Net Flow of Near-bottom Waters on the Inner Beaufort Sea Shelf as Determined from Seabed Drifters

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INTRODUCTION

Particulate material in the water column is commonly partially composed of sediments. Sediments and other particulates in transit emulate pollutants or may adsorb pollutants. As sediments in transit are primarily influenced by currents, studies of sediment related hydrodynamic processes will lead to a better understanding of the potential transport pathways and possible depositional sites of sediments and/or pollutants.

As concentration gradients of sediment in the water column on the inner Beaufort shelf off Alaska almost always increase near the sea bed the bulk of the sediments travel near the sea floor (Barnes, 1974; Drake, 1977). Therefore an understanding of the net motion of near-bottom currents should provide important information on sediment transport directions and rates.

In a study of net flow of near-bottom waters, we placed seabed drifters on the sea floor in March 1979 and released more seabed drifters from the sea surface 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

Previous surface drifter studies on the Alaskan Beaufort shelf (Barnes and Toimil, 1979; Matthews, 1981) suggested that westward surface currents are dominant on the shelf, although an easterly component was suggested for the area east of the Canning River. Seabed 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 prevailing easterly and westerly winds, resulting in predominantly coast-parallel currents (Barnes et al., 1977; Brower et al., 1977; Kozo and Brown, 1979; Matthews, 1978). As a result of common wind and current reversals, the net drift of inner shelf bottom waters could not be specified with certainty.

METHODS

The plastic seabed drifters used (Lee et al., 1965) are yellow perforated saucers, 18 cm in diameter, mounted on a red plastic stem, 55 cm in length. Negative buoyancy for the drifters is assured by attaching a 5-gram brass collar to the lower end of the stems. In March 1979, we set 56 drifters on the bottom through a dive hole cut in the ice in Stefansson Sound (DS-11). During late August and September 1979, 1500 drifters were released in groups of 25-50 from a surface vessel at locations between the Colville and Canning Rivers. Recovery depended upon chance beach observations by the local population and return of drifter serial number to the author for a 50-cent reward.

OBSERVATIONS

Drifter Recovery

Drifter recovery is dependent on open-water conditions to allow drifters (and people) access to the beaches. The drifters released in March were exposed to 3 or 4 months of sub-ice currents prior to the open-water season (mid-July), but then had the entire season (mid-July to mid-September) to travel ashore. The release of seabed drifters during the latter half of the open-water season in 1979 permitted only about a month 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 ice. Although drifters have been found and returned in two consecutive summers following their release, there are no data suggesting whether or not the drifters came ashore before freeze-up in 1979 or in subsequent years. The data on bottom 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
March 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 an under-ice study in March 1979, drifters were placed by divers in a 6 x 6 m area at a depth of 6 m within the underwater study site just east of Prudhoe Bay in Stefansson Sound. Three months later (mid-May), the drifters were seen unmoved by the same dive team. Furthermore the abundant brown kelp covering the boulder-strewn bottom showed 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 study periods (November, February/March, and May) during each of four winters from 1978 to 1982. Currents during the ice-covered period were never strong enough to orient the large blades of brown kelp on the sea floor. Winter current meter studies corroborate these observations indicating sluggish near-bottom currents (Barnes, 1981; Matthews, 1981).

All drifters had left the study site during the 3 months between May and the next diving studies in late July, 1979. The first seabed drifter recovered from this release came from a mid-July return from the beach in Prudhoe Bay. This recovery and all subsequent recoveries from the March release site have been to the west of the release site in Stefansson Sound. Two drifters traveled about 80 km west to Oliktok Point while the bulk of the recoveries were in the Prudhoe Bay area (Fig. 1). The largest percentage of recoveries (16%) from all seabed drifter releases has been from this site (Table I).

