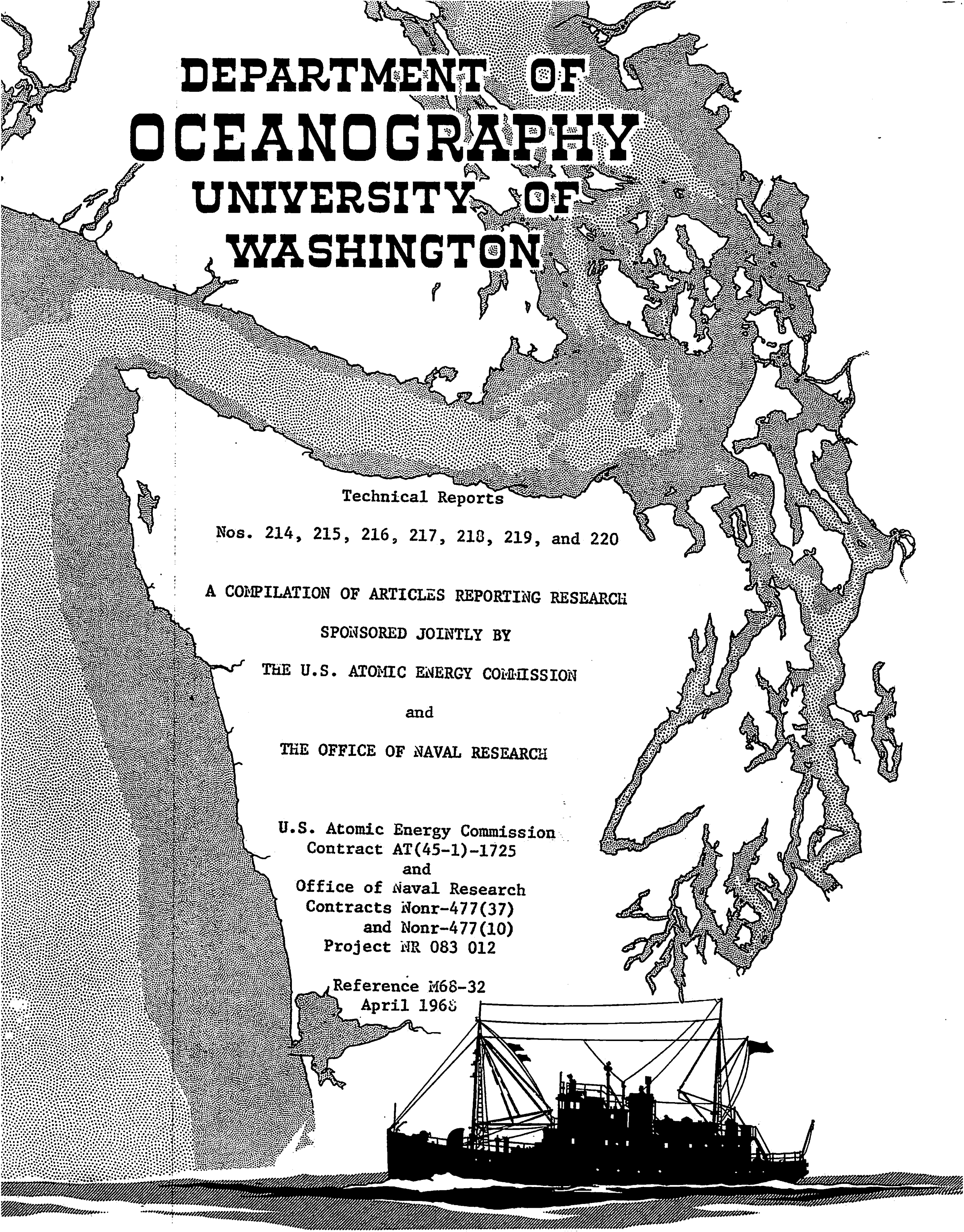

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UNIVERSITY OF WASHINGTON
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TECHNICAL REPORT NO. 220

Sinking Rates of Radioactive Fallout Particles in the North East Pacific Ocean, 1961–62

THE resumption of nuclear weapon testing in the atmosphere in September 1961 provided an opportunity to investigate the sinking rate of radioactive fallout particles in the North East Pacific Ocean. The stopping of weapon testing in the atmosphere between November 1958 and September 1, 1961, gave sufficient time for radionuclides with relatively short half-lives which were released by tests before 1958 to decay. Weapon testing began in the Soviet Union on September 1, 1961, and by November 4, 1961, at least fifty nuclear devices had been detonated in the atmosphere, including fifteen megaton or multimegaton devices[1]. In the North East Pacific Ocean, the beginning of the 1961 test series coincided closely with the beginning of the winter storms and their heavy rainfall. This provided a mechanism for quickly depositing the fallout nuclides, rainfall being the principal mechanism for removing such particles from the atmosphere[2]. Radioactive fallout material from these tests was detected in marine samples in mid-September 1961.

