LATE HOLOCENE SUBMERGED PEAT IN THE SOUTHERN SIDE OF HÓP LAGOON, NORTH ICELAND

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Abstract We drilled in the coastal lowland of the Hóp area using a piston type peat corer in order to identify the end of the age of postglacial glacio-isostatic uplift. The depth of drilling was about 2m below the present sea level, and diatom analysis was carried out for core samples about 3m thick. All the deposits consist of peaty materials deposited under fresh water conditions which intercalate H1 micro-pumice layer that erupted in 1104 A.D. at a depth of about 1.2m. The radiocarbon date of basal peat at about 2m below sea level is 2380±150 yBP (GaK-12199), indicating that the isostatic uplift ended more than about 2400 years ago. Since late Holocene submerged peat layers are found in various parts of Iceland as well as in this area, it is clear that the whole coast of Iceland was submerged in the late Holocene. Glacial loading in the late Holocene seems to have been responsible for this submergence.

1. Introduction

Nearly the whole of Iceland was covered with thick ice sheet in the last glacial stage (Einarsson, 1980). Its melting caused conspicuous isostatic uplift in the postglacial stage, which formed raised coastal features considerably higher than the present sea level in various coasts of Iceland.

Around Hóp lagoon, which is described in this paper, there are many raised shoreline features such as fossil beach ridges; their presence indicates that it is possible to clarify isostatic uplift history. However, littl is known about the postglacial glacio-isostatic movement history, in particular, when the isostatic uplift ended in this region.

In order to shed light on this problem, this paper highlights the lowland deposits below the present sea level. We selected a swampy lowland in the southern side of Hóp lagoon as the investigation site (Fig. 1), because we expected to find lagoonal or swampy fine sediments which make it possible to drill easily with a simple hand auger and to collect samples for micro-fossil analysis. No large river flows in the vicinity of this sampling

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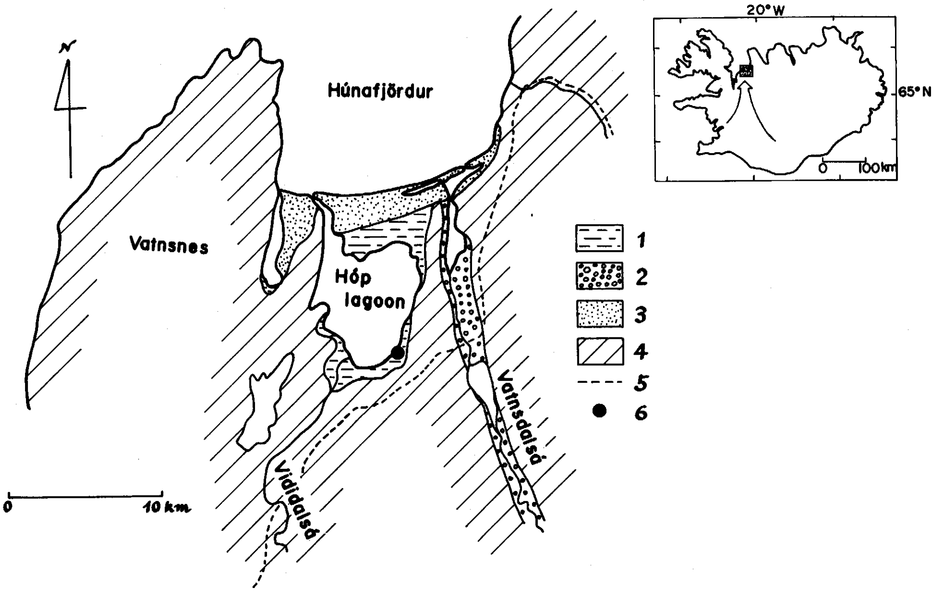

Fig. 1 Landforms around Hôp lagoon, north Iceland, and the investigation site.
1 : Lagoonal lowland ; 2 : Alluvial lowland ; 3 : Barrier bar ; 4 : Highland ;
5 : Drilling site ; 6 : Principal road.

site. As a result, we found submerged peat below the present sea level on the southern side of Hôp lagoon.

