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Article

# Re-Visiting Viking Vinland: I. Locating 'Keelness', a Viking Shipwreck Site in North America

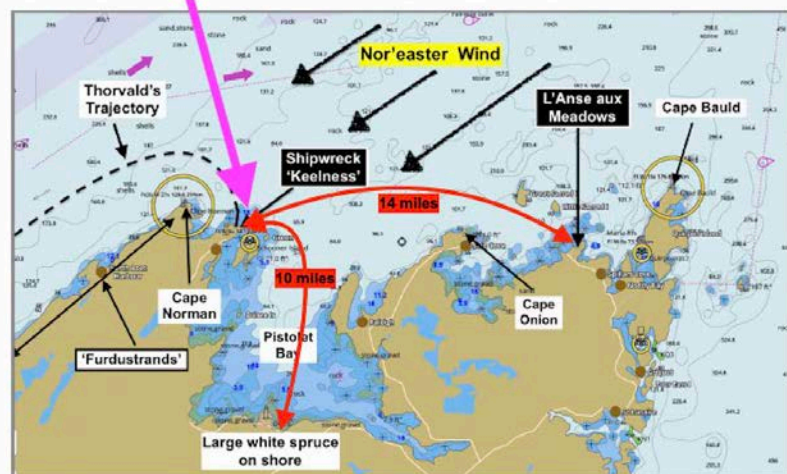
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**Abstract:** The series 'Re-Visiting Viking Vinland' describe re-evaluation of Viking voyages from Greenland to North America, from about 985 to 1026 A.D. American landfalls were located using clues from Norse sagas, logic, creative imagination, and advanced imaging technology. Paper I describes a dramatic voyage of Leif Eriksson's brother, Thorvald, during the second of four successful 'Vinland' voyages. Thorvald borrowed Leif's ship for further exploration, was caught in a storm, "shattering" the keel, and disabling the ship. In *Greenlanders' Saga*: "They had to stay there for a long time while they repaired the ship. Thorvald said to his companions, 'I want to erect the old keel here on the headland and call the place Kjalarnes (Keelness)'. Where was Keelness? Re-imagining the voyage, the search led from 'Leif's Booths', Leif's original 'Vinland' site in New Brunswick, Canada, to the north coast of Newfoundland. Using logic, a single satellite image, and follow-up drone scans, the Keelness site was found, very near L'Anse aux Meadows, the first authenticated Viking site in North America. Covid-19 restrictions, and lack of certified professionals, precluded site-visits or excavation. Advanced data-processing of drone data was used to confirm the site, while unexpectedly revealing several distinctive ship-repair features; with visible and thermal imaging supporting this site as 'Keelness'; perhaps the first Viking site unequivocally named in the Vinland sagas.

## Locating 'Keelness', Viking Shipwreck Site in North America.



**Shipwreck site of Leif Eriksson's ship; only 14 miles from L'Anse aux Meadows**

**Keywords:** Viking; Vinland; Keelness; remote imaging

## Introduction

### 1. Re-visiting Viking 'Vinland''

'Re-Visiting Viking Vinland' is a series of papers re-evaluating Viking voyages from Greenland to North America, dating from about 985 to 1026 A.D. An unconventional approach was used in searching for American landfalls; using, in sequence, clues from the Norse sagas, logic, creative imagination, and advanced imaging technologies. The original plan for this series of papers was to mirror the chronological sequence of the voyages, beginning with Leif Eriksson's historic voyage in about 1003 A.D. He 'discovered' the New World, established a basecamp at 'Leif's Booths' (Houses), and named it 'Vinland' (Norse: 'Wineland'), after his foster-father, Tyrkir, found grapes. Artifact dating for the site is still lacking, so this segment will likely be the subject of a later, out-of-sequence paper.

Only four of the six recorded Vinland voyages resulted in landfalls, and here in paper I we describe an episode during the second successful expedition. Leif's brother, Thorvald Eriksson, had borrowed Leif's ship and Leif's house(s), for his own voyage of exploration. In his third year he suffered a catastrophic shipwreck, completed an heroic ship repair, but was killed a short time later by the local residents, effectively ending the voyage.

Paper I follows our re-creation of the voyage's trajectory, from 'Leif's Booths (Houses)' as the hypothetical departure point, to a shipwreck site on the north coast of Newfoundland, Canada, and subsequent discovery of 'Keelness', the ship repair site. Companion paper II describes a 'virtual excavation' of the Keelness site. Covid-19 restrictions, and lack of certified professionals for excavation permits, left a 'virtual excavation' as the only option. Remote imaging and advanced data-processing was used exclusively, in interpreting ground features accidentally revealed in preliminary drone scans.

## 2. Historical Perspective

Popular interest in the 'Vikings' has endured as entertainment, but history of the real Vikings and their voyages to North America, has largely faded into obscurity. It has been more than 60 years since the discovery and excavation of a Viking site at L'Anse aux Meadows (**LAM**) in Newfoundland, Canada, by Norwegians Helge Ingstad, and his archaeologist wife Dr. Anne Stine Ingstad. It still remains the first and only Viking site authenticated in North America, and the first World Heritage Site, although its existence is scarcely known by today's students of history. There was a brief resurgence of Viking interest in 2000 A.D., for the millennium commemoration of Leif Eriksson's original journey to the New World in around 1000 A.D. (1). Recent 'Viking' news in 2021 described an innovative radiocarbon dating study of wood artifacts recovered from **LAM**. Several wood samples, cut with Viking metal tools, were precisely dated to the fall of the year 1021 A.D. (2). We will show in a later paper how this most likely correlates with a home-ward-bound journey of Thorfinn Karlsefni, returning from his unsuccessful expedition to settle the New World.

## 3. Historical Context - Sagas and Voyages

Since current readers may be unfamiliar with Viking history, a brief summary or 'refresher' is warranted. 'Saga' in Norse means an oral account, or something which is said. The original Norse sagas were a mix of entertaining fictional, historical, and genealogical narratives. These were narrated from memory, by Skalds (poets) and Sagamen (saga narrators), at celebratory gatherings, or to pass the long northern winter nights. The sagas were passed down orally from one generation to the next for hundreds of years, before eventually being written down. With the spread of Christianity, the coincidence of written language (Latin), literate writers (church scribes), robust document substrates (parchment and vellum), and affluent patrons, resulted in sagas transcribed in Iceland, mainly in the 13th and 14th centuries.

For us there are two relevant sagas, Erik the Red's Saga (**ERS**) and Greenlander's Saga (**GS**), with only a few scattered mentions of 'Vinland' in other historical documents. Both **ERS** and **GS** are generally considered descriptions of the same events, presented differently because they were perhaps remembered differently by the original authors. Over

more than a hundred years of modern Vinland scholarship, reliance for the 'truth' in one or the other saga has fluctuated, with a few prominent historians discounting the veracity of both. **GS** (Flateyjarbok - Flat Island Book, for where it was found) was transcribed anonymously and appears the most reliable. It describes in some detail six separate journeys headed for North America, mostly by members of Erik the Red's family, but only four making a landfall. There are two slightly different **ERS** transcriptions, one version (Hauksbok) significantly edited and written by Hauk Erlendsson, after whom it was named; the other Skalholt book for its origin. Perhaps to amplify the 'heroic' accomplishments of his ancestors, Thorfinn Karlsefni and wife Gudrid Thorbjornardottir (9 generations earlier), Hauk combined most of the **GS** voyages into a single one, with Karlsefni as the leader, and Erik the Red's family as only 'bit players' in the drama. For our purposes, we relied on **GS** for most of the journeys, but took Hauk's version into account for Karlsefni and Gudrid's voyage and experiences.

