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THE CHERNOBYL REFERENCE HORIZON (?) IN THE GREENLAND ICE SHEET

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Abstract. Published reports of the presence of radioactive debris from the Chernobyl reactor accident in snow on the Greenland ice sheet raised the strong prospect that such debris might constitute a valuable time stratigraphic marker all over the ice sheet. Large volume snow samples to test this possibility were collected from 7 snowpits as part of a wide ranging regional snow chemistry survey conducted during 1987 and 1988. Snow "labeled" with Chernobyl derived radioactivity was detected in all of the pits. However, the total amount of radioactive debris found at the different locations varied over a 20 fold range. The variability in total fallout showed no clear large scale spatial pattern that could be related to the presumed progress of the radioactive plume over Greenland, suggesting that small scale differences in precipitation pattern and reworking of the snow by wind were predominantly responsible for the patchy preservation of the Chernobyl "layer" on the Greenland ice sheet.

Reports of a distinctive layer of snow with high radioactivity due to the Chernobyl accident in northern (Pourchet et al., 1986) and southern Greenland (Davidson et al., 1987), and our own observation of a similar layer in a snowpit dug at Summit in the 1987 season, suggested that the accident had provided a valuable time stratigraphic marker for researchers over all of the Greenland ice sheet. However, new results from a series of six snowpits sampled during the 1988 season indicate that the amount of Chernobyl fallout in Greenland snow varies markedly over very small spatial scales and may be difficult to detect in some places.

Large volume (ca. 1 kg) samples at continuous 6 cm depth intervals were cut from the sampling wall of the snowpits. An established clean sampling protocol (Mayewski et al., 1986) was followed throughout the sampling process. The snow blocks were double bagged in polyethylene, returned to New Hampshire frozen and stored at -20° C until they were prepared for analysis. The radiocesium in the samples was concentrated by the ion-exchange filter technique of Delmas and Pourchet (1975) and was determined by high resolution gamma spectrometry. The counting facility consists of a Canberra Ge well detector connected to a computer based multi-channel analyzer. ^{137}Cs was determined by the area of the 662 kev photopeak, both the 605 and 796 kev photopeaks were used for ^{134}Cs. Counting times ranged from 12 to 24 hours depending on the activity of the sample.

The depth to the Chernobyl layer in the 1987 and 1988 pits provides local accumulation rates for the period since the accident (Table 1). In southern Greenland accumulation of 1.0 - 1.3 m of snow/year generally agrees with regional estimates for longer periods based on stratigraphic techniques (Benson, 1962). The 3.4 m depth of the Chernobyl layer in pit 8 is somewhat anomalous, but this pit showed extensive melt features which may have caused migration and smearing of the contaminated layer. At Summit and near Camp Century (Pits 1 and 2) recent accumulation rates determined from Chernobyl fallout (ca. 0.8 and 1.0 - 1.1 m of snow/year, respectively) are also similar to previous long-term estimates (Benson, 1962).

The concentration of radiocesium in the individual layers varied over a 30 fold range (if Pit 8 is not considered) (Table 1). While some of this variability certainly reflects real patchiness in the distribution, much of it may be an artifact due to the coarse depth resolution of sampling relative to the short period of fallout. Conversion of the concentration values to areal inventories (considering only the "Chernobyl labeled" layers) eliminates the effects of accumulation rate differences and reduces sampling artifacts, but still shows a factor of 20 variability in the distribution of Chernobyl fallout in Greenland snow (Table 1 and Figure 1). Although there appears to be a tendency for higher levels in northern Greenland, there seems to be no strong relation between the spatial distribution of Chernobyl fallout and altitude, topography and location on the ice sheet with respect to the presumed path of the plume (Figure 1). It may be that there was minimal deposition (or retention) of Chernobyl fallout near the broad saddle between Dye 3 and Summit due to a funneling of wind, but the extreme variability over very small spatial scales suggests that small scale local topography played a dominant role in determining the pattern of Chernobyl fallout preserved in the snow.