Though rather wide lowlands are distributed around Hôp lagoon, most are not suitable for our simple drilling investigation, because these areas are composed of fluvial coarse materials formed by large rivers, the Vididalsâ and Vatnsdalsâ, and of sand and shingle ridge materials derived from those rivers and from the Blandâ river north of this area.

Because the Hôp lagoon is directly connected to the open sea of Húnafjördur through a wide outlet, sea water can freely flow into this lagoon; accordingly, the water level of the lagoon is equal to the open sea level.

The drilling was performed by means of a piston type peat corer (Photo 1), which has a diameter of 3cm and makes it possible to collect a sediment core 5m long. We sampled all the core of the borehole in order to study the depositional environment by diatom analysis. One radiocarbon date was measured in the laboratory of Gakushuin University, Japan. Moriwaki and Hirakawa conducted a field survey and collected samples in Iceland in August 1984, and Ando analysed the diatom fossils in Japan.

2. Results

We drilled four boreholes in this area, of which three were fairly short, reaching hard gravel beds at less than 1m depth. The borehole presented in this paper (Fig. 2) is about 3m long.

Gravel bed occurs at a base of ca. 200cm below sea level in this section. It is possibly of fluvial origin, but the details are uncertain.

Almost all the deposits overlying this basal gravel bed are composed of soft peaty materials (Photo 2). The upper part, shallower than ca. −90cm, consists of sandy or silty

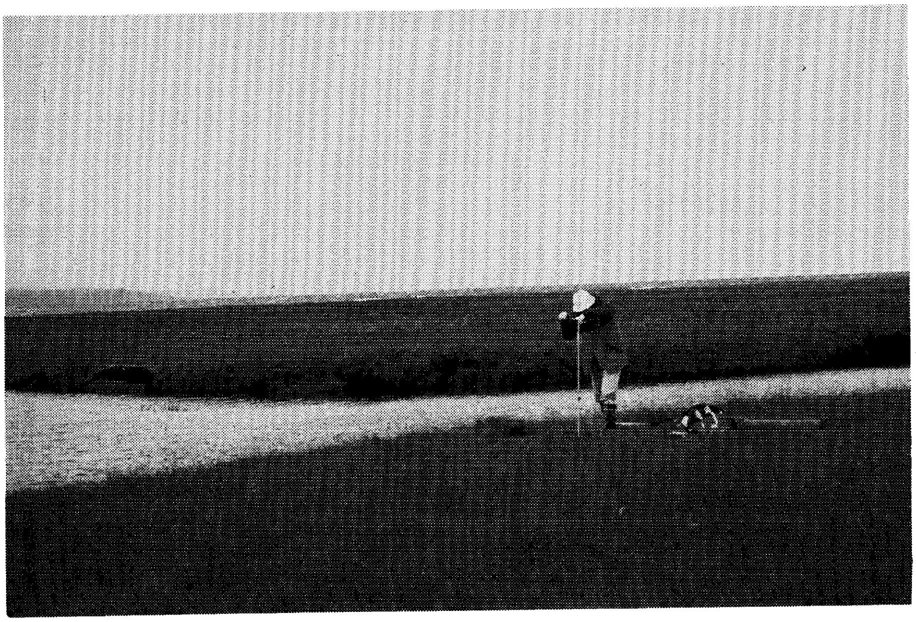

Photo. 1 Sampling site and peat corer.