The gamma-ray activity was analysed in samples of sediment collected in July and August 1961 and in the summer of 1962. No activity caused by the presence of radionuclides from fallout was detected in thirty-nine samples collected in 1961 (general area sampled shown in Fig. 1), while twelve samples collected in June 1962 from this area contained detectable amounts of several radionuclides from fallout.

Special sediment samples were collected in August and September 1962 for analysis of their gamma-ray activity. These samples were collected by siphoning off the muddy water above the interface between water and sediment in open gravity cores. I assume that the sediment particles suspended in the water were resuspended during the coring and retrieval operations and that this sediment was the most recently deposited material.

The muddy water recovered was transferred to a plastic container in which it was dried under infrared lamps aboard ship without washing or further handling, to

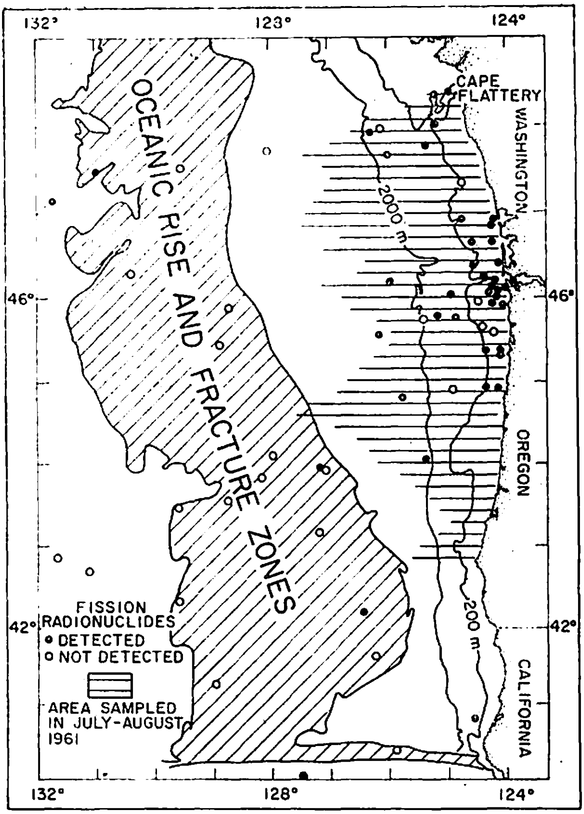

Fig. 1. Locations of sediment samples in which fallout radionuclides were detected (●) and not detected (○) in 1962. Sediment samples collected in July and August 1961 (area shown by horizontal rules) near the continent had no detectable quantities of radionuclides from fallout.

minimize contamination. When the samples were dry the containers were sealed and wrapped in plastic which was changed just before analysing the gamma radiation. Depending on the amount of sediment recovered, the gamma radiation was analysed for 100–1,000 min using a 3 × 3 in. (7·6 × 7·6 cm) sodium iodide (thallium) crystal connected to a photomultiplier and a multichannel analyser. The gamma-ray spectra obtained were analysed using a computer programme which estimated the abundance of eight radionuclides (potassium-40, cobalt-60, zinc-65, zirconium-95–niobium-95, ruthenium-103–106, bismuth-214, chromium-51, cerium-141) and estimated the 95 per cent confidence interval based on counting statistics[3]. The sample was considered to have no significant activity if the calculated activity was equal to or less than the estimated 95 per cent confidence interval.

Of the various radionuclides from fallout detected, the pair zirconium-95–niobium-95 was selected as the best for this study because of its relative short half-life (65 days), its abundance in fallout[2] and its known association with particles in sea water[4]. The apparent absence of zirconium-95–niobium-95 in sediments collected in July and August 1961, just before the resumption of testing, and its presence in shallow water deposits nearly everywhere in 1962 provides convincing evidence that the radioactivity detected was caused not by fallout derived from earlier weapons tested nor by the misidentification of the gamma-ray spectra of radionuclides occurring naturally in these sediments, but by fallout particles deposited after September 1961.

