STATEMENT OF JOSEPH T. KELLEY, Ph.D.
Concerning The Proposal To
Dump Dredge Spoils From The Searsport Fnp
Into The Belfast Bay Pockmarks
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I am a Professor of Marine Geology at the University of Maine, School of Earth and Climate Sciences, in Orono, Maine, where I teach graduate classes in Marine Geology and Coastal Zone Management and undergraduate classes in Beaches and Coasts and the Geology of Maine. I was a Marine Geologist with the Maine Geological Survey for 17 years and testified frequently to this Board on many aspects of our coastline, was on the executive committee of the Casco Bay Estuary Committee where I worked closely with the Army on dredging Portland Harbor and broadly reviewed all Corps of Engineers proposals to dredge along the Maine coast as part of Federal Consistency Review. I was the Governor's appointee to the Oil Spill Advisory Committee and worked several topics relating to petroleum movement. I am a past President of the Geological Society of Maine and remain active in many regional, national and international professional organizations. In both my academic and public service positions, I have conducted extensive studies on the Belfast Bay methane deposits and pockmarks.

I have given more than 200 professional talks on aspects of the Maine coast and published more than 100 peer-reviewed papers on subjects ranging from sea-level changes in Maine to coastal landslides, beach erosion and salt marsh eco-geomorphology. I literally spent years of my life mapping the seafloor of the Gulf of Maine. This work is summarized in an atlas by my PhD student and colleagues, and is available on line at a Maine Geological Survey web site: http://www.maine.gov/dacf/mgs/pubs/online/ics/ics.htm.

In my experience, the most widespread potential geohazard in the coastal Gulf of Maine is the natural gas, or methane, found in Maine's seafloor. Although it does not occur in economic quantities, natural gas is prevalent throughout Maine's muddy coastal embayments and within the Gulf of Maine's deep basins. In recent geologic history, fluid-escape events occurred, and giant craters have formed in the seabed. The frequency and magnitude of these escape events are uncertain, as are the mechanisms responsible for crater formation.

1. Evidence for Natural Gas, Origin of the Gas and Pockmarks

Geologists use acoustic energy (sound) to study ocean sediments. Acoustic signals travel into the seabed and are reflected from layers in the subsurface (seismic reflection) (Rogers et al., 2006). When more than 5% of the volume of the pore spaces between mineral grains is compose of gas bubbles, all the sound is reflected back and no stratigraphy, or layering, is imaged (Figure 1). By acquiring many survey lines, we map out the spatial distribution of the gas (Figure 2). Amounts of gas at greater depths cannot be determined. When < 5% of the volume of the sediment is taken up by gas, that layer strongly reflects back sound (gas-enhanced reflector), but the signal can continue, and reveal deeper stratigraphy. This method is used by oil companies prospect for gas at much greater depths. Thus, we have mapped the distribution of gas in Belfast Bay (and other bays) and observed indications that it has migrated.

How do we know it the gas is methane and not air? We have cored sediments containing gas and flamed off the gas coming from the core. We also had gas samples analyzed and found only methane, and no higher alkanes (propane, butane), suggesting this gas comes from bacterial breakdown of organic matter and not deep-seated petroleum (Barnhardt et al., 1997).

Why do we associate methane with pockmarks? Within a pockmark region, there is no gas evident beneath pockmarks, suggesting it vented to form the crater (Figure 1).

The recent geological materials above Maine's ancient bedrock are till (a deposit of sand, mud and gravel formed by glaciers about 15,000 years ago), glacial-marine mud (muddy material expelled from ice tunnels as the ice melted away) and modern sediment. The modern sediment rests above an erosional surface (unconformity) that was dry land when sea-level was lower. All of the gas we have observed is in the modern material, and not below the unconformity (Kelley et al., 2010, 2013). Pockmarks in nearshore waters do not extend below the unconformity, which has a relatively hard surface.

