Massachusetts Geological Survey
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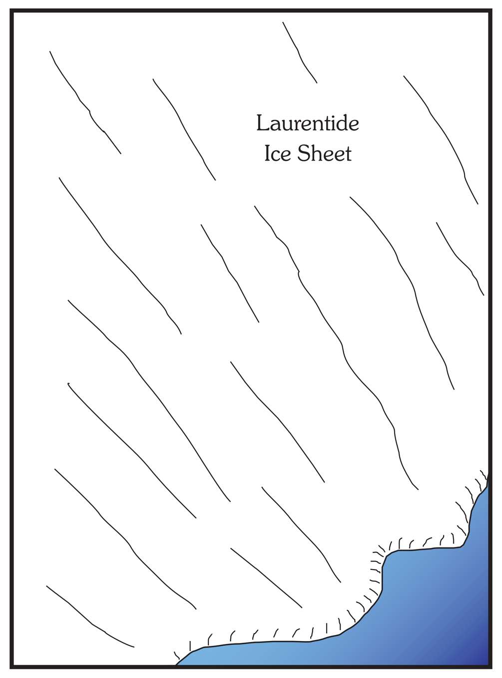
Evolutionary Model

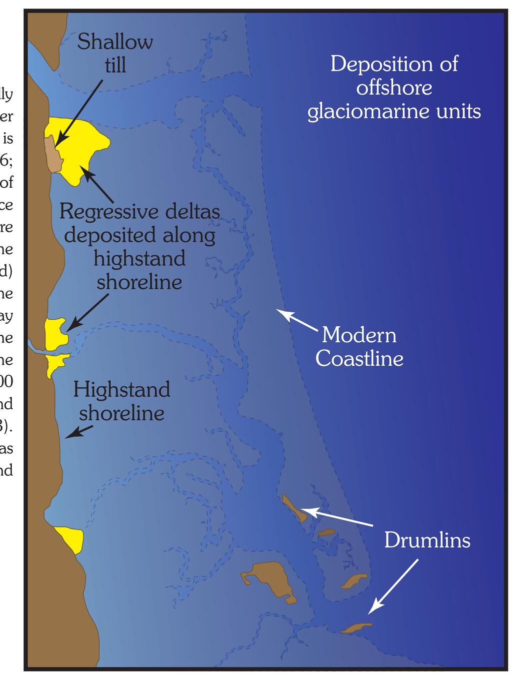
Stage 1:
Last Glacial Maximum to Glacial Retreat
~24 - 17 ka

The Laurentide Ice Sheet advances through northern Massachusetts and the Gulf of Maine, reaching its maximum limit at Long Island (NY) and Martha's Vineyard, Nantucket and Cape Cod (MA) at ~23,200 ± 500 yrs. BP (Balco *et al.*, 2002). Previous sediments are largely eroded and underlying bedrock is smoothed. Thin till (Qtt) is deposited as an unsorted, non-stratified matrix of sand and lesser amounts of silt and clay containing gravel clasts and few large boulders. Locally, till from the Laurentide Ice Sheet and from previous glaciations is reworked into drumlin fields (Qtd), such as that found proximal to the southern end of Plum Island. These shallow till deposits later pin much of the barrier island system and control the location of modern inlets (FitzGerald *et al.*, 1994). Additional thin till (Qtt) is deposited throughout the region directly on top of bedrock.



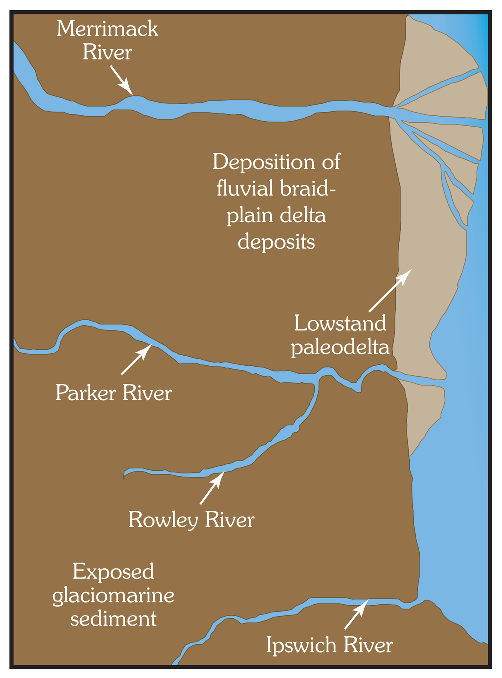
Stage 2:
Sea-Level Highstand
17 - 16 ka

Sea level rises rapidly over the isostatically depressed region as the ice margin retreats further north. The maximum synglacial marine limit is reached at 17–16 ka (Stone and Borns, 1986; Ridge, 2004; Stone *et al.*, 2004) at elevations of 31–33 m above modern mean sea level. During ice retreat, glaciomarine deltas and fans (Qgdf) are deposited along the retreating ice front. With the exception of subaerially exposed till (Qtt, Qtd) deposits, the entire region seaward of the marine limit is draped with glaciomarine silt and clay (Qgsc). Crustal rebound associated with the northerly retreat of the ice front out of the Merrimack Embayment results in briefly (< 1000 years) stable highstand shorelines at +30 m and +15 m (Edwards, 1988; Oldale *et al.*, 1993). Sediments were deposited along these shorelines as a series of regressive fluvial terraces (Qft) and coastal beaches, spits, deltas and fans (Qrs).