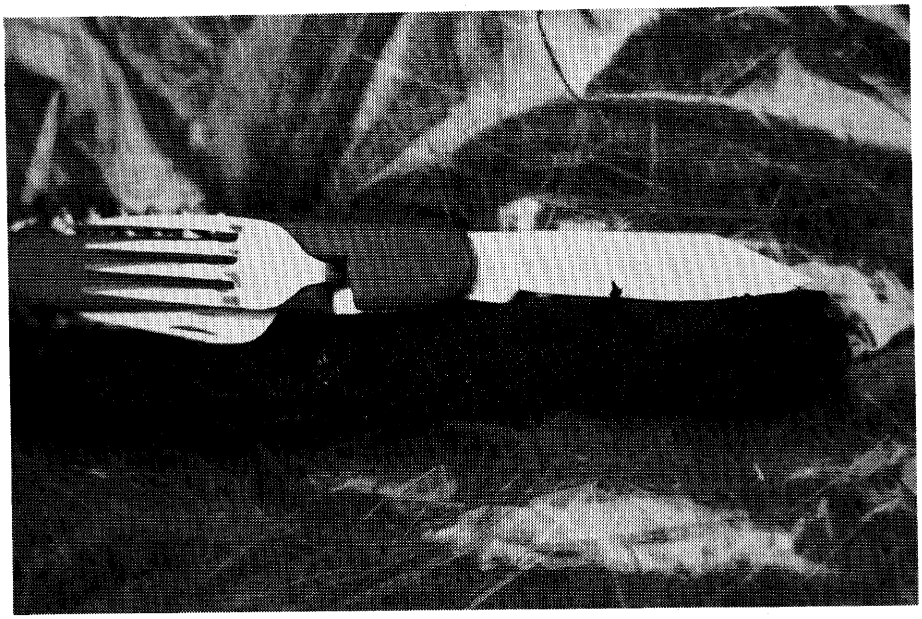

Photo. 2 Peat core sample taken by the corer.

peat, while the lower part is barely decomposed peat. This pure peat layer seems to be of fresh water origin, formed above the former sea level. The base of the peat layer has a depth of 200cm below the present sea level, indicating that a submergence of more than 200cm has occurred in the area.

Diatom analysis

In order to confirm this submergence, we carried out diatom analysis for 25 samples of this core. The procedure for the analysis is as follows.

1) About 5cc of sulfuric acid (H_2SO_4) is added to about 1g of granulated sample in a test tube. 2) The sample in the test tube is boiled over an alcohol lamp for about 10 minutes; then potassium nitrate (KNO_3) is added for bleaching. 3) Two hours after the addition of about 30cc of distilled water, suspended fine sediments are removed by careful decantation. The coarse residue containing diatoms settles at the bottom of the test tube. 4) The residue, refined by repeated washing is mounted on a slide glass with pleurax. 5) The diatom specimens which are at least one quater intact after this procedure are identified and counted by means of 400 times magnification under a light microscope.

As a result, we identified 154 taxa including 33 genera, 133 species, and 21 varieties and forms (Photo 3(1)&(2)). The dominant or subdominant species are as follows. Marine

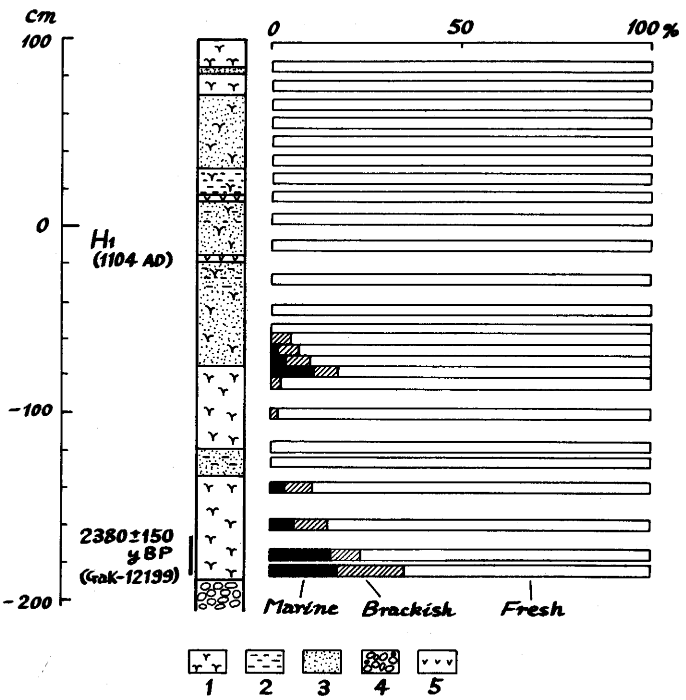

Fig. 2 Borehole section and the environmental composition of diatom assemblages at the southern side of Hóp lagoon. 1 : Peat ; 2 : Silt ; 3 : Sand ; 4 : Gravel ; 5 : Tephra.

