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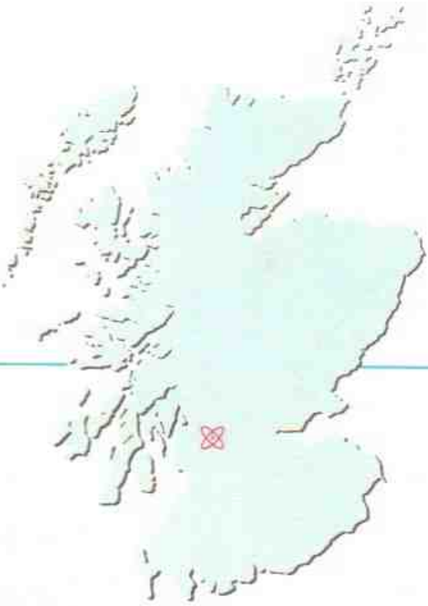

REPORT

AERIAL RADIOMETRIC SURVEY OF PARTS OF NORTH WALES IN JULY 1989

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INTRODUCTION

This report summarises the experience, results and initial conclusions of a brief aerial radiometric survey commissioned by HTV, Cardiff of selected parts of North Wales in 1989. The aim of the work was to demonstrate the use of aerial gamma ray spectrometry in mapping ^{137}Cs and other nuclides in and around parts of the areas subject to livestock movement restrictions since the 1986 nuclear disaster at Chernobyl.

BACKGROUND

Aerial gamma ray survey methods have been used in some parts of Scotland, and in West Cumbria (refs 1-3) to map fallout from Chernobyl. The method depends on detecting the gamma radiation emitted by radionuclides on, or near the surface of the ground, from highly sensitive radiation detectors operated from low flying aircraft. Although this is a relatively new approach in the UK, and is still under development, results from other work have demonstrated that it is an extremely rapid and effective method of locating areas of enhanced gamma ray activity. This has a bearing on the effectiveness of countermeasures such as livestock movement restrictions in limiting the exposure of the British public to contaminated food. It also provides a means of identifying any significant contamination in the vicinity of nuclear power stations, or on coastal or estuarine sites due to deposition of sediments carrying radioactivity discharged into the Irish sea.

The use of aerial survey in North Wales has been under consideration for some time, and has been the subject of media interest. Nevertheless the method was not adopted by the Welsh Office in 1988 or 1989.

The ability to distinguish between fallout from Chernobyl and other possible origins depends on the isotopic composition of each source. As far as aerial methods are concerned the nuclide ^{134}Cs is especially important for this. It was originally present in Chernobyl at roughly 50% of the ^{137}Cs whereas earlier forms of fallout had much lower levels. The radioactive decay of both nuclides (^{134}Cs: 2.06 year half life, ^{137}Cs: 30.17 year half life) results in a progressive reduction in the diagnostic value of this ratio. For this reason it will soon be impossible to identify Chernobyl fallout without ambiguity, although longer lived species such as ^{137}Cs will remain in the environment for several centuries.

Although the work reported here represents a relatively small sample of the total area of interest in North Wales, the HTV commission is of special importance in providing an opportunity to characterise the fallout within the general area before it has decayed further. The value of the data recorded here will, no doubt, be fully appreciated in years to come.

THE SURVEY

The fieldwork was conducted between 11th and 14th July 1989 using an aerospatiale Squirrel helicopter chartered from PLM (Inverness) fitted with a 20 litre NaI gamma ray spectrometer at SURRC. This detector system represents a significant development from the original 7 litre system used for earlier SURRC surveys.

In addition to higher sensitivity (from the higher crystal volume), full pulse height spectra were recorded every 10 seconds using a pair of computer based pulse height analysers coupled to independent detector boxes. Position, from a NAVSTAR radio beacon system, and altitude from the radioaltimeter in the aircraft were recorded along with each set of spectra. Detector gain stability was continuously monitored by displaying the ratio of two window count rates chosen to split the ^{40}K peak symmetrically. Integral count rates for windows surrounding principal gamma ray photopeaks from ^{137}Cs, ^{134}Cs, ^{40}K, ^{214}Bi, and ^{208}Tl were calculated along with a spectral integral from 450-3000 keV.