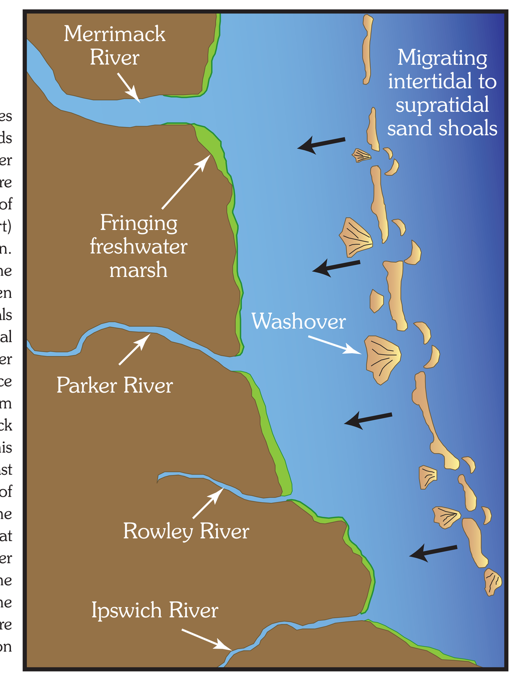
Stage 3:
Regression and Lowstand
16 - 13 ka

Accelerated crustal rebound results in relative sea-level fall and seaward translation of the shoreline (forced regression). Large volumes of glacigenic sediments are exported by the Merrimack River. These are modified and immediately redistributed across the emergent surface plain of glaciomarine silt-clay (Qgsc) by waves and tidal currents, depositing an 8–10-km wide (perpendicular to shore), 16 km-long, and 4–15-m thick (Barnhardt *et al.*, 2009) seaward-prograding, wave-smoothed offlap regressive braidplain delta (lower part of Qsrt). The Parker and Rowley Rivers extend offshore onto the exposed shelf, merge, carve into underlying glaciomarine silt-clay (Qgsc) deposits and deposit fluvial channel sediments (Qfc). An offshore-fining, 20-km long, 4-7 km wide, and up to 20 m thick (Oldale *et al.*, 1993) lowstand delta (Qdl) is deposited predominantly by the reworking of Merrimack River sediments as sea-level fall slowed and the shoreline stabilized near its lowstand position. A glacioisostatic marine lowstand of approximately -45 m depth occurs at 14–13 ka (Oldale *et al.*, 1993), during which time the Merrimack, Parker, Rowley and Ipswich Rivers continue to supply sediment to the proximal braidplain delta and distal lowstand delta (Qdl).



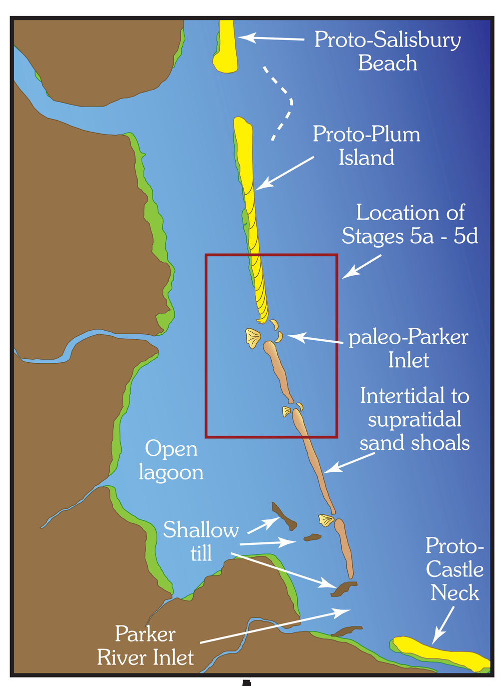
Stage 4:
Transgressive Migration of Sand Shoals
13 to ~6 ka

Crustal rebound slows and relative sea level rises from the lowstand. Topset and upper foreset beds of the lowstand delta (Qdl) are truncated. Upper sections of the regressive shoreline deposits are reworked and winnowed to create a broad plain of mixed regressive-transgressive shoreline (Qsrt) deposits; the depth of reworking is unknown. Eroded lowstand and regressive deposits combine with Merrimack River sediments and are driven onshore as intertidal to supratidal sand shoals (FitzGerald *et al.*, 1994), behind which basal estuarine (Qe) sediments are deposited. Other sediments remain on the transgressive shoreface and are re-deposited on the shallow shelf to form transgressive sand sheet (Qss) deposits. Merrimack River sediments continue to be contributed to this deposit through reworking by dominant northeast storms, resulting in > 9-m thick deposits offshore of southern Plum Island (Barnhardt *et al.*, 2009). The shoreline reaches the site of modern Plum Island at 7–8 ka, accompanied by formation of freshwater marsh (Qm) along the leading edge of the transgression (McIntire and Morgan, 1964). The lower reaches of lowstand river channels are flooded, initiating upstream infilling and deposition of channel-fill (Qfc) deposits (GPR Profile B).



