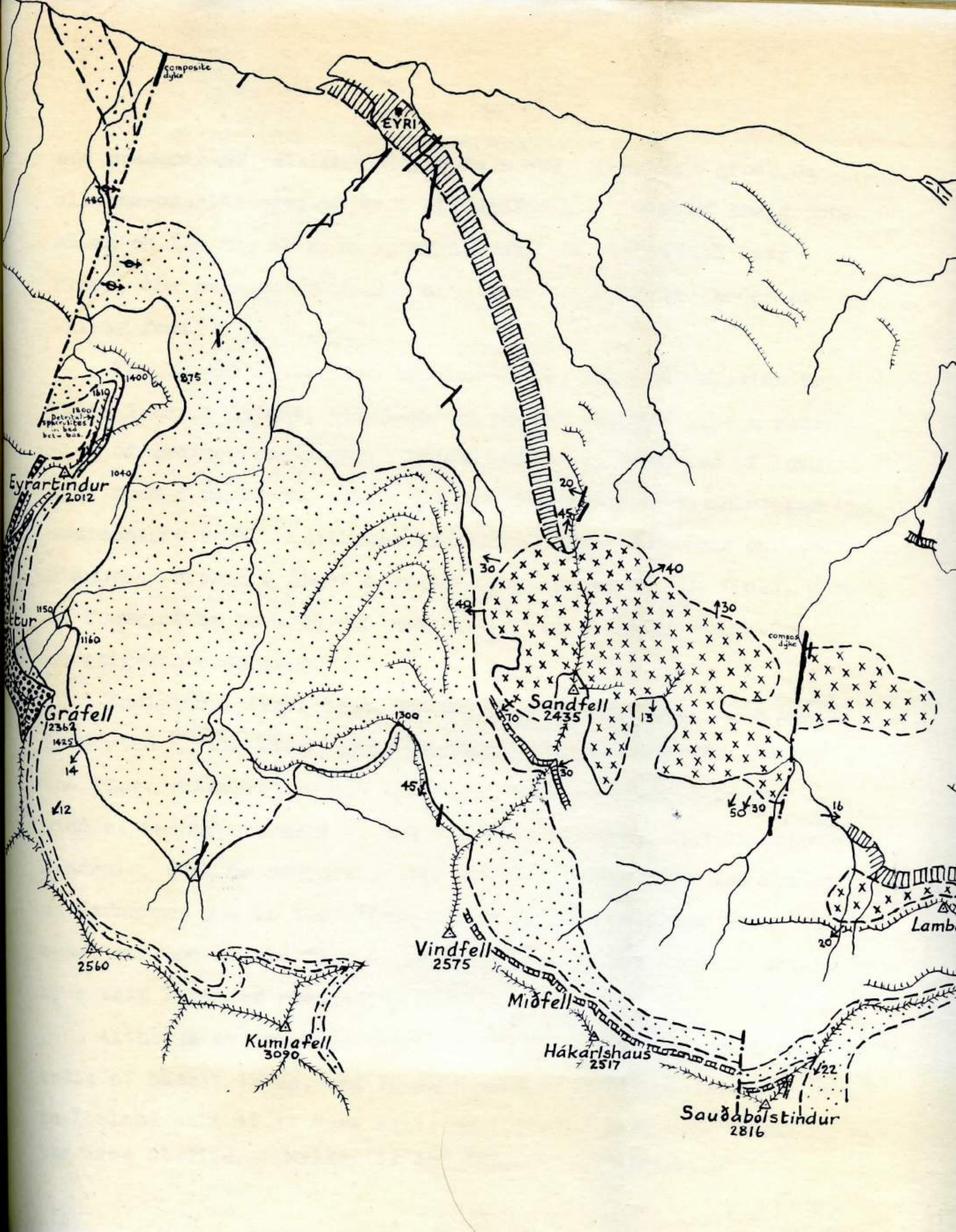
II. 5 GEOLOGY OF THE PENINSULA SOUTH OF FASKRUDSFJORDUR

The ground mapped lies in the Tertiary volcanic region of Eastern Iceland and is composed for the most part of basaltic lavas which are dipping to the west at an average slope of 6-7°. In addition, there are two large bodies of acid rock. One, an intrusive laccolith of quartz-oligoclase porphyry, forms the prominent peak of Sandfjell in the middle of the area mapped. The other, a large mass of rhyolite capping the hills Kottur and Grafjell, forms a lava flow within the basalt succession. In addition, there are several beds of acid tuff.