In the locations nearest the continent, the radioactive particles could have been transported and deposited either by processes near the ocean floor, or by sinking through the overlying sea water or by both. Thus the data for sample locations near the continent provide little information about sinking rates of the radioactive particles.

The deepest localities are apparently shielded from the accumulation of sediment by transport along the bottom of the ocean by the irregular bottom topography associated with the oceanic rise and fracture zones (Fig. 1). Thus the presence and abundance of fallout radionuclides in the sediment from these areas provide information about the sinking rates of the radioactive particles.

If we assume that the first radioactive fallout arrived in the area immediately after the testing began (September 1, 1961), the radioactive particles must have settled about 13 m/day to have reached a depth of 4·4 km (Fig. 2) by the time the sample was collected on August 8, 1962. Even if we discard the data for the deepest station because of possible contamination (for which there is no evidence) we must still assume sinking rates of at least 9 m/day to account for the radioactivity from fallout detected in three samples from depths between 2·6 and 2·9 km (Fig. 2). In short, it seems that the radioactive particles sank at rates near 10 m/day to account for the presence of zirconium-95–niobium-95 (half-life 65 days) in the sediment at these depths.

It is also interesting to note that the observed decrease in activity of zirconium-95–niobium-95 (Fig. 2) with depth corresponds rather closely to the expected decrease resulting from a steady state injection of fallout with the particles sinking at a rate of 10 m/day. This apparent relationship may be entirely fortuitous because it would demand not only a quasi steady state input of fallout

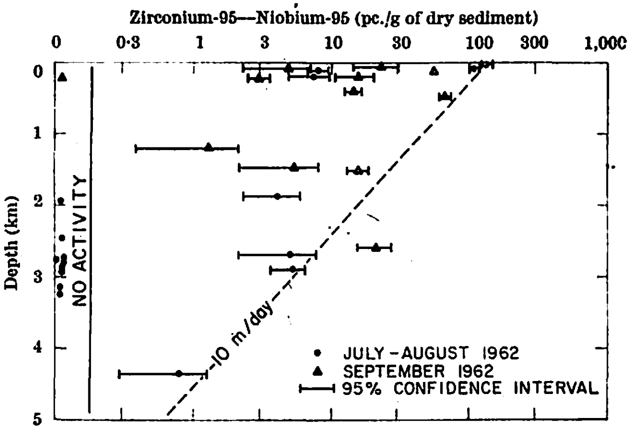

Fig. 2. Observed abundance of zirconium-95–niobium-95 in specially collected sediment samples taken in August-September 1962 from various depths in the region shown in Fig. 1. The dashed line indicates the expected decrease in zirconium-95–niobium-95 activity with depth assuming a constant supply of radioactive particles sinking at a rate of 10 m/day with no dilution by non-radioactive sediment after deposition or during sampling operations.

particles, which seems scarcely likely, but also an absence of appreciable dilution of the recently deposited fallout particles by non-radioactive sediment during deposition and during the coring operations.

I have no data on the grain size, composition or density of these radioactive particles although fallout from other weapon tests has been studied[1,2,5,6]. It is possible to calculate the probable grain size of the radioactive particles, having sinking rates of 10–13 m/day, by assuming that the particles are spherical, have a density of 2·5 g/cm^3 (typical of fused silicate glass), and obey Stokes law during gravitational settling through sea water ($S = 35$ p.p.t., $T = 5°$ C). Such a calculation shows that a sinking rate of 10 m/day corresponds to grains 16μ in diameter, and 13 m/day corresponds to grains 18μ in diameter.

These calculated grain sizes are consistent with the known behaviour of fallout particles where grains less than about 20μ in diameter tend to be transported primarily by atmospheric motions[1,2]. Such grains could easily have been transported long distances from the test sites in the USSR and widely dispersed in the surface layers of the North East Pacific Ocean.

No doubt smaller particles also fell into the ocean surface layers, but my data do not provide any information about possible size distribution in the fallout. Not only do the larger particles sink more rapidly but they also have greater activities than the smaller particles because the activity of fallout particles is proportional to the volume of the particle[6]. Thus the larger particles probably contributed the bulk of the radionuclides from fallout in these sediments when collected in 1962.

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