Although no one has yet pinpointed the specific source of methane in estuarine and coastal sediments, subsurface gas likely originates from organic matter deposited in marshes, lakes, and bogs between approximately 12,000 and 10,000 years ago, when sea level was as much as 200 feet lower than it is today (Rogers et al., 2006; Kelley et al., 2013). Following this low-sea-level interval, Maine experienced a rise in sea level, with the ocean washing inland and depositing tens of feet of mud and sand over these former marshes and bogs (Rogers et al., 2006). Buried under a growing mass of mud, the organic material became deprived of oxygen, anaerobic bacteria decomposed the organic matter and produced methane as a byproduct in a manner similar to how methane is produced in landfills today (Judd and Hovland 2007). Alternatively, the gas originated from organic matter in estuarine mud. Gas is known in most muddy estuaries (Chesapeake Bay, Delaware Bay), but only muddy areas that were formerly glaciated in the US contain pockmarks. Of all the estuaries studied, muddy estuaries in Maine contain gas (and no sandy bays because the gas bubbled out long ago), but only a few contain pockmarks. Many of our embayments are not mapped at all (Rogers et al., 2006).

Pockmarks occur as singular features, or in fields numbering thousands of depressions. Maine's pockmarks range in size from nine to 1,000 feet in diameter and may be up to 120 feet deep (Brothers et al., 2012) (Figures 3, 4). Based on our extensive studies of the Belfast Bay pockmarks, my colleagues and I propose that fluid escape (gas and pore water) created Maine's pockmarks. Seafloor fluid escape can occur steadily or abruptly. Evidence collected in Maine supports each of these pathways, so both may happen. For example, seafarers occasionally report bubbles and sediment plumes in Maine's coastal embayments and local residents have reported them from Belfast Bay (Kelley et al., 1994; Rogers et al. 2006). One geophysical survey imaged an expulsion event (Kelley et al. 1994). A later geochemical survey, however, found little methane in the uppermost sediment near the same field, suggesting that Maine pockmarks are not actively venting gas (Ussler et al. 2003).

There is uncertainty about the activity of the field today. We do not know what initially triggered formation of the field, but earthquakes are considered to be a potential trigger. However, these features also may form episodically with changes in environmental conditions such as changes in ocean temperature, storm- or tsunami-related sea-level changes, or by physical vibration from earthquakes or other sources. If the pockmarks are actively venting it is probably most common at low tide when storm waves roll across the bay (and few people are there to observe). It is an understatement to say that gas-escape pockmarks are enigmatic. They are the largest seabed landform on muddy seafloors, and we have only begun to study them. A fuller understanding of the origin(s) of pockmarks and the ability to predict seafloor expulsion events requires more study.

Belfast Bay, Maine, contains more than 2,000 pockmarks (Figure 4). The largest pockmark in the field could contain the entire University of Maine football stadium (Figure 5). They are segregated into two distinct fields separated by a glacial deposit; the northern field contains smaller pockmarks and the modern sediments are thinner than to the south. In Belfast Bay and all other bays in Maine and New Brunswick where they are mapped, many pockmarks occur as individuals, but others occur in chains of connected/adjacent pockmarks (Andrews et al., 2010). This may be an artifact of gas migration along more permeable layers until the overlying sediment cannot contain the pressure. This is not known, however, and requires study of the sediment strength in relation to the gas pressure (both unknowns).

Pockmarks occur exclusively in muddy sediment. In Belfast Bay, the size of the mud particles is within the clay size range (< 2 microns). This material is relatively impermeable and traps the gas and other fluids until gas pressure becomes too great or a disruption allows escape. It is remarkable that the pockmark inner wall slopes reach angles up to 40˚. One would expect that such a slope of gassy, water-rich mud would fail and fill in the hole. We have conducted studies of the accumulation rate of sediment in the pockmarks using radioactive tracers that remain from bomb testing the 1950's and early 1960's (Cs-137). The distribution of the Cs-rich mud is chaotic, implying episodic landslides of younger and older material into the bottom of the craters (Brothers et al., 2011). Yet, bathymetric comparison of the pockmark field over a time frame of 9 years showed no change greater than 5 m (16 feet) in the pockmark field. A modeling study of the field with respect to tidal currents (Brothers et al., 2011) suggests that currents are capable of scouring the insides of pockmarks, resuspending sediment and possibly enlarging them. Greater confidence would exist following current meter studies within the pockmarks, but that has not been accomplished. While the Corps cites the lack of significant changes in the size and depth of these pockmarks over time to support the hypothesis that the pockmarks are not the site of actively methane venting, the more significant takeaway from the observations relating to known scouring in the Belfast Bay pockmarks is that the currents in this part of Penobscot Bay continually flushes sediment out of these pockmarks – scouring any significant sediment deposits within. In the absence of this scouring, these pockmarks would have filled up with sediment from natural attenuation and changed in depth over time.

