

GEOLOGY OF ISLE au HAUT, ME

Geological Society of Maine Summer Field Trip

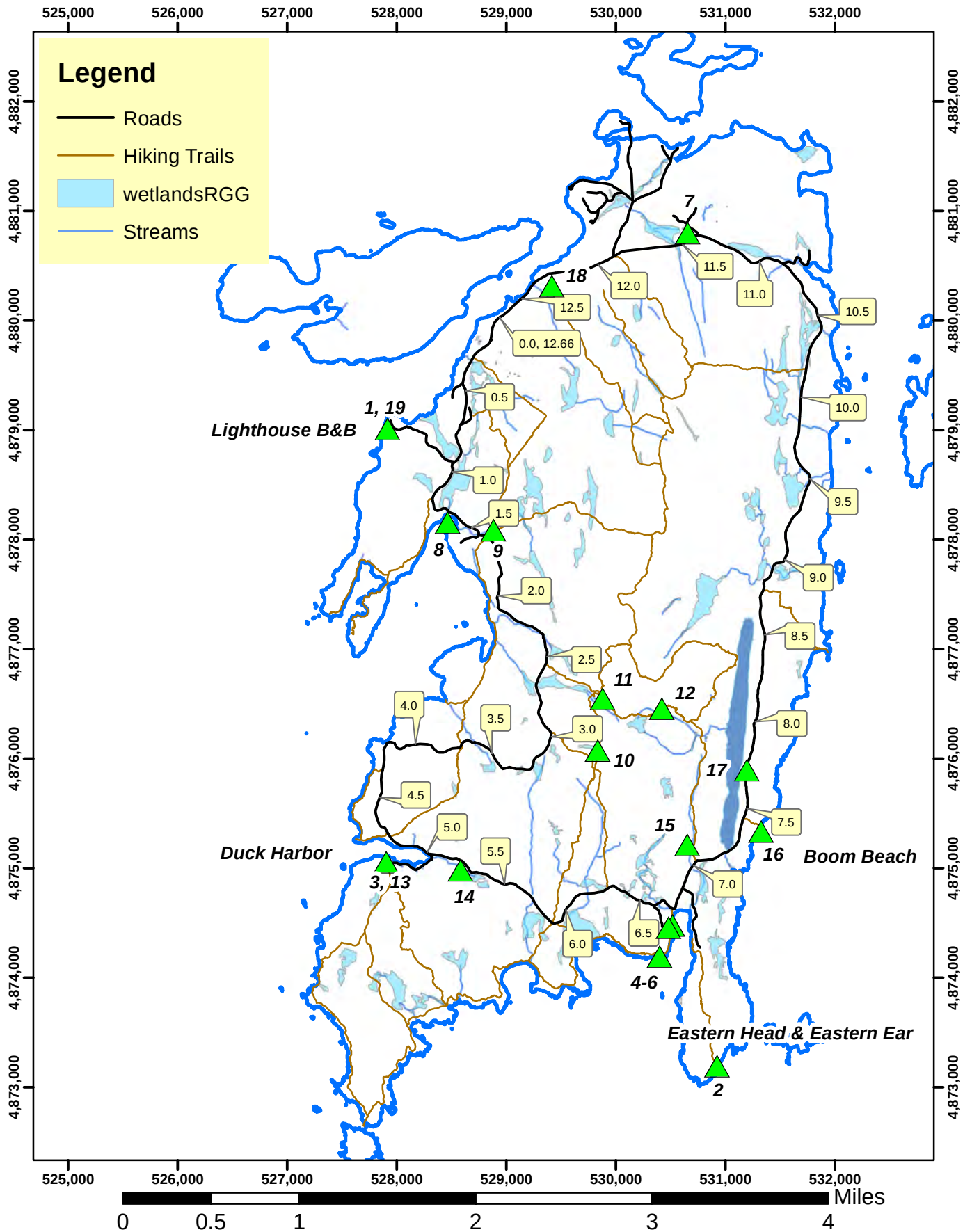
July 25-26, 2015

Field Trip Leaders:

Dr. Marshall Chapman, Morehead State University, Morehead, KY 40351
m.chapman@moreheadstate.edu

Robert Gerber, Ransom Consulting, Inc., Portland, ME 04101
Robert.gerber@ransomenv.com





Trip Stops, Roads, Hiking trails, points of interest on Isle au Haut
Grid is UTM NAD83 19N (meters)

Cover Photo

This aerial photograph, taken by George Cogan's drone in the summer of 2014, is looking northeast down the Isle au Haut Thoroughfare that separates Kimball Island to the left with the main island of Isle au Haut to the right. The hills of Mt. Desert appear in the distance at the top right of the photo. The municipality of Isle au Haut includes a number of smaller surrounding islands. This trip will only visit the main island which is approximately 7 miles long north-south and several miles wide east-west.

Acknowledgements

This trip was complicated to arrange due to the logistics of holding it on an island that is only accessible by boat. We thank Marshall Chapman for the use of his Keeper's House Inn for providing some of the housing and a staging place to begin and end the trip on each day. Marshall also provided camping at his private home. Bob Gerber put a number of participants up at his house. Bruce Hunter made all the off-island camping arrangements and tracking of field trip participants.

The Acadia National Park Service permitted us to drive down their service road at Duck Harbor. John DeWitt and Kendra Chubbuck permitted us to drive to their cottage at the head of the Thunder Gulch ANP trail.

Finally, we are very grateful to all those people who donated vehicles to permit the field trip participants to move around the island each day.

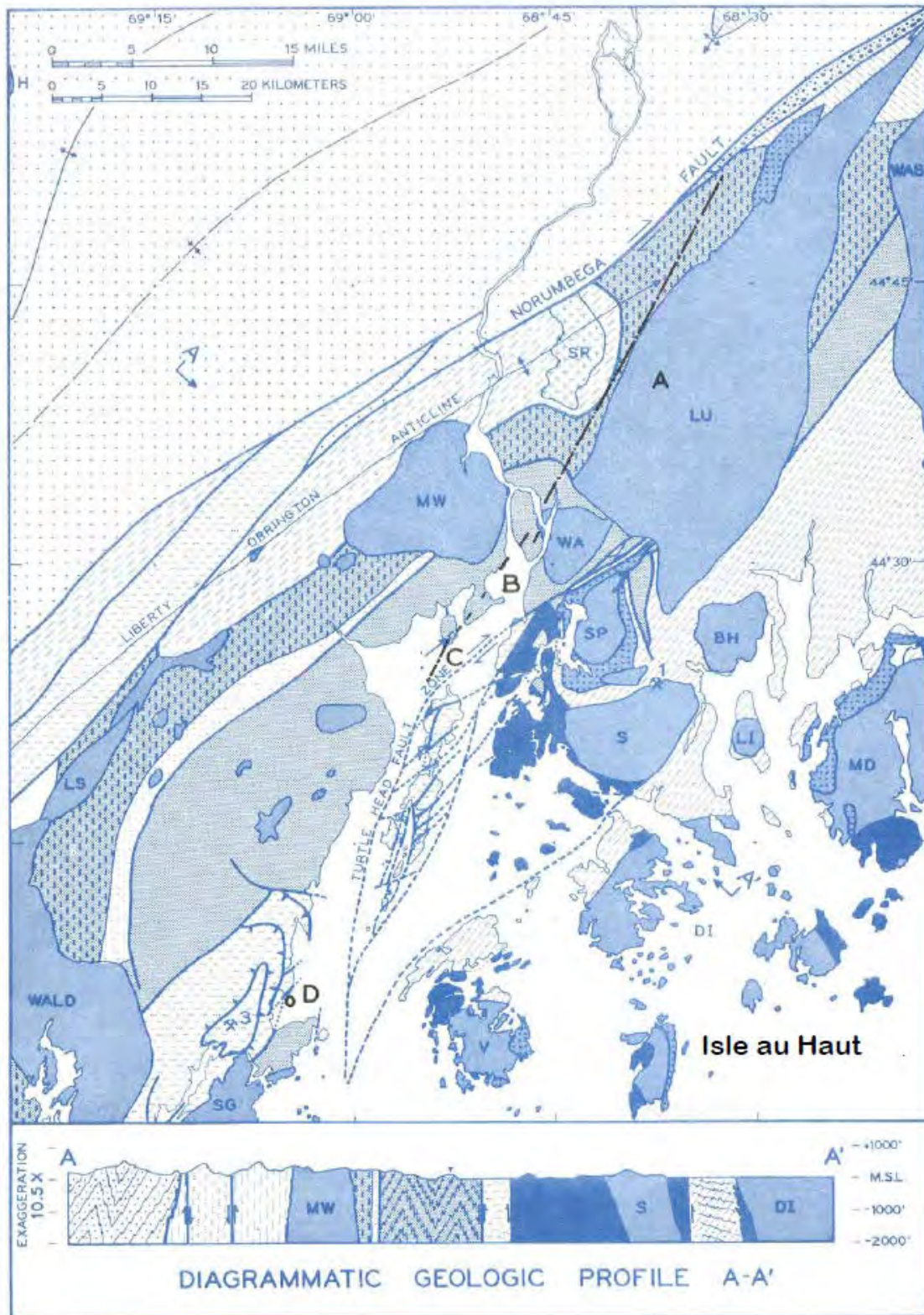
Introduction

This field trip is designed to expose the field trip participant to a variety of geologic terranes:

- 1) Bedrock, including genesis, age relationships, petrology, and structural features
- 2) Surficial geology, including diamicton, glaciomarine sediments, raised beaches
- 3) Hydrogeology, including distribution of well yields and depths, water quality, and controlling bedrock fracture systems
- 4) Marine geology, including beach material size sorting, spit and bar development, and effects of sea level rise on 19th century fishing shacks
- 5) Surface water hydrology, particularly the role of extensive bogs in moderating runoff and sustaining groundwater recharge

Site Setting

The site is within the Maine Coastal Anticlinorium and the southwestern end of the Maine coastal volcanic belt. The Coastal Anticlinorium is characterized as an uplifted segment of Precambrian to Devonian metamorphic rocks consisting largely of schists, gneisses and quartzites, with local occurrences of metamorphosed carbonate rocks and volcano-clastic sequences. The province has been intruded by numerous large masses of Middle Devonian (Acadian) felsic plutonic rocks, and by several smaller, slightly older mafic plutons. Basic dikes of Paleozoic and Mesozoic age have intruded the country rock throughout the area. The general bedrock setting of Isle au Haut is shown in **Figure 1**, with the legend on the following page.



REGIONAL GEOLOGIC SETTING - BEDROCK MAP AND PROFILE

COMPILED BY JOHN R. RAND FROM SOURCES LISTED IN THE TEXT



FIGURE 1

Isle au Haut Bedrock Geology

The Isle au Haut Igneous Complex consists of bimodal plutonic and volcanic units. **Figures 2 and 3** show the distribution of the igneous units and cross-sections of the bedrock of the island. The general trend of the units (as taken from the mafic units) is N 10° E; 35° W. This attitude provides a stratigraphic cross-section of a basal granite-mafic layered sequence to the east, capped by two silicic volcanic units to the west. The contact with the volcanic units, as well as the presence of vugs, indicates that the complex was intruded at a very shallow level.

The Isle au Haut granite (28 km²) is fine-grained and rich with mafic enclaves. Below the granite is a layered gabbro-diorite-quartz monzodiorite complex (51 km²) which forms the eastern third of the island and the small islands and ledges further east. More granite (devoid of mafic enclaves) crops out on small islands to the east of the mafic complex and field evidence indicates that it was emplaced contemporaneously with the layered mafic units. U-Pb-Th dating of zircons from the Isle au Haut granite, the mafic units, and the easternmost granite indicate the same age of 424 +/- 1 Ma. Both the Isle au Haut granite and the easternmost granite on these other islands may therefore be part of the same silicic reservoir. The intervening larger layered gabbro, then, appears to have invaded this previously contiguous silicic reservoir and ponded on its lower solidified or largely solidified base. Contacts between gabbro and granite show chilled pillows, net veining, composite dikes, and coarser grained xenoliths of gabbro within the granite.

The broad chemical variations of the respective layers, combined with the clear field and textural evidence, lead to the conclusion that the composite layering is the plutonic expression of a periodically replenished, or invaded, evolving magma body containing coexisting gabbroic and more silicic magmas characteristic of mafic and silicic layered intrusions. Moving down the succession of layers provides increasingly older "snapshots" of its magmatic development, leading ultimately to the first pulse of invading gabbroic magma. Hence, the easternmost exposures of gabbro and granite provide our first glimpse of the geochemical and petrological development of the Isle au Haut Igneous Complex, whereas the layered sequence provides the later, waning stages of its magmatic evolution.