The detector system was installed in East Kilbride on the 11th and tested. A series of readings was taken en route to Wales at a number of sites already surveyed by SURRC to calibrate the system. These included Eaglesham Moor (surveyed in January 1989), parts of the Solway coast (surveyed in February 1988) and parts of West Cumbria (August 1988), and were selected to provide a range of activity levels for all nuclides.

On arrival in North Wales, on the 11th, two 40 km line surveys were taken running north-south to use the basis for final selection of detailed survey grids.

The first grid for detailed survey was a 6km x 30 km box from OS grid references ST 670580 , ST 730580 in the north to ST 670280 and ST 730280 in the south. This was selected to include regions both inside and outside the restriction zone, together with the immediate surroundings of Lyn Trawsfynydd with its Magnox nuclear power station. The second grid was 8km x 19km from ST 620690 and ST 620770 in the west to ST 810690 and ST 810770 in the east. The two grids were connected by the exploratory line surveys. An additional series of 15 readings was taken along the ridge of Snowdon.

The detailed surveys of these areas were conducted, under favourable weather conditions from 12th to 14th July. A total of more than 1500 readings was acquired from an area of over 33200 hectares. The aircraft was refuelled periodically by RAF Valley in Anglesey, whose prompt and efficient service made a significant contribution to the success of the survey. One of the Cumbrian calibration sites was also visited on the return journey to East Kilbride to confirm constancy of detector performance during the survey.

While the survey was in progress a number of small scale locations of apparently enhanced radioactivity were identified. These included an area of grazing land on the North Wales coast grid reference ST 666746 near the town of Llanfairfechan, a grazing strip adjacent to the River Conway near Canovium Roman fort (ST 779704), and a site adjacent to Lyn Trawsfynydd (ST 698381). 20 cm deep soil samples were obtained from each of these sites at ground level, to be used for high resolution gamma ray spectrometry in the laboratory. Two water samples were also collected from Lyn Trawsfynydd for comparison with published Caesium levels.

ANALYSIS

The survey produced a full set of pulse height spectra labelled with position, time of acquisition, survey altitude and integrated count rates for the six spectral regions of interest for each reading. On return to East Kilbride these were used to calculate equivalent inventory levels in the following steps.

Firstly the detector and helicopter background count rates, measured at high altitude over water, were subtracted from each data point to produce a set of net count rates attributable to radiation originating outside the aircraft. Secondly the data were subjected to a stripping procedure to deconvolute spectral interferences from each nuclide. In previous work a set of linear equations representing each overlap was solved for each data point. The algebraic approach used in this work was extended to use a full matrix inversion, capable of dealing with more complex spectra than encountered previously.

The stripped data set was then calibrated to kBq/m^2 using calibration equations derived from cross comparison of previous survey results with those positions measured en route to Wales. The dose rate channels was calibrated to $mGy\ a^{-1}$. Comparison of recalculated concentrations for parts of Cumbria surveyed last year confirmed that the detectors had been successfully calibrated.

The calibrated data for ^{137}Cs were plotted directly in 10x10km sections using an HP7440 8 pen colour plotter. They were also subjected to a numerical regridding operation to transform the set into a perfect rectilinear grid. In this process each position within the transformed set was assigned a concentration value based on the average of neighbouring observations weighted inversely to euclidean distance. A cutoff of 0.7 km from each target point was imposed, to represent the maximum distance for any influence. It should be noted that this numerical smoothing process tends to reduce the influence of single isolated readings to final maps. The transformed data set formed the basis of the ^{137}Cs map appended here.

Finally average inventories for each nuclide in the whole survey area were calculated to allow for radionuclide budgetary assessments.

RESULTS AND DISCUSSION

Figures 1 to 5 show histograms indicating the main distributions of each nuclide. Mean values over the whole survey were ^{137}Cs: 11.3 kBq m^{-2} ^{134}Cs: 3.6 kBq m^{-2}, ^{40}K: 139 kBq m^{-2}, ^{214}Bi:6.4 kBq m^{-2}, ^{208}Tl: 7.8 kBq m^{-2}. It should be stressed that these inventories refer to integrated area contents to the respective analytical depths of roughly 30 cm, and calibrated to a typical mixed nuclide vertical distribution. The variation shown for all nuclides is greater than one order of magnitude from place to place, and there are a few outlying observations associated with higher readings in isolated locations. It may be worth pointing out that the very much higher levels of natural potassium-40 do not necessarily dominate the external gamma ray fields. This is because only 11.5% of ^{40}K decays give rise to a high energy gamma ray, compared with 85% of ^{137}Cs decays. This is in contrast to the situation for ingested products where the radiation dose per unit activity is more comparable, due to beta radiation.

