Attachment H

Net Flow of Nearbottom Waters as Determined from Seabed Drifters

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INTRODUCTION

The ultimate fate of material released into the water is commonly in or associated with the sediments within the water column or on the sea bed. Thus sediments in transit emulate pollutants or may adsorb pollutants. Thus the ultimate fate of sediments in transit will lead to a better understanding of the potential transport pathways and depositional sites of sediments and/or pollutants on the inner Beaufort shelf off Alaska. As concentration gradients of sediment in the water column almost always increase near the sea bed the bulk of the sediments travel as bedload near the sea floor (Barnes, 1974; Drake, 1977).

In a study of these pathways we placed more than 50 bottom drifters on the sea bed under the ice in March 1979 and released more than 1500 bottom drifters during the following summer. In this report we summarize the returns we have received to date, suggest sediment transport trajectories, and speculate on the implications these trajectories have on the movement and fate of oil or other pollutants that behave like sedimentary particles or adhere to sedimentary particles during transit.

BACKGROUND

Earlier surface drifter studies on the Alaskan Beaufort shelf (Barnes and Toimil, 1979; Matthews, 1981), suggested that surface currents on the shelf were dominantly westward although an easterly component was suggested for the area east of the Canning River. Bottom drifters released in the shallow part of Harrison Bay moved to the west suggesting that the nearshore bottom waters inshore in this area are also dominated by net westerly movements.

Current meter studies on the inner shelf have shown that currents are dominated by winds. In response to prevailing easterly and westerly winds, currents are dominantly coast-parallel. The winds are dominated by easterlies and northeasterlies (Barnes et al., 1977; Matthews, 1978; Kozo, 1979; Brewer et al., 1977). As a result of common reversals the net drift of innershelf bottom waters has been somewhat conjecture.

METHODS

The plastic seabed drifters (Lee et al., 1965) used are a yellow perforated saucer, 18 cm in diameter, mounted on a red plastic stem 55 cm long. Negative buoyancy for the drifter was assured by attaching a 5-gram brass collar to the lower end of the stem. During late August and September 1979 drifters were released in groups of 25-50 from a surface vessel at a location between the Colville and Canning Rivers. Earlier that year, in March 1979, we released 56 drifters thrugh a dive hole cut in the ice in Stefansson Sound.

OBSERVATIONS

Drifter Recovery

Subsequent to the March release, drifters were exposed to 3 or 4 months of sub-ice currents prior to the open-water season (mid-June to mid-September). The release of bottom drifters during the latter half of the open-water season in 1979 permitted only limited time for transit to the beaches before freeze-up. At this time surface water motion ceases and the drifters can become incorporated into the coastal ice or the polar pack. Although drifters have been found and returned in two consecutive summers following their release, there are no data to suggest whether or not the drifters came ashore before freeze-up in 1979 or in subsequent years. The data on drifter releases and recoveries are given in Table I.

Table I - Bottom Drifter Release and Recovery Statistics

	No. released	No. of release stations	No. recovered through 1981	Percent Recovery
Winter release - Through ice - 1979	56	1	9	16%
June release off Colville Delta - 1977	489	33	51	10%
Summer off inner shelf - 1979	1375	19	105	8%

March 1979 under-ice release

In a cooperative under-ice study in March 1979, 56 drifters were placed by divers in a 6 x 6 m area within DS-11 underwater study site. During the next visit by divers to the same site, 3 months later in the middle of May 1979, the drifers were seen unmoved, and the abundant brown kelp had *no* preferred orientation from past current action. The latter observation is in keeping with other under-ice diving observations made at this site during three separate under-ice study periods (November, February/March, and May) during each of four winters from 1978 to 1982. Observed currents during the ice-covered period were never strong enough to orient the large brown blades of kelp. Winter current meter studies indicate sluggish near-bottom currents (Matthews, 1981; Barnes, 1981). All drifters had been removed from the study site between May and the next diving studies in late July, 1979. The first one showed up on the beach in Prudhoe Bay in mid-July. This recovery and all subsequent recoveries have been to the west of the release site in Stefansson Sound (Fig. 1). Two drifters traveled about 80 km west to Oliktok Point. The largest percentage of recoveries (16%) from all bottom drifter release has been from this site (Table I.)