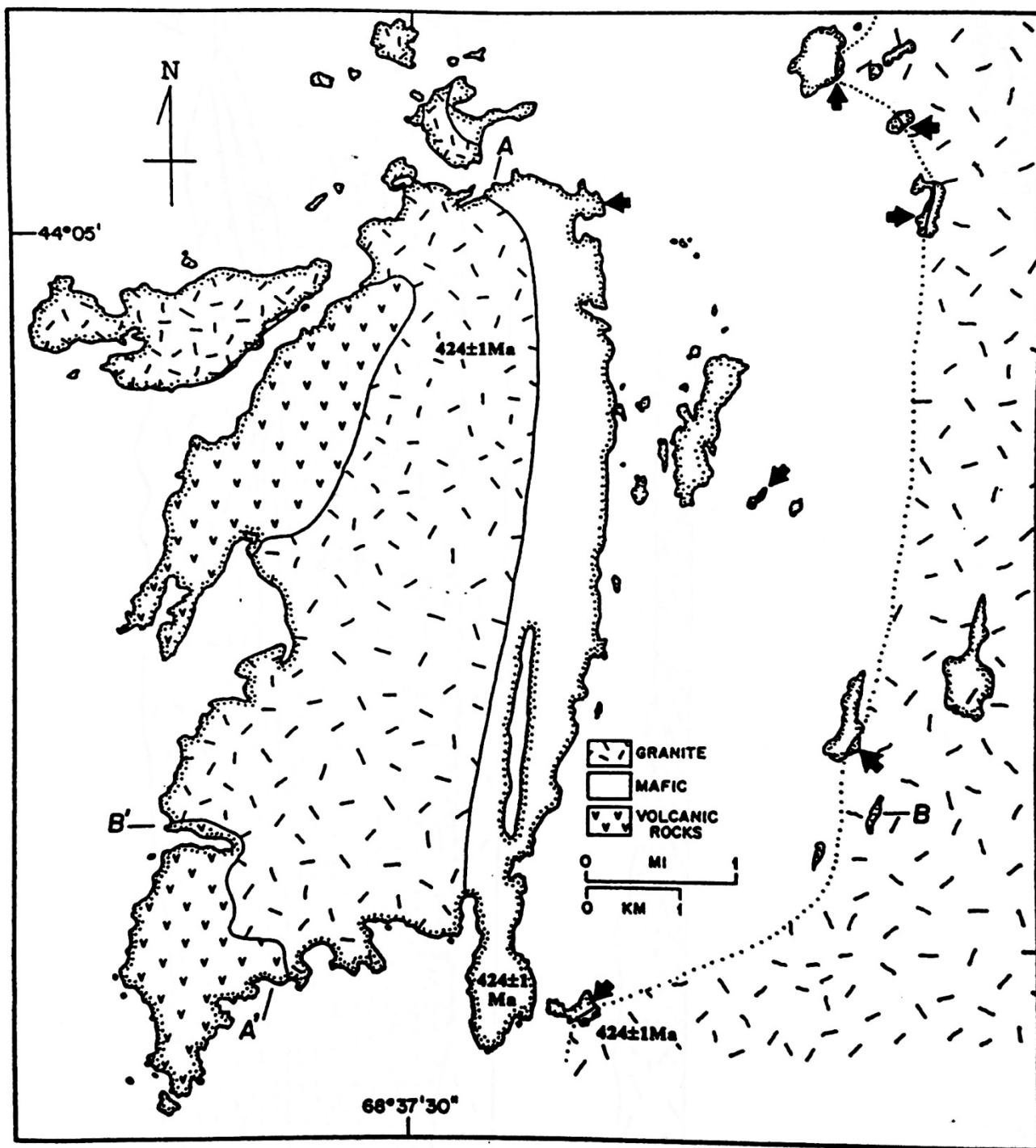


Figure 2—Location and generalized geologic map of the lithologic units which comprise the Isle au Haut Igneous Complex, taken from Smith, et al. (1907) and Luce (1962).

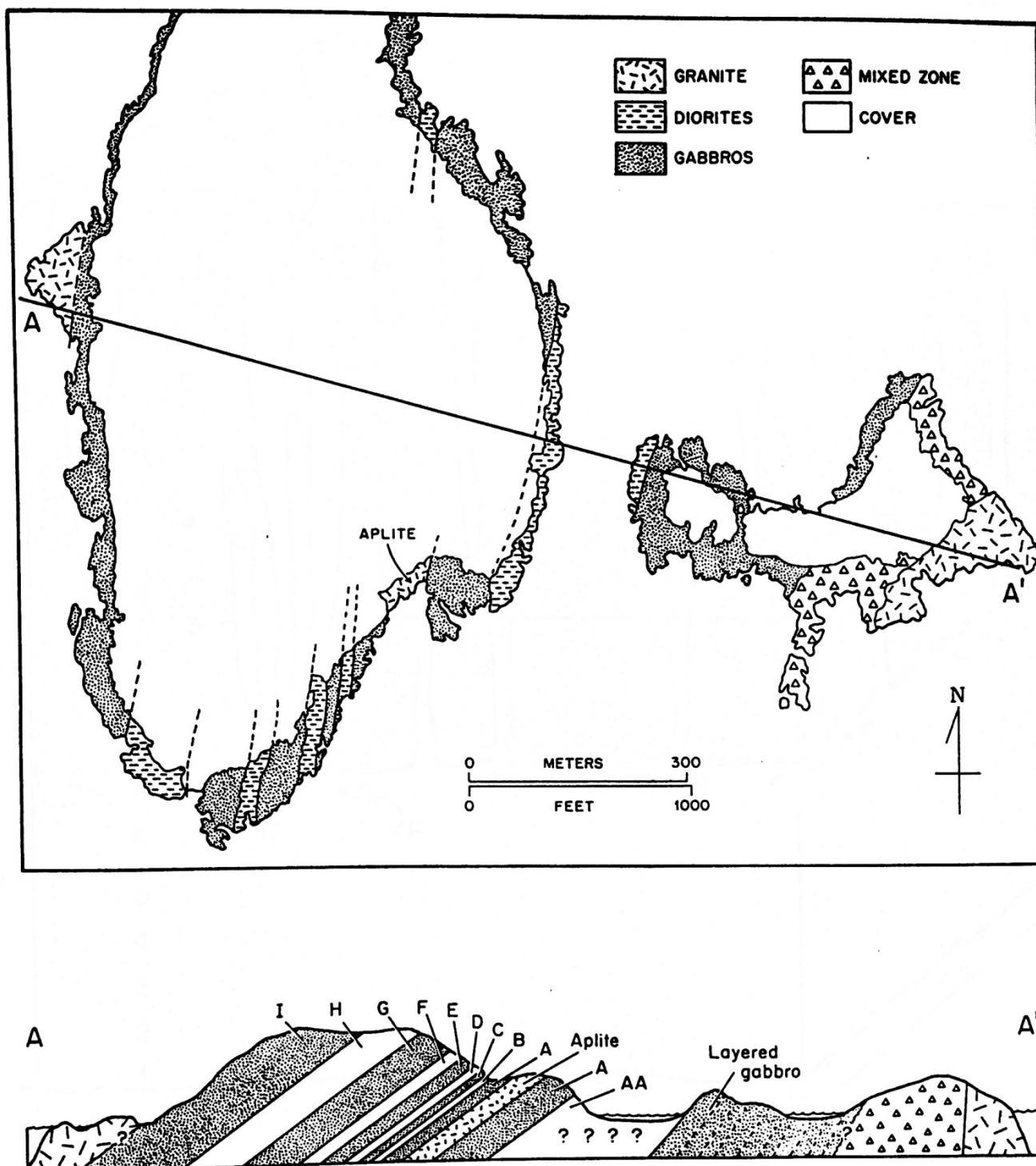


Figure 3—Geologic map and cross-section (vertical exaggeration 4x) of the composite layering of gabbro-diorite units and granites exposed on Eastern Head peninsula and Eastern Ear Island.

Bedrock Fracture Patterns

There are two basic means from which to map bedrock fracture patterns on Isle au Haut. Because the island has thin soil cover, the new 2-meter DEM derived from 2011 LiDAR (**Figure 4**) provides a means to at least construct a rose diagram of bedrock linears (**Figures 5 & 6**). The other method is standard field mapping of strike and dip with a Brunton compass; however, to date a comprehensive field mapping of the fractures has not been completed.