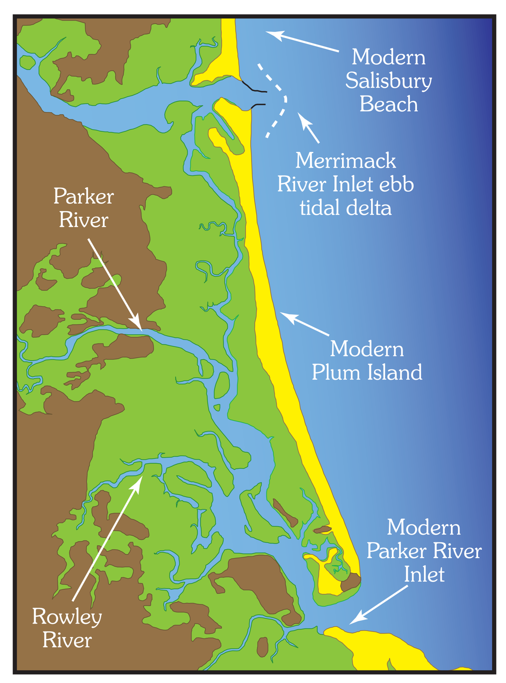
Stage 5:
Pinning, Proto-barrier Formation, and Inlet Development
~6 to ~2 ka

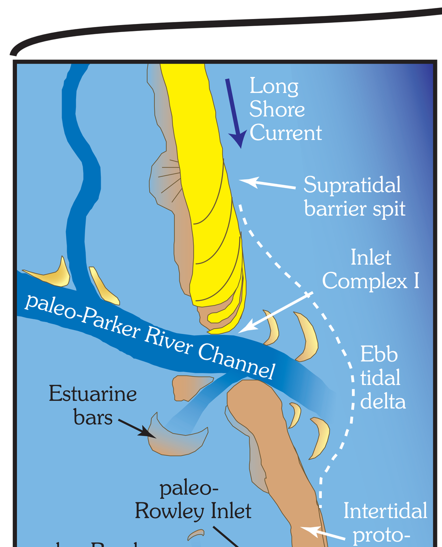
The rate of relative sea-level rise slows. Sand shoals become pinned to shallow bedrock and glacial deposits (Qtd, Qtt) as the transgression proceeds (FitzGerald *et al.*, 1994). A series of supratidal proto-barriers form seaward of the modern barrier chain, as evidenced by the near-ubiquitous presence of estuarine (Qe) and saltmarsh (Qs) deposits under Plum Island. Active estuarine channels migrate in this tidal environment, forming meander scars preserved under Plum Island. Narrow (< 500 m wide) proto-barriers migrate landward to the location of the modern barrier systems and form basal sections of beachface (Qb) deposits. This unit accretes vertically, lengthens by spit elongation and widens by seaward progradation from continued sediment inputs from the shallow shelf and local rivers. Along northern sections of Plum Island, where development is dominated at this time by vertical accretion and interaction with the Merrimack River (Hein *et al.*, 2012), dune (Qd) development initiates. In central Plum Island, a tidal-inlet channel (Qtc) forms in the location of the Parker River channel (see Stages 5a-5d; GPR Profile A).



Stage 6:
Barrier Island Stabilization
~2 ka to Modern

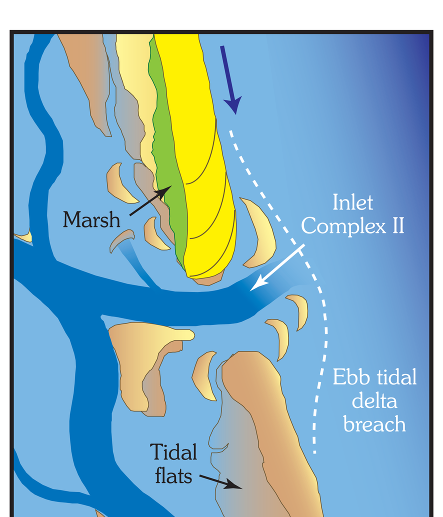
The barriers continue to prograde with sediment contibuted from the Merrimack River and some (likely minor) contributions from the offshore sand sheet (Qss). Meandering of the mouth of the Merrimack River continues to modify the northern end of Plum Island and the southern end of Salisbury Beach (Costas and FitzGerald, 2011). This process has greatly decelerated since the construction of jetties at the Merrimack Inlet in 1881. Extensive dune (Qd) systems develop along the entire length of each of the barriers. Along the shallow shelf, shoreface and sand sheet sediments (Qss) are reworked by modern wave and current processes. Bedform geometries within the sand sheet (Qss) indicate occasional reworking of the upper portions of this unit during high-energy events. Shoreline-proximal sections of Unit Qss (< ca. 10 m) are reworked by both calm-condition and storm waves and actively exchange sediment with the beachface (Qb) and ebb-tidal deltas (Qed). Offshore of the sand sheet (Qss; beyond 60-m contour), fine fluvial and marine sand, silt and clay (Qmsc) continue to be deposited.