<u>II. History of Pockmark Use for Dredge Spoils Disposal</u>

To the best of my knowledge, no permit has ever been issued for dredge spoils disposal into the methane vent pockmarks in Belfast Bay. In fact, I know of no place in the United States (or the world for that matter) where this has been deliberately attempted in a controlled manner. The Corps *claims* that there is "anecdotal" evidence of some dredge spoils disposal in Belfast Bay, and there is evidence on acoustic records that someone may have dumped dredge spoils in Belfast Bay. The nautical chart has an arrow with text that says that a part of Belfast Bay is "Disposal Area 67 depths from survey of 1872" (sic), but my memory is that the acoustic returns we interpreted as spoils were outside that area. It remains unclear if any earlier dredge spoils dumps were actually over gas or just near it; no one – including the Corps of Engineers or its contractors -

- has specifically tried to determine whether the prior Searsport dredge spoils disposal was over a methane deposit.

Indeed, in the late 1990s, the Corps proposed using pockmarks to dispose of dredge spoils for the earlier (abandoned) version of this same project. At that time, the area the Corps now calls the "Penobscot Bay Disposal Site" or "PBDS" became the subject of extensive, though unrelated, scientific assessment and study to map and understand the origins of the Belfast Bay pockmarks and methane deposits. As noted above, these studies funded by the National Science Foundation, Maine Sea Grant, the Minerals Management Service (now BOEM) and the National Environmental Satellite, Data, and Information Service, not the Corps of Engineers, were never focused on the impact of dredged spoils disposal. However, in the late 1990s, when the Corps first proposed dumping dredge spoils from deepening the Searsport FNP in the Belfast Bay pockmarks, the data obtained through these unrelated scientific studies was evaluated by the Corps' private contractor to determine and recommend *if* this area, and the Belfast Bay pockmarks, was a plausible or safe area to dispose dredge spoils.

At that time, during which I was the senior Marine Geologist for the State of Maine, the State and federal government officials that reviewed the scientific evidence compiled for this area, then expressly rejected disposal of dredged spoils in pockmarks. All of the scientific data that exists clearly states that the area in and around the Belfast Bay methane deposits and pockmarks formed by methane venting is too geologically unstable and unsafe for use as a site for dredge spoils disposal.

There was no understanding then (in the late 1990s), and there remains no understanding now, what sort of load the gas-rich sediment column could sustain, and no understanding of whether gas would migrate elsewhere within the field if it were disrupted, though turbidity and methane in possibly large quantities could be released to the water column if disrupted. Indeed, there is no evidence of any governmental entity in the U.S. or elsewhere intentionally using methane vent-formed pockmarks or areas of known methane deposits, like those found in the PBDS and "Belfast Bay," as a dredge spoils disposal site.

Further, the Belfast Bay pockmarks are not demonstrated as being capable of being used as a confined aquatic disposal site (CAD) as the Corps proposes. There are modeling observations that sediment in pockmarks are winnowed out and released by tidal currents and that this "scouring" is why the pockmarks have not filled in with sediment through natural attenuation over the years, but rather have remained essentially unchanged in size and depth for years. In addition, loading the inner walls of the pockmark with sediment might push them outward and induce more pockmarks around the original pockmark. There are many possible scenarios, but in the absence of focused study, we cannot predict the result of sediment loading of these features.

Accordingly, there is no reason to suppose, based on the currently known scientific evidence, that dredged spoils will remain in any of the Belfast Bay pockmarks – including the three pockmarks identified by the Corps for use in disposing spoils from the proposed project. It is also unclear why these three were chosen over thousands of others and what the selection criteria were. Significantly, despite knowing of these issues for more than 15-years since authorization for a Feasibility Study was provided by Congress, the Corps has undertaken *no study* of this "scouring" in the pock marks to be able to assess whether dredge spoils would or could remain in them even if successfully placed as planned, or to determine the level and effects of turbidity in the water column that would result from disposing of spoils in these pock marks and in these conditions and currents. Further, no effort has been made to assess the pressure of the gas or strength of the sediment confining it, nor any investigation of the capability of the gas to migrate.