Figure 4

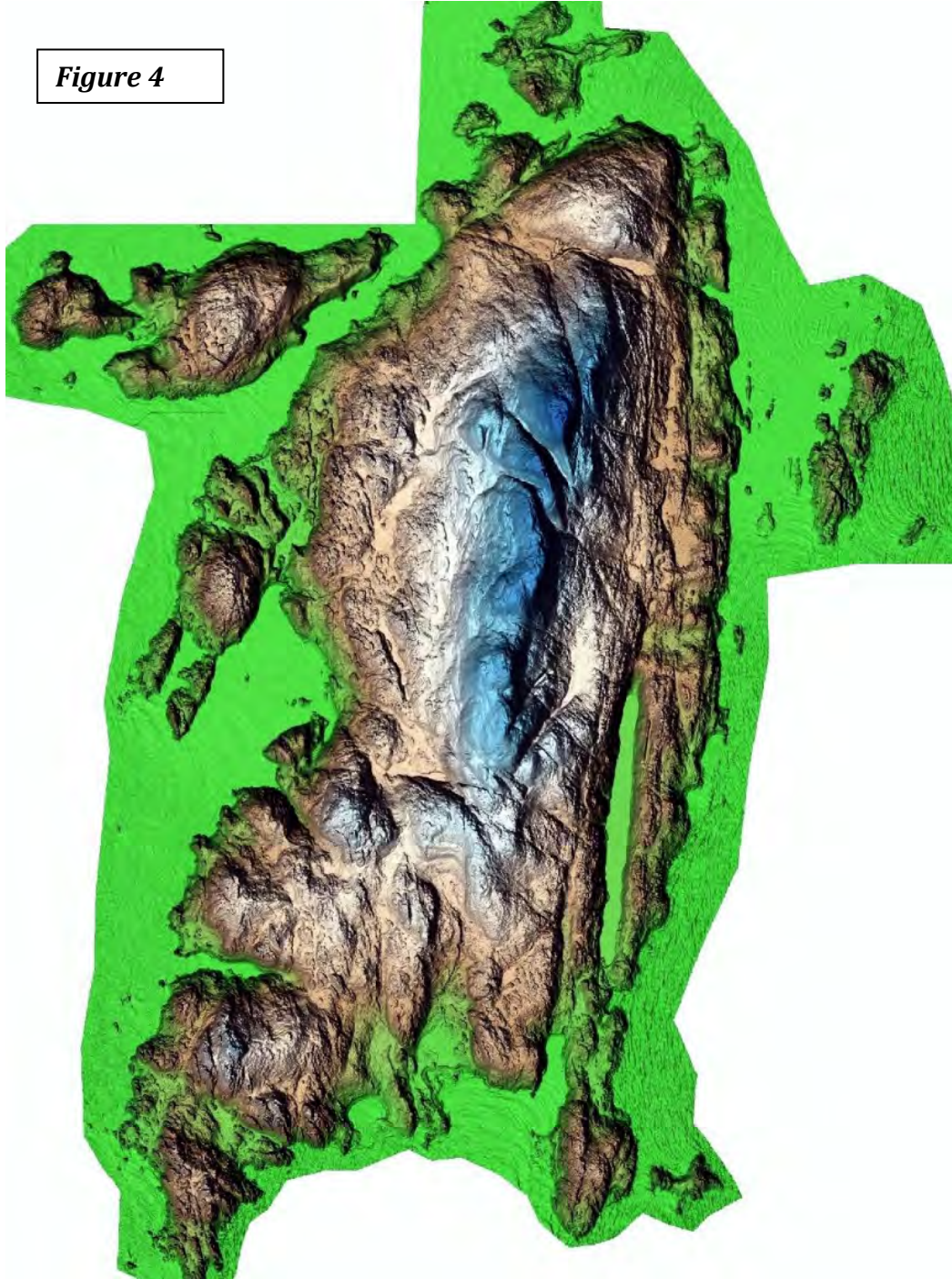


Figure 5

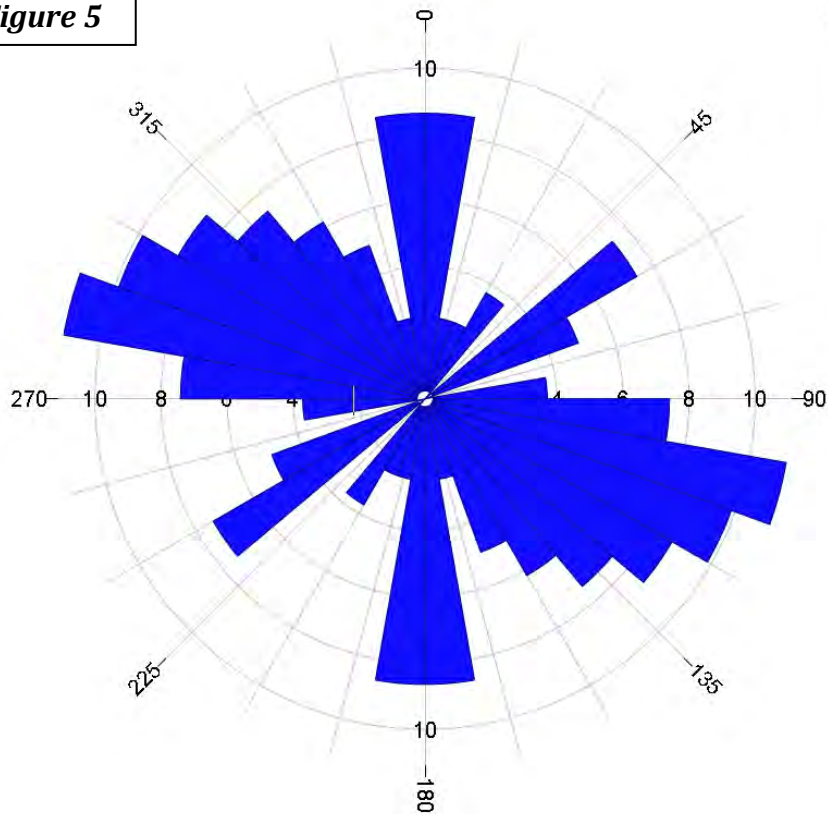


Figure 6

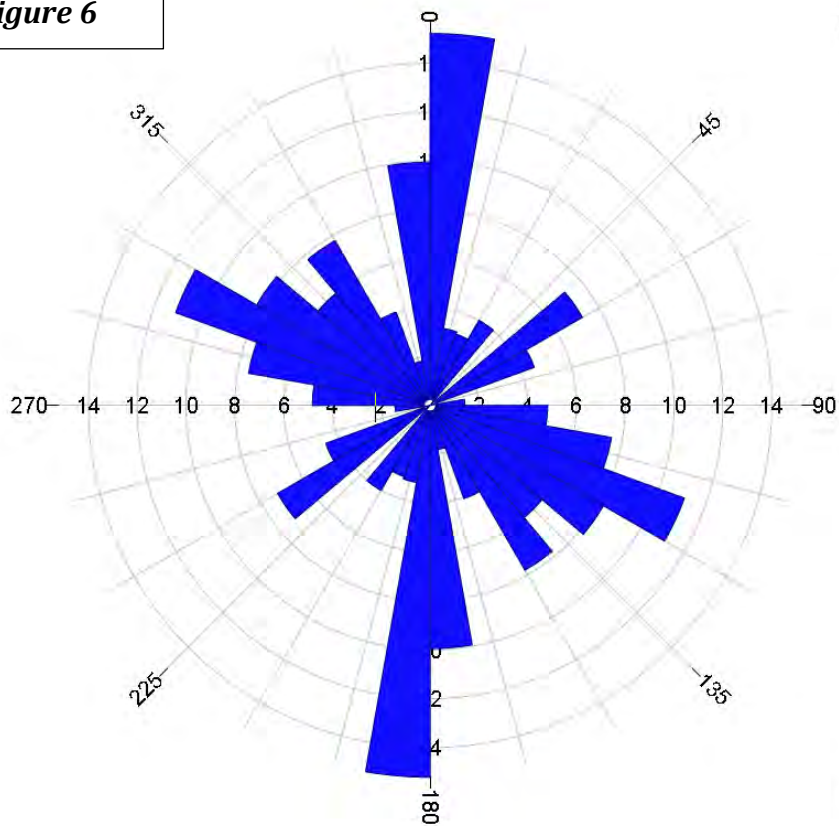




Figure 4 shows a highly processed digital elevation model (DEM) of Isle au Haut. **Figure 5** is a rose diagram of the strikes of the major lineaments, distributed by the frequency of the strike directions. **Figure 6** shows a rose diagram with the strike directions distributed according to the length of each lineament. The above photograph (**Figure 7**) was taken looking northwest from the shore just near the southwestern entrance to Head Harbor (at a place called “Bungi Head”) which is one of the stops on the field trip. This photo shows examples of the prominent northwest-southeast striking nearly vertical fractures in the rock.

(The tectonic origins of the major fracture patterns expressed in the linears has not been unraveled yet, so we invite your suggestions.)

Surficial Geology

Because of the low population density of Isle au Haut, not much attention has been paid to mapping the surficial geology of the island. There have been two government-sponsored mapping efforts: 1) Smith and Anderson (1974)¹; and 2) Gilman, et al. (1988)². The second map followed closely the first map, but with more detail. The 1988 map is shown in **Figure 8** below.

¹ Smith, Geoffrey W. and Björn G. Anderson, 1974, **Surficial Geologic Map of Knox County (Preliminary)**. Physical Resource Series, Bureau of Geology, Dept. of Conservation, State of Maine. Map at scale: 1:125,000

² Gilman, Richard A., Chapman, Carleton A., Lowell, Thomas V., and Borns, Harold W., Jr., 1988, **The geology of Mount Desert Island; a visitor's guide to the geology of Acadia National Park**; Maine Geological Survey (Department of Conservation), Bulletin 38, 50 p.

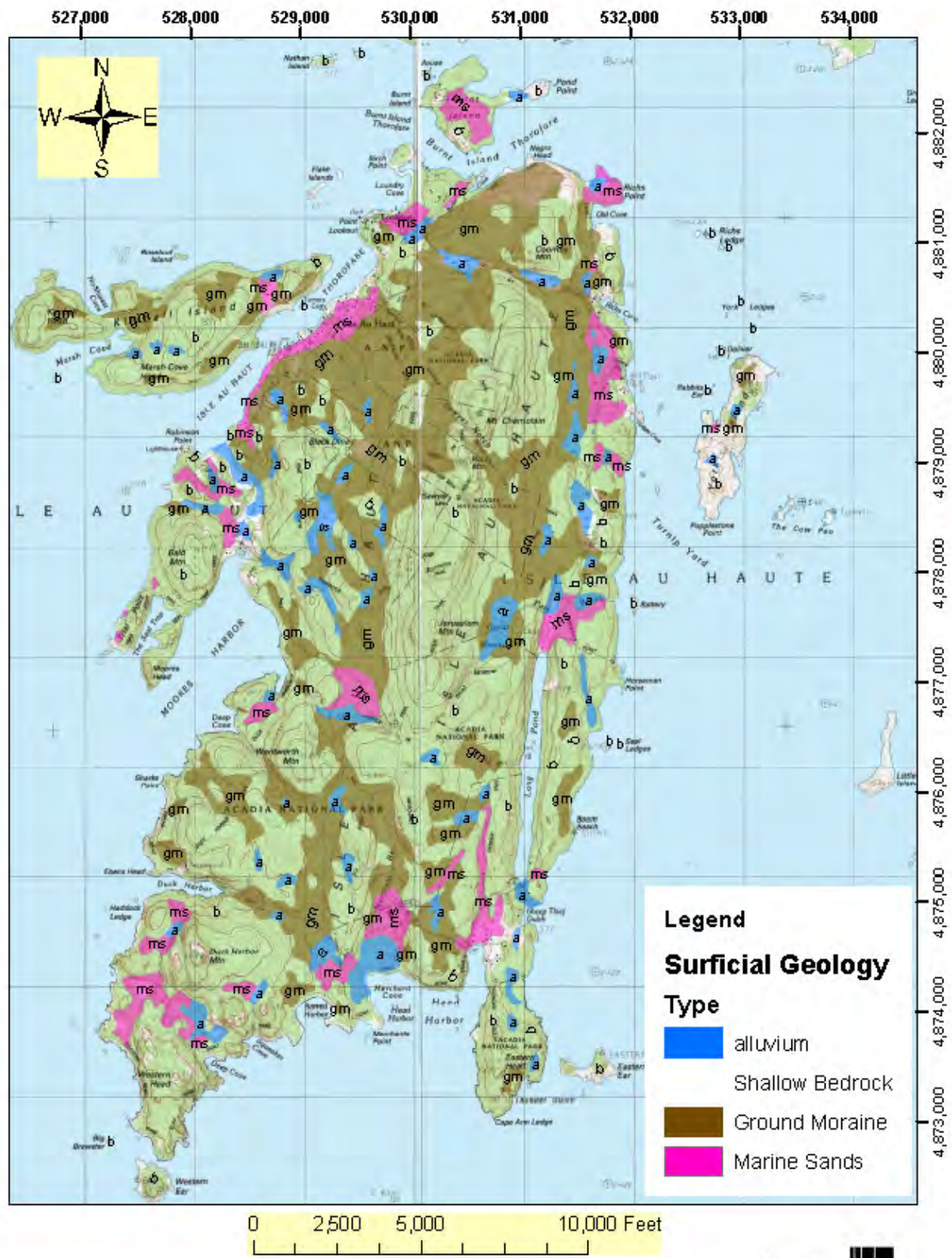


Figure 8

Based on a lot of hours in the field on Isle au Haut, I conclude that the surficial geology map needs a lot more work. The areas shown as alluvium are moderately accurate in terms of delineating areas of wetland soils. The areas shown as marine sands is indicative generally of ground that is a little flatter and a little smoother than typical ground at Isle au Haut and some of these areas definitely have either glaciomarine sands or a thin surface of sand and gravel that may be marine-reworked till. The areas shown as ground moraine are probably the most in error as some of these areas have extensive exposed and shallow bedrock, and some of the area shown as shallow bedrock should be mapped as ground moraine. Due to extensive and dense spruce tree cover on Isle au Haut, it is nearly impossible to map surficial geology using aerial photography. Therefore, much more extensive field mapping is required than usual to map the surficial geology. The 2-meter DEM will be helpful, however, in separating stratified material from diamicton.

As is common with Maine offshore islands, areas of sand and gravel are very limited on Isle au Haut. Further, most of the original deposits were mined out as part of the construction of the loop road around the island in the 1930's and 1940's. Near the road on Isle au Haut there are many troughs and hollows in the ledge and other areas where shallow water-worked materials were mined for road fill. There is one large extensive pit complex on the south side of Coombs Mountain that is mostly mined out (**Stop 7**), and several extensive mined out pit areas within and next to the southeast corner of Acadia National Park. Most of the current pit exposures show poorly sorted material in the top 3' or so, with many cobbles, grading downward into somewhat better sorted cobbly and gravelly sands, and then some fine sands below that. Some additional gravel resources remain at scattered locations within Acadia National Park (**Stop 14**) and one large partially excavated pit with stratified material left in the ground on the southwest side of Long Pond (**Stop 15**) on property owned by the Church. In the village area, Kennedy Field north to the Kennedy boathouse is the largest remaining sandplain left in place. The cemeteries on the island also give clues as to the location of stratified drift on the island. **Figure 9** shows the locations of known or inferred stratified drift and glaciomarine sands on Isle au Haut.

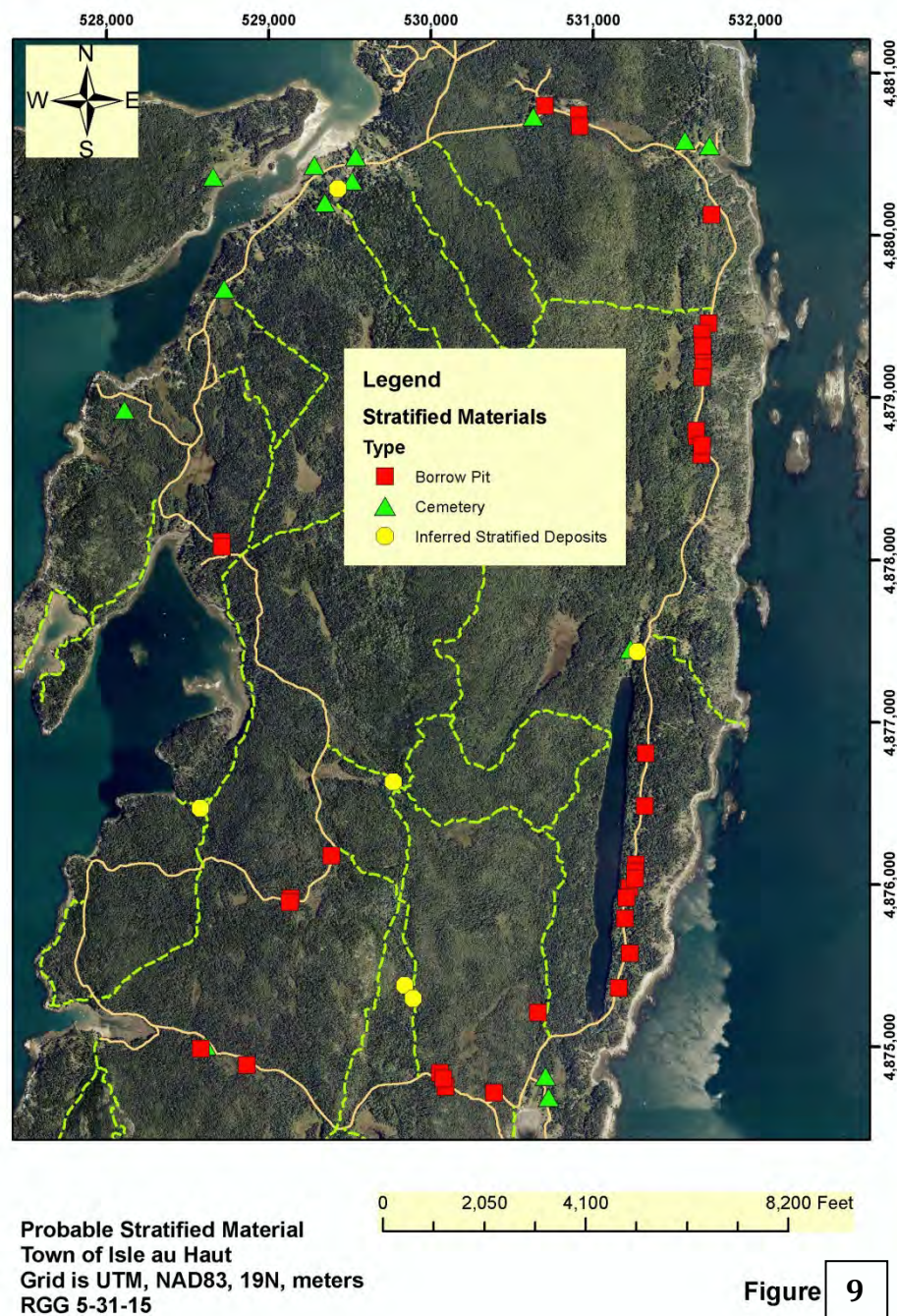
Of the wetlands and bogs on Isle au Haut we can say little about the depth and nature of the underlying soils and thickness of peat. We are unaware of any borings or peat surveys that analyze this resource. However, as described later, the bogs are very important to island hydrology and hydrogeology.