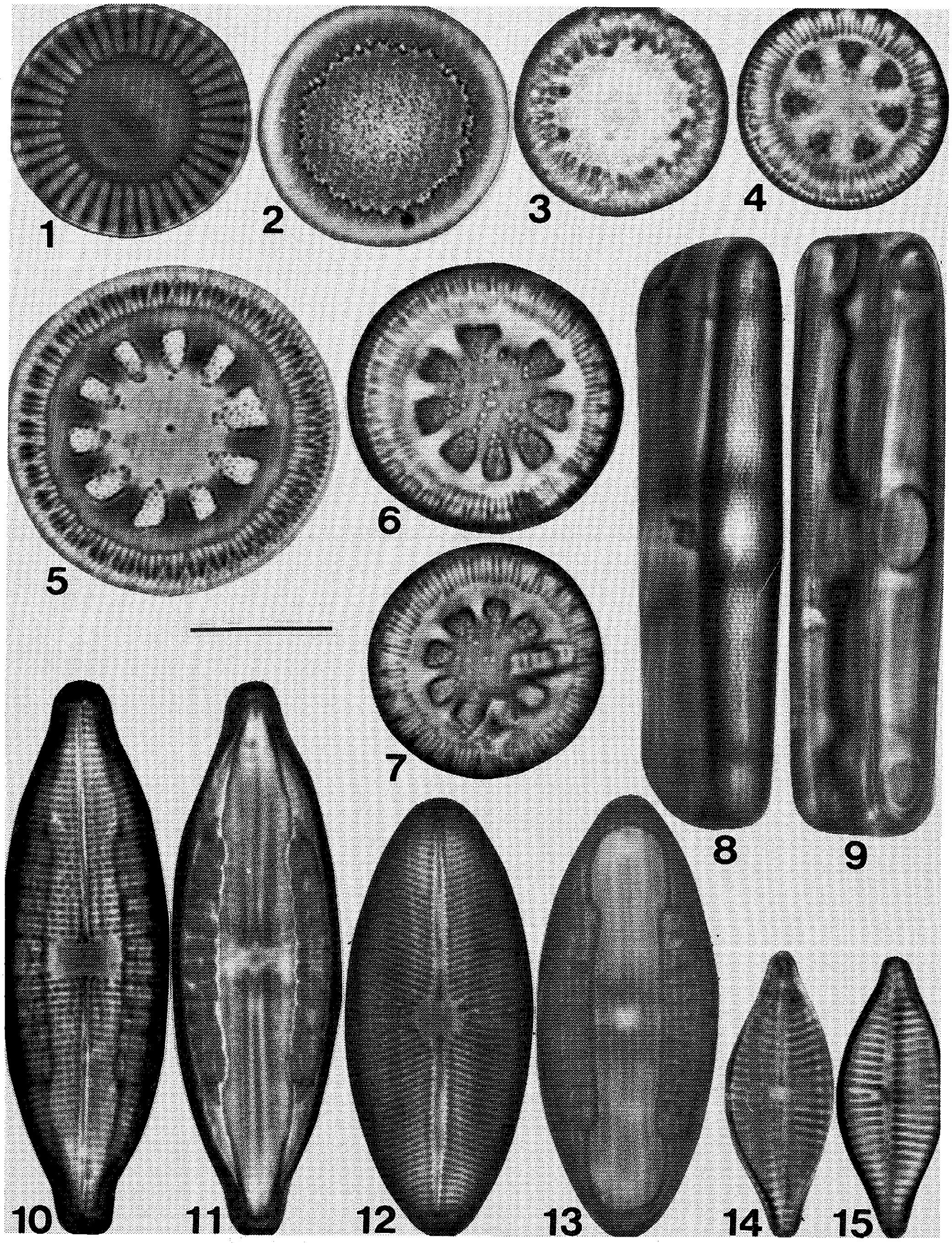

Photo. 3(1) Representative diatom fossils in the peat core sample. 1 : *Cyclotella meneghiniana* Kütz ; 2, 3 : Hyalodiscus sp ; 4-7 : *Cyclotella antiqua* W. Sm ; 8, 9 : *Grammatophora* sp ; 10, 11 : *Mastogloia smithii* Thwaites var. *lacustris* Grun. 12, 13 : *M. elliptica* Agardh ; 14, 15 : *Achnanthes delicatula* (Kütz.) Grun. var. *robusta* Hust. (Scale=10μm).