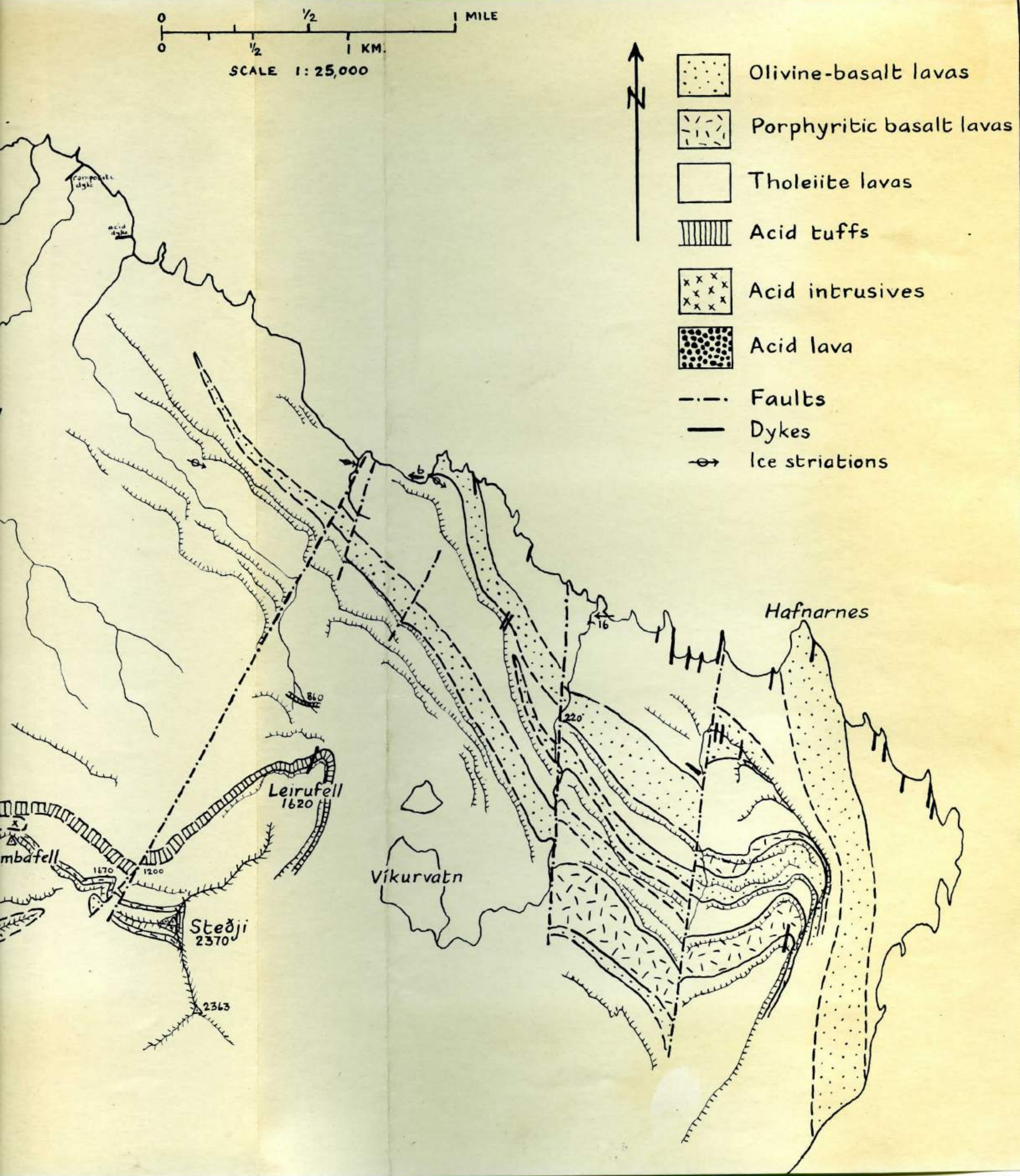
The Sandfjell laccolith was mapped by L. Hawkes in the early 1930's and a detailed description published in the Quarterly Journal of the Geological Society for 1935. In this paper Hawkes mentioned the acid lava of Kottur. An acid dyke nearby was described by Hawkes in the Mineralogical Magazine for 1932. Apart from these papers nothing has hitherto been published on the geology of this part of Iceland, and the basalts have never been studied.