Similar to the unknowns relating to bogs, there are also a lot of unknowns relating to the thickness and distribution of the clay-silt phase of the Presumpscot Formation. We have not seen any direct exposures of pure Presumpscot Formation. Since this is an offshore island, the conditions favorable to the formation of thick uniform clay-silt glaciomarine deposits were generally not present. Currents and wave action and the lack of large areas of quiescent conditions needed for the settling of clay-silt would have minimized the formation of these deposits. There is anecdotal evidence of soft mud in the pond formed in the pits south of Coombs Mountain. Other evidence suggesting at least the possibility of thin clay-silt deposits are the alder-overgrown areas around the fringe of wetland areas.

Diamicton displays several different unique characteristics on Isle au Haut. There is a standard dense, generally olive to dark gray fine-grained till with scattered gravel and cobbles (**Stop 17**). The top of these deposits is often partially water-worked, perhaps in places by melt-out at the base of an ice sheet and perhaps in other locations from marine wave action reworking to beach deposits.

Another style of diamicton is a reworked fine-grained glaciomarine deposit from up-glacier areas that was overridden and moved around and compacted under ice (shoreline exposure, **Figure 33**). This type

of diamict is usually less dense than normal lodgment till and lacks the cobbles and gravel present in typical lodgment till. This type of till was investigated in detail in the Sears Island fault investigation³.



The third basic type of diamict on Isle au Haut is an extremely dense and partially cemented heterogeneous mix of cobbles, gravel, sand and silt with a lower percentage of fines than the usual

³ Rand, John R. and Robert G. Gerber, 1976, **Sears Island Fault Investigation, Sears Island, Searsport, Maine**. A consultant report for Central Maine Power Company. Available through the Maine Geological Survey.

lodgment till (no current exposures). Island backhoes have great difficulty excavating this material which has been identified in at least two excavations in the southeastern corner of the island by the author, but also reported in other parts of the island by William Stevens, the main island earthworks contractor.

Raised beaches, remnants of beaches that formed in the material left after the last glacier melted, have been left on several south and southeastern slopes in the southern end of Isle au Haut. A particularly interesting example is a cobble beach that looks much like the modern Boom Beach, but occurring generally in the elevation range of 220' to 240' NAVD88 (**Stop 12**), which appears to be the high sea level stand in this area. The time of deglaciation is estimated to be about 15,500 years ago (a radiocarbon date of $15,595 \pm 400$ B.P. was obtained on calcium carbonate accretions in glaciomarine deposits on Sears Island—see Rand & Gerber (1976), *ibid.*). There is another obvious lower elevation raised beach (**Stop 11**) composed of sand and gravel west of the raised cobble beach. Other thin stratified deposits occur throughout lower elevations of the island and their upper surfaces may in some cases represent materials reworked into beach deposits.

Coastal Geology

There is a lot of coastline to just the main island of Isle au Haut, not to mention the 30 to 40 islands that are located within the municipal boundaries. Most of this coastline is typical of “bold coast” with exposed steep bedrock shores. But there is a variety of beaches, bars, spits, flats, and marshes.

One of the more complex areas is the northeastern entrance to the Thoroughfare between Kimball Island and Isle au Haut where the area is somewhat sheltered from waves but the currents of tides that move in and out of the Thoroughfare form bars of sand and shell hash near the dredged channel and sand flats and mussel bars form southeast of the channel (**Figure 10**). Twin tomobolos



Figure 10



Figure 12

form a brackish marsh to the north of Rich's Head that has a permanent duck blind (**Figure 11**).

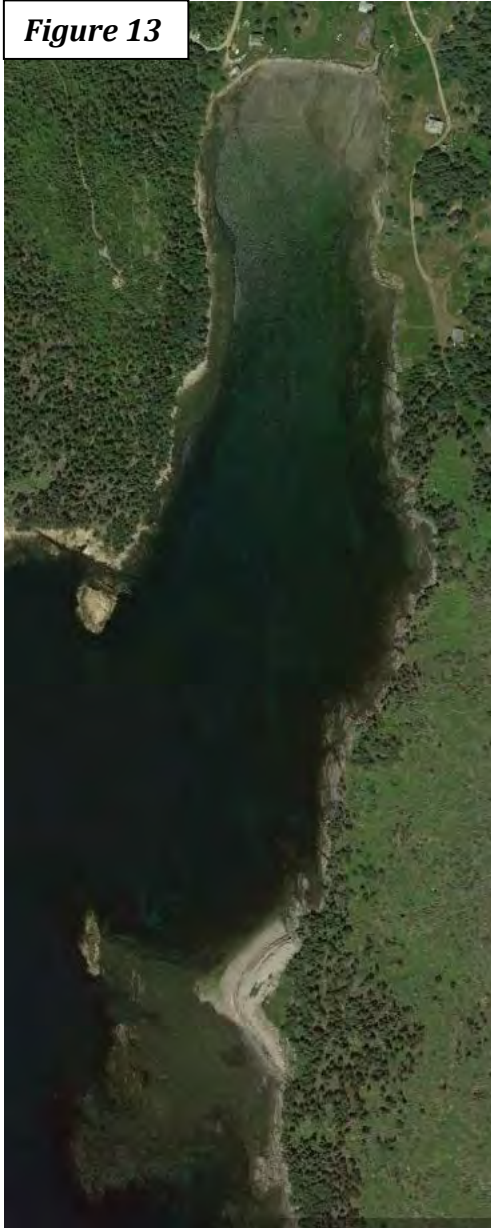
There is a long bar (**Figure 12**) across the outlet of Merchant Brook into Merchant Cove at the southern end of the island. A large freshwater marsh has formed north of the bar. The surface of this bar has a lot of rounded gravel and small cobbles as it is exposed to some significant wave energy at high tide.



Figure 11

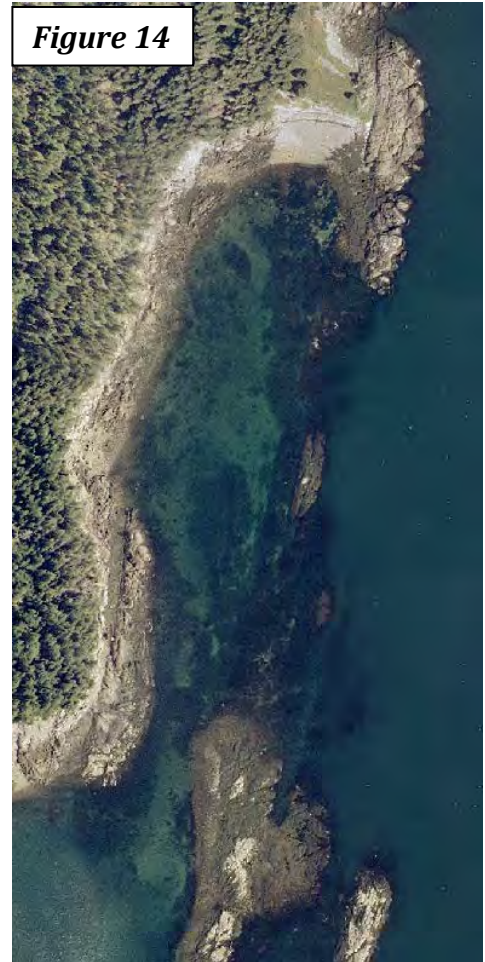
The unusual curved spit at the head of Moore's Harbor can be viewed at **Stop 8**.

Figure 13



There are a number of marine features of interest in Head Harbor which can be viewed from the perch at **Stop 4**. **Figure 13** shows beach-trying-to-become-a-bar at the entrance to the harbor, flats at the head of the harbor, and arcuate small height beach berm that forms the upland edge of the head of the harbor. We will also be viewing the remnants of an 1800s-era fishing village on the west side of Head Harbor (**Stop 5**) where the effects of sea level rise are rather dramatically illustrated.

Figure 14



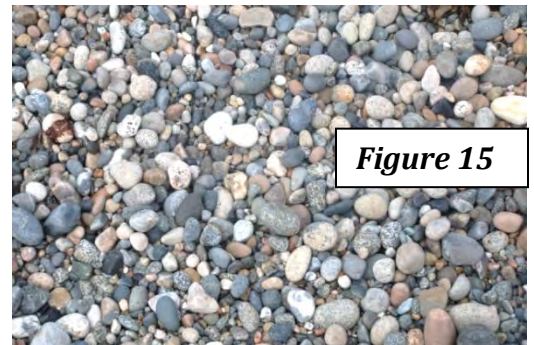
Around the island the size of beach material is based on the amount of wave energy reaching the beach. Boom Beach is the best example of a very high energy beach where the beach material is primarily rounded cobbles and boulders (**Stop 16**). An unusual beach is at Horseman's Point on the middle eastern part of the island (**Figure 14**). This location sports a double tombolo connecting the main island with the ledge running parallel and to the east. Other ledges to the south of the southern beach modulate the

wave energy into this cove. The main beach material consists of a beautiful variety of rounded pebbles (**Figure 15**) of all varieties of rock.

Mapping Flood Zones on Isle au Haut

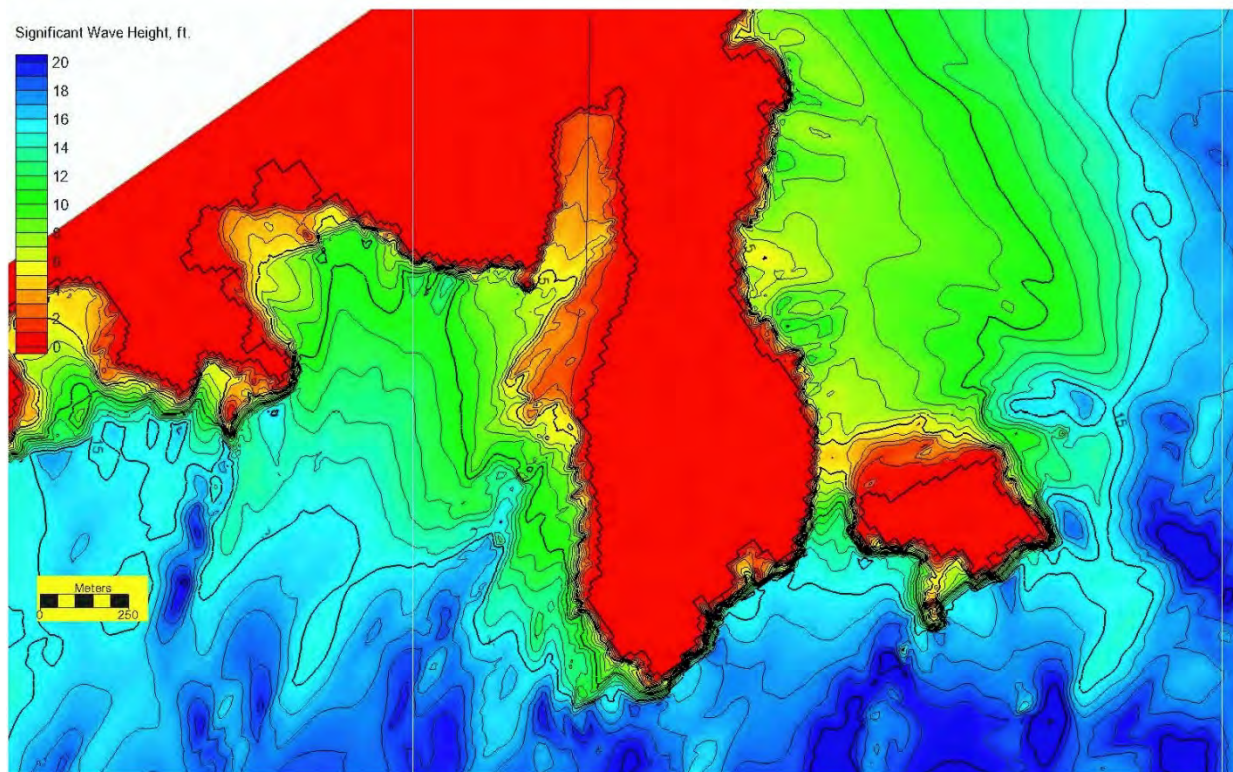
In 2014, the Federal Emergency Management Agency (FEMA) mapped for the first time the coastal flood hazard zones on Isle au Haut. There were only four wave transects for the entire main island and therefore, basically only four major base flood elevations (BFEs). We will not go into all that goes into the mapping of coastal flood zones but it may be instructive to show a few aspects of mapping the flood zones in Head Harbor where Bob Gerber challenged the FEMA flood mapping and was successful in the appeal.