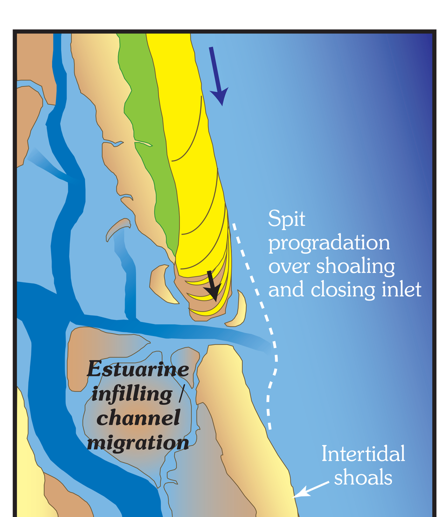
Stage 5a:
Southerly Inlet Migration
~4 - 3.6 ka

The northern half of Plum Island stabilizes first and lengthens via elongation of a spit (Unit Qb) over a subtidal to intertidal spit platform formed from estuarine (Qe) sediments. This process is driven by southerly longshore transport resulting from dominant northeast storms (Nor'easters). The paleo-Parker Inlet (Qtc) fully occupies the lowstand Parker River channel (GPR Profile B) and begins to migrate to the south, driven by the southerly elongating spit system (Inlet Channel Complex I; GPR Profile A). A secondary inlet (Qtc) forms in the location of the lowstand Rowley River. Tidal exchange between Plum Island Sound, an open estuarine lagoon at this time, and the coastal ocean occurs through the paleo-Parker Inlet, a likely paleo-Rowley Inlet, and the Parker Inlet at the southern end of Plum Island (Stage 5, above). Tidal flows deliver fine fluvial and nearshore reworked sediment through the inlet and deposit them as an estuarine (Qe) unit, filling the lagoon and reducing the tidal prism through the paleo-Parker Inlet.



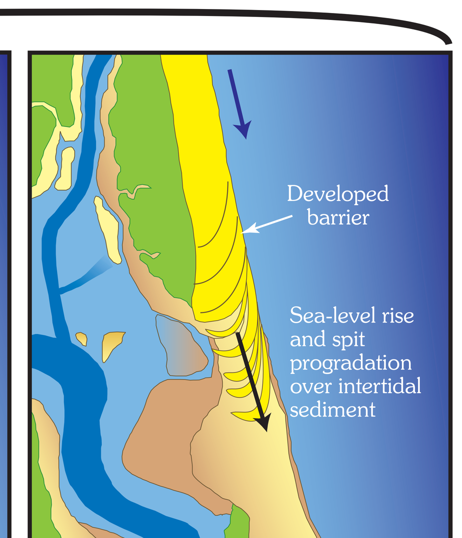
Stage 5b:
Ebb Tidal Delta Breaching
3.6 ka

Southerly migration of the paleo-Parker Inlet continues until tidal flows through the inlet become hydraulically inefficient. Ebb-delta breaching results in deflection of the inlet channel to the north, truncating the southerly prograding spit and platform and forming Inlet Channel Complex II (GPR Profile A). Sediment that formed the old ebb delta (Qed) is transported landward and welds onto the barrier near the northern end of the inlet to form additional beachface (Qb) sediments. The new inlet is ~3–4 m deep and active at 3.6 ka (Hein *et al.*, 2012). To the south, the likely secondary inlet associated with the Rowley River (paleo-Rowley Inlet) closes and is filled with estuarine (Qe) sands. Any tidal prism associated with this inlet is captured by the paleo-Parker Inlet or the Parker Inlet at the southern end of modern Plum Island (Stage 5, above). Infilling of the backbarrier lagoon continues via the deposition of additional estuarine (Qe) sediment.