Geological succession and structure:

The main geological features of the peninsula are seen on the accompanying geological map (Fig.17). It can be seen that the geological succession is made up, essentially, of an alternation of three types of basalts - tholeiites, olivine-basalts, and feldspar-porphyritic basalts. Of these three, tholeiites



composite dyke
EYRI
480
875
1400
1610
1800
Detrital spherulites in bed betw bas.
Eyrartindur
2012
1040
1150
1160
Gráfell
2362
1425
14
12
2560
Kumlafell
3090
20
45
30
40
1300
Sandfell
2435
13
70
30
45
compos dyke
50
30
16
20
Vindfell
2575
Miðfell
Hákarlshaus
2517
22
Sauðabolstindur
2816



0
½
1 MILE
0
½
1 KM.
SCALE 1: 25,000
N
Olivine-basalt lavas
Porphyritic basalt lavas
Tholeiite lavas
Acid tuffs
Acid intrusives
Acid lava
Faults
Dykes
Ice striations
Hafnarnes
b
16
220
860
Leirufell
1620
Víkurvatn
mbafell
1670
1200
Steðji
2370
2363

are predominant, although there is a very prominent group of olivine-basalts exposed west of Sandfjell. Each of the groups shown on the map is made up of a number of individual lava flows, the average thickness of a flow being of the order of thirty feet.

The basalt lavas form tabular units, thin in relation to their lateral extent, piled on top of one another like a succession of sedimentary rocks; indeed mountains composed of lava are, from a distance, almost indistinguishable from mountains of sedimentary rock. Although individual lavas may thin out and disappear within a short distance when traced in the field, groups of flows often persist for many miles, hence their value for stratigraphic mapping.

Individual flows have chilled tops and bottoms, this being indicated by the finer grain in these areas. Towards the top of the flow, vesicles, or gas bubbles, which are sparse in the middle, become abundant. The vesicles commonly contain secondary minerals, such as members of the zeolite group which are common at Hafnarnes and in the olivine-basalts west of Sandfjell. The upper surface of the flow is often weathered and usually overlain by a thin layer of red earth.

Although columnar jointing is commonly regarded as characteristic of basalt lavas, and in fact many of the post-Tertiary lavas in Iceland exhibit it very well, no examples have been found in the area studied. Evidently the Tertiary volcanics of

Fig. 18: Glaciated Plain in Faskrudsjfordur

Fig. 19: Stone Polygons

Faskrudsfjordur were not erupted in a favourable environment for columnar jointing to result.

The structure of the area is very simple. The lavas in general are inclined at 6-7° dipping towards the west, although the dip decreases by 2-3° towards the tops of some of the mountains.

Petrology:

Tholeiites: These are the most abundant basalt lavas constituting 1750' of the lower part of the succession near Hafnarnes, and a further 600' near the top. The flows are usually thicker than those of olivine-basalt, 40-50' being typical. They are also distinctive in possessing a strong fluxion structure, usually approximately parallel to the base of the flow, and the tops of the flows are very rubbly, of typical aa type. Vesicles are fewer in the tholeiite flows than in the other types, and pipe-amygdules are absent.

In the field the tholeiites are very fine-grained, and even in thin section the grain size is so small that the constituent minerals are hard to identify. The rocks are composed of plagioclase, pyroxene, and magnetite, together with a certain amount of interstitial glass. The plagioclase is labradorite, and it is the parallel orientation of the tiny plagioclase crystals that gives it its fluxion structure.

Although usually non-porphyritic, it is not uncommon to find

<u>Fig. 20</u>: Frost shattered boulder

occasional phenocrysts of plagioclase up to 1.5 mm. long, and of a composition more calcic than the plagioclase in the groundmass.

Porphyritic basalts: These are uncommon in the area. Their distinguishing feature is the abundance of phenocrysts of plagioclase feldspar. Sometimes these are quite large, and occasional crystals have been seen in the field as long as ¾". The phenocrysts have rounded, corroded outlines and show slight zoning. Associated with them are sparse phenocrysts of augite, much smaller than those of plagioclase. The groundmass of the porphyritic basalts is finegrained and similar in character to the tholeiites.

In most of the specimens examined, the rock has suffered considerable alteration, probably hydrothermal in origin, which has resulted, for instance, in the conversion of augite to chlorite. The alteration is most intense along the upper and more vesicular parts of the flows, and where most intense, the rock has a dark green colour. This alteration is found especially west of Leirufjell and may have been caused by the permeation of steam or hot solutions from the dykes, and, in the area of Sandfjell, from the laccolith itself.