#### 4. *The Viking Vinland Voyages*

The first voyage, of Bjarni Herjolfsson in about 985 A.D., was accidental and without a landfall. He was trying to sail from Iceland to join his father in Greenland, but was blown past Greenland, ending up in a lengthy detour along the Labrador coast, before reaching his Greenland destination.

The second voyage was the famous journey of Leif Eriksson in about 1003 A.D. He found grapes, named his landfall 'Vinland' (Norse: 'Wineland'), built temporary housing ('Leif's Booths'), and later more substantial 'Leif's House(s)' for overwintering. Loading his ship next spring, with valuable hardwood lumber, 'grape-wood' (Norse: 'vinber') and raisins, he returned to Greenland, rescuing a shipwrecked crew enroute, subsequently rich and renowned; Leif "the Lucky".

The third journey was by Leif's brother, Thorvald Eriksson, probably 1006 to 1010 A.D. He had borrowed Leif's Houses and Leif's ship, but in his third year suffered a major shipwreck at 'Keelness' (Keel Point). This, and subsequent repair of the ship, are described in papers I and II of this series. Shortly after completing an incredible ship repair, Thorvald was killed by 'Skraelings', ancestors of Canada's First Nations people. He was most likely the first European killed and buried in the New World, a dubious distinction. The follow-up fourth voyage was even more disastrous. Thorvald's brother, Thorstein, set out to repatriate Thorvald's body a few years later, but a summer of terrible North Atlantic weather foiled his attempt, with he and many of his crew dying in an epidemic shortly after returning to Greenland.

The fifth voyage, about 1017 to 1022 A.D., was that of Icelandic merchant Thorfinn Karlsefni, and his wife Gudrid Thorbjornardottir (Thorstein's widow, whom Karlsefni had subsequently married). Karlsefni was accompanied by another ship of Icelanders, and a ship of Greenlanders; totaling around 160 people. They brought a variety of livestock, because their intention was to settle in Vinland if they could. Conflicts with the Skraelings, and near mutiny of his crew, forced a retreat; returning to Greenland, then on to Norway, before settling down in Iceland, very rich. Evidence for his transient stay at both 'Keelness' and L'Anse aux Meadows will be covered in a later paper.

The sixth and final recorded journey was that of Freydis Eriksdottir, sister of Leif, Thorvald and Thorstein, accompanied by another ship and crew of Norwegian traders. During the second year, Freydis had the Norwegian crew killed, stole their ship, loaded it with lumber, grape-wood and raisins, and returned to Greenland as if nothing had happened. Her treachery was found out, and her family stigmatized.

Voyages west from Greenland, to at least as far as Markland (Wooded Land) (Labrador), continued long after those of the sagas. The last recorded voyage mentioned in the Iceland annals in 1347 A.D., while trying to return from Markland to Greenland with a load of wood. It was a small ship with a crew of 15 men, missing their anchor, and accidentally blown to Iceland. The Greenland colonies were ultimately unsustainable, and finally abandoned in the 15th or 16th century. There is unsubstantiated speculation, that

in desperation, some Vikings may have again sailed to Vinland, but no irrefutable proof yet.

During the four successful voyages, several distinctive areas were named, Helluland (Flat Rock Land), Markland (Wooded Land), and Vinland (Wineland), and several specific locations; Leifsbudir (Leif's Booths/Houses), Keelness (Keel Point), Krossanes (Crosses Point), Furdustrands (Marvelous Strands), Straumsey (Streams Island), Straumfjord (Fjord of Currents), and Hop (Tidal Estuary). During the early years, Greenland Norse probably made hundreds of American landfalls, but only extended and persistent occupation of a site might have left visible traces after 1000 years. It was the more intensively occupied sites for which we chose to search; Leif's Booths, Keelness, Straumfjord, and Hop. Our optimistic objective was to locate and validate one of these sites. This paper describes 'Keelness', perhaps our first success, finding the site of Thorvald Eriksson's shipwreck and ship repair. Our presumptive location of Leif's Booths will remain tentative, until a dating study can be carried out.

### 5. Historical Context - Thorvald's Voyage of Exploration

Leif Eriksson is widely known as the first European to land in North America, naming 'Vinland' (Norse: 'Wineland') for the grapes which Tyrkir found. Leif never returned to America, but his ship did; borrowed by brother Thorvald, with a crew of 30 men. Thorvald and crew uneventfully sailed from Greenland to 'Leifsbudir' ('Leif's Booths'/'Vinland'), in about 1006 A.D. After their first winter, Thorvald sent some of the crew west, in the larger of the two 'after-boats', exploring up the St. Lawrence River, perhaps as far as present-day Quebec City. The saga does not say where Thorvald and the rest of the crew went in the big ship, but likely explored the southern shores of the Gulf of St. Lawrence. Next spring, Thorvald left a 'caretaker' group at Leif's Booths, taking the big ship, and most of the crew, on a voyage of continued exploration.

The outcome was a catastrophic shipwreck, the ship severely damaged, but not lost. Skillfully rebuilt over "a long time", it eventually carried the crew back home to Greenland; alas without Thorvald, killed in a revenge attack by the 'Skraelings'. We believe we have located both shipwreck and ship repair sites on the north coast of the Great Northern Peninsula in Newfoundland, Canada. When confirmed, the 'Keelness' (Keel Point) site may be the first **specifically named** Viking site found in North America, located at **51.36.54.36 N, 55.51.21.02 W**. Only 22 km (14 miles) west of L'Anse aux Meadows (**LAM**), it suggests a definite connection between the two sites, explored in Paper II.

In the last 200 years, relatively few Viking-era ships have been found and investigated. Almost all have been either (a) 'grave ships' (b) old ships deliberately sunk to deter invasion, or (c) ships destroyed while in port (accidentally or intentionally). On ordinary ocean voyages, probably hundreds of Viking ships succumbed to poor maintenance, bad weather, or bad luck; disappearing without a trace. Remarkably, imaging evidence suggests important remnants of Leif Eriksson's original ship may still be preserved in sphagnum moss at the ship-repair site, and only a few miles from **LAM**. Coincidence? or perhaps not!

## Materials and Methods

### 1. This Project

As non-professional historians, our approach to archaeology was somewhat unconventional; sometimes by design, but mostly by necessity. Fallout from the Covid-19 epidemic limited us to a 'virtual excavation'; substituting non-invasive drone imaging for traditional excavation. A process of logic and narrative-creation suggested answers to the 'what', 'who', 'when' and 'where'. Advanced data-processing, and creative imagination provided tentative answers to the 'how', and 'why'. Lessons learned in this study could be valuable for future professional research at the site; while these techniques might be more widely applicable at other historically important sites.

## 2. The 'Vinland' Sagas

Foundational 'materials' were obviously the Norse 'Vinland' sagas, *Greenlanders' Saga (GS)*, and *Erik the Red's Saga (ERS)*. Some Vinland scholars, even today, still consider these sagas as merely fiction. We embraced them (with reservations), in imagining the locations and events which they vividly describe. This seemed justified, since the sagas (while indisputably flawed) are the only documentary eye-witness reports in existence. Our reliance on, and confidence in, the sagas was amply justified by our study results. Thorvald's entire voyage and shipwreck is described in **GS** in only these three cryptic sentences; highlighted with 'facts' or 'clues' on which we based our hypotheses. Not much to go on, but all there is!

