere from the announced atmospheric nuclear detonation near Lop Nor, western China, on December 28, 1966 determined by meteorological trajectories.

Fig. 7. The successive areas covered by the leading edge in the upper troposphere from the announced atmospheric nuclear detonation near Lop Nor, western China, on December 24, 1967 determined by meteorological trajectories.

Fig. 8. The successive areas covered by the nuclear cloud from a cratering event (Palanquin) on April 14, 1965 determined by meteorological trajectories.


NOT VENTED
VENTED
CRATERING
U.S UNDERGROUND
UNDERGROUND U.S.S.R.
ATMOSPHERIC CHINA
ATMOSPHERIC FRANCE
MAXIMUM I-131 IN PASTEURIZED MILK (pCi/liter)
150
100
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JAN
FEB
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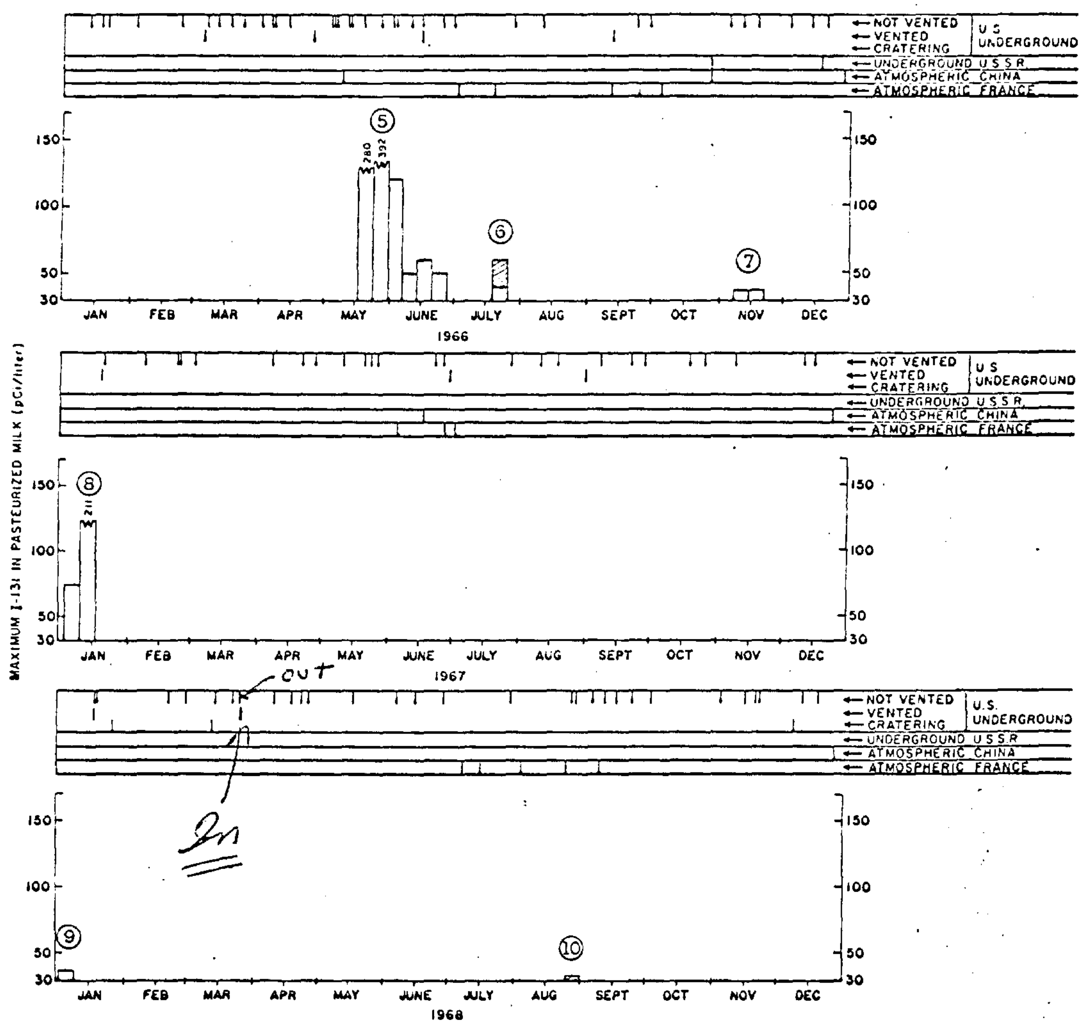
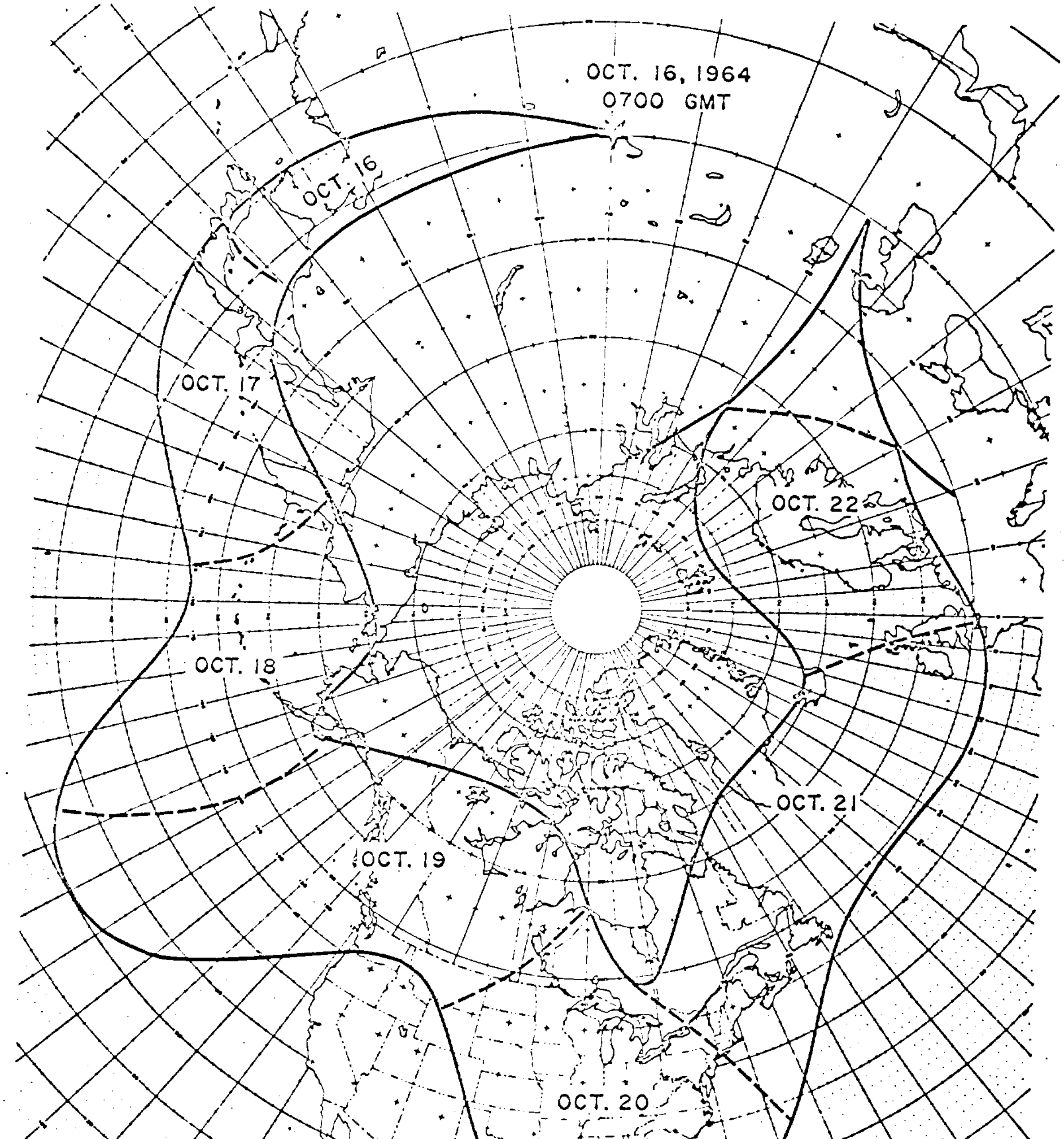
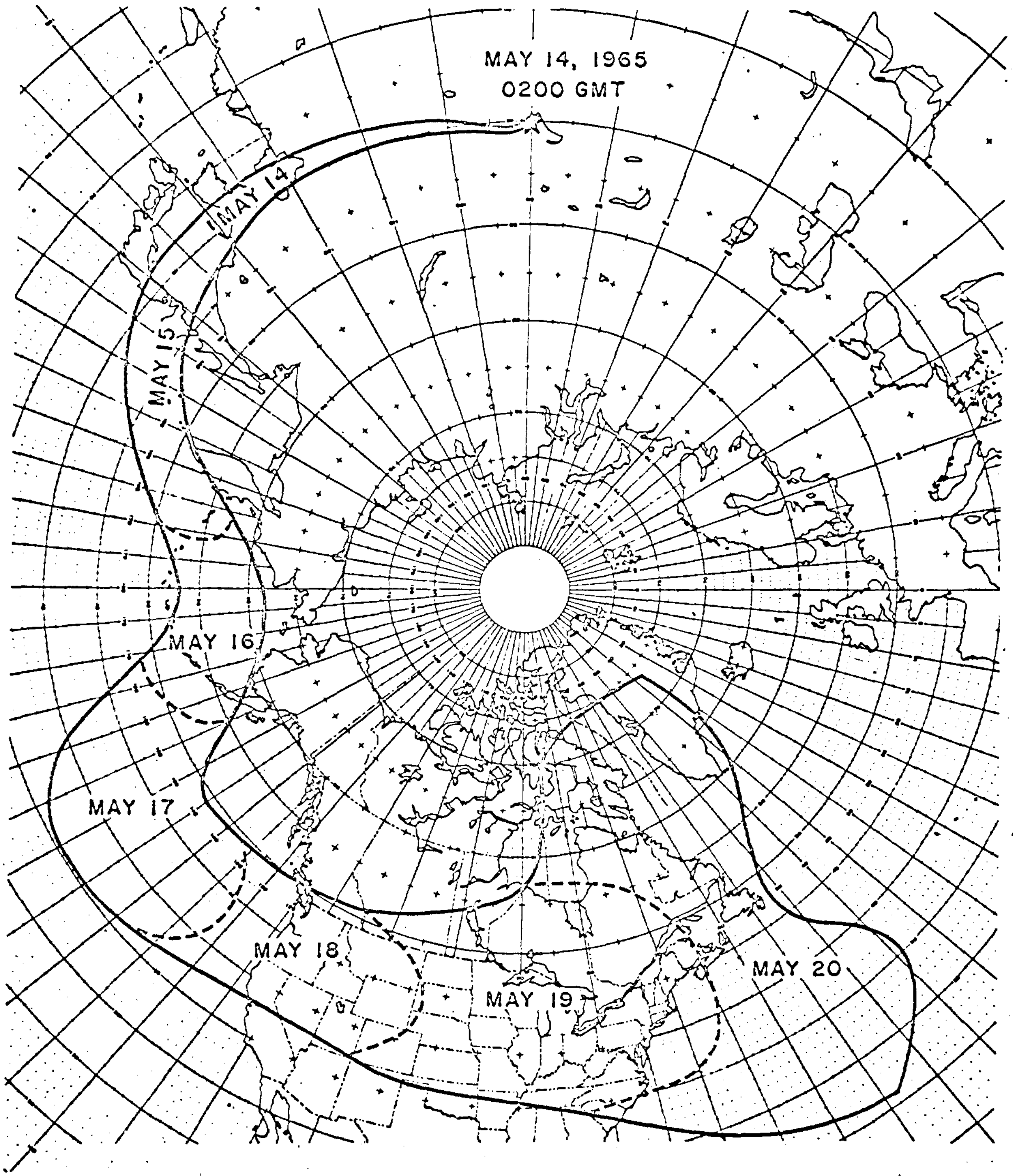
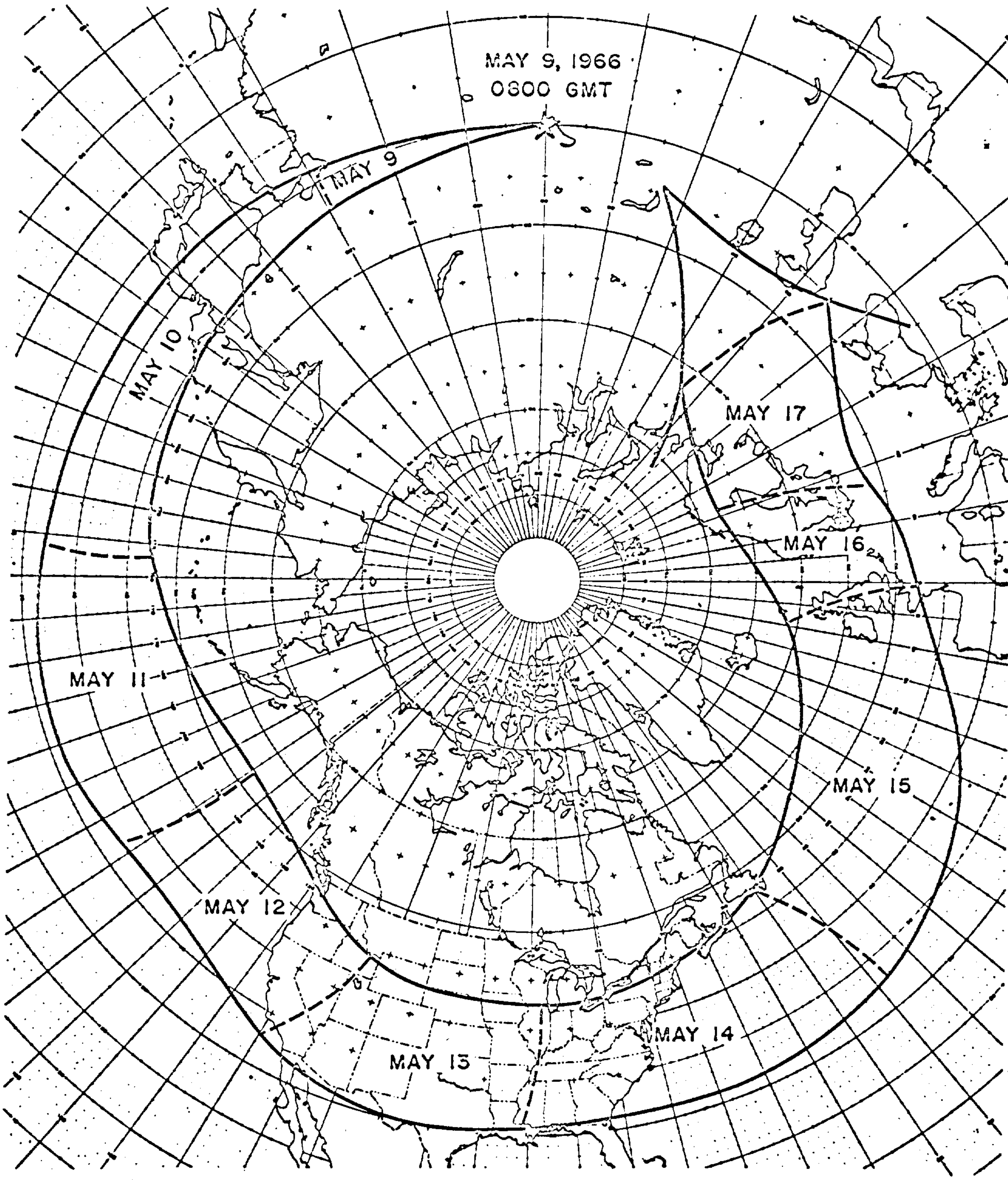
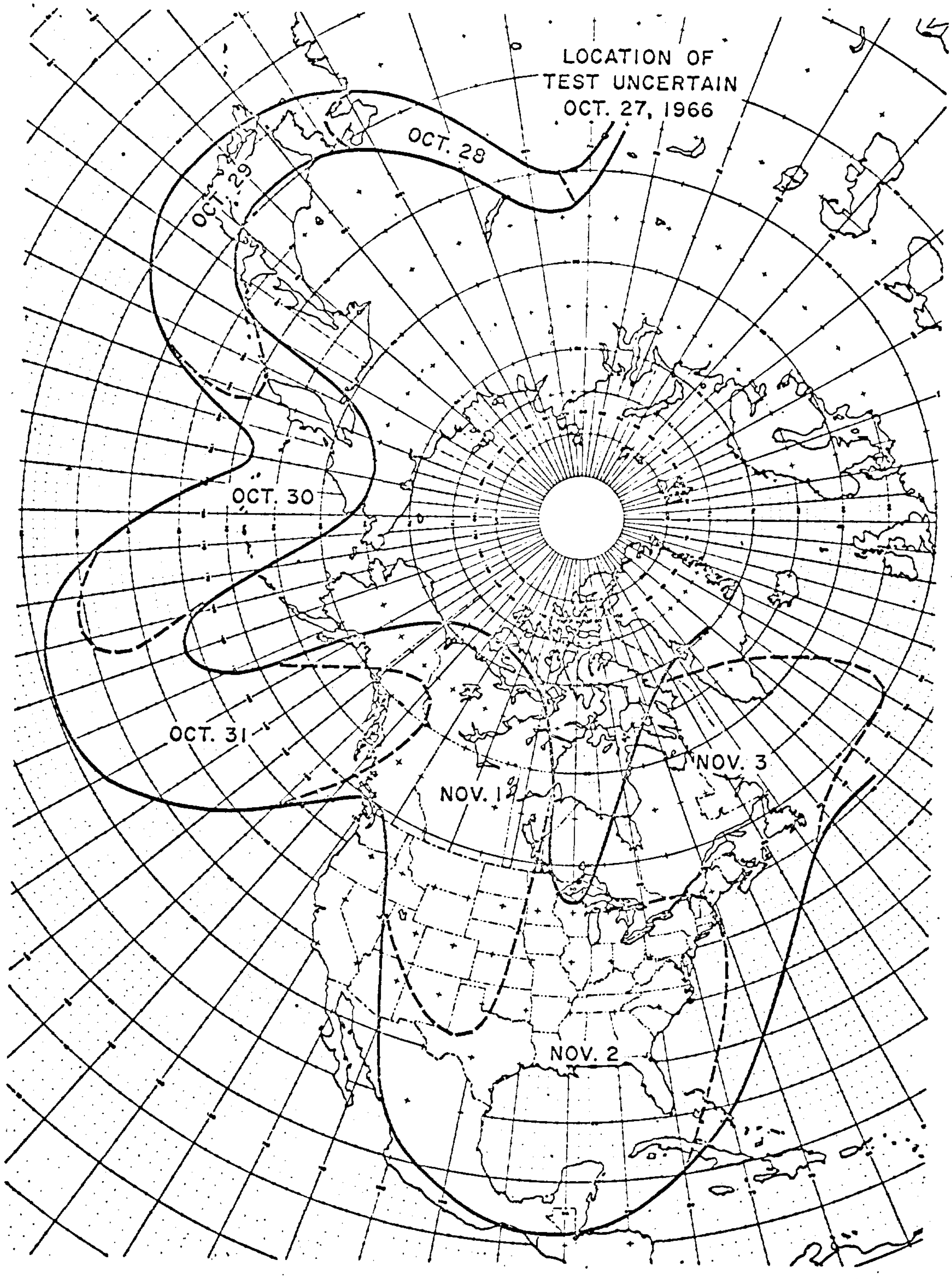
3
4