Olivine-basalts: These are distinguished by their relatively coarse grain, by the typical spheroidal weathering of the outcrops, by the possession of a pahoehoe type of top in contrast with the aa which is more characteristic of the tholeiites, by the common presence of pipe amygdules (these are peculiar to the olivine-basalts), and by the greater abundance of secondary minerals (zeolites, etc.) in the amygdules.

In thin section fresh olivine is not often seen, but when it does occur it is seen to be of a forsteritic variety. The plagioclase is labradorite, the augite is a pale brown titaniferous variety, sometimes granular, and sometimes ophitic.

Acid tuffs: Although three or four tuffs have been found, only one is thick and really conspicuous; this is the Eyri tuff, well seen at Eyri on the coast, where it is about 100' thick, and also well exposed on Leirufjell. The rock is bright green in colour, and very soft, being composed mainly of crushed pumice fragments together with occasional small fragments of basalts.

Rhyolite: A rhyolite lava several hundred feet thick caps the hills of Kottur and Grafjell. It rests on basalt lavas, but on Eyrartindur later basalts are seen banked up against the northward termination of the rhyolite. So far as is known the rhyolite forms a single lava flow, but as much of the exposure is covered by scree this cannot be regarded as established. A glassy facies is well developed towards the top of the rhyolite.

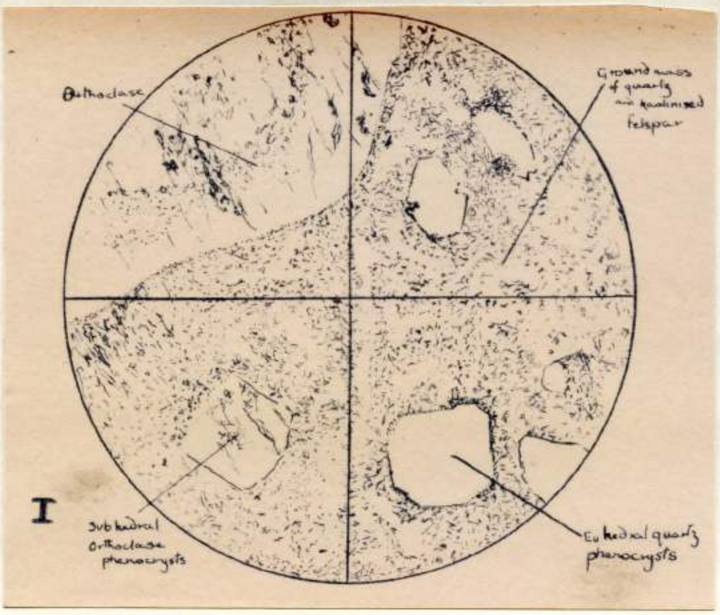
An interesting bed was found on the west side of the ridge of Eyrartindur, between a pair of basalt lava flows. This bed contains an abundance of spherulites of rhyolitic material, and it is clearly detrital in origin, the spherulites having been derived by perecontemporaneous erosion of the rhyolite.

Intrusive rocks: The large rhyolite intrusion composing

Sandfjell is the most striking geological feature of the area, with its pale colour compared with the dark basalt lavas, and with the extensive aprons of scree below the craggy rhyolite summits. The updoming of the basalt lavas to the south and west, is strikingly seen. The intrusion was mapped by Hawkes in the 1930's and our examination fully bears out his conclusions on the structure and origin of the mass.

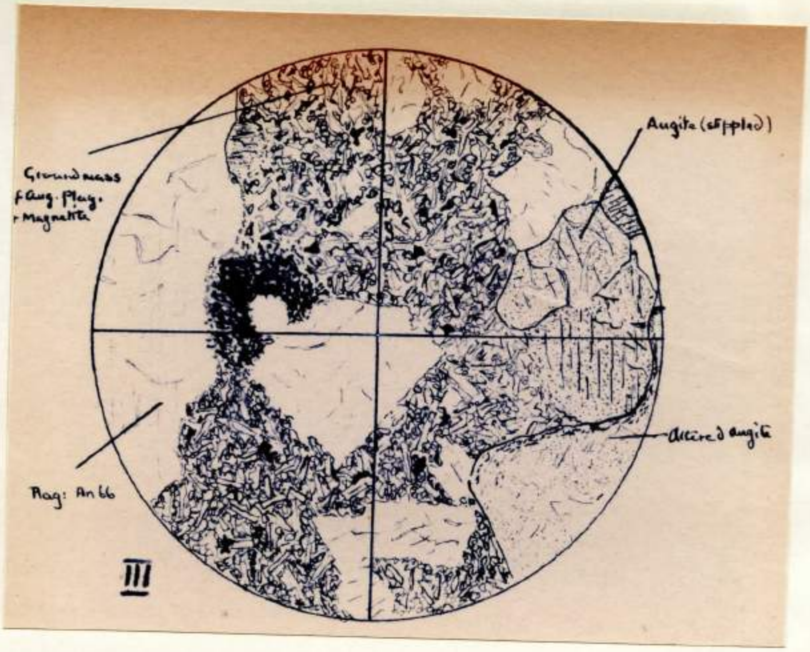
Dykes are numerous throughout the area. Most are basic, with composition approximating to that of the basalt lavas, but a few composite dykes are also seen, with basic margins and acid (quartz-porphyry) centres. These composite dykes are much thicker than the basic dykes, 50' being a typical figure for the thickness compared with the 10' which is common for the basic dykes.