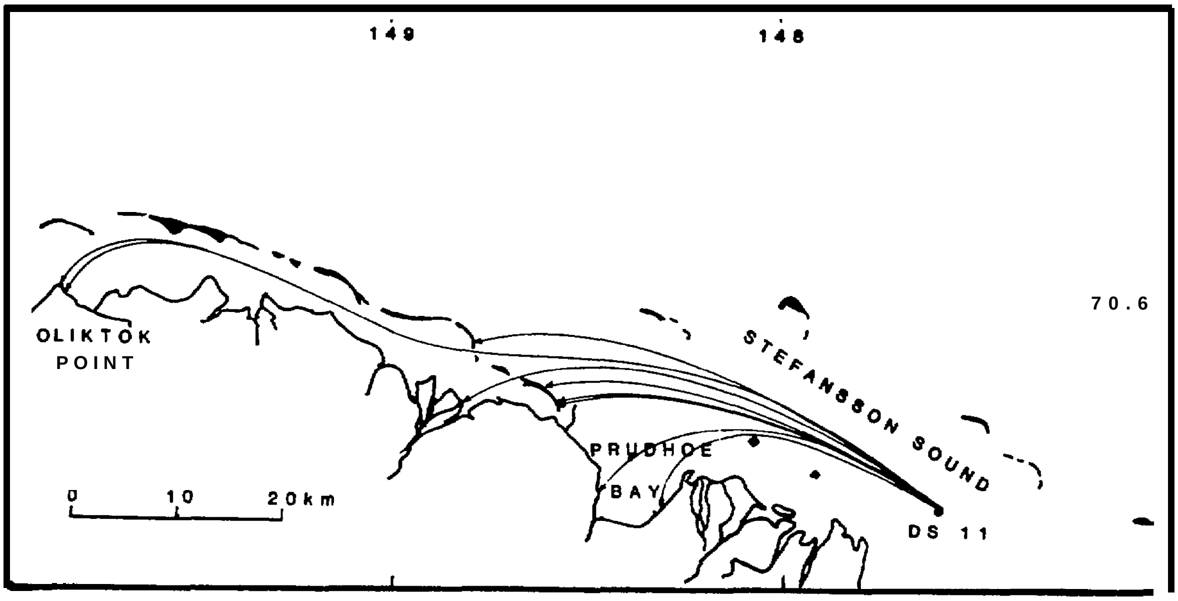

Figure 1. Sub-ice release site (DS-11) for bottom drifters released in March 1979. Idealized trajectories are shown for recoveries through 1981.

Summer 1979 release

All of the *recoveries* from the 1979 summer release indicate westerly and onshore movement of the drifters. Recoveries have come from all release points, even those offshore and the 8 percent returned represent a good sampling of those released (Table I). The drifter recoveries have been concentrated in Simpson Lagoon, in western Harrison Bay and along the open coast just to the west of Cape Halkett (Fig.2). The drifter traveling the farthest reached Barrow in 1979, the same year it was released.

Update of 1977 Colville delta release

We have added about 10 additional recoveries to the data published in 1979 (Barnes and Toimil, 1979, Fig. 3). Recovery sites continue to be located in the western part of Harrison Bay. This suggests that the drifters were onshore during the first summer (1977), are not migrating alongshore from year to year. Recoveries in more recent years from their initial landing sites *is due* to increased coastal usage. It is interesting to note that only one drifter from all three releases has traveled far beyond Cape Halkett (Figs. 1,2, and 3).