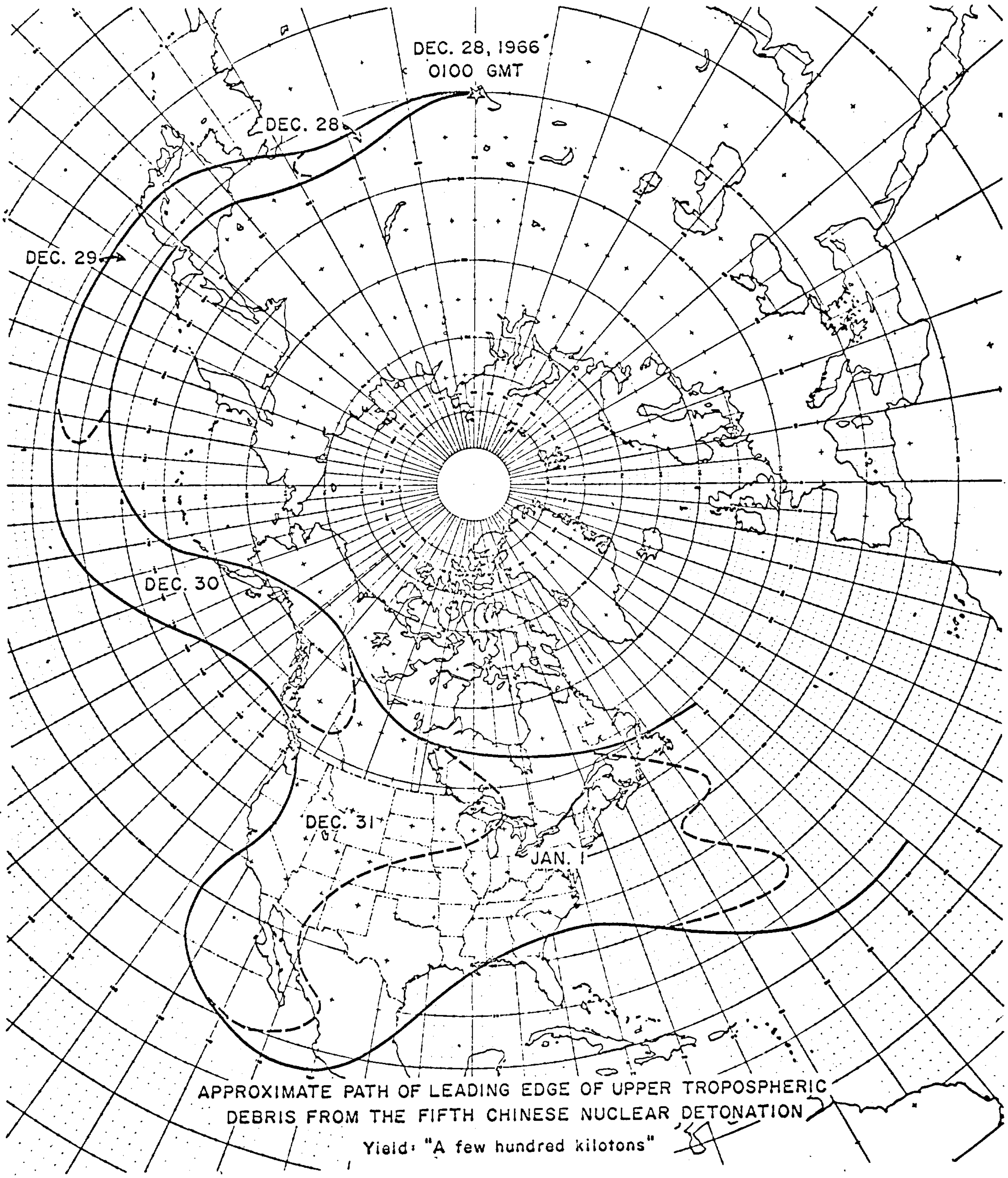

NOT VENTED
VENTED
CRATERING
U.S. UNDERGROUND
UNDERGROUND U.S.S.R.
ATMOSPHERIC CHINA
ATMOSPHERIC FRANCE
MAXIMUM I-131 IN PASTEURIZED MILK (pCi/liter)
5
280
392
6
7
8
211
9
10
150
100
50
30
JAN
FEB
MAR
APR
MAY
JUNE
JULY
AUG
SEPT
OCT
NOV
DEC
1966
1967
1968
out
In