Footnote: The results of Dr. Walker's work in Eastern Iceland over the past few years will be published later in the form of papers to the various learned Societies.

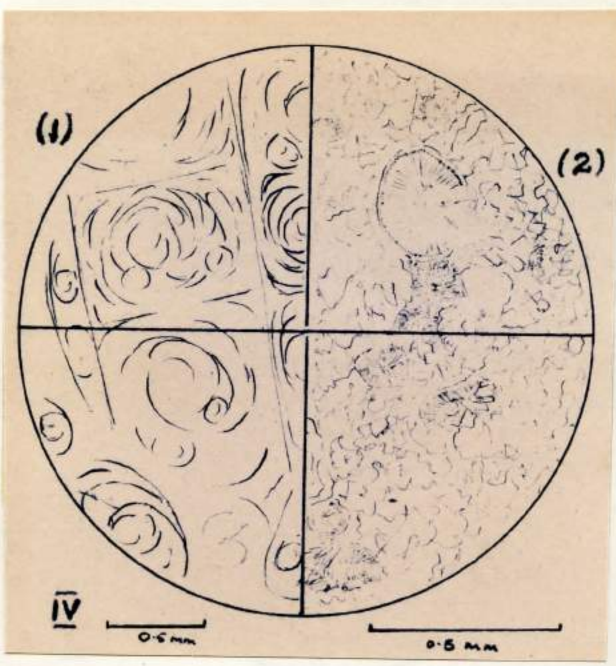


I. Microscope Slide of Dyke Rock of Quartz Porphyry

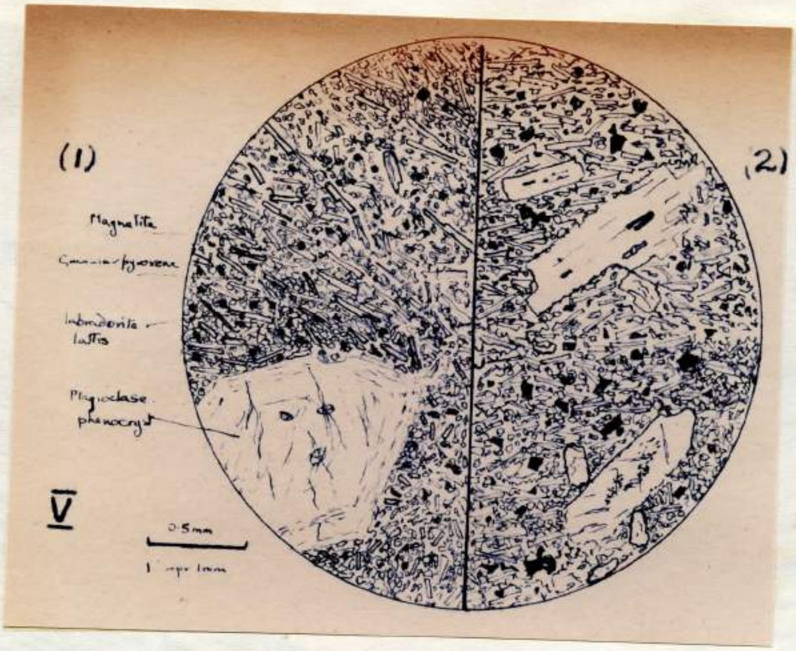
II. Microscope Slide of Coarse Grained Basalt