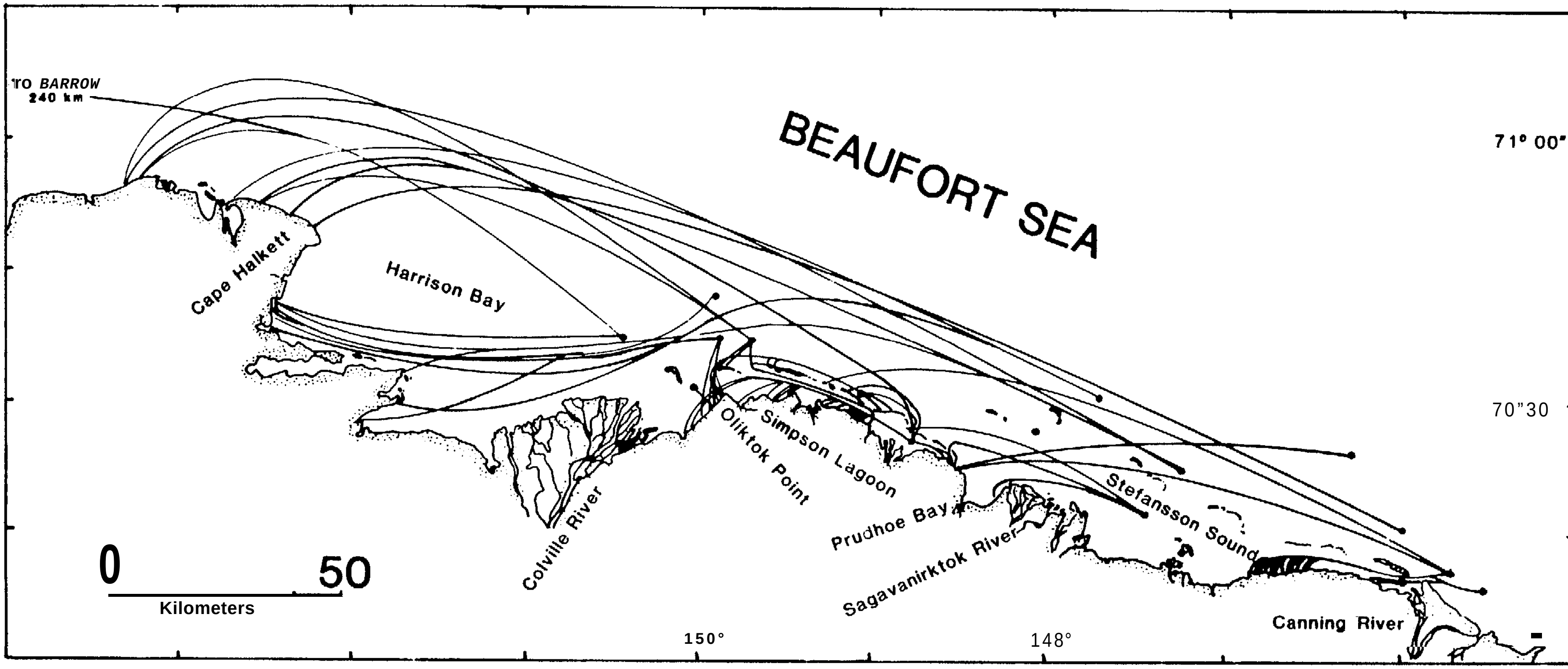

Figure 2. Summer open-water bottom drifters **release.** Idealized trajectories of bottom drifters released in 1979 from recoveries through 1981.