OCT. 16, 1964
0700 GMT
OCT. 16
OCT. 17
OCT. 18
OCT. 19
OCT. 20
OCT. 21
OCT. 22


MAY 14, 1965
0200 GMT
MAY 14
MAY 15
MAY 16
MAY 17
MAY 18
MAY 19
MAY 20

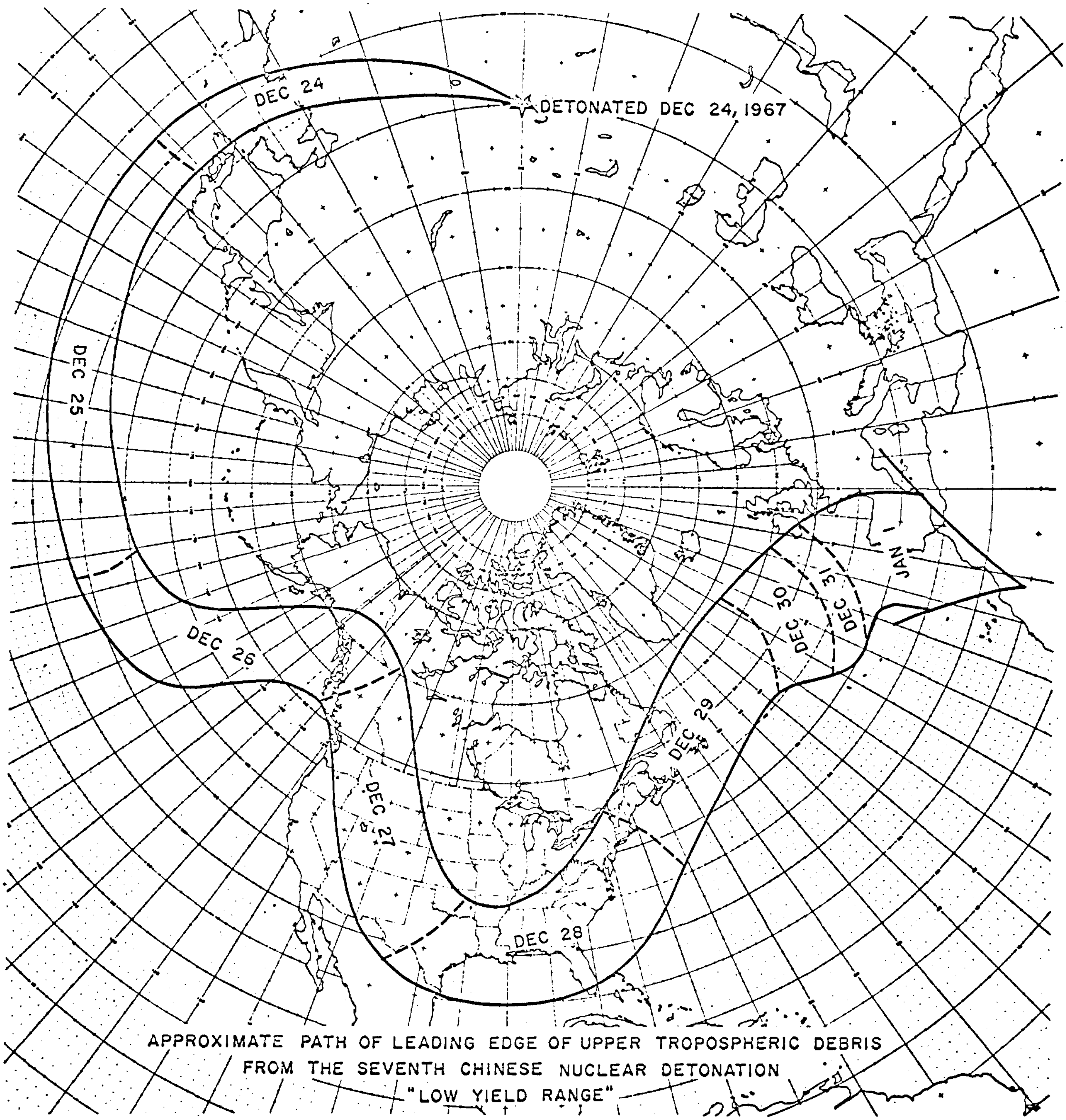

MAY 9, 1966
0800 GMT
MAY 9
MAY 10
MAY 11
MAY 12
MAY 13
MAY 14
MAY 15
MAY 16
MAY 17


LOCATION OF
TEST UNCERTAIN
OCT. 27, 1966
OCT. 28
OCT. 29
OCT. 30
OCT. 31
NOV. 1
NOV. 2
NOV. 3