Stage 5c:
Inlet Shoaling and Closure
~3.6 - 3 ka

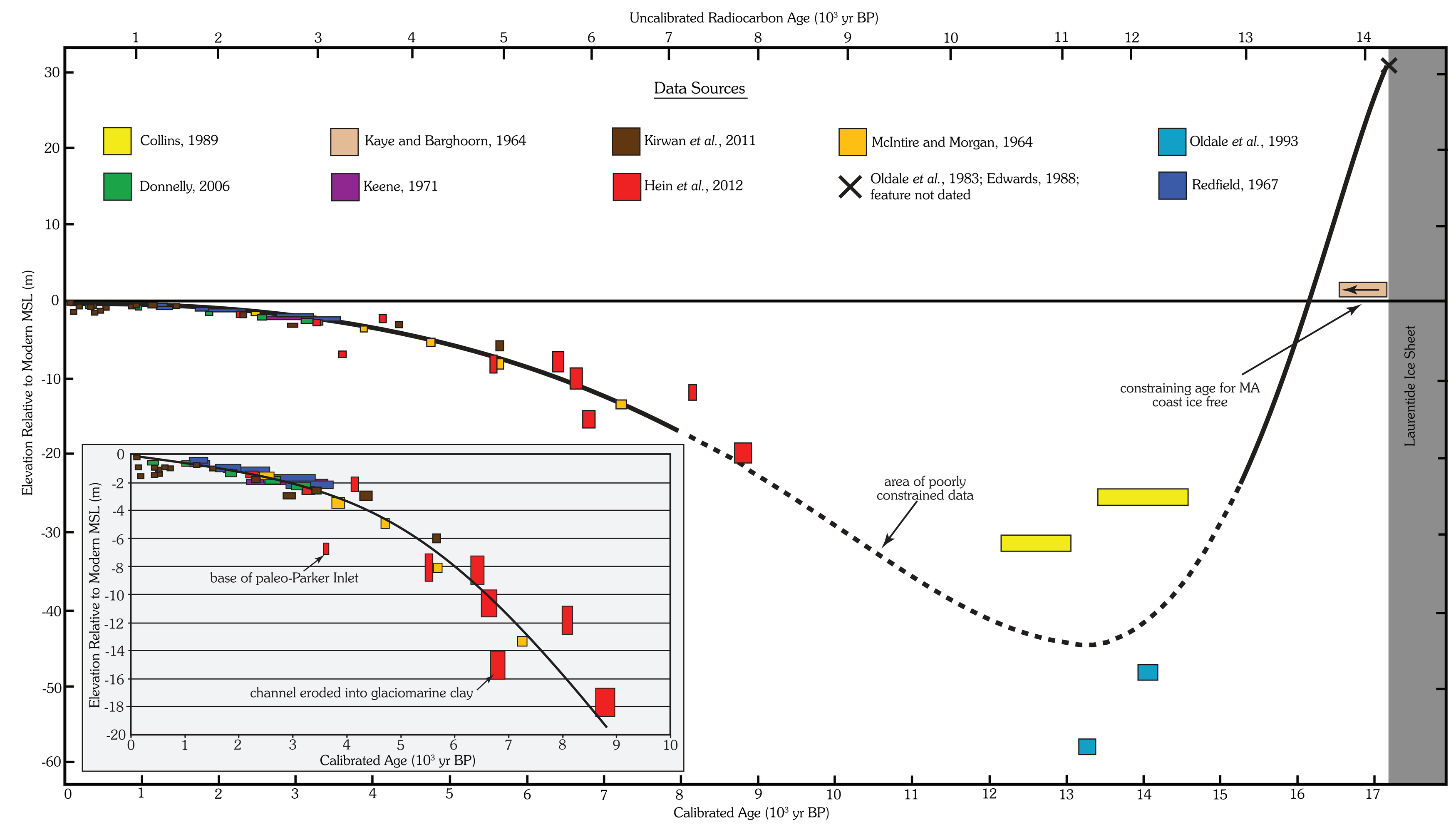
Continued longshore transport and southerly spit elongation drive the new inlet south. The lagoon continues to fill due to deposition of estuarine (Qe) sediments, forming extensive subtidal to intertidal tidal flats and migrating tidal channels. An extensive saltmarsh (Qs) system begins to develop on top of estuarine (Qe) sediments. Tidal-prism reduction continues due to shallowing of the lagoon; tidal fluxes between the lagoon and coastal ocean decrease, resulting in the narrowing and shoaling of the paleo-Parker Inlet as it migrates south. The inlet at this time is only 1–2 m deep (GPR Profile A). Infilling results in the complete shoaling and eventual closure of the paleo-Parker Inlet. The modern Plum Island Sound drainage system develops as the Parker River joins the Rowley and Ipswich Rivers as a single estuary with one inlet (the Parker Inlet) at the southern end of Plum Island (Stage 6), stabilized between two drumlins (Qtd).



Stage 5d:
Barrier Elongation / Progradation
3 - 2 ka

Final shoaling and closure of the paleo-Parker Inlet allows the spit (unit Qb) to rapidly prograde south, overtopping previous estuarine channels, inlet-fill sequences and intertidal / supratidal bars to the south. Saltmarsh (Qs) south of paleo-Parker Inlet is overtopped by the spit 2.3 ka (PIG9D5-S3 in radiocarbon results table to right) as Plum Island elongates and widens. Over this time, spit progradation accounts for more than 60% of Plum Island's total length. Nearly 90% of its modern width is from seaward progradation, with only a minor contribution from overwash and landward migration (Hein *et al.*, 2012). Dunes (Qd) develop soon following spit progradation. Continued esturaine (Qe) infilling and tidal-flat and saltmarsh (Qs) accretion allow for the development of the extensive "Great Marsh" system behind the Salisbury, Plum Island and Castle Neck barriers. This is the largest marsh system in New England.

Merrimack Embayment Relative Sea-Level Curve



Post-glacial calibrated relative sea-level curve for northeastern Massachusetts and adjacent inner continental shelf. Modified from Oldale *et al.* (1993) with additional dates derived from Redfield (1967), Donnelly (2006), Kirwan *et al.* (2011) and Hein *et al.* (2012). Select marine and terrestrial limiting points are incorporated after Oldale *et al.* (1993) and Engelhart and Horton (2012). Vertical and temporal errors are given by heights and widths of data rectangles. Standard vertical errors of ± 1 m given to ages of all possibly reworked material. Ages are calibrated 1-sigma ranges. Vertical and temporal errors are given by heights and widths of data rectangles. See calibration table (below) for details. Inset shows zoom-in of Holocene section of sea-level curve, modified and updated from Hein *et al.* (2012).