Figure 15



The mapping of coastal flood zones is based on the assumption of the simultaneous occurrence of 100-year surge elevations, 100-year sustained winds, and 100-year wave conditions. For southern Isle au Haut, the 100-year surge elevation is 8.7' NAVD88; the 100-year, 2-hour sustained wind velocity is 56.1 miles per hour; and the 100-year offshore significant wave height and period are 31.3 feet and 11.5 seconds. FEMA considered that the 100-year wave condition is from waves coming in from the Gulf of Maine from the southeast. To determine the wave climate within Head Harbor, we used the model STWAVE starting with the offshore 100-year wave characteristics and wind conditions as boundary conditions, then letting the waves attenuate as they approach the island and enter the harbor. The wave height and period within the harbor is used as inputs to a FEMA program called CHAMP containing using the modules WHAFIS and RUNUP2, which simulate the wave profile of the highest 1% of the 100-year waves and the highest 2% of the wave runup. The wave profile also includes an estimate of wave setup. FEMA used an empirical formula—Direct Integration Method (DIM)—but we used the SWAN 1-D method. The setup is the amount of additional rise in water elevation above the surge elevation due to the momentum transfer of the horizontal wave energy being moved up a sloping surface. The SWAN 1-D method gave a setup estimate of 3.1'. If a 2-D model such as the coupled ADCIRC/SWAN model were used, this setup would have been less due to other lateral energy losses in the waves moving in and along the sides of the harbor.

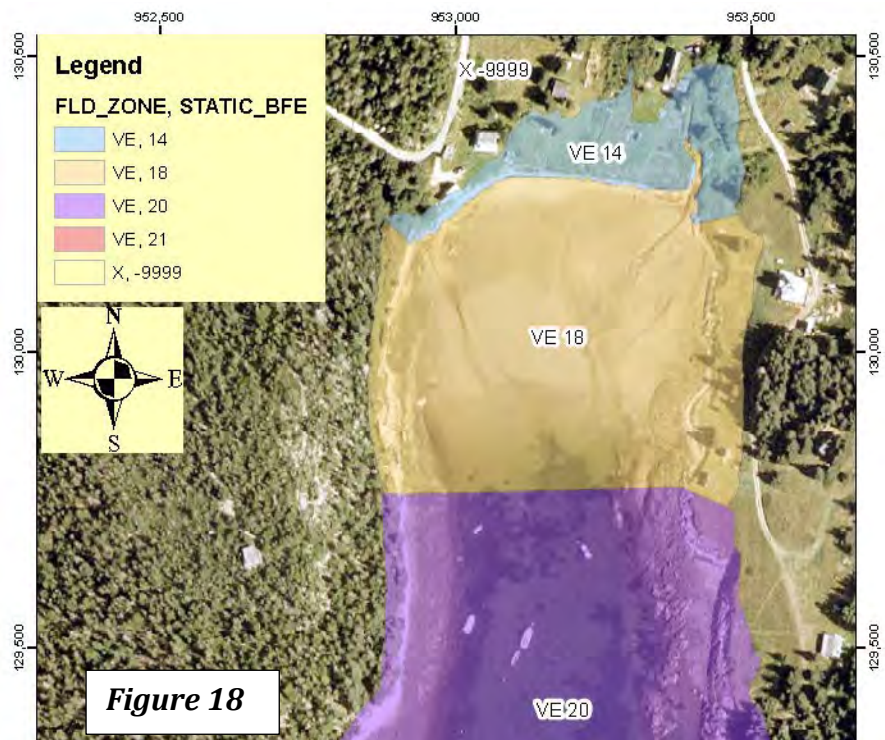
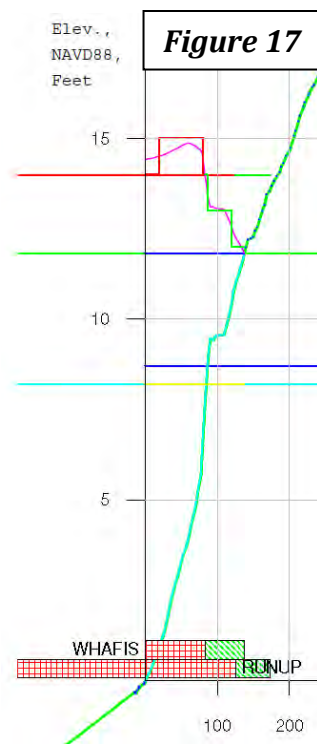
The results of the STWAVE model showing the contours of significant wave height is shown in **Figure 16**.



Significant Wave Height, Head Harbor, Isle au Haut, from 100-year wave conditions from the Southeast

Figure 16

The wave profile developed from the FEMA CHAMP program is shown in **Figure 17** and the final SHFA mapping is shown in **Figure 18**. FEMA had mapped a VE-zone up to elevation 17' NAVD88 everywhere.



Surface Water Hydrology

The surface water hydrology of Isle au Haut is unusual and different from much of the rest of Maine. There are very few perennial streams. Most streams are intermittent or ephemeral that flow in the spring and during heavy runoff, but are dry during most of the summer, fall, and winter. Those streams that are perennial are fed by one of the many bogs on the island. The bog that drains into the head of Moore's Harbor is shown in **Figure 19**. This picture was taken looking northwest from Black Dina Mountain. Another picture taken of a typical bog on the eastern side of the island at ground level is shown in **Figure 20**.



The bogs lie on both sides of the main mountain ridge down the center of the island. The bogs seem to collect runoff flowing off the mountain and then store the water and release it slowly. Therefore, the streams are relatively narrow and difficult to pick out on aerial photos and even the LiDAR-based DEMs. The relatively dense cover of mature spruce trees that covers most of the island seems to provide an

interception barrier (tree interception can capture and then allow evaporation or sublimation of 10 to 20% of rainfall and snowfall) and a relatively tenacious and root-reinforced ground cover, much of which had never been disturbed. The duff layer and topsoil is apparently capable of storing a lot of infiltrating water. However, there are signs that climate change is increasing runoff. There are indications in the middle of the island that streams are forming where no stream previously existed (**Figure 21**). In other established streams, the streambed appearance suggests huge streamflows on occasion although the normal flow condition is a trickle of flow (**Stop 9**). One of the more deeply incised streams in soil on the island is along Merchants Brook, as shown via a



Figure 21

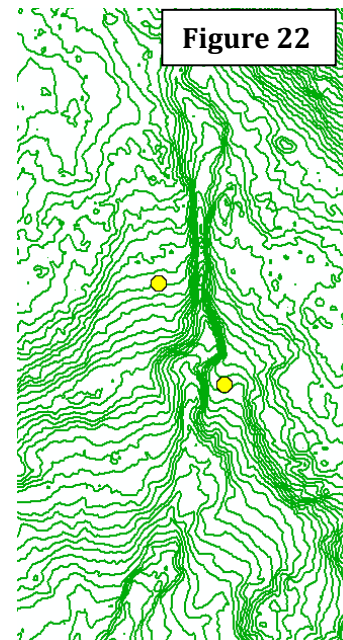


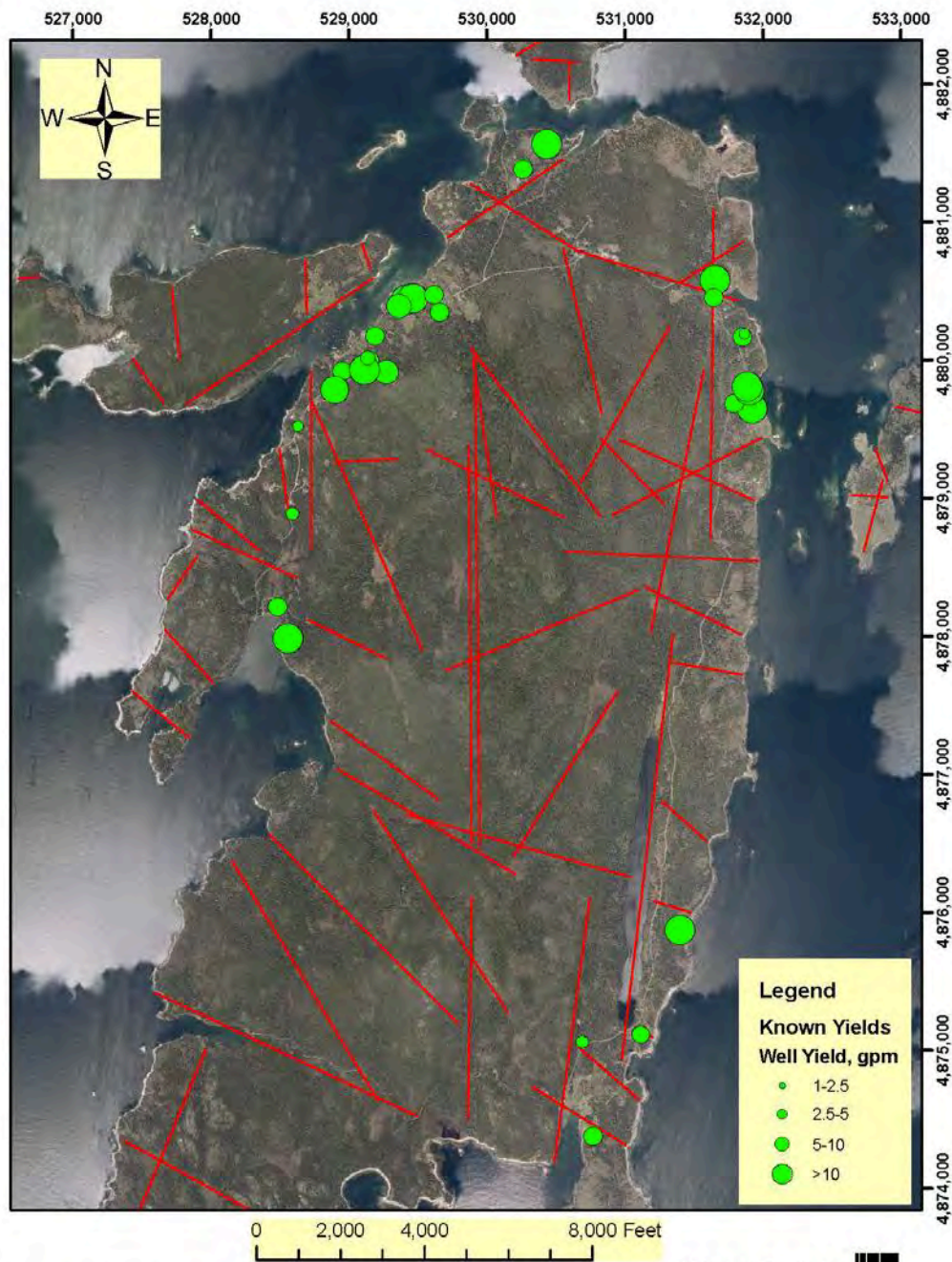
Figure 22

2-foot contour map in **Figure 22**. The streambed consists of gravel and cobbles and the high steep banks appear to consist of gravelly soil.

Groundwater Hydrology on Isle au Haut

In 2009 Bob Gerber was retained to do a groundwater resource evaluation by the Town of Isle au Haut as part of an update to their Comprehensive Plan. As you can see from the collection of maps that follow (**Figures 23, 24, 25, and 26**), most of the residences are located next to the island Main Road and most are wrapped around the north end of the island. Considering the large area of the island compared to the few wells for which we have data, the meaning of the data is still uncertain, but we provide it here. The general conclusions from the data were: 1) the metavolcanics are relatively lower in yield and consequently the wells are deeper than the wells in the granite and gabbro; 2) there are very few cases of saltwater intrusion on the island and some of those cases can be tied directly to bedrock structural features; 3) the water quality is generally good, with iron and manganese being the most frequent complaints.