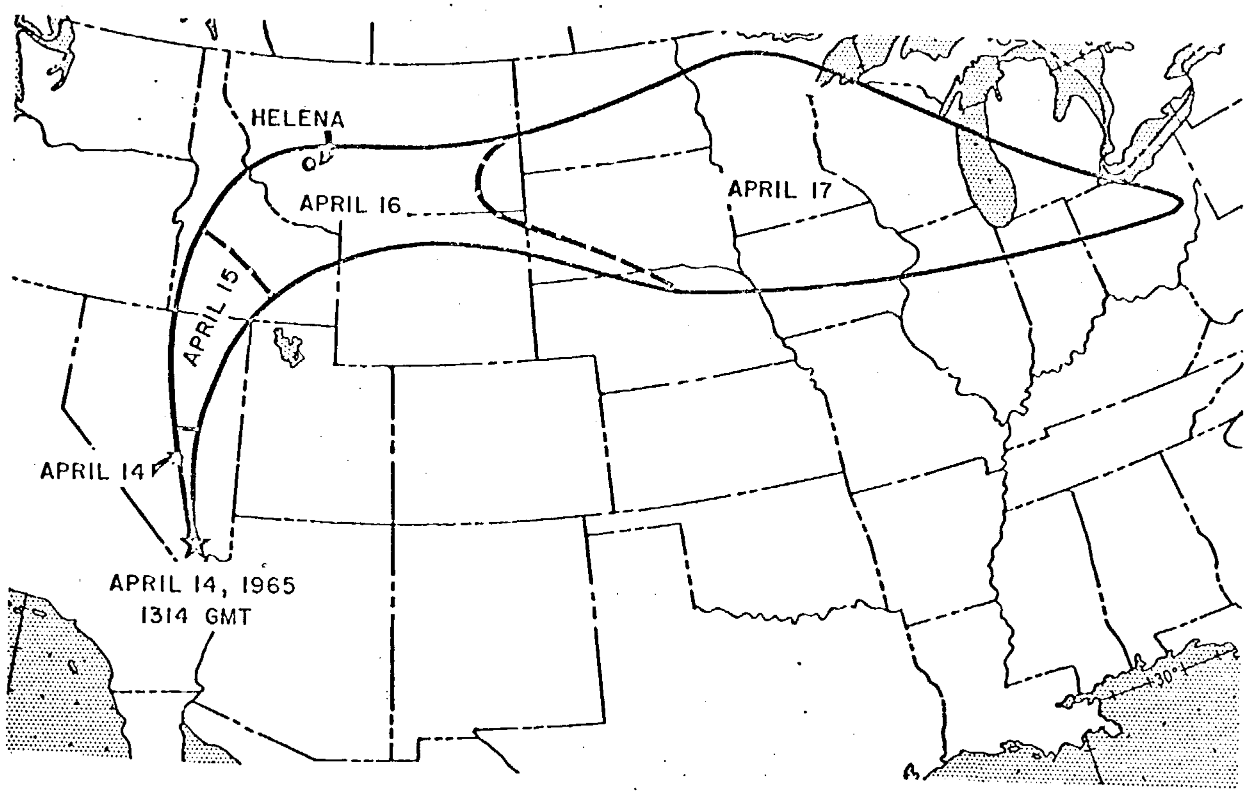


APPROXIMATE PATH OF LEADING EDGE OF UPPER TROPOSPHERIC DEBRIS FROM THE FIFTH CHINESE NUCLEAR DETONATION

Yield: "A few hundred kilotons"



APPROXIMATE PATH OF LEADING EDGE OF UPPER TROPOSPHERIC DEBRIS
FROM THE SEVENTH CHINESE NUCLEAR DETONATION
"LOW YIELD RANGE"


HELENA
APRIL 16
APRIL 17
APRIL 15
APRIL 14
APRIL 14, 1965
1314 GMT
30°