The levels of ^{137}Cs found overall are slightly lower than observed in the livestock movement restriction zone in West Cumbria surveyed in 1988 : peak levels in North Wales tend to be in the 20-30 kBq m^{-2} region rather than 30-40 kBq m^{-2}.

The caesium distribution is presented as a colour map in figure 6. The peak Chernobyl fallout occurs, oriented from SSE to NNW across the central line of the restriction zone. It is immediately clear that there is no simple relationship between the location of the fallout and the boundary for livestock movement restrictions. To the south and west it would appear that there is a considerable degree of over-restriction, whereas the implied trajectory from which the main fallout approaches the restriction boundary is strongly suggestive of the boundary being cut rather fine on parts of the eastern side. Clearly it would take an extension of the survey to demonstrate this more categorically. Fallout levels on Snowdon incidentally were of the order of 15 kBq m^{-2}, showing that although height above sea level may be one factor which influences deposition, it is by no means the only one.

On the north coast there was strong evidence of elevated caesium levels on the mudflats close to Penryn Castle. Perhaps more significant from a radiological point of view were the two locations sampled which were on land, close to the shore near Llanfairfechan and in the Conway valley close to the Canovium roman fort. High resolution gamma spectrometry for these two site produced similar results. From 0-20 cm soil samples the specific activities of ^{137}Cs were 1640+-30 and 1520+-25 Bq kg^{-1} respectively, equivalent to integrated area depositions of approximately 328 and 305 kBq m^{-2}. The corresponding specific activities of ^{241}Am were 210+-15 and 177+-20 Bq kg^{-1}. This nuclide is a plutonium decay product, normally contained within fuel cladding in nuclear reactors. The most likely explanation is that these features arise from the spread of radioactivity discharged from Sellafield, probably attached to sedimentary particles. The calculated gamma dose rates from these locations are both greater than 4 mGy a^{-1}, which is 5-10 times the natural gamma background.

Close to Trawsfynydd the high aerial readings were in fact generated by stack emissions, principally the radioactive gas ^{41}Ar generated by neutron irradiation of cooling air inside the reactor structure. This is subject to an authorised discharge, and we have no evidence to suggest that this limit was being exceeded despite the high readings. However the ground level samples collected produced results which do merit further comment. The water samples firstly, collected in the "hot lagoon" showed ^{137}Cs levels of 0.153+-0.003 Bq l^{-1} and ^{134}Cs of 0.019+-0.003 Bq l^{-1} whereas the middle of Lyn Trawsfynydd yielded 0.100+-0.002 Bq l^{-1} of ^{137}Cs and 0.016+-0.003 Bq l^{-1} of ^{134}Cs. The somewhat higher $^{134}Cs/^{137}Cs$ ratio in the centre of the lake may be a reflection of dilution with runoff from the surrounding areas due to low levels of Chernobyl fallout. Both sets of results however are consistent with published data from various sources (refs 4,5,6).

The two ground samples were more surprising. A deep mud sample (to 20cm) at the lake edge was uncontaminated, despite expectations from other monitoring programs that it might be. However a soil and litter sample collected 5 m inland on the edge of some woods showed a ^{137}Cs activity of 977+-16 Bq kg^{-1} averaged from 0-20 cm; equivalent to roughly 195 kBq m^{-2}. There was less than 1 Bq kg^{-1} of ^{134}Cs, which implies a considerably aged deposit (at least 12-13 years old), and clearly one which is not connected with any current activity in the hot lagoon. Although published reports show comparable activities in Bq kg^{-1} for mud samples from the Lake, this is not a particularly useful unit for comparison, since these are likely to be rather thin layered samples. The inventory implied by the 0-20cm sample is of greater radiological concern, and merits further attention. The deposition pathway to this site is also unknown at present.

The results at Trawsfynydd and on the coast were reported to the power station operators, and to MAFF, with the permission of HTV, to enable subsequent investigations to take place.