"Next summer Thorvald sailed **east** with his ship and then **north along the coast**. They ran into a **fierce gale** off **a headland** and were driven ashore; the keel was **shattered** and they had to stay there for a **long time** while they repaired the ship. Thorvald said to his companions, 'I want to **erect the old keel** here on the headland, and call the place **Kjalarness (Keelness)**'" (Magnusson and Palsson, 1965),(3).

## 3. Three Phases of Study

There were three distinct phases to our study, the first two described here in Paper I.

### Phase 1 - Point of Departure

Retracing Thorvald's voyage, we needed to find 'Leif's Booths' as the likely departure point. Ms. Birgitta Wallace, Senior Archaeologist Emeritus for Parks Canada, was a key excavator of the L'Anse aux Meadows (**LAM**) Viking site, in the 1960s and 1970s. She suggested that Leif's Booths was most likely in the Miramichi/Bay of Chaleur area of New Brunswick (map, Fig. 1) (4). Using the sagas and logic, we tentatively placed Leif's Booths at Nepisiguit in the Bay of Chaleur (Mi'kmaq; 'Rough Waters'), today's Bathurst, New Brunswick. We based it on geographic similarities, saga clues, and a satellite image suggesting a Norse structural 'footprint'.

### Phase 2 - Voyage Trajectory and Shipwreck Site

With this start point, we carried out phase 2, determining the likely trajectory of the voyage. With **GS** text, we imagined the route; heading east, then north, rounding a promontory, and ending in a shipwreck on the north coast of Newfoundland. A single satellite image near our hypothetical target area suggested a man-made feature, subsequently confirmed with drone imaging, and pointing to a possible ship repair location.

### Phase 3 - Analysis of Ship Repair Site

Dealing with Covid-19 lockdowns, phase 3 started with non-contact, drone imaging, to verify the satellite image. These flights accidentally revealed other features, completely unexpected, but consistent with Viking ship repair activities. Advanced data-processing of these images evolved into extensive analysis, and narrative construction for the entire ship repair episode; presented in paper II as a 'virtual excavation'.

## 4. Maps and Geography

Publicly available satellite imaging (Google Earth, Apple Maps, ESRI, Maxar Technologies, satellites.pro, etc.) was used to track the trajectory of the ship (see map, Fig.1). Starting from Nepisiguit in the Bay of Chaleur, heading east across the Gulf of St. Lawrence, and then north along the Newfoundland's west coast, with Cape Norman as the most prominent and probable 'headland' (Norse: 'ness'). Since a shipwreck was involved, we integrated nautical maps and underwater topography, to create a hypothetical sequence of events leading up to the shipwreck itself. Master James Cook (later Captain Cook) surveyed here in 1765, in Great Britain's territorial disputes with France. Using Cook's survey map we identified underwater structures which could have contributed to

a shipwreck. Modern charts, with greater detail, were used to create a detailed, imaginary scenario, consistent with both topography and climatology.

#### 5. Remote Sensing - Satellite

Satellite imaging was used to locate 'Leif's Booths'/'Vinland', the likely point of departure, prior to the shipwreck narrative. It was used again when scanning the Newfoundland coast for visual evidence of human activity. Scanned locations were not randomly chosen, and not based on guess-work. Instead, the most probable locations were based on saga texts, and simple deductive logic. Honesty demands the disclosure that our first attempt ended with a common, but still embarrassing failure; mis-identifying modern structures as possibly Viking. Trying again, with hubris and more realistic criteria, this time a feature was prominent enough, and satellite imagery detailed enough, that we successfully detected a ground pattern suggestive of human activity, very close to where we estimated one should be. With our point of departure, and the saga text as itinerary, maybe logic had led us to the correct site. A single satellite image, a suspicious ground pattern, perhaps a ship repair structure; and the mental challenges began.

#### 6. Remote Sensing - Drone

To confirm the satellite image, we turned to drone imagery, controlled from a public right-of-way to protect the physical integrity of the site, and respect Newfoundland's laws and regulations. The scans were conducted in a manner similar to that described in Spera et.al, (2022) (5). After seeing a suspicious satellite image of parallel lines, we took heed of another recent attempt at locating a Viking site in Newfoundland. A satellite image had shown an unusual ground pattern, erroneously suggesting a 'man-made' feature. The researchers transitioned directly from satellite image to exploratory/confirmatory excavations, which we had also originally envisioned for our study, before Covid-19 intervened. After two excavation seasons, in their final report the team concluded that they "*found no evidence whatsoever for either a Norse presence or human activity at Point Rosee prior to the historic period. ... None of the team members, including the Norse specialists, deemed this area as having any traces of human activity.*" (6). Pretty conclusive! We would have needed professional collaboration to pursue an excavation anyway, but enlisting help based on a single satellite image was highly unlikely. Instead, we contracted for close-up drone imaging of the site, primarily just to confirm the provocative satellite image.

The site was rather remote, with considerable cost in drone deployment alone. But since this cost was already committed, we made the strategic decision to scan as much area as geographically and economically feasible, and to also add thermal (FLIR -forward looking infrared) imaging to the sensing suite. Even though slightly outdated, the following paper gives an excellent description of thermography in archaeology (7). If the satellite feature turned out to be true, there might be other features not detectable by satellite imaging alone. It was a calculated gamble, but one which ultimately paid off, as described in paper II; Re-Visiting Viking Vinland: II. 'Virtual Excavation' of 'Keelness', a Viking Shipwreck Site in North America.

In confirming the satellite image, the drone accidentally captured not only numerous additional surface features, but also sub-surface features (via thermal/infrared), further supporting our still-evolving, hypothetical narrative. Prevented from in-person follow-up, advanced digital data-processing was applied to the preliminary drone data, using ArcGIS software, creating virtual images as described in Results and Discussion below.

#### 7. Imagination and Logic

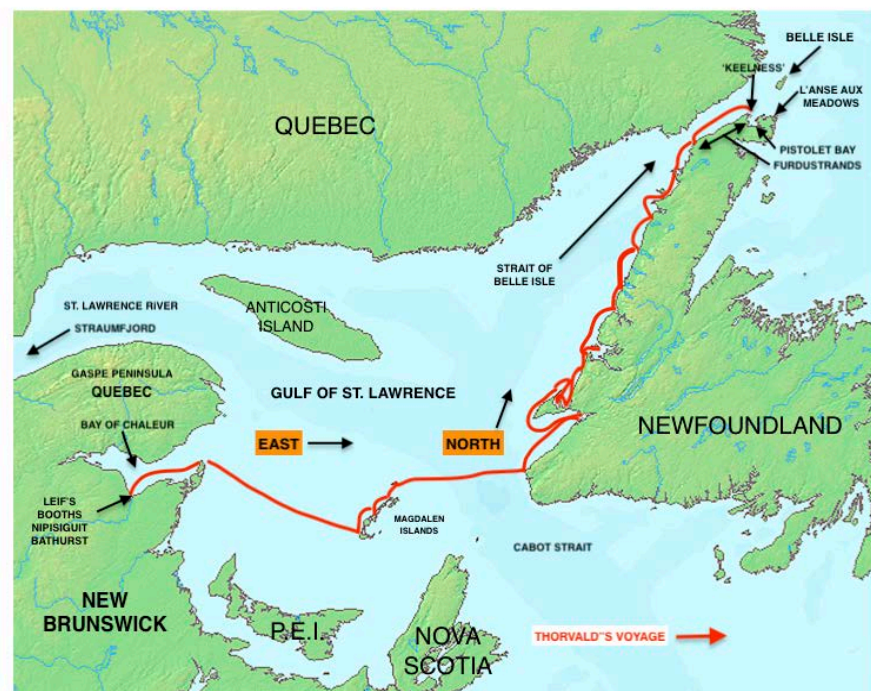
Advanced imaging technology can be a powerful tool in archaeology, but undirected is still of limited value. Imagination and deductive logic are equally, if not more important, when documentary information is sparse or non-existent, as with the sagas. Analyzing the few saga 'facts' led us to look first for the 'where', while an imaginary ship-

repair narrative primed us to recognize the 'what'. Finally, we stitched together the informational strands to create a narrative for the whole episode; still hypothetical, but realistic and plausible.