Even the August 2013 DAMOS study conducted by the Corps, reported in 2014, ignored the greatest issue presented by the proposal to dispose of dredge spoils in the PBDS. Specifically, the Corps has failed to address the profound uncertainty that continues to exist about the relative stability of the field with respect to being loaded, even accidently, by dredge spoils (particularly in this volume). Until there is a physical/geological oceanographic study of sediment/tidal current interactions, we will not understand how long spoils will remain in place. Until there is an engineering/geotechnical study of the gas pressure and sediment strength and sediment column permeability, we cannot really be confident what will happen when gassy sediment is disrupted, including disrupted by the introduction of almost a million cubic yards of sediment through dredge spoils disposal.

The result could be significant and on-going turbidity in the water column that could have deleterious impacts on the ecology and fisheries in Penobscot Bay. This effect could be especially damaging to lobster settlement and survivability. Neither the 2013 FSEA, nor the 2013-2014 DAMOS study address or even consider the potential consequences of such a calamity of turbidity on the valuable fisheries in Belfast Bay and the surrounding Waldo County waters or in Penobscot Bay and the Penobscot Watershed that NOAA designated in 2014 as having special significance to U.S. fisheries.

III. Personal Knowledge Regarding This Corps' Proposal

In my role as Marine Geologist for the State of Maine, I was personally involved in the decision to reject the Belfast Bay pockmarks for use in dredge spoils disposal in the late 1990s. In fact, over the years I have referenced this proposal to use the pockmarks for this purpose in talks as an example of an absurd proposal that proper scientific study was able to avoid. The Maine Policy Review paper (Brothers et al., 2010) by my former PhD student, Laura Brothers, and colleagues was written specifically to call attention to the hazard that gas in sediments can pose to engineering operations.

In the Spring of 2013, the Corps contact Dr. Laura Brothers, now with the U.S. Geological Survey (USGS) and me to discuss this most recent proposal to expand and deepen the Searsport FNP and dump large amounts (almost a million cubic yards) of dredge spoils into the pockmarks off Islesboro. I was surprised by this proposal in light of the prior rejection of this area for this purpose and the known risks of using this area for this purpose.

Corps staff assured me that they could be more accurate in the method of placement with current equipment and could place the spoils in the center of a pockmark and asserted that, if that if this proved not to be the case when they started to dump the dredge spoils, they "would stop dumping." Based on my prior experience with working with the Corps of Engineers in other projects, in Maine and New Orleans, I am skeptical that this would actually be the case, no matter how sincerely staff believes these representations now.

When I queried staff about why this geologically unstable site was their preferred disposal site they stated that "it would cost too much" to use another disposal site, including the Rockland Disposal Site (RDS) that had previously been proposed for this purpose. While I do not believe that the Rockland Disposal Site is an appropriate disposal site for this or any other dredge spoils disposal, based on my own study of the RDS and its characteristics, currents and geologic features, the decision to place dredge spoils in the site the Corps is calling the "Penobscot Bay Disposal Site (PBDS) because of cost considerations is not sound. As stated above, this site is not appropriate for use as a CAD due to scouring and loading the pockmark walls and the presence of methane in the sediment.

The Corps has conducted no studies to suggest that the use of geologically unstable pockmarks in Belfast Bay can be safely accomplished, although the Corps has had fifteen years since obtaining Congressional authority in July 2000 to conduct a Feasibility Study of the proposal to deepen the Searsport FNP to conduct such studies. Based on the existing, extensive scientific data that is available however, in my opinion this site is not geologically suitable or safe for the proposed use in dredge spoils disposal and no permit should be issued for this purpose. The calamity of turbidity which scientific evidence suggests would result could be devastating even if all spoils disposed there are clean and free of contamination. However, the possibility of re-suspension of buried contaminants, including HoltraChem-contaminated material, makes the use of pockmarks in this area even more dangerous, and threatens the reputation for wholesomeness of all Penobscot Bay fishing resources.