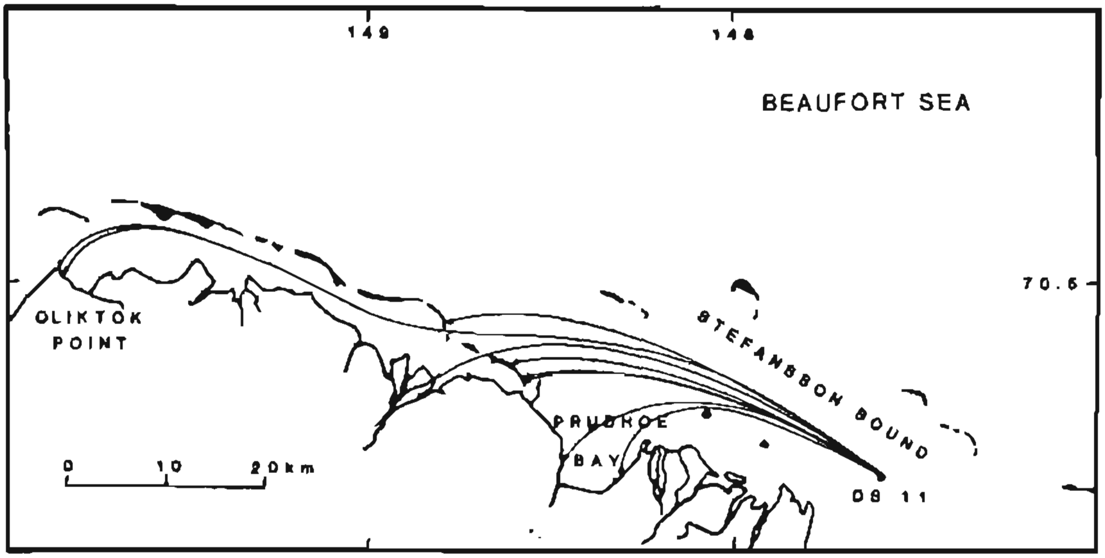

Figure 1. Sub-ice release site (DS-11) and idealized trajectories for seabed drifters released in March 1979. Recoveries through September 1981.

Summer 1979 Release

All recoveries from the 1979 summer release indicate westerly and onshore movement of the drifters. Recoveries throughout 1981 came from all release points, including those well offshore and the 8 percent returned represent a good sampling of those released (Table I). The recoveries were concentrated in Simpson Lagoon, in western Harrison Bay and along the open coast west of Cape Halkett (Fig. 2). One drifter was recovered near 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). Recovery sites continue to be located in the western part of Harrison Bay (Fig. 3). This suggests that the drifters were onshore during the first summer (1977) and are not migrating alongshore from year to year. Recoveries in recent years are believed due to increased coastal usage. It is interesting to note that only one drifter from all three releases has traveled beyond Cape Halkett - Lonely Area (Figs. 1,2, and 3).