The fallout from Chernobyl observed in Europe immediately following the accident was noteable for its extreme spatial heterogeneity (Ambach et al., 1988; Clark and Smith, 1988; Fry et al., 1986; Haeberli et al., 1988; Hohenemser et al., 1986). In one 40,000 km^2 region of Germany 30 fold differences in total deposition were observed (Hohenemser et al., 1986). Much of the variability in Europe was attributed to patchiness in both the radioactive plume so near to its source and in precipitation intercepting the plume (ApSimon et al., 1988). The greater transport distance to Greenland should have tended to homogenize the plume, minimizing this source of variability. It is hard to imagine a combination of wet and dry deposition processes creating the 3 - 4 fold difference in the amount of Chernobyl fallout in Pit 7 and the site 23 km SW of Dye 3 (roughly 25 km apart), let alone the 3 fold difference between the pits sampled by Davidson and coworkers in 1986 and 1987 at essentially the same location (separation ca. 1000 m). However, the ready redistribution of newly fallen snow by wind, and the tendency of this process to fill in depressions in the surface at the expense of local highs (Gow, 1965; Palais, 1984), would seem capable of creating such variability on the scale of meters.

Fallout from the Chernobyl accident does now constitute a very useful time horizon in firn on the Greenland ice sheet. However, the relatively quick passage of the radioactive plume created just a very thin layer of labeled snow which appears to have been redistributed by post-depositional processes. As a result, the Greenland ice sheet has preserved a very patchy, perhaps even discontinuous, layer of Chernobyl debris. The uneven preservation of the Chernobyl "horizon" in Greenland should serve as yet another warning of the extreme care that must be exercised when extrapolating findings from samples of such limited spatial extent as snowpits or ice cores to larger regions. As a minimum precaution, deep coring efforts must include a companion study of spatial variability based on high resolution sampling of a network of snowpits or shallow cores.

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TABLE 1. Chernobyl Fallout in Greenland

Location	Date	Depth of Labeled Layers	Concentration[a] pCi/kg ^{134}Cs	^{137}Cs		Inventory[a] pCi/m^2 ^{134}Cs	^{137}Cs
Station Nord[b]	5/8/86	Fresh	3.6	6.7		18-54	34-102
81°36' N	5/12/86	Snow	3.6	7.7		18-54	38-115
16°40' W					Total	36-108	72-217
23 km SW of Dye 3	July 1986[c]	10-20	2.0 ±.8	6.2 ±1.4		72	220
ca. 65° N	July 1987[d]	95-100	0.69±.14	2.26±.20		14	45
ca. 44° W		100-105	0.27±.05	1.54±.15		6	37
					Total	20	82
Summit	5/8/87	80-90	5.10±.30	16.56±.54		175	570
Pit 1[e]	5/2/88	192-198	0.17±.15	0.43±.05		4-5	10-12
77°11' N		198-204	0.93±.08	3.44±.14		22-25	83-93
60°43' W		204-210	1.14±.15	2.67±.12		27-31	64-72
		210-216	0.43±.15	0.62±.09		10-12	15-17
					Total	63-73	172-194
Pit 2[e]	5/8/88	216-222	1.24±.15	3.85±.19		30-34	92-104
77°12' N		222-228	2.16±.25	6.06±.40		52-58	145-163
59°12' W					Total	82-92	237-267
Pit 5[e]	5/19/88	257-263	0.54±.15	0.96±.07		13-15	23-26
66°57' N							
44°29' W							
Pit 6[e]	5/21/88	228-234	0.36±.04	0.55±.05		8-10	13-15
67°12' N		234-240	0.46±.20	1.03±.06		11-13	25-28
43°48' W					Total	19-23	38-43
Pit 7[e]	5/28/88	222-228	0.41±.15	0.60±.05		10-11	14-16
64°46' N		228-234	0.72±.30	1.35±.12		17-20	32-36
44°07' W					Total	27-31	46-52
Pit 8[e]	5/31/88	33-339	0.37±.16	0.22±.04		9-10	5-6
65°38' N		339-345	0.03±.05	0.09±.03		≤1	2
43°40' W					Total	9-10	7-8

a Corrected to 5/1/86.
b From Pourchet et al., 1986. For estimation of inventory a snowfall depth of 5 cm and a density range of 0.1 - 0.3 g/cm^3 were assumed.
c From Davidson et al., 1987.
d From Davidson et al., 1989.
e Estimation of inventories for 1988 UNH snowpits assumed a density range of 0.40 - 0.45 g/cm^3.