## Results and Discussion

### 1. 'Leif's Booths' - the original 'Vinland' site

Re-creating the trajectory of Thorvald Eriksson's voyage, required identification of 'Leif's Booths' as the departure point. Ms. Birgitta Wallace, Senior Archaeologist Emeritus for Parks Canada, had persuasively argued that Leif's Booths, the original 'Vinland' site, would be located in the Miramichi/Bay of Chaleur area of New Brunswick, Canada [4]. Accepting this expert opinion for guidance, we began our search.



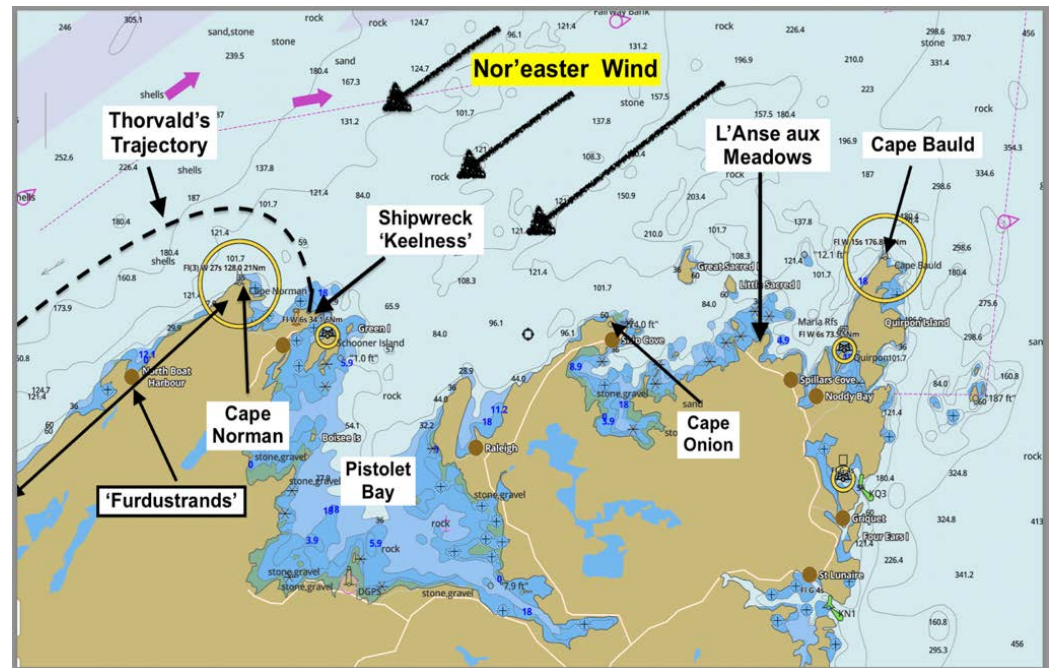
**Fig. 1.** Central area of 'Vinland', with hypothetical route of Thorvald Eriksson's voyage. 'Leif's Booths', 'Keelness', L'Anse aux Meadows, and other key locations are indicated. (Derived from demis.com image under Creative Commons License).

Studying the New Brunswick coastline, we sought distinctive geographical, geological, and environmental features mentioned in the sagas. We narrowed down the 'Leif's Booths' location to Nipisiguit (Mi'kmaq: 'Rough Waters'), present-day Bathurst, New Brunswick. A satellite image resembling the 'footprint' of a Viking house foundation, was detected only a few hundred feet from our hypothetical target location. Whether coincidental or prophetic still remains to be seen. It was however, reminiscent of Helge Ingstad's first encounter with L'Anse aux Meadows; being shown ground patterns of 'Viking houses' in a pasture, by 'headman' George Decker. Similar patterns of **known** Viking provenance, at LAM and in Norse Greenland, support our working hypothesis, but will require excavation and/or radiocarbon dating to resolve. Maybe later.

### 2. Logic

Returning to the saga, with Nipisiguit as a hypothetical starting point we followed the trajectory described. Leaving the Bay of Chaleur, Thorvald sailed **east**, across the Gulf of St. Lawrence to Newfoundland, and **north along the coast**, Newfoundland's west coast. This brought us to Cape Norman at the northwest tip of the Great Northern Peninsula.

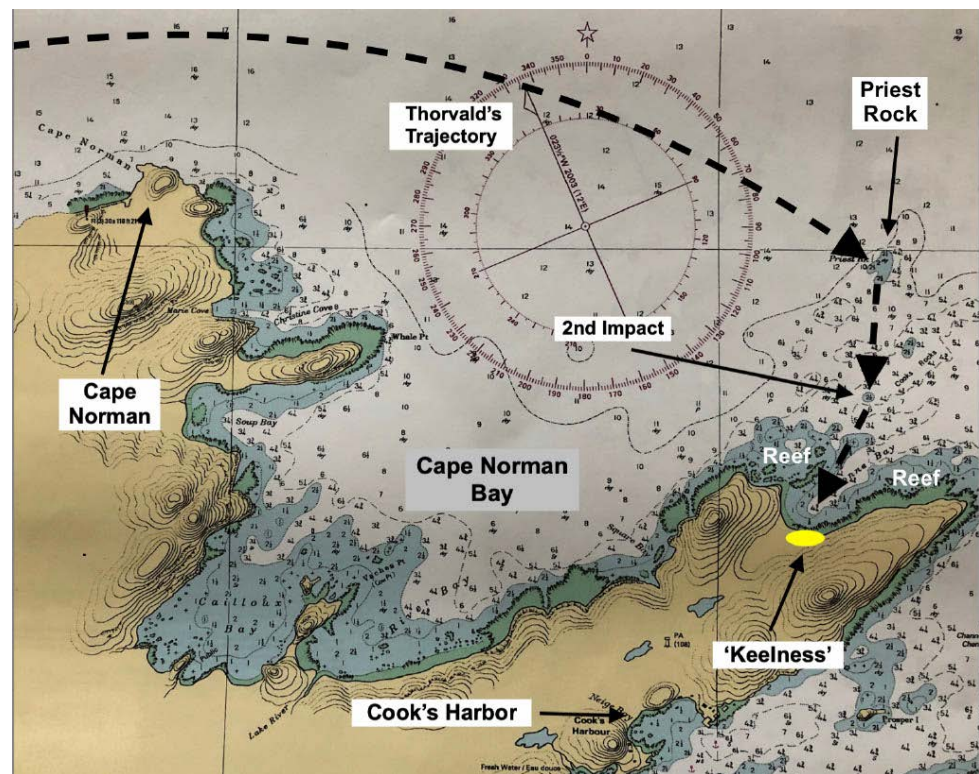
The promontory is described in one saga translation as "a certain cape"; so perhaps not just any promontory, but a familiar and recognizable landmark (see maps, Figs.1 & 2).