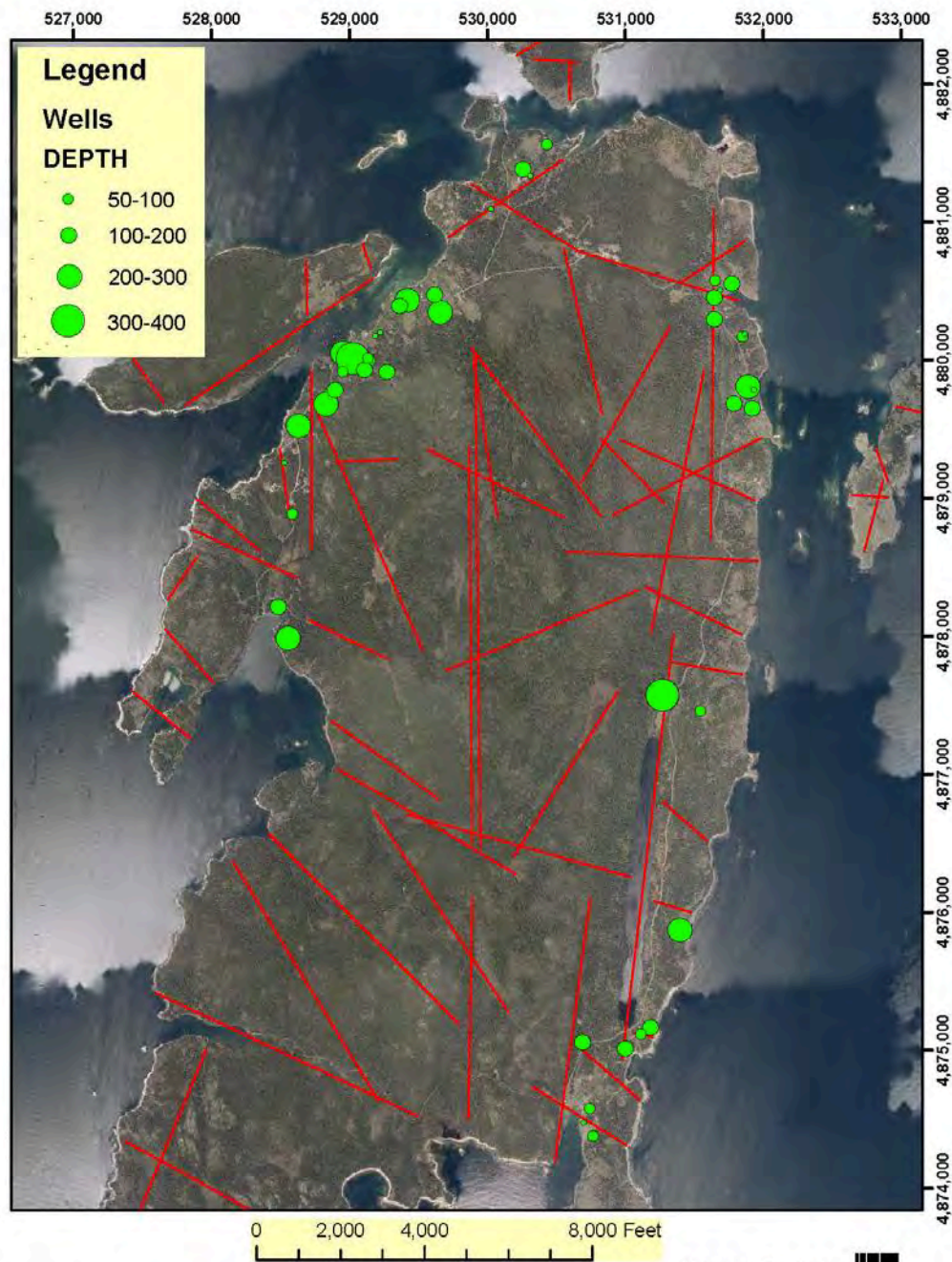
A high school student, Noah Williams, sampled wells on Isle au Haut in summer of 2012 and the samples were analyzed at Dartmouth University for trace metals. Other than iron and manganese, 2 arsenic hits were the only other hits where drinking water standards were exceeded out of 12 trace metals tested at each of 19 household wells. The distribution of the hits is shown on **Figure 27** (multiple hits are shown for several wells on the mapped results).



Well Yields, gallons per minute
Town of Isle au Haut
 Grid is UTM, NAD83, 19N, meters
 RGG 7-3-09 08616

Sebago Technics
 Engineering Expertise You Can Build On
 One Chudut Street
 Westbrook, ME 04090-1338
 Tel: (207) 856-0277

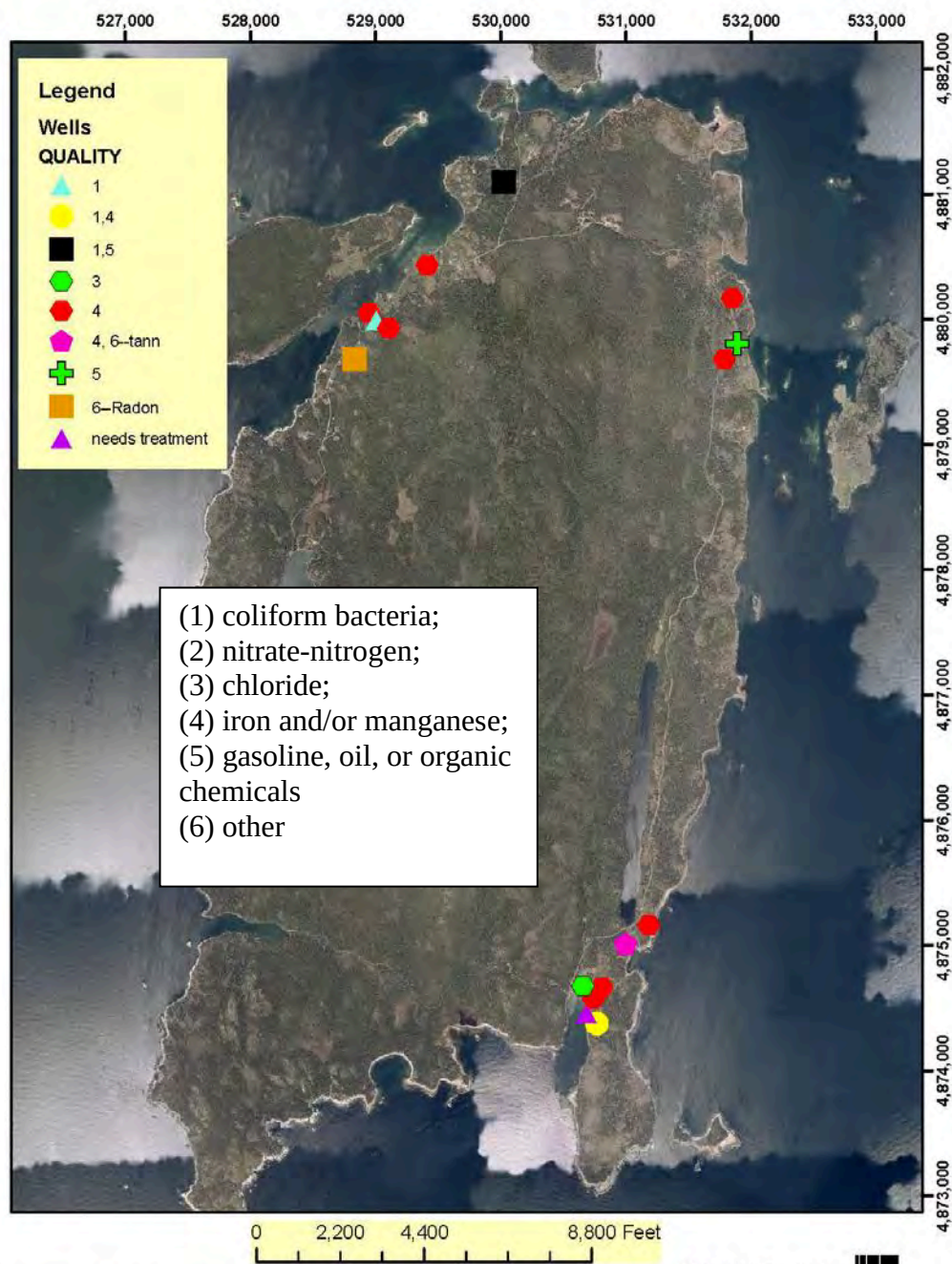
Figure 23



Well Depths from Well Surveys in Feet
Town of Isle au Haut
 Grid is UTM, NAD83, 19N, meters
 RGG 7-3-09 08616

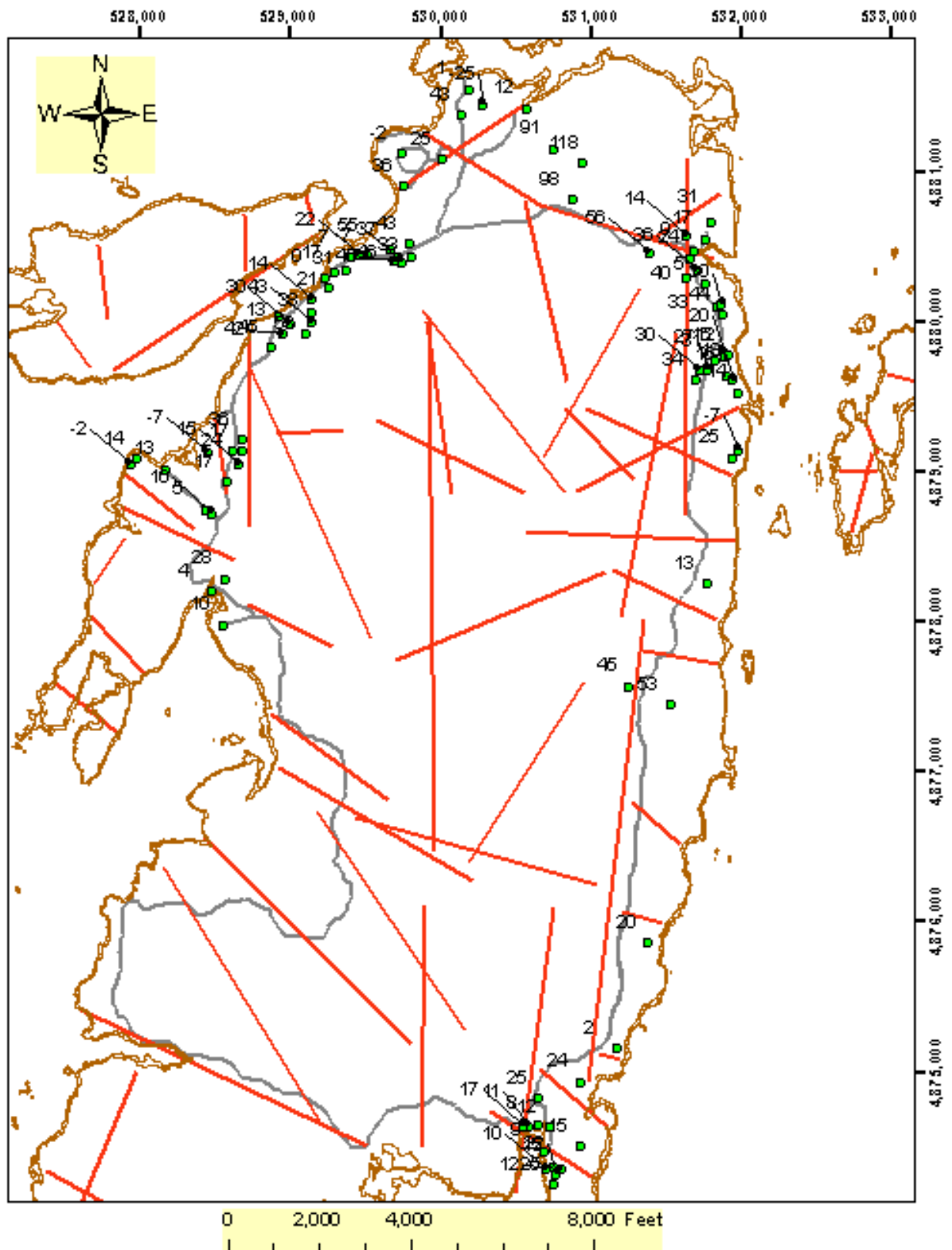
Sebago Technics
 Engineering Expertise You Can Build On
 One Chudut Street
 Westbrook, ME 04090-1330
 Tel (207) 856-0277

Figure 24



Groundwater Quality Issues (refer to Table)
Town of Isle au Haut
 Grid is UTM, NAD83, 19N, meters
 RGG 7-3-09 08616

Figure 25



Well Water Elevations Surveyed by Barker
Town of Isle au Haut
 Grid is UTM, NAD83, 19N, meters
 RGG 7-3-09 08616

Figure 26

Isle au Haut Drilled Well Statistics as Correlated with Bedrock Geology

Cranberry Island volcanics

5 median yield, gpm	150 median depth, feet
13 total number	13 total number
0.5 min	80 min
30 max	320 max

Gabbro & Diorite

15 median yield, gpm	116 median depth, feet
11 total number	17 total number
<1 min	12 min
30 max	350 max

Granite

9.5 median yield, gpm	115 median depth, feet
2 total number	2 total number
4 min	80 min
15 max	150 max



- = Elevated Iron (>300 ppb)
- = Elevated Manganese (>50 ppb)
- = Elevated Arsenic (>10 ppb)
- = High Iron (10-15 ppb)

Noah Williams, 2012
Well Water Quality
Survey

Figure 27

Trip Stops

Due to the difficulties of moving people around Isle au Haut, potential vehicle breakdowns, the inevitable difficulty in tearing people away from the water once they get there, and other exigencies peculiar to island life, we may have to modify our trip stop plan as we go along. However, for those that have the time and interest, or want to revisit this trip on their own and see all the stops, we will describe all the stops we would *like* to make. We just may not be able to make it to all of them during the actual field trip.