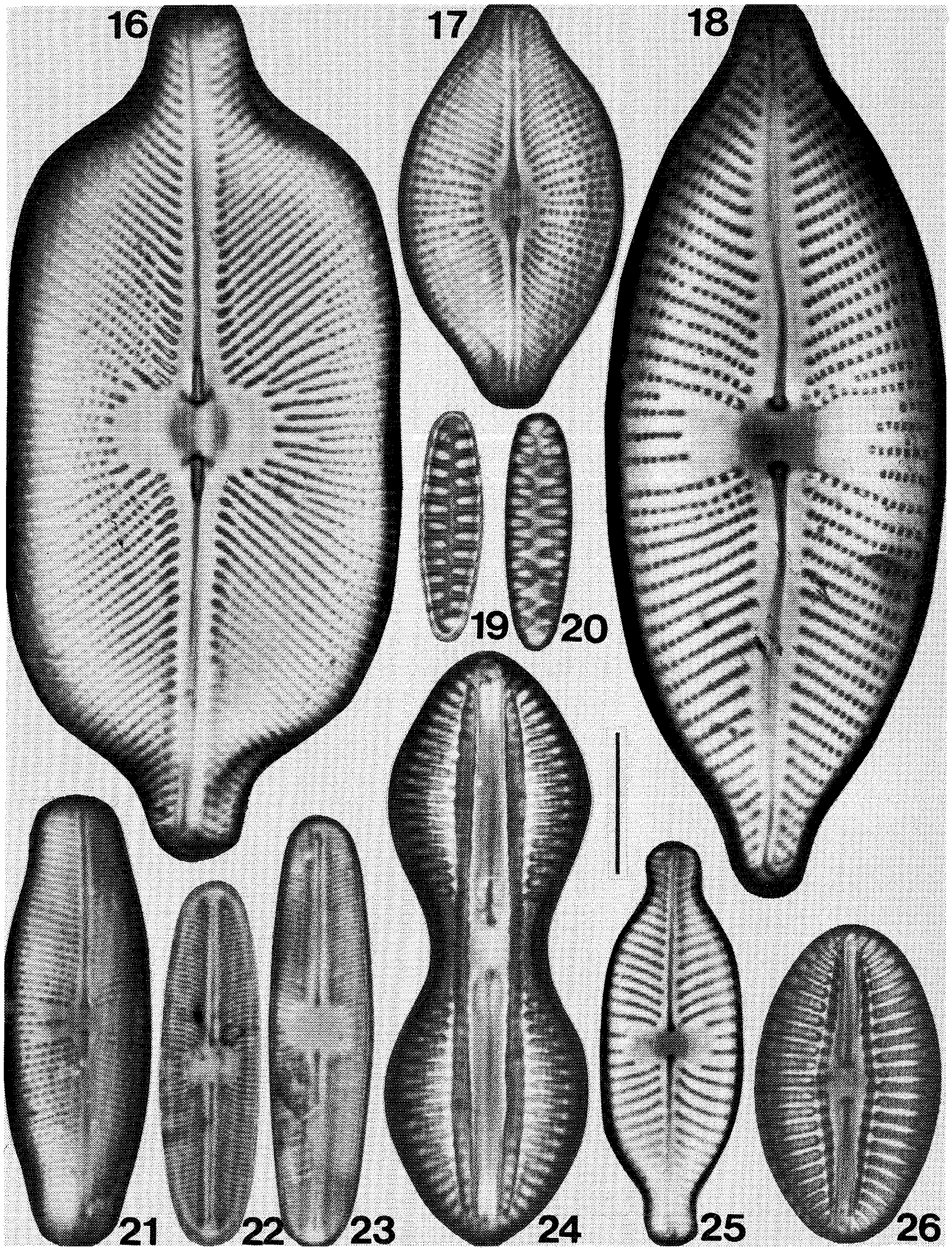

Photo. 3(2) 16 : *Navicula humerose* Breb ; 17 : *N. pusilla* W. Sm ; 18 : *N. amphibola* Cl ; 19, 20 : *Opephora martyi* Herib ; 21. *Navicula subinflata* Grun ; 22, 23 : *N. variostriata* Krasske ; 24 : *Diploneis* sp ; 25. *Navicula elinensis* (Greg.) Ralfs ; 26 : *Disploneis pseudovalis* Hust. (Scale=10 μm).

species: *Diploneis smithii* (Breb.) cl., *Diploneis* sp. (Photo. 3(2), no.24), *Grammatophora* sp. (Photo. 3(1), no.8,9), *Hyalodiscus* sp. (Photo. 3(1), no.2,3), *Navicula subinflata* Grun., and *Nitzschia marginulata* Grun. Brackish water species: *Diploneis pseudovalis* Hust., *Mastogloia elliptica* Agardh, *Navicula flabellata* Meist., *N. humerosa* Breb., *N. peregrina* (Ehr.) Kütz., *Nitzschia sigma* (Kütz.) W. Sm., *N. tryblionella* Hantz., *Synedra pulchella* (Ralfs) Kütz. and *S. tabulata* (Agardh) Kütz. Fresh water species: *Achnanthes lanceolata* (Breb.) Grun., *Cyclotella meneghiniana* Kütz., *Diatoma elongatum* (Lyngb.) Agardh, *Epithemia adnata* (Kütz.) Breb., *Fragilaria brevistriata* Grun., *Mastogloia smithii* Thwait. var. *lacustris* Grun., *Meridion circulare* (Greg.) Agardh, *Pinnularia borealis* Ehr., *Rhopalodia gibba* (Ehr.) O. Müll. and *Tabellaria flocculosa*.

The environmental change in the composition of these diatoms (Fig. 2) indicates that fresh water conditions were dominant in all cores, though some marine and brackish water species are observed in the two horizons of −60cm - −80cm and −140cm - −180cm. Since these species, however, are contained in pure and hardly decompose peat layers, in which fresh water species unable to live with these marine species are fairly abundant, it is most probable that these marine and brackish water species were derived from the outer marine or lagoonal water in the course of submergence after the peat was formed.

Age of the submerged peat

Let's consider the age of the formation of the peat layer on the basis of tephra layers and radiocarbon dating. Four Holocene marker tephras derived from Hekla volcano have been known in this region: H1 (1104 A.D.), H3 (ca. 2800 C-14 yBP), H4 (ca. 4000 yBP) and H5 (ca. 6200 yBP) (Larsen and Thórarinsson, 1977). It is possible to identify each of them by the characteristics of thickness and faces in the field. We found two thin tephra layers in the borehole section. The upper tephra, 80cm deep, is composed of micropumices scattered in peaty sands. We cannot correlate it with any other tephras found in this region. The lower tephra, ca. 1cm thick, and cleanly layered is composed of micro-pumices. These characteristics agree with those of H1 tephra. This tephra occurs at a depth of 120cm in this section.