**Figure 2.** Detailed nautical map of shipwreck area, with landmarks and hypothetical ship's trajectory. (Derived from image on fishing-app.gpsnauticalcharts.com, based on CHS data). FOR ILLUSTRATION PURPOSES ONLY! THIS PRODUCT IS NOT TO BE USED FOR NAVIGATION.

Cape Norman is a key landmark even today, for mariners entering the Gulf of St. Lawrence, through the Strait of Belle Isle; 61 feet high, visible in good weather from across the strait, only 14 miles wide here, as the seagull flies. Rounding the cape, they were hit by a sudden storm, driven ashore, and "shattering" the keel. Lucky to have survived, a Viking ship consultant advised that they would have repaired the ship right where they landed, fortunately circumscribing a limited search area for scanning satellite images. If our interpretation was correct, their landfall must be close by, somewhere east of Cape Norman.

Satellite imagery was successful in finding archaeological sites in Egypt, South America, and Asia, but failed in other previous searches for Viking sites in Newfoundland. Here, we used logic and a hypothetical trajectory to select possible sites, before employing satellite imaging. Saga translations of "breaking", "smashing" or "shattering" the keel suggested catastrophic damage. The keel of a Viking 'knarr' was a substantial piece of lumber, likely strong oak wood in this case, and here estimated about 36 inches high, and perhaps 10-12 inches wide; unlikely to be permanently compromised just by running aground, even onto rocks. "Shattering" suggested 'blunt force trauma', a sudden, sharp, violent impact. For this we imagined a large swell picking up the ship, and dropping it straight down, close to amidships, on a barely submerged rock. Searching for possible candidates east of Cape Norman, we found 'Priest Rock' (which we humorously renamed 'Thorvald's Shiprock').



**Figure 3.** Northwest tip of Newfoundland's Great Northern Peninsula, showing site of 'Keelness', nearby landmarks, and trajectory of Thorvald's voyage. FOR ILLUSTRATION PURPOSES ONLY! THIS PRODUCT IS NOT TO BE USED FOR NAVIGATION.

The site of our focus, Cook's Harbor peninsula, is only 14 sea miles (22.5 km) from LAM, (see map, Fig. 2); immediately suggesting a connection, explored in paper II. Andrew Fossum, a previous Vinland historian, had used similar logic, also identifying Cape Norman as the shipwreck site 100 years ago! (8). Because the coastal steamer did not serve that stretch of coast, he and a companion hiked 105 miles round-trip in 6 days, from Flowers Cove to Cook's Harbor. In retrospect, he may have walked within about a mile of his objective without even knowing it; 'Keelness'. A near miss, but a remarkable piece of detective work; sadly, now long forgotten!

### 3. Imagining the Shipwreck

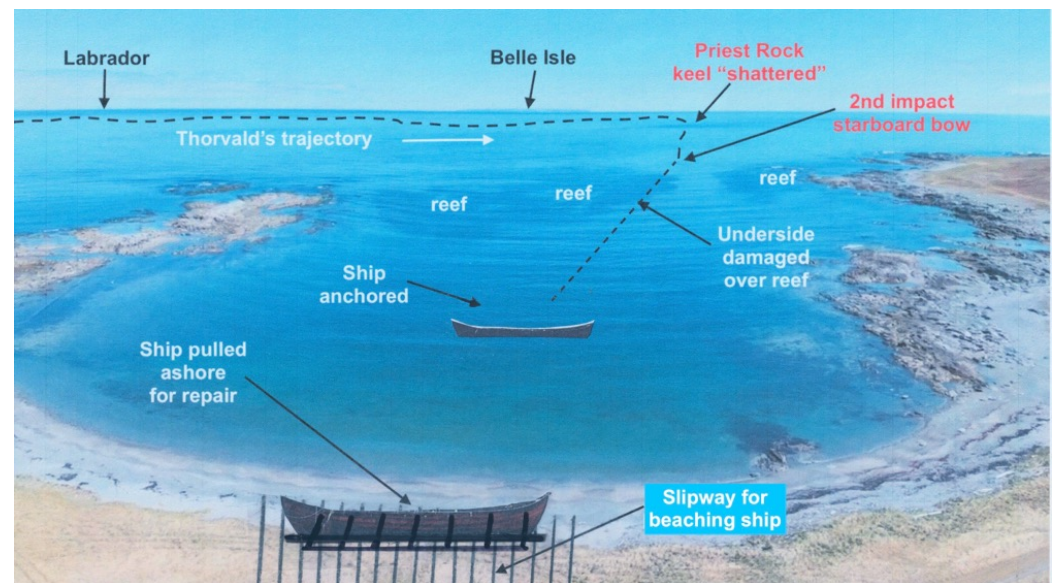
Thorvald sailed northward along a boring, harborless stretch of limestone rock, rubble, and sand, known today as the 'Straight Coast'. In the saga it is later named '*Furdustrands*' (Norse: '*Marvelous Strands*') by Viking explorer/settler Thorfinn Karlsefni, because "they were so long to sail past" (GS), (see maps, Figs.1&2). Fossum also concluded that this coast was '*Furdustrands*'; and along with Keelness, he matched the saga texts exactly. Sailing along '*Furdustrands*', Thorvald was largely protected from the weather by low land to starboard (his right); until they rounded Cape Norman. Now they were hit with the full force of a "fierce gale", most likely a '*Nor'easter*', a cyclonic coastal storm well known in this region; almost like a mini-hurricane. A hypothetical trajectory is re-created in Figure 3.

Rounding Cape Norman, tacking back and forth against the wind, but still trying to head east, Thorvald was now trapped. Unable to make headway, and already only about a mile from shore, the northeast wind pushed him relentlessly southward from his track; but trying to turn around, and he could capsize. The sustained northeast wind would have also pushed the sea into huge swells, sweeping onto the shallow limestone reef east of the cape. It was originally named '*Norman Ledges*' by English Master James Cook (see Fig. 3), during his 1767 survey, but later renamed '*Cook's Rocks*' in his honor, as Captain Cook.

The most prominent feature is a submerged outcrop of hard limestone named 'Priest Rock'. The rest of the scenario relies on our interpretation of damage sustained by the hull planks ('strakes') as revealed in the drone imaging (see paper II). Close to low tide, a giant swell may have picked the ship up, and as the swell ebbed, dropped it straight down several feet onto this partially submerged outcrop, undoubtedly "*shattering*" the keel exactly as stated in the saga.