CONCLUSIONS

The brief aerial survey reported here has produce a number of interesting observations. The peak fallout from Chernobyl can be located with some confidence within those parts of the livestock restriction zone which were measured. It would be a simple matter to extend this work to the whole of north wales, and the signs are that if this were done the restricted areas might well be reduced significantly. This is not only important to farmers, but would also offer potential savings in the considerable compensation and investigation costs incurred since the Chernobyl accident.

The other localised features due to indigenous nuclear activities require further attention. Although discharges into the Irish sea from Sellafield have been reduced by nearly two orders of magnitude in recent years (eg ref 7), a great deal of radioactivity has been discharged in the past on the assumption that it would dilute and disperse. The enhancements reported here are the consequence of the failure of such dispersion assumptions, under conditions which are at present obscure. It is important that the effects of past discharges should continue to receive attention to ensure that activity already discharged does not reach hazardous levels on land. The sites reported here also merit further detailed mapping at ground level.

Further investigations are also needed at Trawsfynydd to evaluate the extent of terrestrial contamination in the vicinity of the hot lagoon. It is to be hoped that this will be shown to be a small, localised, feature which will not result in significant public, or critical group, exposure.

REFERENCES

1. Sanderson,D.C.W., Scott,E.M., Baxter,M.S., and Preston T.,1988, A feasibility study of airborne radiometric survey for UK fallout, SURRC report 88-03

2. Sanderson D.C.W. and Scott E.M.,1989, Aerial radiometric survey in West Cumbria 1988, MAFF Food Science report N611

3. Sanderson D.C.W., Baxter M.S., and Scott E.M., 1989, The use and potential of aerial radiometrics for monitoring environmental radioactivity, Proceedings of an International Conference on the Water Resource Consequences of a Nuclear Event, Institute of Civil Engineers.

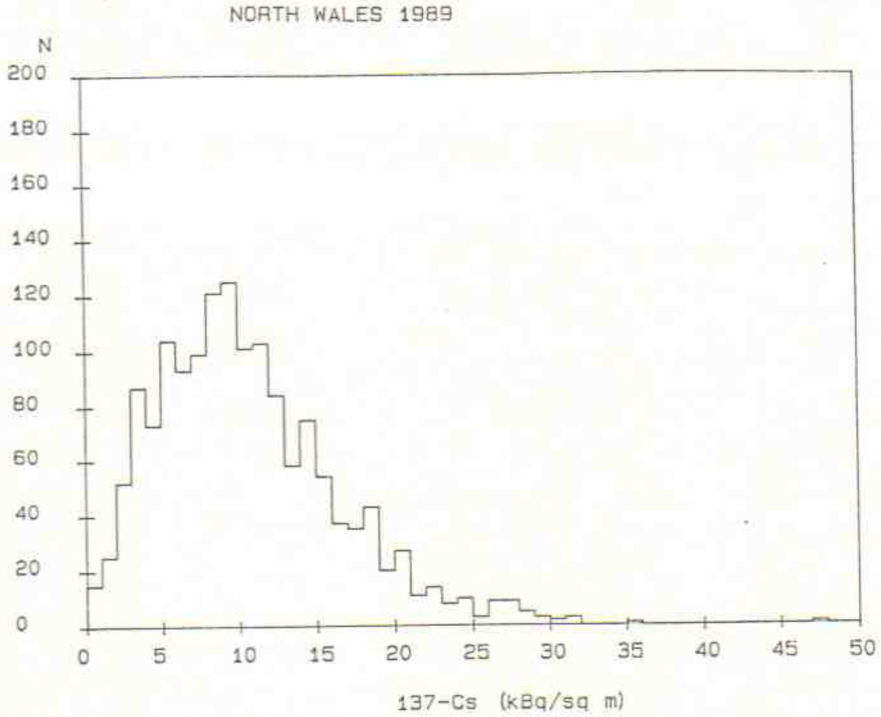
4. Friends of the Earth, 1987, Trawsfynydd- Power at a Price - A report on the radioactive discharges from the Trawsfynydd nuclear power station. FOE, London.

5. University College of North Wales,1987, Radiation and Radioactivity in Gwynedd, Report to Gwynedd County Council.

6. Welsh Office, 1988, Trawsfynydd nuclear power station environmental monitoring. Report no 23.

7. BNFL,1987, Annual report on Radioactive Discharges and Monitoring of the Environment 1986, Health and Safety Directorate, BNFL, Risley.