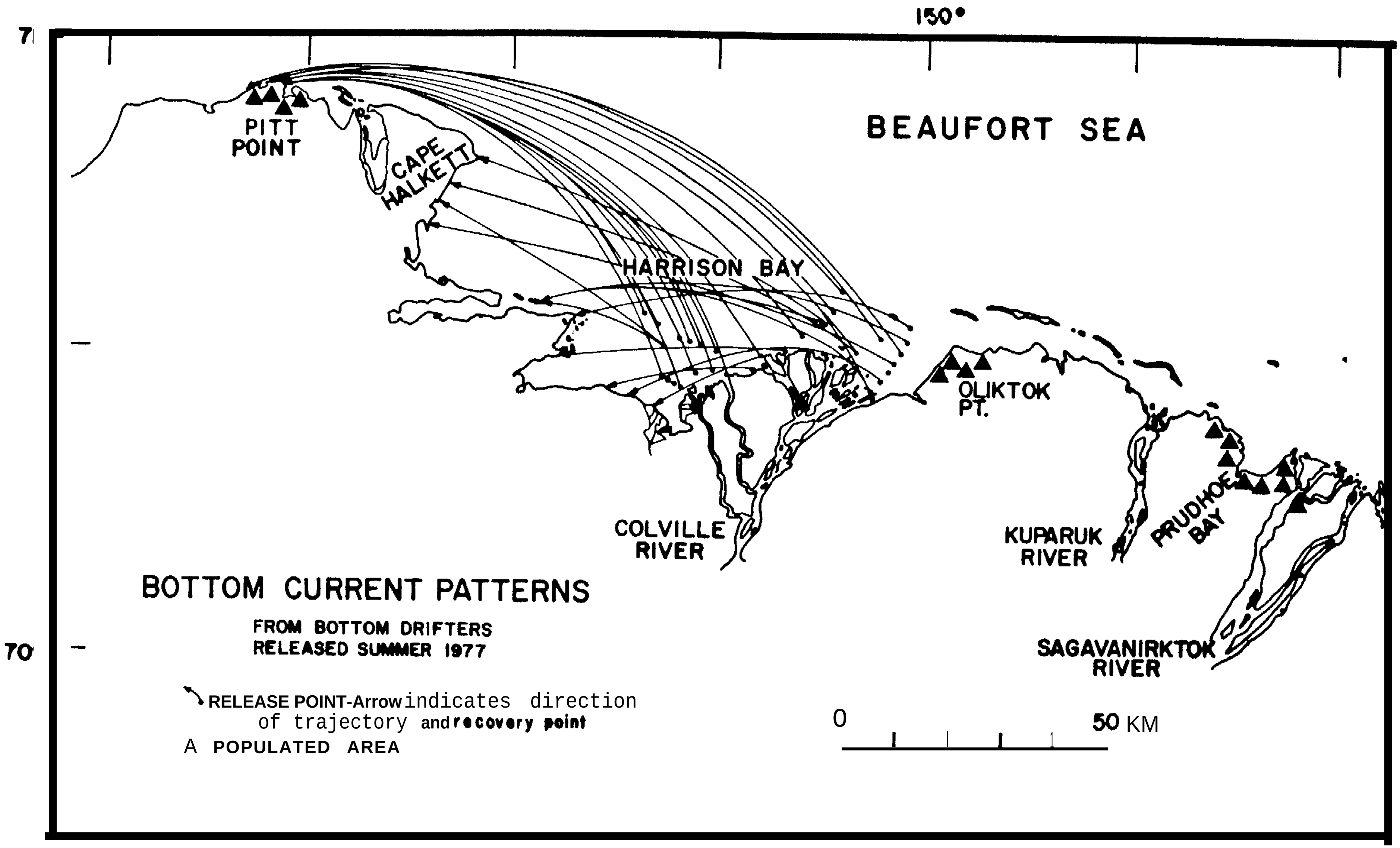

Figure 3. Idealized trajectories of bottom driftersd released in late June 1977 from recoveries through 1981 (modified after Barnes and Toimil, 1979).

RATE OF DRIFT

March 1979 release

The first and only 1979 recovery of this release occurred shortly after there was open water at the release site. Open-water conditions occur about mid-July at DS 11 and the recovery occurred in late July in Prudhoe Bay. As we know that the bottom drifters were still at the release site-three months after their March release, we assume that the drifters remained at the release site until open-water conditions generated sufficiently strong currents to cause them to move. If we use this assumption then the distance from the drop site to the recovery site is about 20 km and the drifter would have been in transit for less than 20 days (open-water conditions during later part of July) . This would suggest a drift rate of nearbottom water of at least 1 cm/sec (1 km/day). This compares favorably with the 1 - 3 cm/sec drift observed for bottom drifters released off the Colville in late June, and which also had to wait until mid-July for open-water conditions in Harrison Bay.