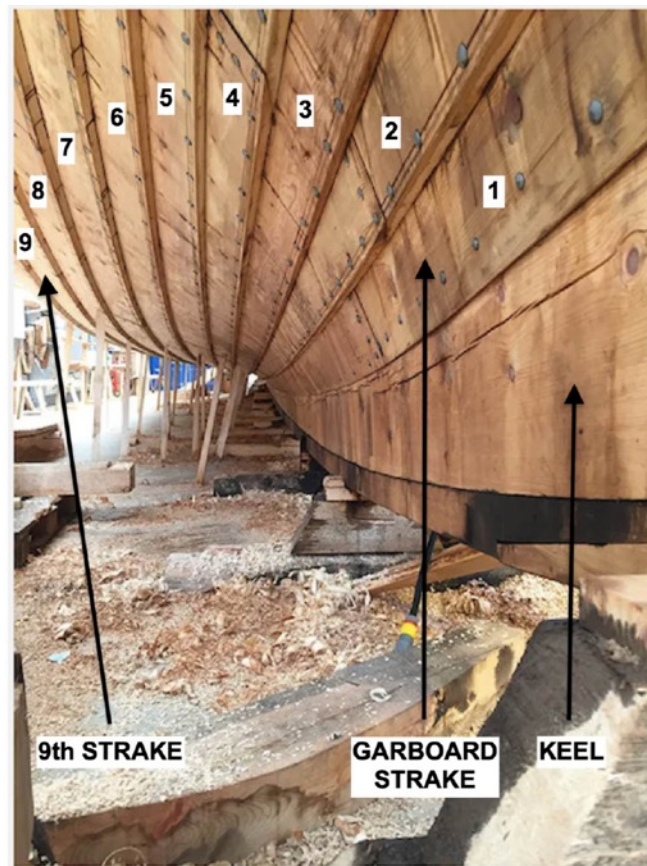
Taking on water fast, they were now in serious trouble, and would have immediately headed for the closest land, now about a half mile away. Getting there would still be treacherous, and with storm-waves pounding the partially-submerged ship, they appear to have suffered additional collision damage. The thermal imaging in particular suggests severe damage to strakes 7, 8, and 9 (counting from the keel), with pieces of the strakes unaccounted for. This suggests that they probably hit another smaller submerged rock with the front, starboard side as they headed to land (see fig. 5). All of the remaining underside strakes would then be compromised, as the ship was pummeled by waves, and wallowed across the remaining limestone reef, before getting into the relative safety of a small cove (*Bonne Bay*).

As shown in Fig. 4, for a better visualization of the shipwreck, we grafted our narrative onto a panoramic drone image of the actual shipwreck site. Using nautical charts and drone images of the cove, we created a composite view of the episode; albeit without the mountainous waves. The partially submerged hull, dragging across the hard, sharp, limestone reef, would have seriously damaged all of the bottom 'strakes', almost up to the waterline, nine on either side of the keel.



**Figure 4.** Narrative of shipwreck event graphically superimposed onto drone image of the site.

Figure 5 shows the underside of *Myklebust*, a reproduction of a similar Viking knarr, recently built in Norway, giving some idea of the hull area damaged in the wreck. The damage was immense, but the crew seem to have survived (or at least no casualties were mentioned in the saga). But if they were unable to repair such catastrophic damage with local resources, with only the tools they had on board, they could still end up dying out there on this bleak headland. Their resolve, ingenuity, and success are something to marvel at.



**Figure 5.** Underside of reproduction Viking ship, Myklebust, demonstrating extent of damage to Leif's ship in shipwreck; keel and 18 strakes, 9 on each side of keel. (Reproduced by kind permission of photographer Christina Keune).

#### 4. Satellite Imaging

Up to this point, our story was hypothetical, but now some evidence was required. Satellite imaging in archaeology had proven both convenient and affordable for some studies; a good place to start. With Priest Rock as the point of impact, our hypothetical narrative as a guide, and the coastal area around Bonne Bay as the closest landfall, we turned to satellite imagery. The objective was just to look for evidence of human activity, any activity; but dealing with a shipwreck, obviously attuned to any indicator of ship repair activity.

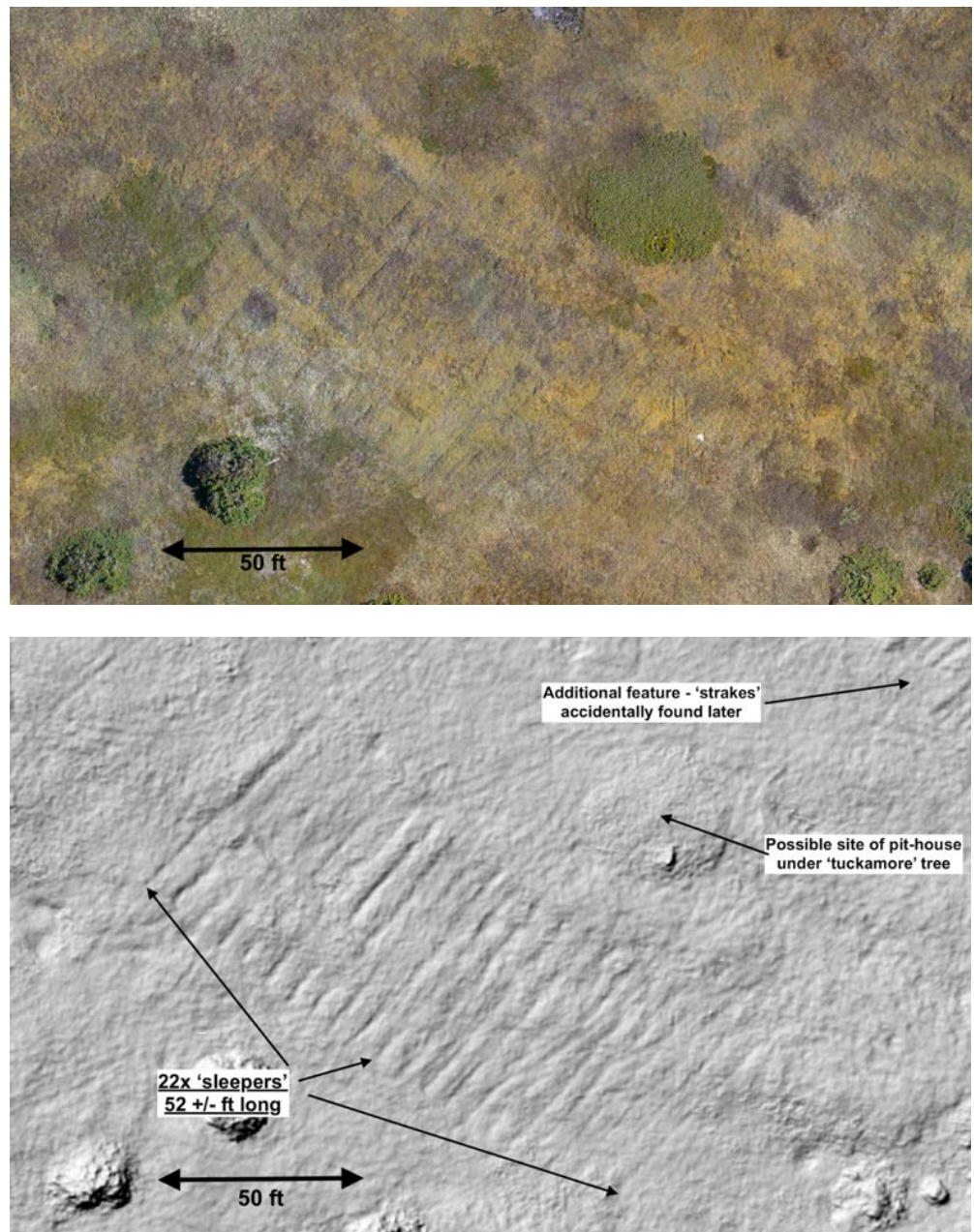


**Figure 6.** Satellite image of ground pattern, Cook's Harbor peninsula, Newfoundland, Canada. (Derived from image by Maxar Technologies ©).