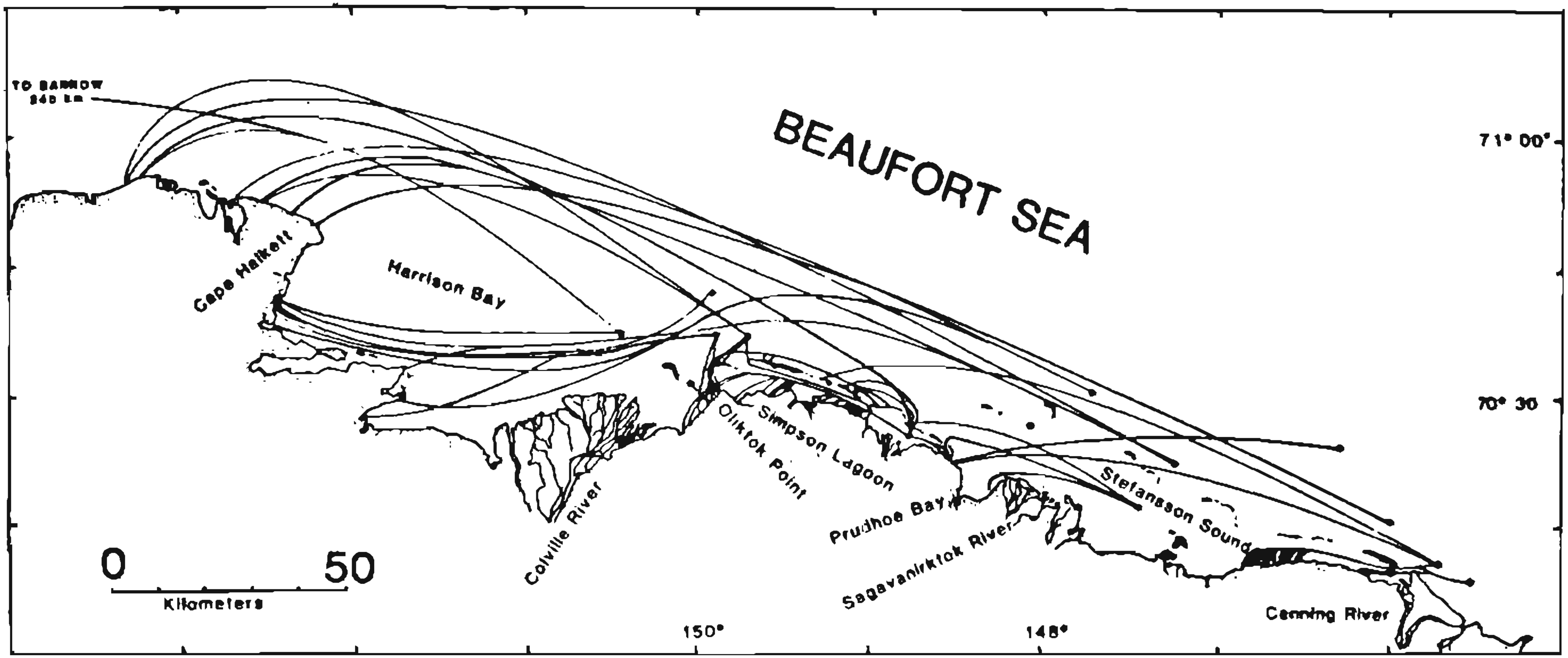

Figure 2. Summer open-water bottom drifters release. Idealized trajectories of bottom drifters released in 1979 from recoveries through 1981.