Each day, the plan is to start at the Keeper's House Inn on the northwest corner of Isle au Haut at the Robinson Lighthouse. The plan is for the Old Quarry water taxis to drop off and pick off participants staying on Stonington at the Inn dock each day. The vehicles assembled to transport the participants will leave from there and return to there. The first day is devoted largely to bedrock stops. The second day is devoted largely to surficial stops.

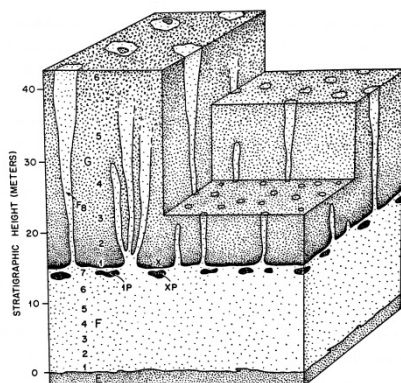
Stop 1—0.0 mile (the Keeper's House Inn). The chalky volcanic deposits around the lighthouse represent one episode of repeated eruptions of a bimodal, stratified magma chamber. The Isle au Haut Volcanic series is a 3.4 km thick deposit with flow-banded rhyolite at the base and three cycles of welded tuffs overlain by basaltic-enclave bearing deposits above. This outcrop is a lithic, vitro, crystal lapilli tuff with basaltic enclaves scattered within. Also contained within the tuff are pieces of the Isle au Haut granite, some of which have a basaltic enclaves adhering to the granite fragments.

The current model, as explored by Whitman et al., 2015, is one in which invasion of basaltic magma into the crystallizing granite chamber of the Isle au Haut granite created a large, supervolcanic eruption. The eruption entrained basaltic magma within the superheated pyroclastic rhyolitic deposits along with pieces of the Isle au Haut granite.

Stop 2—7.6 miles clockwise around island from Keeper's House Inn. Park in the yard of Kendra Chubbuck and John DeWitt (this field trip only; for people going later and following this guide on their own, park on the main road about 7.2 miles from the Keeper's House Inn and walk in the private road that leads around the east side of Head Harbor, then pick up the ANP trail (a sign will point the way across a field to the start of the trail)).

Once you have disembarked from the vehicles at the Chubbuck/DeWitt property, pick up the ANP trail and walk to its southern end at Thunder Gulch, 0.7 miles.

The southernmost exposures on Isle au Haut reveal an alternating layered sequence of five diorites sensu lato and five gabbros (Units AA – I) dipping to the west (**Figure 3**). The gabbroic units are biotite hornblende gabbros and range in thickness from 7 to 106 m. At their bases, they have fine-grained rinds, approximately 4-5 cm. thick, which appear to have chilled against the underlying dioritic units.



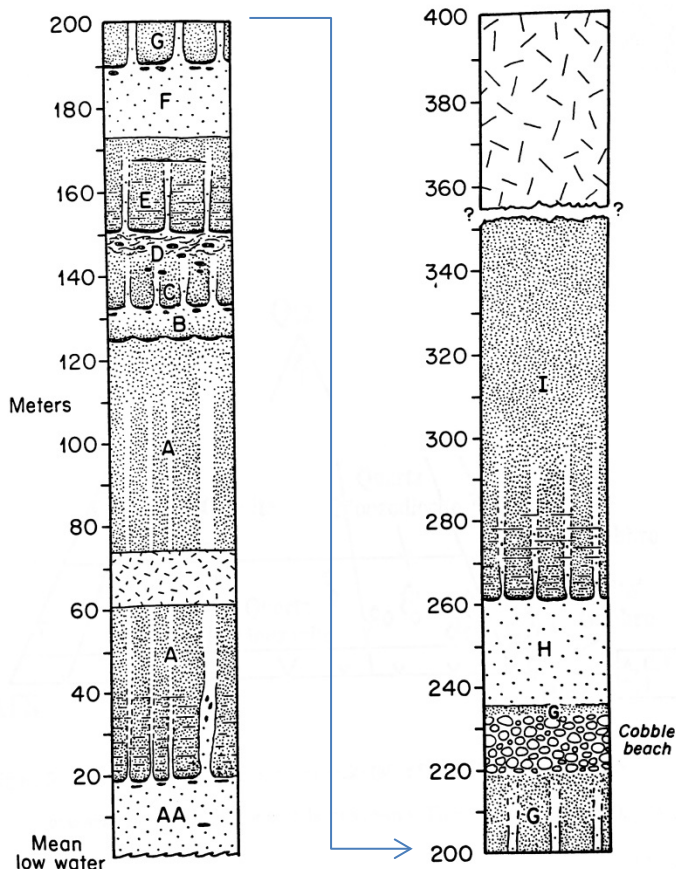
Immediately above this chilled rind, the grain size progressively coarsens through a thickness of 5 meters to a coarse gabbro with 6 mm plagioclase laths and large 11 mm equant hornblende crystals. Local wisps of coarse plagioclase-rich pegmatite occur randomly throughout the units. At the interface of the gabbro and the underlying diorite units are lobate, cusped structures (**Figure 28**) which can best be described as “load cast structures”.

Figure 28

Within the dioritic units, immediately below the chilled contacts, are randomly spaced, globular, mafic “pillow-like” structures ranging in size from a few centimeters up to a meter in diameter. These “load ball structures” are completely detached from the gabbro.

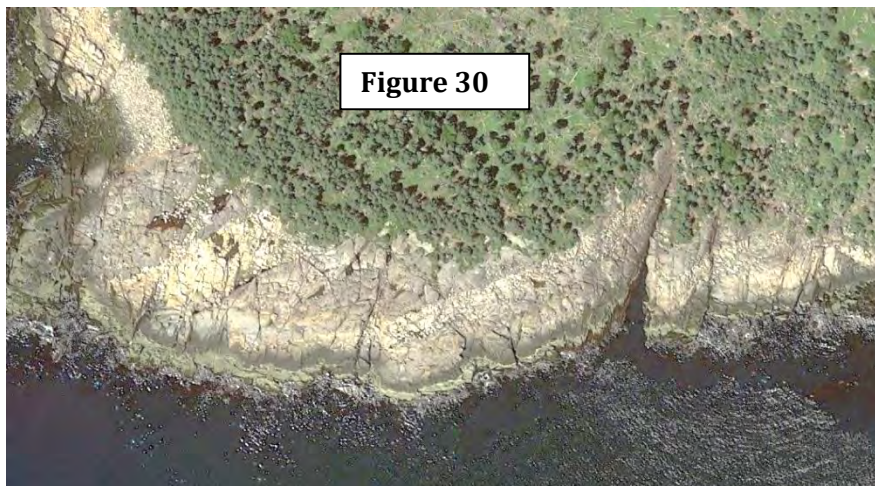
At the same interfaces, fingers or pipes of a part of the dioritic unit penetrate upwards into the gabbro unit for several meters. These fingers and pipes plunge 53°; E 9° S, a direction which coincides with the poles to the planes of the layered units, and further confirms that the magma layers were originally horizontal when emplaced. The pipes are cylindrical in form and, where they occur, tend to be spaced about 1 – 1.5 meters apart. The gabbro has chilled against the pipes for tens of centimeters above the

diorite-gabbro contact. The pipe diameter tends to increase from about 8 cm. to as much as 50 cm. with increasing height in the gabbro (15 meters).



The dioritic units generally are homogeneous with little variation in texture or structure. Stratigraphically lower units are biotite-hornblende quartz diorite changing upwards through the section to hornblende quartz monzodiorite. These range in thickness from 7 to 24 m. At contacts where dioritic units overlie the gabbros, several relationships occur. At stratigraphically higher levels, the contacts are somewhat diffuse and wispy over a restricted area. As opposed to gabbro overlying diorites, no penetration of one unit into the other is apparent and the gabbros and quartz monzodiorites do not appear to interact away from the contact. With lower units, however, the contacts can be obscured by physical mixing and hybridization (**Figure 29**).

Figure 29



Several photographic views of the southern end of Eastern Head are shown in **Figures 30 & 31**. **Figure 30** is a Google Earth view in which the banding of the gabbro with the silicic units is clearly shown. **Figure 31** is a view looking directly north at Thunder Gulch from the water showing a distinct difference in structural pattern across Thunder Gulch.

Figure 30

Figure 31

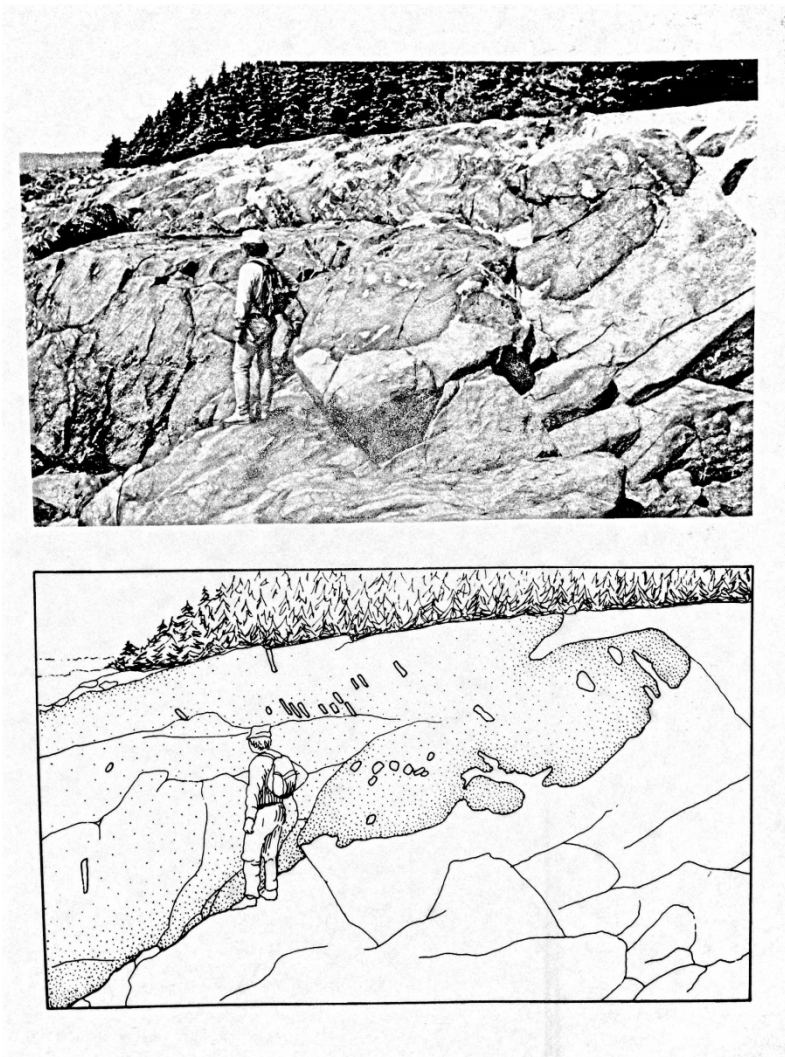
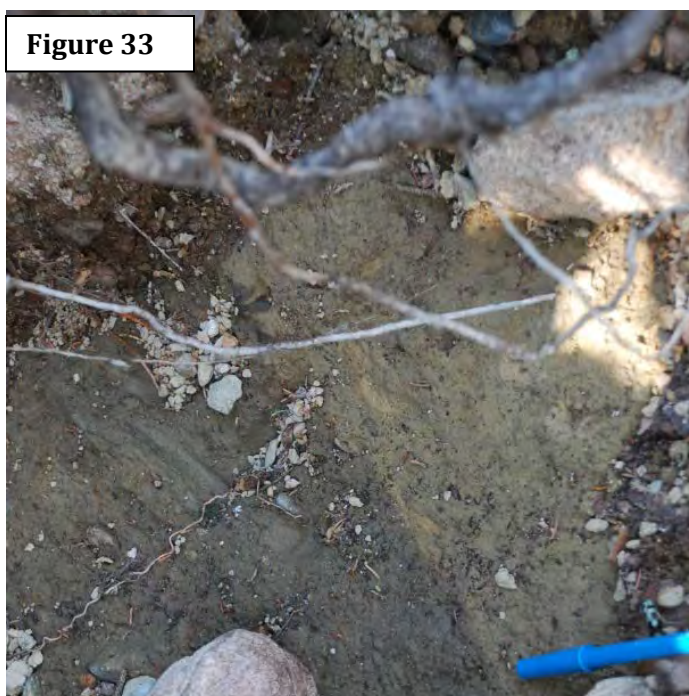


Figure 32,, This is a photograph and sketch of the contact between the gabbro and the underlying quartz monzonite. The contact shows cusped "load cast" structures of gabbro and silicic pipes intruding into the gabbro.