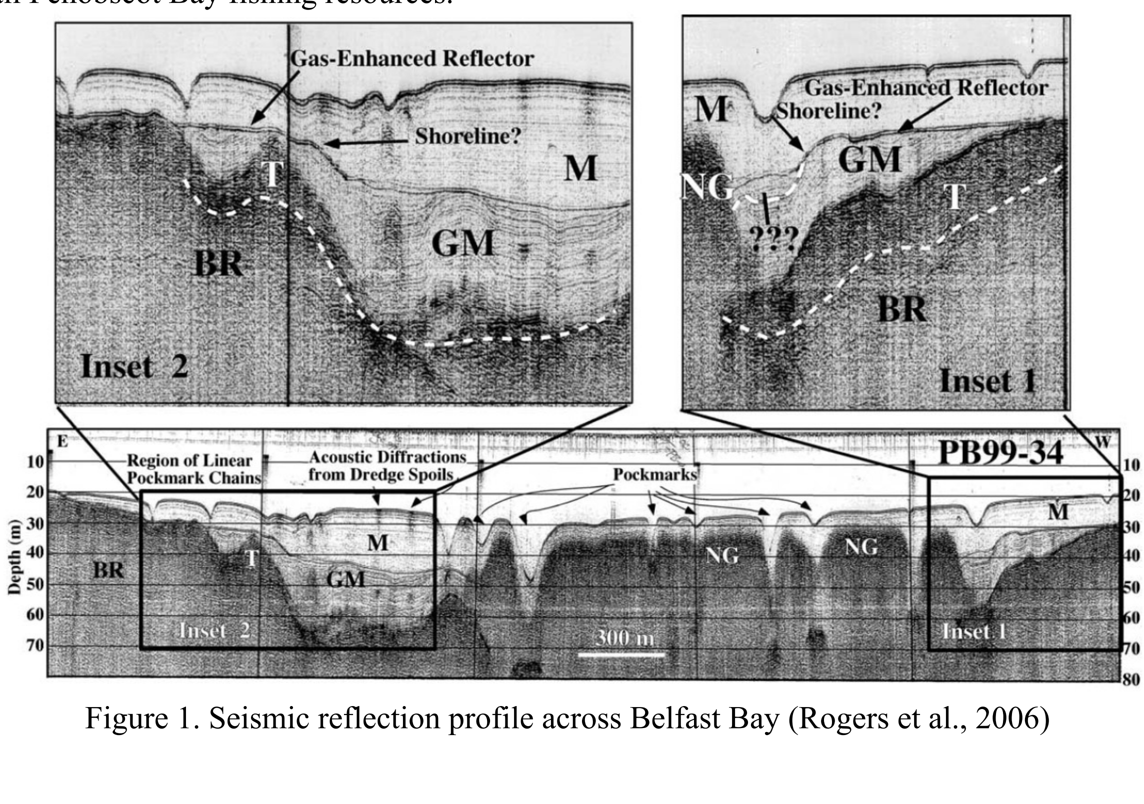

Figure 1. Seismic reflection profile across Belfast Bay (Rogers et al., 2006)