Logic dictated that they would not move a large, heavy ship any further from the beach than absolutely necessary. Weeks were spent scanning satellite images of coastline from Cape Norman and east. Finally, on only a single image, there was a vague pattern of parallel lines; suggestively not natural (Fig. 6). In retrospect, we speculate that the image was taken after an early, heavy frost; showing variable frost damage to vegetation, due to differential vegetative coverage of the site.

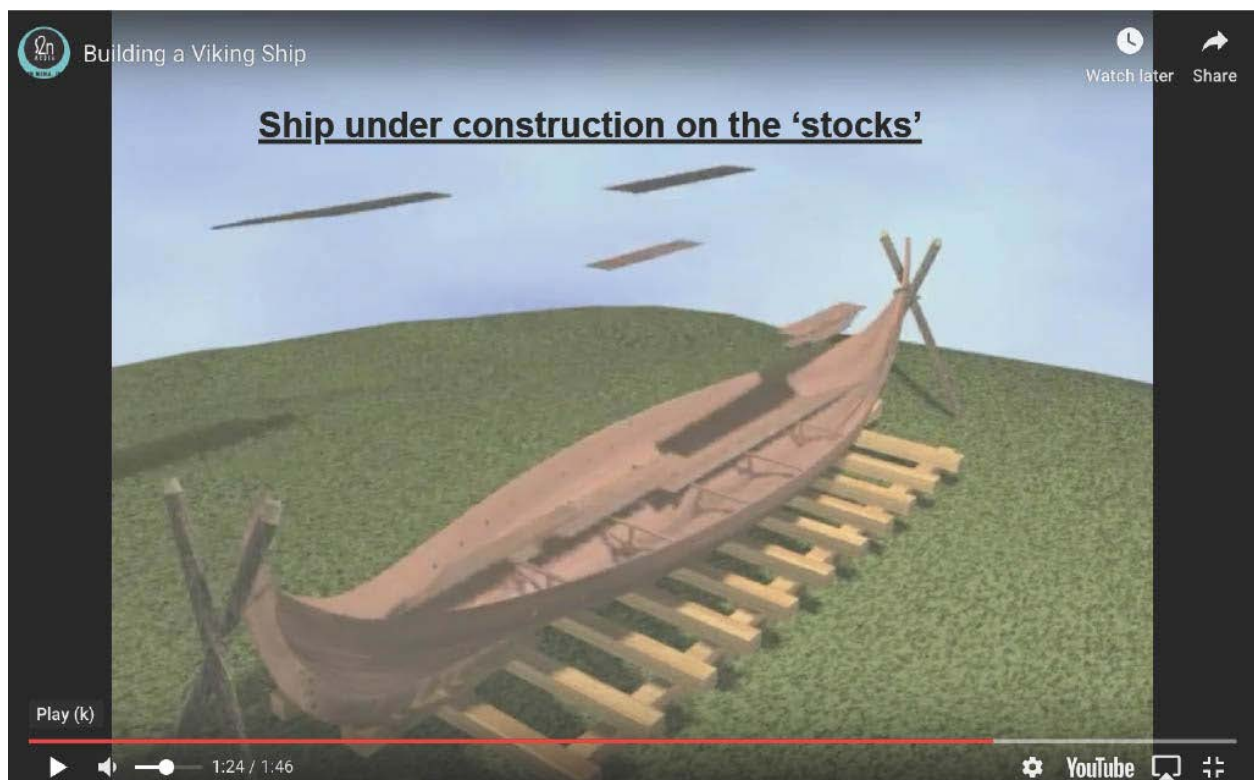
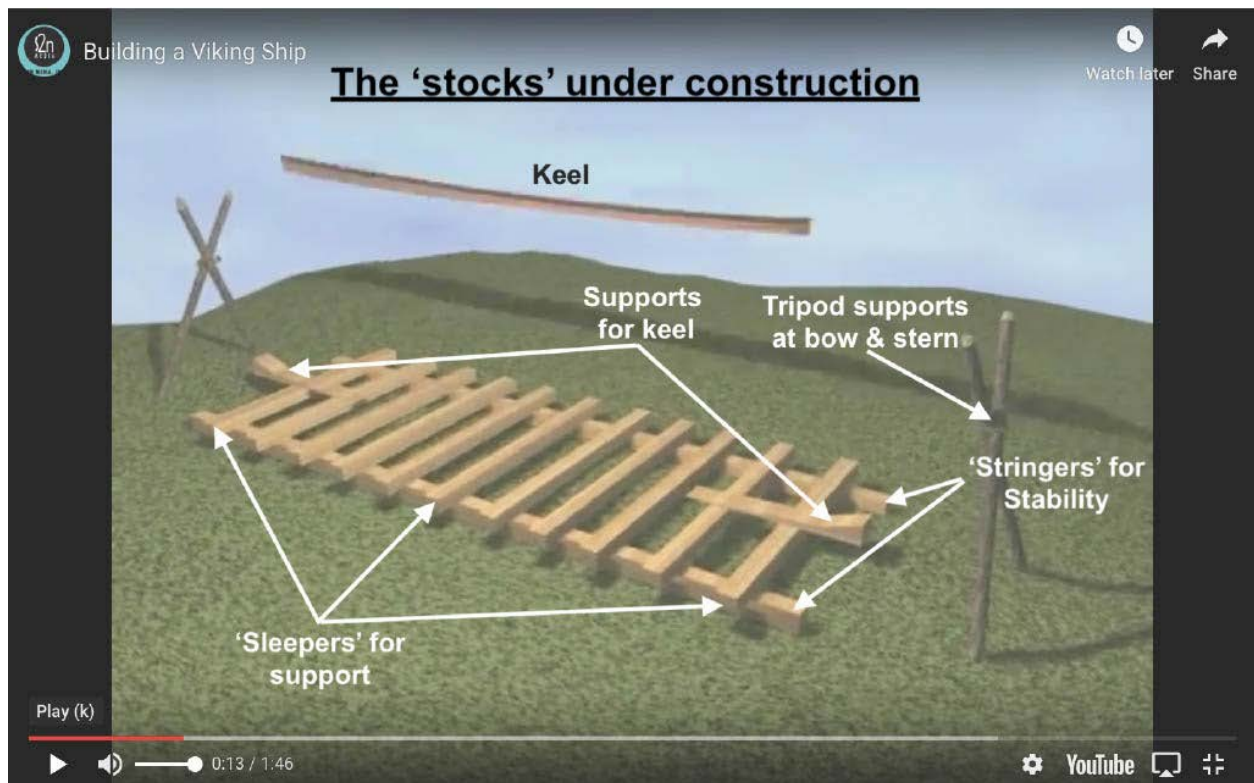
##### 5. Drone Imaging

As mentioned earlier, the drone imaging results were used to verify the unusual satellite image. Side-by-side images of both visible, and computer-processed (hillshade) virtual images of this feature are shown in Fig. 7 A, B. Drone scans in the visible (Fig. 7A), confirmed the 'zebra stripe' pattern as authentic, but no further clues as to its identity or purpose. Advanced data-processing by our GIS (Geographic Information Systems) analyst resulted in various images of the site via ArcGIS software; including hillshade imaging (Fig 7B). These 'quasi-3D' results were impressive, providing a more detailed image, but what was it?