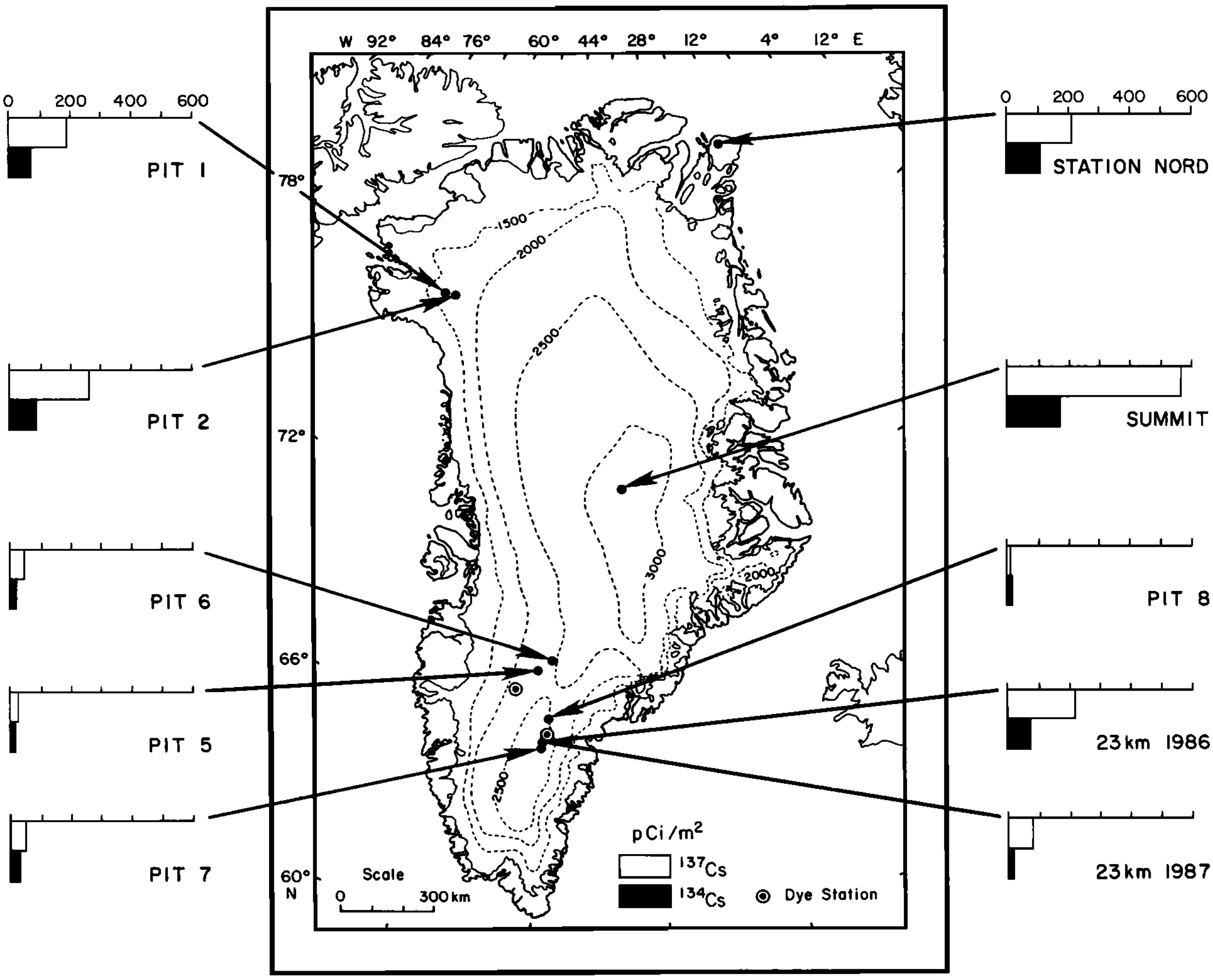

Fig. 1. Inventory of radiocesium from the Chernobyl accident in snow on the Greenland ice sheet. The high end of the ranges listed in Table 1 are plotted.

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