FIGURE 1



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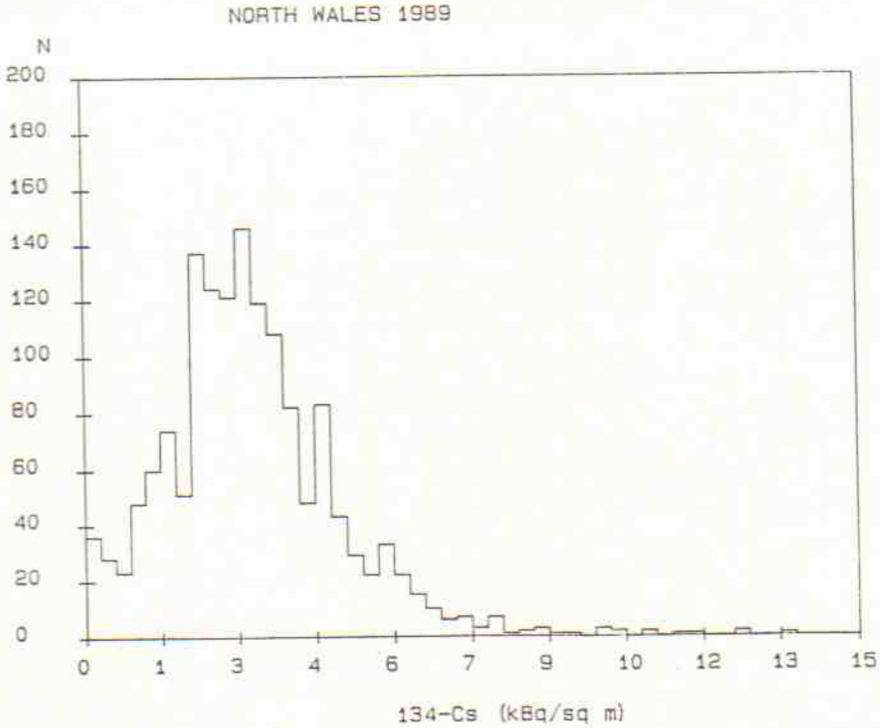

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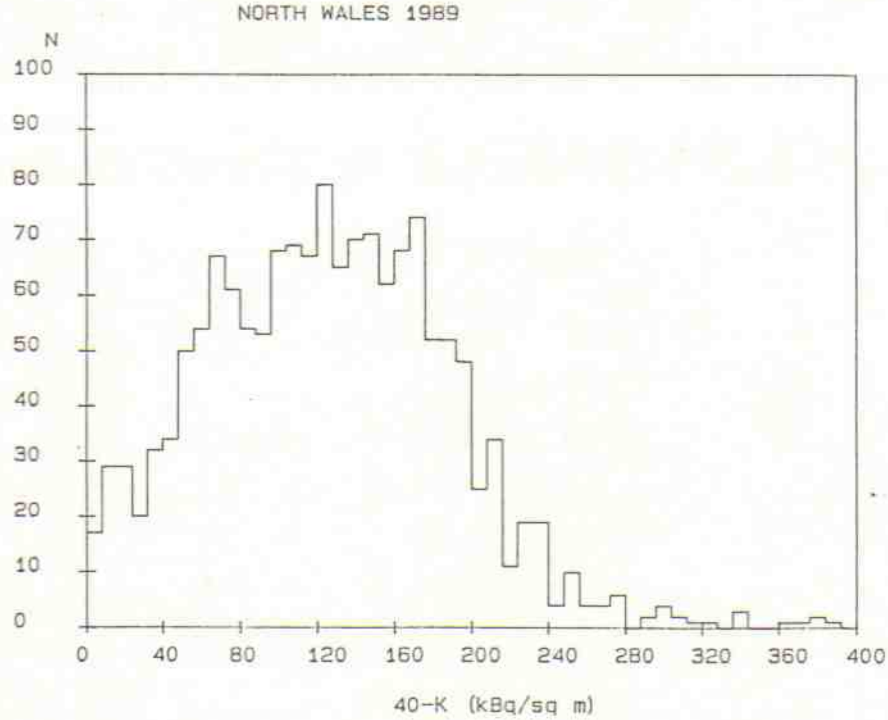