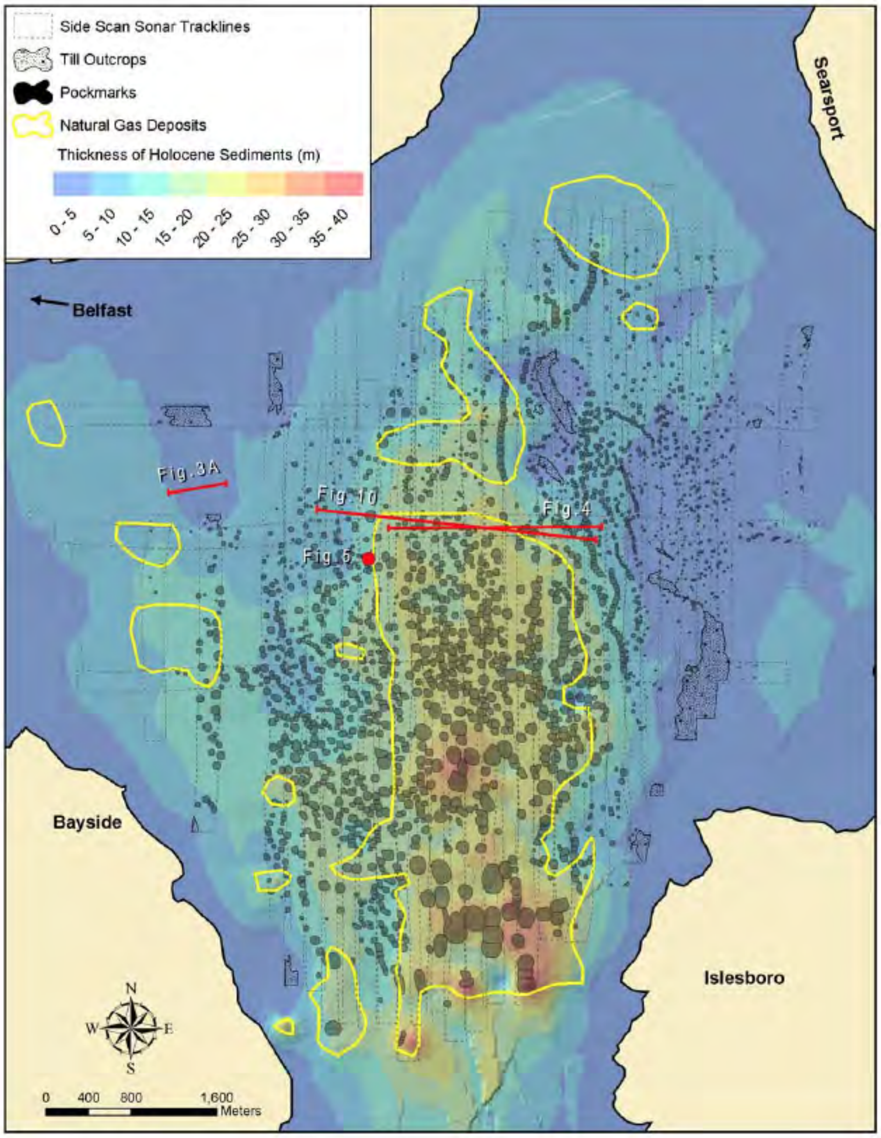

Figure 2. Gas field and associated pockmarks, Belfast Bay (Rogers et al., 2006).

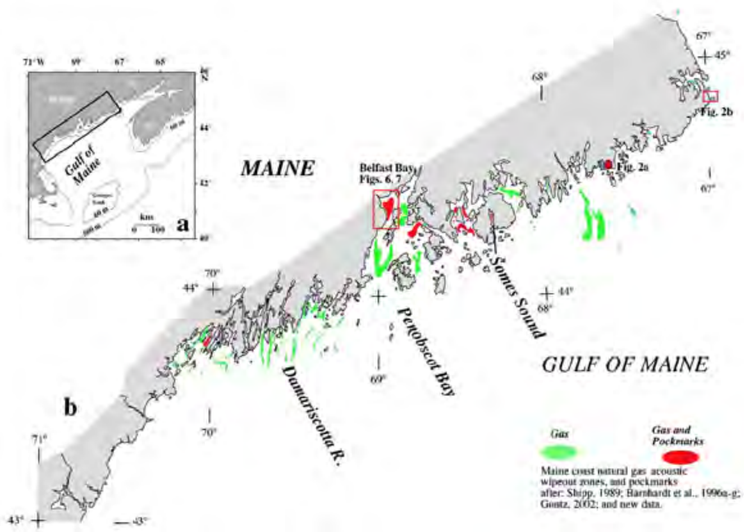

Figure 3. Extent of gas and pockmarks in Maine (modified from Rogers et al., 2006)