Summer 1979 release

As with the DS-11 drifters, only 1 of our summer drifters was recovered in the same open-water season when we released it. Thus extrapolation regarding net drift rates for near-bottom waters would be most speculative with the present data. The drifter was released on 16 September in Harrison Bay and recovered at Pt. Barrow on 15 October. Assuming it was recovered soon after it beached at Pt. Barrow, the rate of drift would have to be 9.3 cm/sec (8 km/day) to cover the 240 km from release to recovery. This rate is much faster than bottom drift rates noted elsewhere (Conomos et al., 1971) and is more comparable to our calculations of surface drift at this time of year in the Beaufort Sea (Barnes and Toimil, 1977).

DISCUSSION AND CONCLUSIONS

The movement of drifters demonstrates a strong westerly net transport of nearbottom waters. The lack of movement at the winter release site suggests that the most nearbottom transport of water, sediments and entrained pollutants would be overwhelmingly dominated by currents during the open-water period. The net westerly drift is to be expected, given the dominant easterly winds in summer (Brewer et al. , 1977) and the onshore northeasterly sea breeze that also develops during the summer (Kozo, 1979). The fact that any bottom drifters were recovered is indicative of an onshore component to the nearbottom water circulation. We believe this onshore component results in part from the northeasterly winds which drive surface waters offshore as evidenced by ice drift, to be replaced by onshore flow along the bottom. Coastal upwelling and nearbottom onshore flow is also suggested by temperature, salinity and current observations near Oliktok (Barnes et al. , 1977) . We note in Figure 3 the abundant recovery of bottom drifters in the vicinity of Oliktok Point, which also tends to support these earlier observations. The numerous recoveries just west of Cape Halkett (Figs. 1 and 3) suggest that there may be a stronger onshore component to the bottom water associated with this stretch of coastline.

The observations and recovery data from the bottom drifters do not support the model of inshore circulation presented by Matthews (1981). In his model, bottom drift at DS-11 in the winter of 1979 should be offshore at mean speeds of 1.5 cm/sec and less as determined from November through February current observations. Offshore flow results after dense brine formed during freezing of the ice canopy sinks and flows offshore along the bottom. This drainage is replaced by an onshore flow at the under-ice surface. Surface drifters immediately sub-ice moved onshore and along shore to be-recovered early in the following open-water season thus supporting the model. Our winter bottom drifters should move offshore to support the model. But, in fact, our bottom drifters did not move from March to May, indicating that any offshore current would be less than necessary to move these drifters. Furthermore, the first bottom drifters recovered emulated the movement of the surface drifters (Matthews, 1981, Fig. 6), once open-water conditions were present, moving onshore and alongshore.

The preponderance of drifter recoveries in the western parts of Harrison Bay, in western Simpson Lagoon, and the coast west of Cape Halkett (figures 2 and 3) suggest that these sites should be the location of sediment deposition. However, studies by Cannon and Rawlinson (1979) and Hopkins and Hart (1978) show these sites to be areas of active coastal erosion over the past 25 years. This is further substantiated by our own observations that depths in western Simpson Lagoon measured in 1950 by the Coast and Geodetic Survey have not changed significantly in 30 years, suggesting very slow or non-existent sedimentation. Thus, at least in the long term, these cannot be sites of long-term deposition of sediments. Perhaps the recoveries indicate areas of sluggish sediment movement in some years or sites of temporary deposition which are "cleaned out" during episodic storms. However, for short-term considerations, these areas should be considered sites of deposition for nearbottom transported sediments and potential impact sites for associated pollutants.

SUMMARY

1. Net movement of nearbottom water during summer on the inner shelf (<20 m) of the Beaufort Sea is to the west at 1-9 cm/sec.

2. Net movement of nearbottom water during winter on the inner shelf is very sluggish as indicated by bottom drifters, diver observations, and current-meter studies.

3. Temporary sediment depocenters are indicated for Simpson Lagoon and W. Harrison Bay, although rapid coastal erosion rates suggest these are not sites for long-term sediment accumulation.

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