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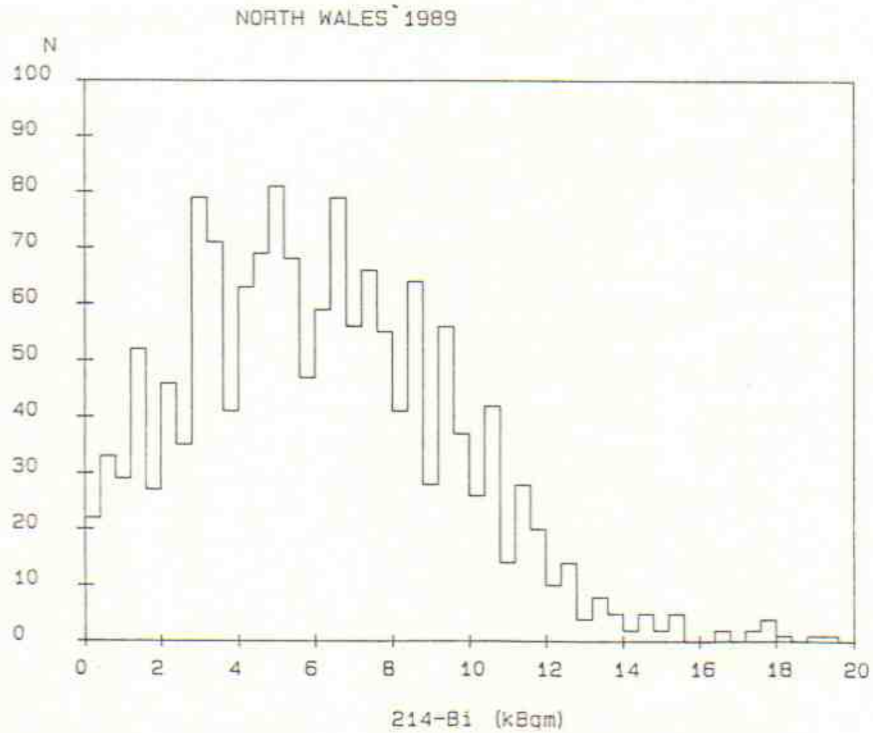

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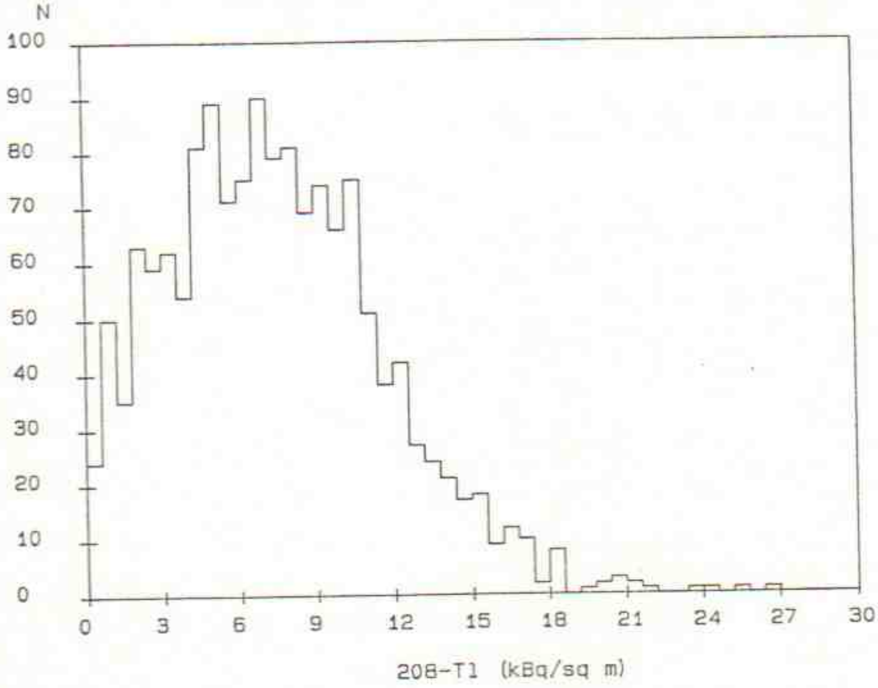