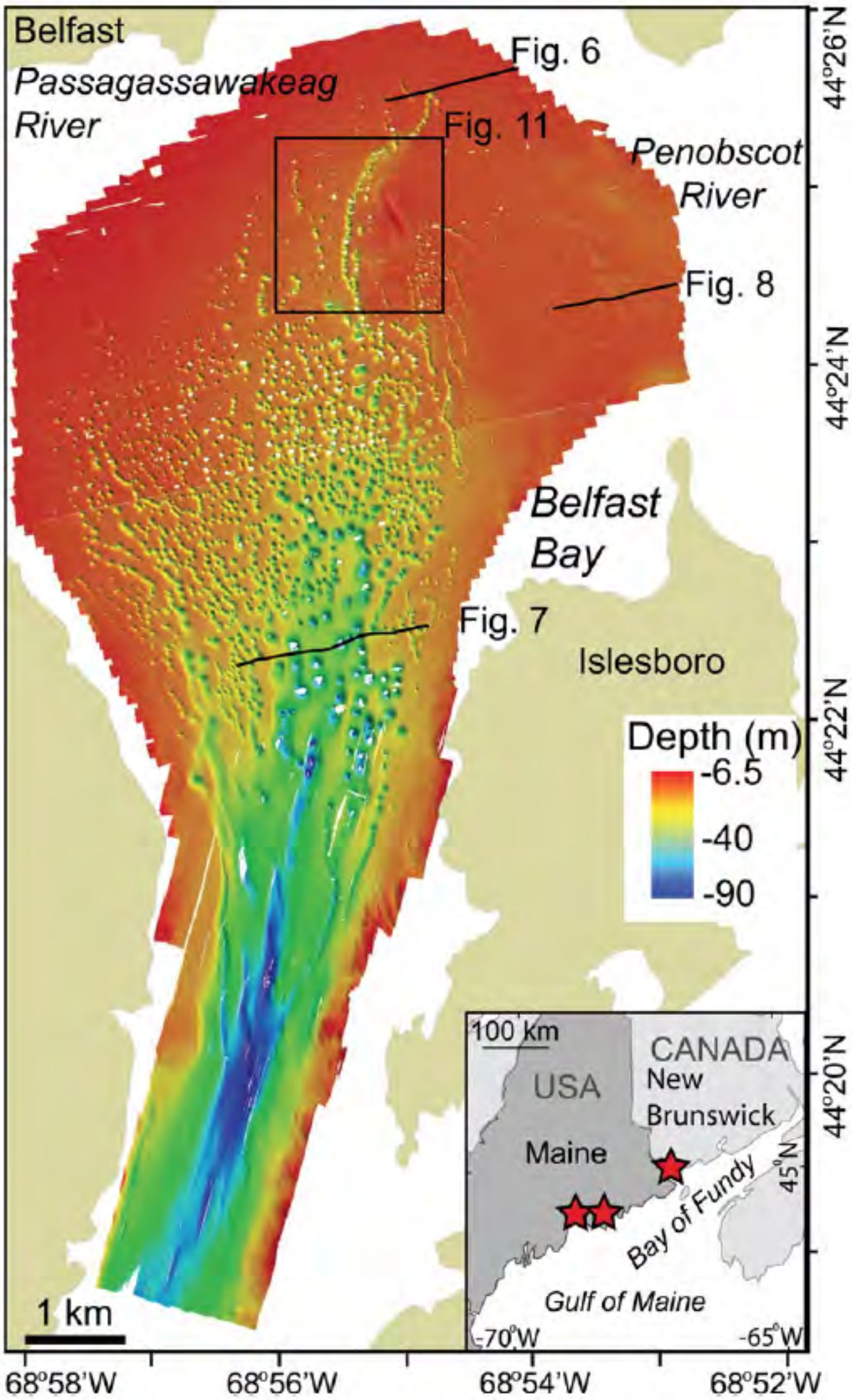

Figure 5. Belfast Bay pockmark field (Brothers et al., 2012).

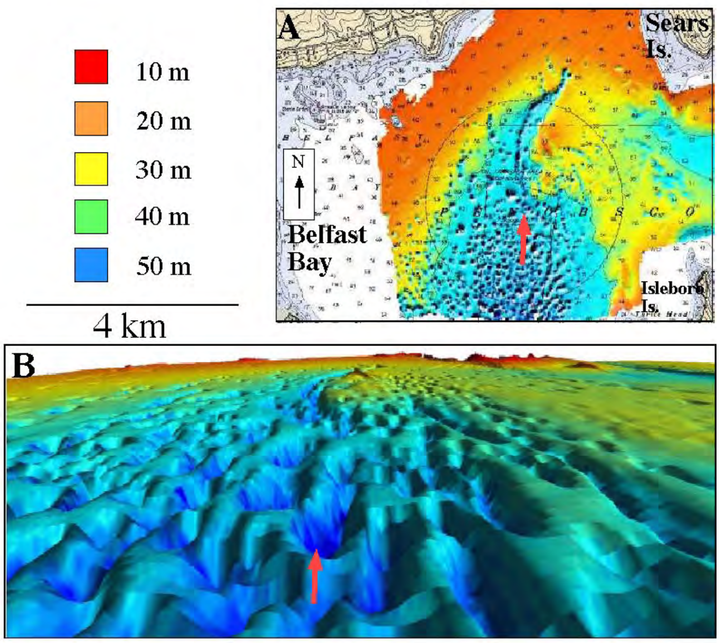

Figure 5. Oblique view of Belfast Bay pockmarks (Rogers et al., 2006).