Moreover, radiocarbon dating shows that the basal peat at 170-190cm below the present sea level, was formed in 2380±150 yBP (GaK-12199). It is concluded that a submergence of about 2m occurred during the past 2400 years in this region.

3. Discussion

The age and depth of the submerged peat in this area pose some interesting problems on postglacial sea level change and isostatic movement. What processes effected this late Holocene submergence: eustatic, isostatic or tectonic? When did postglacial isostatic movement end in Iceland?

As shown in Fig. 3, submerged peat layers have been found in other coasts of Iceland by Jónsson (1957). Diatom analyses for some of these layers clearly show that they were submerged below the present sea level after subareal deposition (Jónsson, 1957). They occur at deeper positions than that of Hōp lagoon. The one found in Dyrhōlaōs coast (Fig. 3, D), south Iceland, is the deepest of them; it occurs at the maximum depth of −8m. In Fagriskōgur (G) along the coast of Eyjafjördur, north Iceland, and in Heggsgerdislōn (C) to the coast of Vatnajökull, southeast Iceland, these layers are more than 6m deep.

Though there are no data on the age of the lowest parts of these submerged peats, it is possible to estimate the age of the basal submerged peat in southeast Iceland on the basis of an intercalated marker tephra and a radiocarbon date for the upper part of the peat. The pumice layer derived from the eruption of Öraefajökull in 1362 A.D. is an important maker tephra for determining the age of the submerged peat in southeast Iceland (Thōrarinsson, 1958). In Heggsgerdislōn, southeast Iceland (Fig. 3, C), this tephra occurs at a depth of about 2m below sea level (Jōnsson, 1957), indicating a submergence of more than 2m in about the past 600 years. Judging from this age, a basal peat 6m deep, overlying marine clay (Jōnsson, 1957), is estimated to have been formed about 2000 years ago. In Stokksnes (Fig. 3, A), immediately northeast of Heggsgerdislōn, submerged peat taken at a depth of about 2m below sea level was dated at 6500 years (Jōnsson, 1957).

Since the submerged peat layers are found in various coasts of Iceland, it is clear that the whole coast of Iceland was submerged in the middle and late Holocene, though the rates of submergence probably differ from place to place. This submergence seems to correspond to the Nucella transgression, named by Thōrarinsson (1955), in Hrūtafjördur, north Iceland (Fig. 3), on the basis of sea level change in the light of tephrochronological and radiocarbon datings. According to Thōrarinsson, the sea level rise of 7-8m

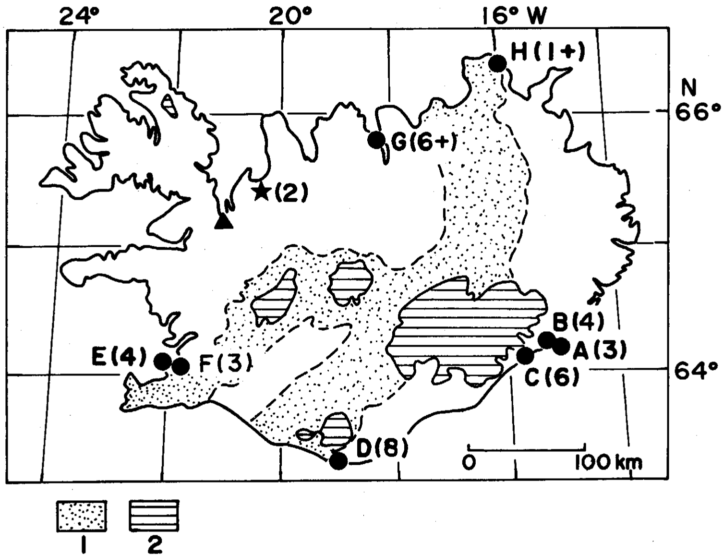

Fig. 3 Localities where submerged peats were found on the Iceland coast. 1 : Median zone ; 2 : Ice cap. Circles : Localities reported by Jōnsson (1957), Triangle : Locality of Nucella transgression found by Thōrarinsson (1955), Star : Locality investigated in this paper. Figures in parentheses show the maximum depths of submerged peat layers.

associated with the Nucella transgression occurred in the middle and late Holocene after the early Holocene rapid regression, which was caused by postglacial glacio-isostatic uplift. At the culmination of this transgression, 4000-4400 years ago, the maximum height of the sea level was about 4m above the present sea level. Thórarinsson attributed this sea level rise to eustatic sea level change.