Stop 3—ANP outhouse at Duck Harbor, 2.5 miles from Stop 2. After lunch at Eastern Head, return to cars, travel back to the Town Road, then continue to travel clockwise on the Loop Road around the Island, into ANP and across to Duck Harbor so that those that need an Outhouse can use the one at Duck Harbor. There is a well with a hand pump on the service road into the ANP outhouse that produces potable water. We'll discuss some of the groundwater data and interpretations while people line up to use the outhouse.

Stop 4—travel back to the east to the west side of Head Harbor, 2.0 miles, and park in the MCHT driveway entrance. Walk in on the former driveway, and near the end, look for a path to the left leading to a cliff overlook of Head Harbor. From here you get a view of the Head Harbor village and several marine features of interest.

Stop 5 –Leave the cliff site, return to Loop Road, walk east toward Head Harbor and take a small path to the right across from a small parking space, walk to the shore on this path (0.4 miles). This stop displays the effects of sea level rise on an 1800's-era fishing village on the west side of Head Harbor. Spring high tides today regularly wash into what were the floor areas of former dwellings.



Stop 6 – Time permitting, we will walk an additional 0.2 miles to see a very interesting talus pile along the western edge of an inferred fracture (fault?) zone running north-south through Head Harbor. In this area the major dip of the rock fractures is toward the west, so the blocks of rock are falling east off the face of the cliff by toppling. Head Harbor is one of the few areas on Isle au Haut where there is saltwater intrusion in the wells. At the southwest end of Head Harbor, there are some excellent examples (**Figure 7**) of the prominent bedrock structural features on Isle au Haut that are also expressed as linears in the DEM and on aerial photos.

Although not a specific stop, there is an area of eroded till (**Figure 33**, left) on the shore on the southwestern side of Head Harbor with an exposure of till composed of overridden glaciomarine clay-silt. There is a predominance of fine sand and silt-size material and a general

lack of gravel and cobbles in the matrix.

Stop 7—Return to the Loop Road via the path you followed into the MCHT property, and walk back up the hill to retrieve the vehicles (0.4 miles). Travel counterclockwise on the Loop Road back toward the northern end of Isle au Haut. Stop at the pit on Town-owned land next to the Coomb Cemetery (about 5 miles from MCHT property).

The pit complex on the south side of Coombs Mountain was probably the largest deposit of borrow material on the island. It is difficult to tell at this point what the nature and origins of all the borrow materials were. The Coomb cemetery is near the main road. On a cut bank to the north of the cemetery there is a till-like material exposed (**Figure 34**). A lot of uniform fine sand exists around the edges now and this pit was the source of what locals referred to as “sugar sand.” Local kids swim in the water holes left where water was pumped down to excavate materials from below the water table. They claim there is soft clay in places on the bottom of the ponds.

There are some nice glacial striae and chattermarks (**Figure 35**) on an outcrop on an access road into the pit. On the north side of the pit complex are some very large granite faces with several major joint sets of interest. One of the most prominent WNW-striking linears on the island separates Coombs Mountain to the north from Champlain Mountain to the south (both granite) and this gash probably represents another prominent fracture zone that is parallel to many other linears on the island.

Figure 34



Figure 35

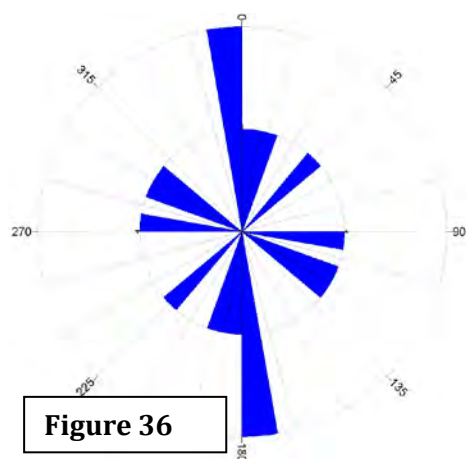


Figure 36

As part of the planning for a moderate income non-profit housing subdivision on land on Coombs Mountain, some basic bedrock mapping was performed, lineament analysis performed, and several new wells drilled. The granite north of the large exposed face on the north wall of the pit has very widely-spaced

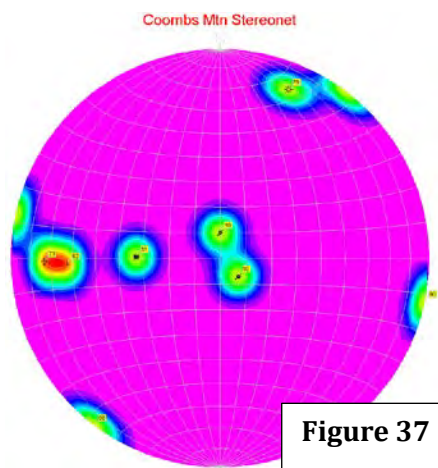


Figure 37

fractures (tens of feet between fractures to the north, away from this face). The well driller's first well went over 300' with basically no water. He was moved over onto a faint linear and instructed to frack the well as he was drilling it in 100-ft increments and the well was able to produce the required 2 gallons per minute required for FHA-financed housing. Another well was also drilled successfully that way and two existing wells that had essentially no measurable yield were improved with fracking. The lower hemisphere Schmidt diagram of the mapped bedrock fractures and a rose diagram (frequency based) of the fracture strikes are shown on the previous page (**Figures 36 & 37**).

End of Day 1—Return to Keeper's House Inn by traveling 2.6 miles counterclockwise from **Stop 7**. There will be a social hour at the Inn before the water taxis return to Old Quarry in Stonington

Begin Day 2

Stop 8—Leave Keeper's House Inn and travel 0.9 miles counterclockwise on Town Road. Stop at Moore's Harbor where you get a view of the ocean to the west. This stop provides a view of a very stable spit built at the northeast end of the harbor where two separate streams draining large areas of bog enter the ocean.

The Moore's Harbor spit is unusual for its size and position, given the fact that rarely is there more than a trickle of fresh water entering the area on the land-side of the spit from the large bog to the northeast. There is a slightly larger perennial water flow entering to the southeast side of the end of the spit, but only during very major runoff events (like once a year) does freshwater flow with any force into this area



Figure 38 is a portion of an 1880 nautical chart that shows the configuration of the cove in 1880. The current configuration of the cove (2014 Google Earth photo) appears identical with the 1880 chart configuration. Given 135 years of passage, this stability is rather remarkable since most spits migrate landward with sealevel rise. There is some bedrock and riprap protection around the house and barn property at the head of the cove that might account for some of this stability.

Stop 9 – Leave Moore’s Harbor and travel south about 0.2 miles and park as much off the road as possible next to an old borrow pit on the left side of the road. Walk south on the road to meet the Duck Harbor Trail about 0.1 mile from the cars, then walk north on this trail about 0.05 mile and turn left at the intersection with the Bowditch trail and go to the foot bridge that crosses a stream. This stop will illustrate the stream that empties into Moore’s Harbor. During last August’s heavy rainfall the headwater bogs filled up to overflowing and sent a huge torrent of water down the stream leaving it boulder strewn. The normal state of this stream is a very small flow. This would have been something like a one in 10-year to one in 25-year storm prior to 2000, but now might be a once-a-year storm.



Stop 9

Stop 10



sand and gravel.

Stop10 – Return to cars from **Stop 9** and drive south (very carefully) about 1.5 mile past the entrance to the Nat Merchant trail to park in an old borrow pit area to the west. Walk back north about 0.03 mile and walk east on the Nat Merchant Trail to Median Ridge Trail. Going north on the Median Ridge Trail one sees a cobble pavement leading uphill north of Nat Merchant Trail. The beach face appears to start as low as elevation 195’. At elevation 230’ on the Median Ridge Trail there is a subtle, but distinct former storm berm.

Stop 11 –This is an optional stop that can be accessed by walking west about 0.06 mile west of the intersection of Median Ridge and Long Pond Trails. This stop is a somewhat subtle beach berm at elevation 170’. This berm has a few cobbles on the surface but probably consists primarily of

Stop 11



Stop 12 – From the intersection of Median Ridge and Long Pond Trails, walk east on Long Pond Trail 0.5 mile to a clearing with many rounded cobbles on the ground. This raised cobble/boulder beach appears to be at the former maximum sea level stand on Isle au Haut. It was mentioned in Stone⁴ where he reports on page 48: “Near the southwestern extremity of the island I traced a line of beach gravel up a valley to a

⁴ Stone, George H. (1899) *The Glacial Gravels of Maine and their Associated Deposits*. US Geological Survey Monograph 34, 499 pages

height of 250 feet by aneroid. Here the rolled gravel suddenly disappeared, and above that elevation, only ordinary till could be found. Guided by the barometer, I then went nearly around the island at this elevation, and at every valley found rounded gravel and boulders up to 225 feet, at which elevation the rolled gravel began to thin out, and the contour of 250 feet was plainly above the water-washed drift."

The Penobscot Bay Folio⁵ basically repeated what was stated in Stone. Leavitt & Perkins (1934) does not contain any maps for Isle au Haut. This particular spot is on a direct line, striking northwest, from Boom Beach and seems to lie on a linear bedrock depression. This suggests that in order for a particular size of beach stone to develop, there may need to be a fracture zone having certain fracture spacings.

Stop 12



Other raised beach deposits can be found sporadically at about the 225-ft elevation contour as one travels around the island but not at all places where a beach might have been expected to have been developed. So a rock source such as a thick till deposit or a bedrock fracture zone of a certain type, combined with a particular exposure to large waves appear to be factors that favored this raised beach development.

Stop 13 – Return to the cars by walking back west from **Stop 12** along Long Pond Trail until the intersection with Median Ridge Trail, then walk south on Median Ridge Trail to the intersection with the Nat Merchant Trail, then walk west back to the Park Loop Road, then south to the cars, a total of about 1.4 miles. Drive south 2.3 miles (turning right onto the Park Service Road at the eastern end of Duck Harbor, to go to the ANP Duck Harbor outhouse.



Stop 14

Stop 14—From the ANP Duck Harbor outhouse, go back up the Service Road and turn right, going east on the Park Loop Road for a total of 0.5 mile to a dirt road on the right that leads to a small cemetery and borrow pit at the end of the road. Here we see an old cemetery developed in the side of a valley that is apparently developed in stratified materials. The LiDAR topography suggests there was a water flow pattern in this area going from east to west toward Duck Harbor.

⁵ US Geological Survey (1907) The Penobscot Bay Folio. Geologic Atlas of the United State, No. 149

Stop 15



Stop 15 -- This is an optional stop. From **Stop 14**,

Stop 15



continue east on the Park Loop Road, then north from Head Harbor on the Town Road 1.7 miles. Park cars and walk 0.15 mile north up an old haul road. This is one of the largest remaining borrow pits on the island. This appears to have developed by meltwater washing under and through wasting ice.

Stop 15



Stop 16 – Return to cars from Stop 15 and travel north on the Town Road about 0.5 mile and park on the grassed parking area on the right. Walk 0.1 mile east to the ocean. Boom Beach consists of rounded cobbles and boulders developed in a cove where bedrock is exposed near the low tide line and at the north and south ends of the shallow cove. The cobbles and boulders seem to have been derived in part from what was probably a moderately thick layer of glacial till that existed in this area at the time of deglaciation and a fracture pattern in the gabbro here that favored a breaking of the bedrock into

cobble- and boulder-sized blocks. Notice the basic shape sorting that occurs at different elevations of the beach.



Near the low tide line there are a lot of rod-shaped rocks with interspersed rounded rocks. A collection of different shapes occur at mid- and high-tide but round and rounded rectangular blocks are most common. At the storm-tide level near the top of the beach, you will find a lot of disc-shaped rocks.



Stop 17 – From the Boom Beach parking lot, travel north on the Town Road 0.3 mile. There are two borrow pits on the east side of the road, east of Long Pond. These pits are somewhat typical of what was probably very common on the island and mined for borrow to build the Town Road. One of the two pits had a thinner soil deposit than the other and is floored on exposed bedrock. The other pit (this Stop) has thicker soil with the partially-sorted silt-sand-gravel and cobbles overlying a dense gray glacial till.



Stop 18

Stop 18 – From Stop 17, travel counterclockwise around the Town Road 4.7 miles. This stop shows no exposed material but you will see some of the largest expanse of relatively flat land on Isle au Haut, the surface of which undoubtedly has some granular and water washed material. There is both a lack of large surface cobbles and boulders and a general droughtiness to the soil surface. There is a large cemetery on the westerly edge of this area next to the Thoroughfare. The area is divided into two terrace levels. The one most inland is called “Kennedy Field” and is the local softball field. The lower terrace stretches from the road to the Thoroughfare and includes the cemetery area. The thickness of the stratified material is unknown, but based on the depth of the local incised streams is likely to be no greater than 4 to 6 feet. The areas to the northeast, southeast, and southwest are shallow to bedrock and glacial till with large surface boulders.

Stop 19—Return from Kennedy Field to the Town Road and continue southwest 1.8 miles to end at the Keeper’s House Inn to end the field trip.