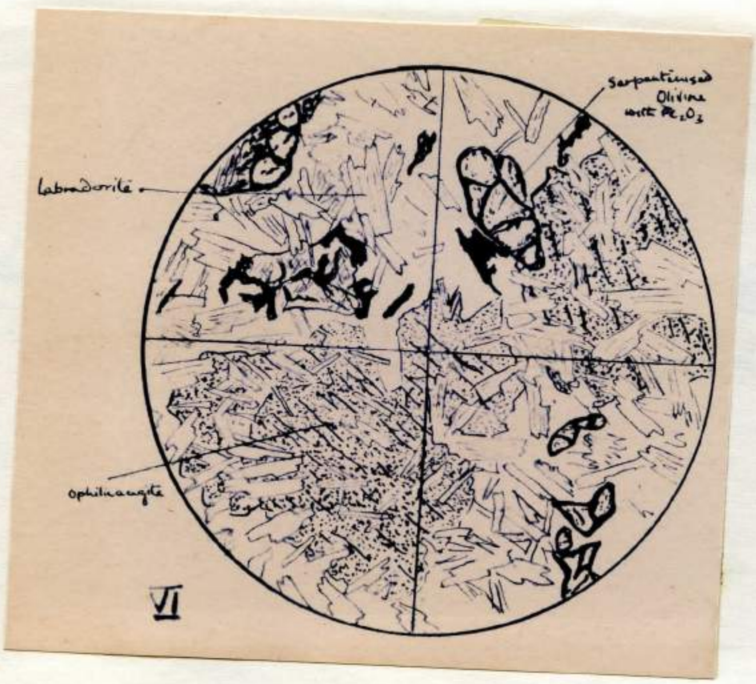
III. Microscope Slide of Porphyritic Basalt



IV. Microscope Slide of (1) Porphyritic Obsidian
(2) Devitrified Rhyolite with Small
Spherulites

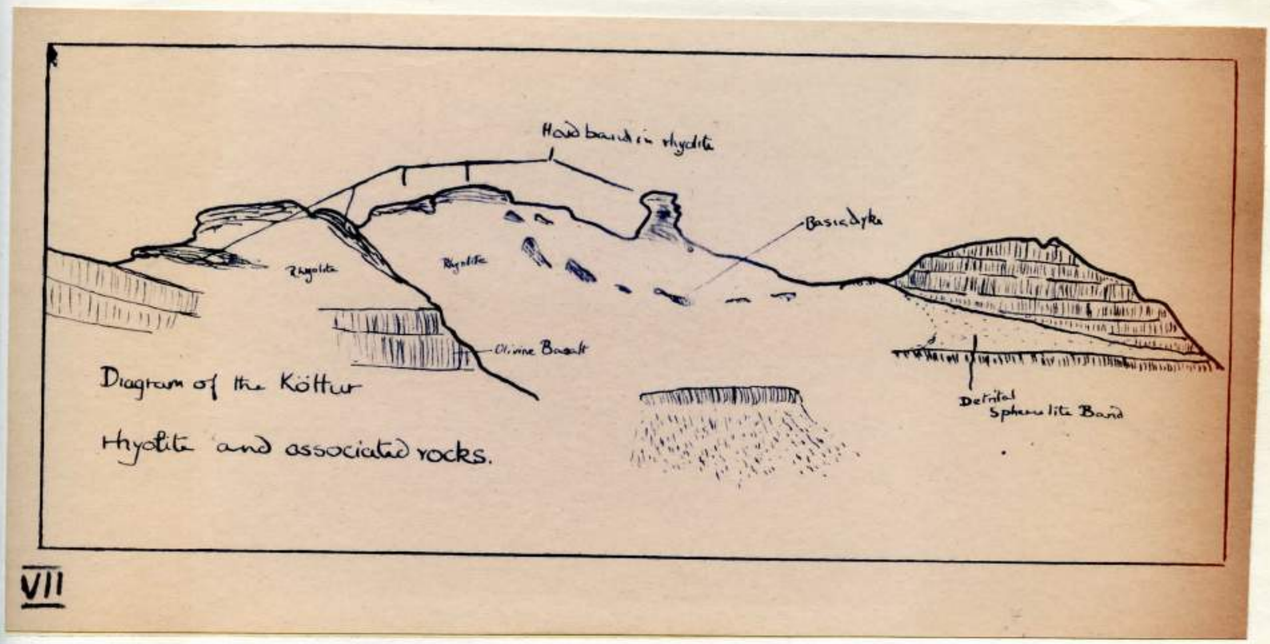


V. Microscope Slide of (1) Tholeiite with Accidental Pheonocryst, (2) Porphyritic Tholeiite.



VI. Microscope Slide of Olivine Dolerite Dyke Rock

VII. Field Sketch of Glaciated Valley with Typical U-shaped Profile, W. side of Sandfell.



VIII. Field Sketch of Köttur showing the Relationship between the Basic Lavas and the Thick Acid Flow from the North-East.