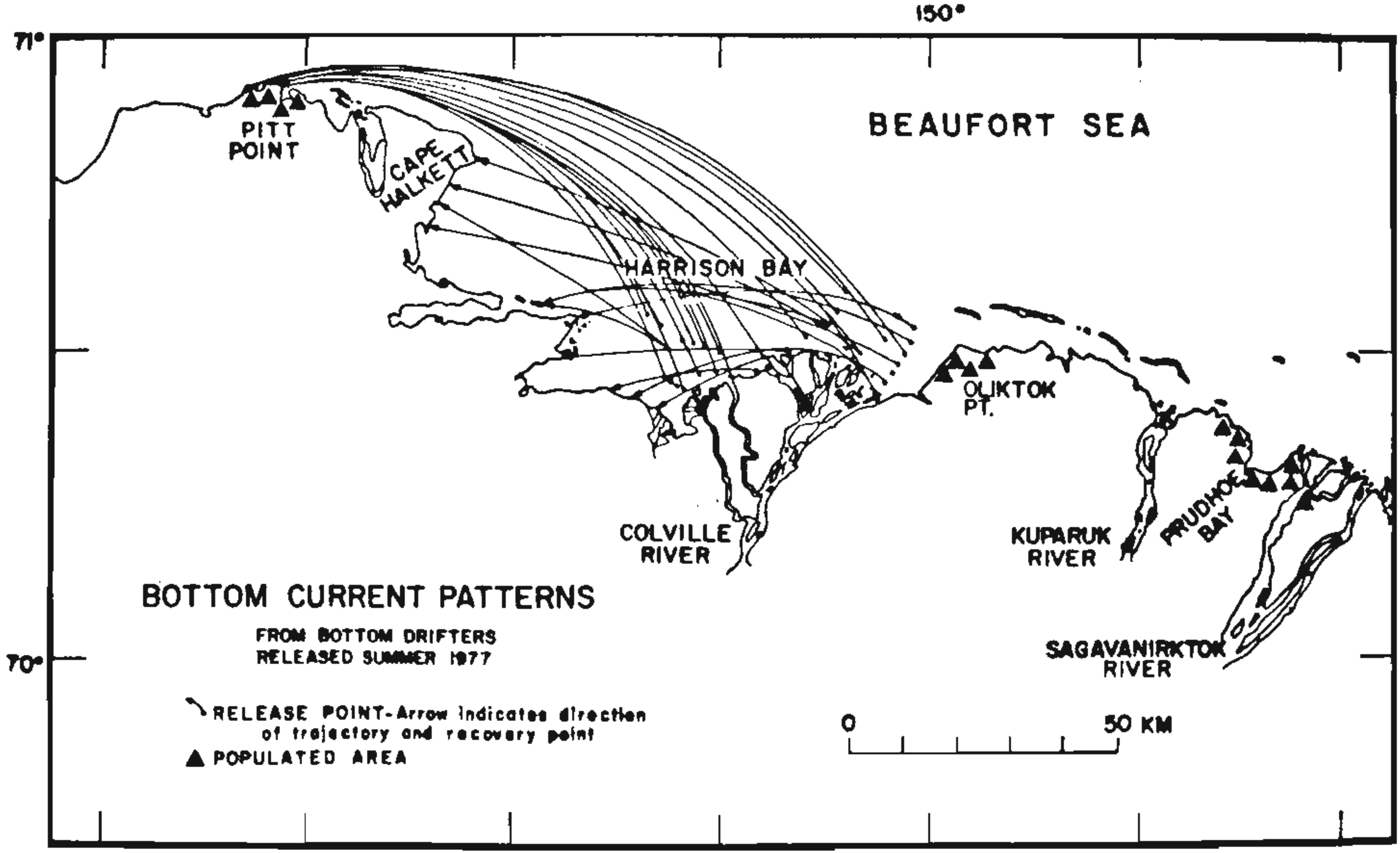

Figure 3. Idealized trajectories of bottom driftersd released in late June 1977 from recoveries through 1981 (modified after Barnes and Toimil, 1979).

RATE OF DRIFT

March 1979 Release

Open-water conditions occur about mid-July at DS 11. The only 1979 recovery of this release occurred in late July in Prudhoe Bay. Because the seabed drifters were at the release site three months after their March release, we postulate that the drifters remained at the release site until open-water conditions generated sufficiently strong currents to cause them to move. Using this assumption, 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 suggests a drift rate of near-bottom water of at least 1 cm/sec (1 km/day) and compares favorably with the 1 - 3 cm/sec drift observed for seabed drifters released off the Colville River in late June 1977 (Barnes and Toimil, 1979).

Summer 1979 Release

Only one of our summer drifters was recovered in the same year released. A drifter released on 16 September in Harrison Bay and recovered at Pt. Barrow on 15 October traveled 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 comparable to calculations of late open-water season surface drift in the Beaufort Sea (Barnes and Toimil, 1979). The single recovery and the high velocity suggest to us that extrapolation regarding net drift rates for near-bottom waters would be most speculative with the present data.

DISCUSSION AND CONCLUSIONS

The movement of drifters demonstrates a strong westerly net transport of near-bottom waters. The lack of movement at the winter release site suggests that the near-bottom 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 (Brower et al., 1977) and the onshore northeasterly sea breeze that also develops during the summer (Kozo and Brown, 1979).

An onshore component to the bottom water circulation is indicated as drifters released well offshore were recovered onshore (Fig. 2). 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 near-bottom onshore flow is also suggested by temperature, salinity and current observations near Oliktok Point (Barnes et al., 1977). We note in Figure 2 the abundant recovery of seabed drifters in the vicinity of Oliktok Point, which also tends to support the earlier temperature and salinity observations. The numerous recoveries just west of Cape Halkett (Figs. 2 and 3) suggest that there may be a stronger onshore component to the bottom water associated with this stretch of coastline also.

The observations and recovery data from the seabed drifters do not support the model of inshore winter circulation suggested by Matthews (1981). In his model, offshore bottom drift at DS-11 in the winter of 1979 should occur at mean speeds of less than 1.5 cm/sec, as determined and extrapolated from November 1978 through February 1979 current observations 2 m above the sea floor. Offshore flow is postulated to result from dense brines formed during freezing of the ice canopy which sink and flow seaward along the bottom. This drainage is replaced by an onshore flow at the under-ice surface. Surface drifters placed by Matthews in the dive hole were recovered early in the following open-water season onshore and to the west of DS-11 thus supporting the model. Our winter bottom drifters should have moved offshore to support the model. However, 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 westward.

The preponderance of drifter recoveries in the western parts of Harrison Bay, in western Simpson Lagoon, and along the coast west of Cape Halkett (Figs. 2 and 3) suggest that these are sites 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. 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, suggests very slow or non-existent sedimentation. Thus, at least in the long term, these cannot be sites of sediment deposition. 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 as potential impact sites for sediment associated pollutants.

SUMMARY

1. Net westerly movement of near-bottom water occurs during summer open-water season on the inner shelf of the Beaufort Sea at 1-9 cm/sec.

2. Net movement of near-bottom 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 suggested for western Simpson Lagoon western Harrison Bay and the coast west of Cape Halkett, although bathymetry and rapid coastal erosion rates suggest these are not sites for long-term sediment accumulation.

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