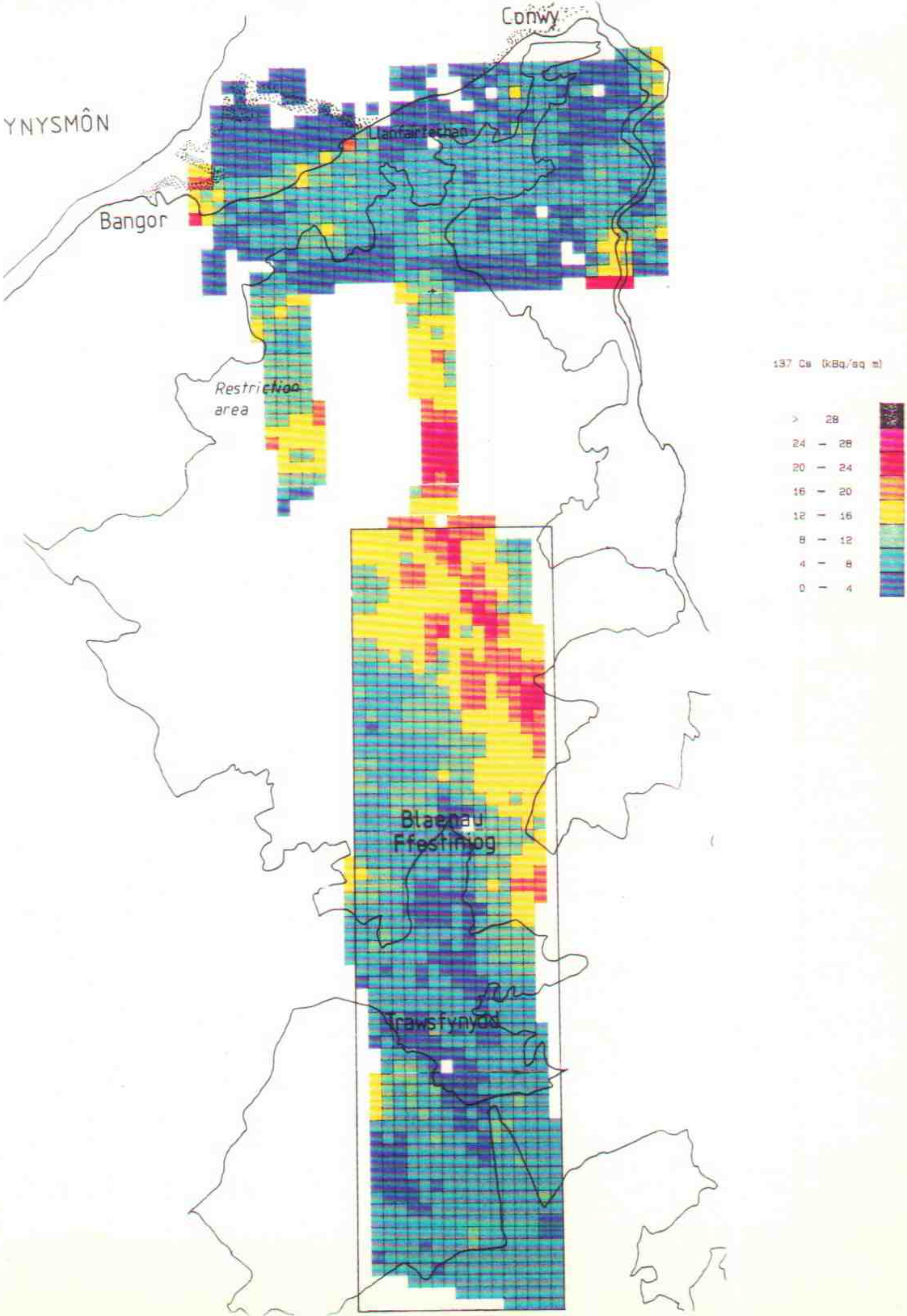

Conwy
YNYSMÔN
Llanfairfechan
Bangor
Restriction area
Blaenau Ffestiniog
Trawsfynydd
137 Cs (kBq/sq m)
> 28
24 – 28
20 – 24
16 – 20
12 – 16
8 – 12
4 – 8
0 – 4