II. 6 ORNITHOLOGY

Several members of the expedition were interested in the birds of Iceland, and a certain amount of time was spent in this pursuit. Most of the birds listed in Table II are to be expected in the type of country we visited, and correspond closely with data given on Icelandic birds in "A Field Guide to the Birds of Britain and Europe" by Peterson, Mountford and Hollom.

The list of sightings in Table II has been roughly divided according to the fjords where the observations were made, with three additional columns; one for the period of travelling, (which includes the sea voyage from the time we lost sight of Scotland until the end of the bus journey across the island, and the return trip), one for the icecap, Thrandarjokull (this only including birds actually seen on the cap), and the other for birds seen at Myvatn.

Probably the commonest bird in the area was the Arctic Tern, many colonies occuring on each of the fjords. From the attitude of the terns towards intruders, especially ourselves, we are led to believe that the local population raid the colonies for eggs. On coming within say 30 yards of a colony certain of the birds would keep up a continuous attack, diving from all angles, and just pulling out before they hit the intruder's head. One member of the expedition was hit twice on the head by a very large tern, and on another occasion they attacked a theodolite as it stood on its tripod. Arctic Terns were seen to attack Arctic Skuas in Seydisfjordur, where the terns were feeding on floating waste from the fish gutting processes, and the skuas were trying their usual piratical tricks.

Another common bird was the Eider Duck, now protected under Icelandic law with regard to killing for the down. Heavy penalties are incurred for killing these birds. Many other ducks were present too, but they soon went into eclipse, and this made identification difficult.

In Seydisfjordur there were large flocks of gulls. These were mainly Herring Gull, and they fed from the fish wharves. Among these were a few black-backed gulls of both varieties, and some "albino" gulls which were rather difficult to identify. The only conclusion we could come to in the field was that they were Iceland Gulls, but that they had strayed from their usual breeding grounds in Greenland. The birds had pure white wing tips and were about the same size as the Herring Gulls. On consulting Dr. Finnur Gudmundsson, of the Natural History Museum in Reykjavik, it was decided that they might have been Glaucous Gulls just living with the Herring Gulls, but not breeding, or more likely they were Herring Gulls with faded wing tips.

On the island of Skrudur, between Reydarfjordur, and Faskrudsfjordur, there was a large colony of Kittiwake and Fulmar, with a few Gannets. This is a steep rocky island, 161 m. high, rising straight out of the sea. The local farmers-cum-fishermen visit this island periodically during the breeding season to collect young Kittiwake, which is apparently a local delicacy.

At Djupivogur there are many skerries, and small inlets on which many birds can be seen. Large flocks of duck were seen, but not identified. Also a Gyr Falcon, sitting on one of the skerries. A Red-throated Diver was seen fishing here too. By far the most important sighting of the whole trip occurred here. Only one day was spent watching in this locality, but in that day a group of 6 to 8 Swifts were seen several times by two members of the expedition. Previously (private communication - Gudmundsson) only a few odd pairs have been seen in Iceland. There is absolutely no doubt as to their identity, as they were viewed at only 20 yards, and with their distinctive colouring, shape, and general habits no mistake could have been made.

According to the distribution maps in Peterson, Mountford and Hollom, Oystercatchers do not breed on the eastern fjords of Iceland. At least one pair, and usually more, were seen on each fjord, and at Seydisfjordur several of the chicks from one nest were found. At the time three of the expedition were trying to find a Red-necked Phalarope's nest, but due to the insistent warnings of the Oystercatchers she would not lead us to her nest. However we did find three of the Oystercatcher's chicks.

An interesting sequence of events was observed with the Golden Plover. When the expedition first reached Reydarfjordur they were in the middle of the nesting season, our camp being surrounded by nesting birds, these giving us good warning of anyone approaching. This was at the end of June and the beginning of July. At the beginning of August the chicks had fledged, and the birds were collecting in flocks of 30-40, which were feeding on the newly mown hay fields. By 26th August, when we returned from the ice-cap, there were none of this species left. The Ringed Plover had not at this time migrated.

One member of the expedition spent a few days at Myvatn, the famous lake in central Iceland, on and near which there is a fantastic collection of birds. Unfortunately most of the ducks were in eclipse, thus making identification difficult.