**Figure 7 A,B** The 'stocks', support structure for Viking ship repair. (A) Image of ground pattern in visible spectrum (B) Drone data, processed in ArcGIS for hillshade image showing detailed ground contours.

Fortuitously, at about that same time, a short but informative YouTube video was accessed, depicting construction of a Viking ship (8 A, B). The video was part of the Viking millennium commemoration in 2000 A.D. (9). The video showed a series of beams laid out on the ground, serving as a stable base on which to lay the keel, and then build a Viking ship (Fig 8A/8B). The array of parallel beams in the video, ship construction activity, and our satellite/drone imaging certainly suggested connections.



**Figure 8 - A.** 'Stocks' under construction **B.** Ship under construction on the 'stocks' (Screenshots from YouTube video, used with permission, courtesy of Dr. William Fitzhugh, Smithsonian Institution).

In *'The Viking Ship'* book, this structure is named the **'stocks'**, with an array of parallel wooden beams ('sleepers'), laid on the ground, (or perhaps stabilized with longitudinal 'stringers'). This structure supported and stabilized the hull of a Viking ship while it was under construction (10). The stocks for construction of Norwegian King Olaf Tryggvason's

'Long Serpent', one of the longest Viking warships ever built, were reportedly still visible 200 years later, obviously a substantial structure!

This feature, confirmed by drone scans, was interpreted as originally consisting of 22 wooden beams (*'sleepers'*); probably no longer there, but their former positions perhaps revealed by centuries of differential vegetation growth. Each sleeper was about 52 +/- ft (16m) long, and 6.5 ft (2m) apart on-center, with the whole array stretching about 135 ft (41m) long (see Fig. 7B). As a base for repairing a Viking 'knarr', this suggested a huge ship for its time, perhaps 90 ft (27 m) long.

#### 6. Transition to 'Virtual Excavation'

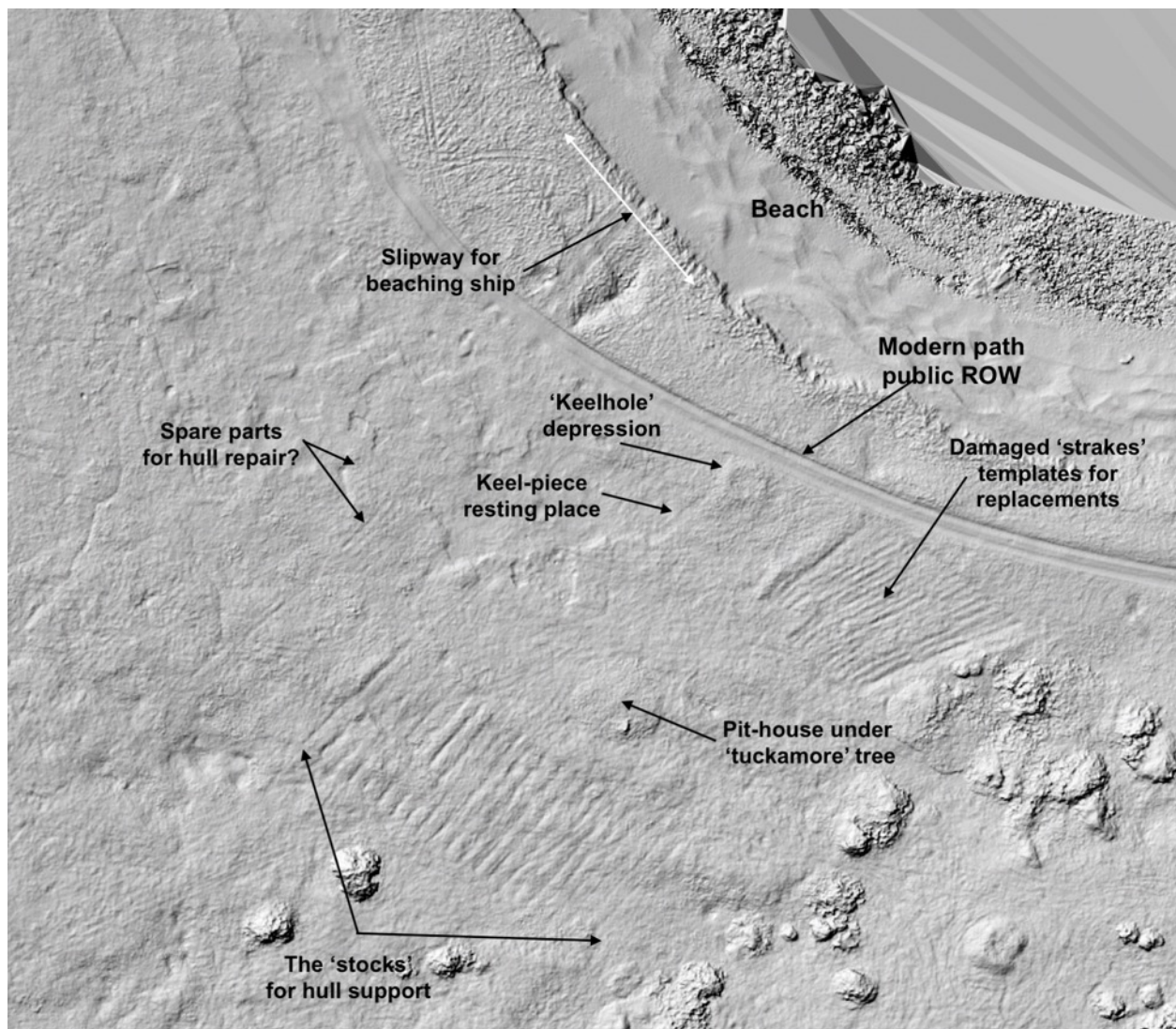


Figure 9. ArcGIS hillshade image of entire ship repair area, with primary features indicated.

This is the point at which we transitioned, from merely confirming a satellite image, into a full-fledged 'virtual excavation', using only imaging data. With no site access or professional assistance available, we 'mined' the preliminary drone imaging to reveal and interpret distinctive features of what now appeared to be an obvious ship repair site. Figure 9 shows the entire ship repair area in ArcGIS hillshade, the latter simulating a 3D surface perspective in great detail, with individual features indicated. The finely detailed resolution allowed creation of a realistic and plausible narrative of what occurred on the site. The 'virtual excavation' and resulting continuing narrative are described in paper II;

"Re-visiting Viking Vinland: II. 'Virtual Excavation' of 'Keelness', a Viking Shipwreck Site in North America".

### Conclusions

Based on clues from the Norse sagas, logic, and creative imagination, we were able to re-create the voyage of Thorvald Eriksson, placing 'Keelness' on the north coast of Newfoundland, Canada. This Viking shipwreck site, is specifically named in Greenlanders' Saga, and located relatively close to L'Anse aux Meadows, strongly suggesting a connection; physical, historic or both. A satellite image initially revealed an unusual ground pattern close to the site we had selected, pointing to a man-made structure, with drone scans confirming the satellite image. Similarities with other published images, pointed to this feature as the remains of the 'stocks', a support structure for construction (or in this case repair) of a Viking ship. The drone scans also accidentally revealed additional features, recognized as being related to ship repair activities. This set the stage for a 'virtual excavation' of the site, utilizing only remote imaging and advanced data-processing, and the subject of paper II in this series.

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