Sample Location	Cited Sample ID	Latitude (° N)	Longitude (° W)	Reported Material Dated	Elevation (m MSL)	Reported Age (yrs BP)	Cal. 1-σ age (yrs BP)	Probability	Cal. 2-σ age (yrs BP)	Probability	Data Source
Romney Marsh (Revere, MA)	R1	42.428	70.989	Juncus gerardi, Spartina patens	-2.56	3050 ± 50	3278 ± 65	1.000	3258 ± 118 3118 ± 9 3086 ± 6	0.967 0.018 0.016	Donnelly, 2006
Romney Marsh (Revere, MA)	R2	42.428	70.989	Distichlis spicata	-2.25	2950 ± 60	3135 ± 77 3037 ± 16 3010 ± 5	0.821 0.136 0.042	3310 ± 162 3307 ± 22	0.958 0.042	Donnelly, 2006
Romney Marsh (Revere, MA)	R3	42.428	70.989	Spartina patens	-1.83	2510 ± 50	2547 ± 54 2703 ± 24 2625 ± 16	0.589 0.238 0.173	2598 ± 147 2378 ± 12 2405 ± 7 2440 ± 4	0.948 0.029 0.014 0.008	Donnelly, 2006
Romney Marsh (Revere, MA)	R4	42.428	70.989	Juncus gerardi, Spartina patens, Scirpus spp.	-1.29	1900 ± 40	1855 ± 42 1748 ± 4 1916 ± 2	0.957 0.034 0.010	1827 ± 100	1.000	Donnelly, 2006
Romney Marsh (Revere, MA)	R5	42.428	70.989	Juncus gerardi, Spartina patens	-0.58	260 ± 50	305 ± 24 402 ± 28 161 ± 9 364 ± 5 3 ± 2	0.429 0.368 0.132 0.041 0.030	367 ± 100 180 ± 35 10 ± 11	0.769 0.184 0.467	Donnelly, 2006
Romney Marsh (Revere, MA)	R6	42.428	70.989	Spartina patens	-0.68	1040 ± 40	952 ± 28 1042 ± 3	0.966 0.034	982 ± 75 839 ± 7 805 ± 1	0.980 0.018 0.002	Donnelly, 2006
Plum Island Barrier	PID03-S09	42.755	70.801	bivalve fragment	-8.3	6090 ± 40	6385 ± 65	1.000	6402 ± 124	1.000	Hein *et al.*, 2012
Plum Island Barrier	PID03-S13	42.755	70.801	bivalve fragment	-10.6	6290 ± 40	6621 ± 73	1.000	6616 ± 141	1.000	Hein *et al.*, 2012
Plum Island Barrier	PID03-S19	42.755	70.801	terrestrial wood fragment	-11.6	7260 ± 40	8136 ± 21 8038 ± 20 8102 ± 13	0.393 0.383 0.224	8085 ± 87	1.000	Hein *et al.*, 2012
Plum Island Barrier	PID04-S05	42.757	70.804	terrestrial wood fragment	-8.1	4740 ± 70	5543 ± 41 5353 ± 23 5472 ± 17	0.517 0.275 0.208	5513 ± 81 5372 ± 53	0.646 0.354	Hein *et al.*, 2012
Plum Island Barrier	PID05-S15	42.752	70.800	bivalve fragment	-17.7	8350 ± 30	8783 ± 103	1.000	8781 ± 171	1.000	Hein *et al.*, 2012
Plum Island Barrier	PID11-S28	42.732	70.789	bivalve fragment	-15.0	6430 ± 40	6788 ± 72	1.000	6789 ± 138	1.000	Hein *et al.*, 2012
Plum Island Barrier	PIG9-D5S3	42.732	70.789	basal saltmarsh peat (*in situ*)	-1.5	2180 ± 40	2270 ± 35 2155 ± 29	0.581 0.408	2215 ± 112 2074 ± 11	0.967 0.033	Hein *et al.*, 2012
Plum Island Barrier	PIG9-D5S12	42.732	70.789	base-of-basal saltmarsh peat (*in situ*)	-2.6	3060 ± 35	3294 ± 47	1.000	3286 ± 79 3175 ± 9	0.975 0.025	Hein *et al.*, 2012
Plum Island Barrier	PIG11-D04S04	42.756	70.803	peat fragments (reworked)	-2.1	3750 ± 35	4117 ± 37 4019 ± 16 4212 ± 2	0.772 0.211 0.017	4121 ± 61 4019 ± 34 4215 ± 18	0.654 0.243 0.103	Hein *et al.*, 2012
Plum Island Barrier	PIG12-D07S08	42.754	70.801	muddy organics	-6.7	3350 ± 30	3598 ± 40	1.000	3597 ± 47 3511 ± 31 3673 ± 12	0.745 0.195 0.060	Hein *et al.*, 2012
West Lynn, MA	W-735	42.467	70.981	barnacles (Balanus *hameri*)	1.6	14250 ± 250	16848 ± 311	1.000	16712 ± 845 15700 ± 23	0.995 0.005	Kaye and Barghoorn, 1964
Hampton Marsh (Hampton, NH)	I-4908	42.930	70.863	basal saltwater peat	-2.0	2740 ± 310	2867 ± 385 2476 ± 5	0.992 0.008	2866 ± 752 3626 ± 2 2075 ± 1	0.999 < 0.001 < 0.001	Keene, 1971
Plum Island Backbarrier	Core 1: 75 cm	42.725	70.856	saltmarsh peat rhizome	-1.1	815 ± 30	714 ± 24	1.000	731 ± 49	1.000	Kirwan *et al.*, 2011
Plum Island Backbarrier	Core 1: 257 cm	42.725	70.856	saltmarsh peat rhizome	-2.9	2830 ± 70	2931 ± 77 3024 ± 13 3055 ± 6	0.856 0.097 0.047	2932 ± 152 3123 ± 36	0.923 0.077	Kirwan *et al.*, 2011
Plum Island Backbarrier	Core 1: 560 cm	42.725	70.856	saltmarsh peat rhizome	-6.0	5030 ± 35	5742 ± 20 5849 ± 40	0.329 0.670	5801 ± 94 5678 ± 16	0.921 0.079	Kirwan *et al.*, 2011
Plum Island Backbarrier	Core 2: 100 cm	42.745	70.831	Distichlis spicata	-1.4	510 ± 25	528 ± 10	1.000	529 ± 23	1.000	Kirwan *et al.*, 2011
Plum Island Backbarrier	Core 2: 379 cm	42.745	70.831	saltmarsh peat rhizome	-3.1	3900 ± 30	4380 ± 34 4314 ± 19	0.625 0.375	4332 ± 86	1.000	Kirwan *et al.*, 2011
Plum Island Backbarrier	Core 3: 306 cm	42.744	70.826	saltmarsh peat rhizome	-2.4	3450 ± 35	3704 ± 23 3807 ± 14 3654 ± 12 3757 ± 7	0.456 0.242 0.208 0.094	3733 ± 98	1.000	Kirwan *et al.*, 2011
Plum Island Backbarrier	Core 4: 85 cm	42.746	70.823	Distichlis spicata	-1.2	475 ± 35	518 ± 13	1.000	515 ± 33	1.000	Kirwan *et al.*, 2011