Nevertheless, there are some problems that remain unsolved if this rise is attributed only to eustatic change. One is whether a sea level rise of such large magnitude as 7-8m could be caused only by eustatic rise after the end of glacio-isostatic uplift. It seems possible to attribute the rise to eustasy alone if the isostatic uplift ended in the early Holocene, but impossible if the uplift continued until the middle or late Holocene, because many reports on postglacial sea level change around the world indicate that eustatic sea level was lower than the present sea level in the early Holocene, and nearly the same as the present level in the middle and late Holocene (Moriwaki, 1978). However, no data on the sea level position in the early and middle Holocene are available from Hrútafjördur.

Another problem is that sea level change after the culmination of the Nucella transgression, *i.e.*, in the past 4000 years, is not fully documented in this area. As mentioned above, the relative sea level in the late Holocene was clearly lower than the present in other areas of Iceland. Thick peat layers uninterrupted by marine deposits in those areas indicate that continuous submergence ocurred in the late Holocene. This submergence history is not necessarily in accord with that associated with the Nucella transgression, whose high sea level was experienced ca. 4000 years ago. Accordingly, the submerged peat layers of Iceland hardly seem attributable to only eustatic sea level change in the late Holocene.

We should also consider the submerged peats from the tectonic and isostatic viewpoints. They are observed in a recently active tectonic zone (*e.g.* Fig. 3, H) as well as in the tectonically stable area around this zone, suggesting that tectonic factors have not been dominantly responsible for the submergence. Concerning the isostatic factor, we would like to take special note of the submergence in historic time which is indicated by the existence of the Öraefajökull tephra layer, dated to the year 1362, in the submerged peats in the southeast coast of Iceland. This age is in agreement with the little ice age in which Vatnajökull grew. This fact suggests that a slight isostatic subsidence occurred in this area owing to the load of ice. Because thick submerged peats are also deposited under this tephra in this region, subsidence affected by the load of ice may have continued from further older age. Further detailed investigation on the age and depth of submerged peats like that carried out in Hóp lagoon is necessary in other areas of Iceland before we come to our final conclusion.

Acknowledgements

H. Moriwaki and K. Hirakawa investigated as members of the Iceland Research Project team from Tokai University, Japan. This work was financially supported by Kyoikusha Co. Ltd. We would like to thank the staff of the project. We also acknowledge

Prof. Tatsuro Asai, group leader of the project, and Prof. Kazuo Nakamura for their encouragement; Dr. Jón Eiríksson, our Icelandic collaborator; Dr. Hreggvidur Norddahl and Mr. Ólfar Ingólfsson for their helpful advice and discussion; and the National Research Council of Iceland for permission to work in Iceland.

References Cited

Einarsson, Th. (1980): *Geology**. Mal og Menning, Reykjavik, 240p.

Jónsson, J. (1957): Notes on changes of sea-level on Iceland. *Geografiska Annaler*, **39**, 143-212.

Larsen, G. and Thórarinsson, S. (1977): H4 and other acid Hekla tephra layers. *Jökull*, **27**, 28-46.

Moriwaki, H. (1978): Problems concerning Holocene sea level changes. *Geogr. Repts. Tokyo Metropol. Univ.*, **13**, 49-64.

Thórarinsson, S. (1955): The Nucella shoreline at Húnaflói in the light of tephrochronological and radiocarbon datings**. *Náttúrufraedingurinn*, **25**, 172-186.

—— (1958): The Öraefajökull eruption of 1362. *Acta Nat. Islandica*, **II, 2,** 1-100.

(* in Icelandic, ** in Icelandic with English abstract)