Plum Island Backbarrier	Core 5: 68 cm	42.739	70.839	saltmarsh peat rhizome	-1.1	360 ± 30	456 ± 28 343 ± 18 371 ± 5	0.577 0.350 0.073	460 ± 39 362 ± 46	0.500 0.500	Kirwan *et al.*, 2011
Plum Island Backbarrier	Core 5: 132 cm	42.739	70.839	saltmarsh peat rhizome	-0.7	1210 ± 30	1146 ± 29 1098 ± 17	0.633 0.367	1122 ± 63 1223 ± 20 1253 ± 4	0.874 0.116 0.010	Kirwan *et al.*, 2011
Plum Island Backbarrier	Core 5: 182 cm	42.739	70.839	saltmarsh peat rhizome	-1.2	1650 ± 30	1547 ± 25 1592 ± 10	0.822 0.178	1565 ± 57 1442 ± 24 1680 ± 8 1495 ± 6	0.867 0.095 0.026 0.012	Kirwan *et al.*, 2011
Plum Island Backbarrier	Core 5: 254 cm	42.739	70.839	saltmarsh peat rhizome	-1.9	2190 ± 25	2272 ± 32 2150 ± 15	0.695 0.305	2172 ± 42 2265 ± 46	0.599 0.401	Kirwan *et al.*, 2011
Plum Island Backbarrier	Core 6: 76 cm	42.729	70.839	saltmarsh peat rhizome	-0.7	125 ± 30	90 ± 28 255 ± 13 134± 12 30 ± 10 224 ± 8	0.425 0.173 0.145 0.138 0.115	103 ± 48 229 ± 45 29 ± 19 176 ± 3	0.158 0.470 0.353 0.010	Kirwan *et al.*, 2011
Plum Island Backbarrier	Core 9: 65 cm	42.743	70.840	saltmarsh peat rhizome	-1.0	925 ± 30	877 ± 29 819 ± 12 800 ± 5	0.633 0.268 0.099	849 ± 76	1.000	Kirwan *et al.*, 2011
Plum Island Backbarrier	Core 10: 56 cm	42.719	70.820	Distichlis spicata	-1.5	385 ± 25	478 ± 23 342 ± 7 441 ± 1	0.787 0.193 0.020	467 ± 39 351 ± 27	0.745 0.255	Kirwan *et al.*, 2011
Plum Island Backbarrier	Core 10: 77 cm	42.719	70.820	saltmarsh peat rhizome	-1.7	205 ± 30	168 ± 18 283 ± 13 6 ± 6	0.507 0.335 0.158	180 ± 38 385 ± 20 12 ± 12	0.545 0.292 0.163	Kirwan *et al.*, 2011
Plum Island Backbarrier	Core 11: 54 cm	42.732	70.840	saltmarsh peat rhizome	-0.4	130 ± 35	91 ± 27 256 ± 13 26 ± 12 136 ± 12 222 ± 9 191 ± 2	0.372 0.171 0.160 0.139 0.124 0.028	104 ± 48 226 ± 54 27 ± 19	0.428 0.408 0.159	Kirwan *et al.*, 2011
Plum Island Backbarrier	Core 17: 51 cm	42.729	70.823	Distichlis spicata	-0.9	275 ± 30	304 ± 16 409 ± 17	0.537 0.463	394 ± 44 308 ± 25 161 ± 7 450 ± 1	0.510 0.449 0.040 0.001	Kirwan *et al.*, 2011
Plum Island Backbarrier	Core 17: 137 cm	42.729	70.823	Distichlis spicata	-1.7	415 ± 60	476 ± 45 344 ± 13	0.814 0.186	477 ± 58 364 ± 49	0.654 0.346	Kirwan *et al.*, 2011
Merrimack Paleodelta	NHAT-4	42.873	70.708	wood fragment	-48.0	12200 ± 80	14043 ± 125	1.000	14172 ± 365	1.000	Oldale *et al.*, 1993
Jeffreys Ledge Paleobarrier (Offshore Cape Ann)	MAAT-6	42.642	70.654	jackknife clam	-60.5	11900 ± 110	13253 ± 105	1.000	13273 ± 218 12995 ± 30	0.983 0.017	Oldale *et al.*, 1993
Plum Island Backbarrier	PR-A	42.700	70.834	basal freshwater peat	-1.5	2450*	2465 ± 38 2667 ± 30 2392 ± 29 2604 ± 11 2534 ± 4	0.349 0.281 0.251 0.091 0.028	2488 ± 132 2670 ± 38	0.761 0.239	McIntire and Morgan, 1964
Plum Island Backbarrier	SR-L	42.743	70.831	basal freshwater peat	-3.5	3550*	3862 ± 42 3778 ± 17 3739 ± 14	0.640 0.203 0.157	3817 ± 118 3955 ± 17	0.931 0.069	McIntire and Morgan, 1964
Plum Island Backbarrier	PR-B-3	42.762	70.834	basal freshwater peat	-4.9	4225*	4730 ± 28 4830 ± 22 4661 ± 10	0.460 0.415 0.125	4689 ± 80 4824 ± 42 4591 ± 8	0.600 0.383 0.017	McIntire and Morgan, 1964
Plum Island Backbarrier	SR-K	42.744	70.831	basal freshwater peat	-8.1	4900*	5625 ± 36 5696 ± 2	0.987 0.013	5662 ± 80 5496 ± 8	0.980 0.020	McIntire and Morgan, 1964
Plum Island Backbarrier	PR-L	42.757	70.800	basal freshwater peat	-13.3	6290*	7213 ± 46	1.000	7234 ± 81 7071 ± 48	0.877 0.123	McIntire and Morgan, 1964
Neponset River Marsh (Milton, MA)	I-2275	42.270	71.050	high saltmarsh peat	-0.37	1310 ± 95	1238 ± 71 1149 ± 14 1099 ± 8	0.838 0.106 0.056	1219 ± 168 1015 ± 18 991 ± 2	0.971 0.027 0.002	Redfield, 1967
Neponset River Marsh (Milton, MA)	I-2216	42.270	71.050	high saltmarsh peat	-0.67	1360 ± 105	1276 ± 102	1.000	1240 ± 184 1487 ± 30 1437 ± 8 1020 ± 3	0.950 0.040 0.008 0.003	Redfield, 1967
Neponset River Marsh (Milton, MA)	I-2217	42.270	71.050	high saltmarsh peat	-0.98	1860 ± 100	1797 ± 104 1641 ± 8 1917 ± 6	0.923 0.044 0.032	1773 ± 231 2031 ± 2	0.998 0.002	Redfield, 1967
Neponset River Marsh (Milton, MA)	W-1451	42.270	71.050	high saltmarsh peat	-1.1	2100 ± 200	2104 ± 234	1.000	2075 ± 467 2667 ± 32 2602 ± 14 2566 ± 1	0.971 0.021 0.008 < 0.001	Redfield, 1967
Neponset River Marsh (Milton, MA)	W-1452	42.270	71.050	high saltmarsh peat	-1.71	2790 ± 200	2976 ± 242 3235 ± 1	0.996 0.004	2907 ± 473 2379 ± 14 2400 ± 8	0.985 0.009 0.005	Redfield, 1967
Neponset River Marsh (Milton, MA)	W-1453	42.270	71.050	high saltmarsh peat	-2.19	3110 ± 200	3312 ± 249 3044 ± 3	0.993 0.007	3284 ± 444 2811 ± 18 3808 ± 15 3757 ± 8	0.976 0.010 0.009 0.004	Redfield, 1967

Calibration or recalibration of published radiocarbon dates from northern Massachusetts and southern New Hampshire. Only dates incorporated into regional sea-level curves (above) are shown. Select marine and terrestrial limiting points are incorporated after Oldale et al. (1993) and Engelhart and Horton (2012). Elevations were extracted from 2003 Mass GIS Digital Terrain Model data and are given as meters above modern mean sea level. All dates were calibrated using Calib 6.0.1 (in conjunction with Stuiver and Reimer, 1993). Mixed and terrestrial samples (peat and organic matter) were calibrated with IntCal09 (Heaton *et al.*, 2009) calibration curves. Marine samples (all mollusks) were calibrated using Marine09 (Reimer *et al.*, 2009), corrected to a regional-averaged ΔR of 107 ± 37 years. All dates discussed in map are reported as 1-sigma calibrated ages before present (1950 AD). * - no lab error reported in published literature; standard error of ± 50 applied in calibration.

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ONSHORE-OFFSHORE SURFICIAL GEOLOGIC MAP OF THE NEWBURYPORT EAST AND NORTHERN HALF OF THE IPSWICH QUADRANGLES, MASSACHUSETTS

SHEET 3: Evolutionary Model, Sea-Level Curve, and References

By
Christopher J. Hein, Duncan M. FitzGerald, Walter A. Barnhardt and Byron D. Stone
2013

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