TABLE II

Bird Check List

	Trav.	Seydis.	Reyd.	Fask.	Dj.	Ice.	Myvat
Eider Duck	✓	✓	✓	✓	✓		
Mallard	✓	✓	✓	✓	✓		
Scaup	✓	✓					
Goosander				✓			
Teal							✓
Gadwall							✓
Widgeon							✓
Pintail							✓
Tufted Duck							✓
Barrows Goldeneye							✓
Longtailed Duck							✓
Scoter			✓				✓
Red Breasted Merganser				?			
Oystercatcher							
Ringed Plover	✓	✓	✓	✓	✓		
Golden Plover	✓	✓	✓	✓	✓		
Merlin	✓	✓	✓	✓			
Whimbrel	✓	✓	✓	✓	✓		
Purple Sandpiper			✓	✓		✓	
Redshank	✓	✓	✓	✓	✓		
Dunlin	✓		✓	✓	✓	✓	
Snipe	✓	✓	✓	✓			
Turnstone				✓			
Ptarmigan				✓			
Red-necked phalarope	✓	✓	✓	✓	✓		
Great Skua	✓				✓		
Artic Skua	✓	✓	✓	✓	✓		

	Trav.	Seydis.	Reyd.	Fask.	Dj.	Ice.	Myvatn
Gannet	✓		✓	✓			
Fulmar	✓	✓	✓	✓	✓		
Herring Gull	✓	✓	✓	✓	✓		
Blackheaded Gull	✓	✓	✓	✓	✓		
Gt. Black Backed Gull	✓	✓	✓	✓	✓		
Ll. " "	✓	✓	✓	✓			
Arctic Tern	✓	✓	✓	✓	✓		
Kittiwake	✓	✓	✓	✓			
Manx Shearwater	✓						
Guillemot	✓		✓	✓			
Puffin	✓	✓	✓	✓			
Slavonian Grebe							✓
Gt. Northern Diver	✓		?				
Barnacle Goose			?				
Greylag	✓						
Whooper Swan	✓						
Gyr Falcon	✓				✓		✓
Raven	✓	✓	✓	✓	✓		
Wheatear	✓		✓	✓	✓	✓	
White Wagtail	✓	✓	✓	✓			
Meadow Pipit	✓	✓	✓	✓	✓		
Redwing	✓	✓	✓	✓	✓		
Snowbunting	✓	✓				✓	
Swift					✓		
Spectacled Guillemot			✓	✓			
Black Guillemot		✓	✓	✓			
Red Throated Diver	✓				✓		

Seydis. - Seydisfjordur
Reyd. - Reydarfjordur
Fask. - Faskradsfjordur

Dj. - Djupivigor
Ice. - Icecap

III. APPENDICES

III. 1 SURVEYING TECHNIQUES USED ON THE RAISED BEACH PROJECT

The principal object of the surveying party was to find the heights of the raised beaches in the various fjords along the east coast of Iceland, and by relating these heights to a common datum, to find whether the island had tilted as a whole during the uplift process which led to the formation of the raised beaches.

The relating of the heights of the beaches to a local datum was thought to be a relatively easy task, but the correlation of these data was considered to be more of a problem. There were several possible methods available:

1) To select an arbitrary datum, and transfer this from one fjord to the next by spirit levelling round the coast, over the mountains, or over the road passes.

2) As (1) but to use tacheometric levelling techniques. This would be a far faster process on the whole, as, although the actual setting up of a theodolite takes longer than that of a level, far less set ups would be needed.

3) To select mean sea level as a datum (or some other datum which could be compared with mean sea level), and to relate the heights of the beaches to the observed mean sea level in each fjord.

After consultation with Dr. Walker, (the leader of the Expedition), who had been in the area several times before, and study of the maps available, it was decided that it was impracticable to carry the levels overland from one area to the next. This meant that mean sea level had to be determined in the relevant fjords.

Determination of mean sea level:

Commander Gordon of the Hydrographic Department of the Admiralty was consulted on this matter. From data supplied by him it was decided that the tidal range in the area did not exceed ten feet, and with this knowledge two twelve foot tidal staffs were made (Fig. 7). Each was made from two 6' x 6" x 1" lengths of teak, hinged together end to end, two brass rods attached by bolts and wing nuts being used to stiffen the staff when extended. On the faces of the staffs, one foot, and tenth foot markings were scribed, the staffs painted white, and alternate one-tenth sections painted black. The one foot markings were numbered from the bottom of the staff, with, contrary to the usual practice when marking staffs, the bottom of the number indicating the one foot interval. The numbers were six inches high, painted red, and the symbols V, N, O, and 1 were used to indicate five, nine, ten and eleven respectively. The

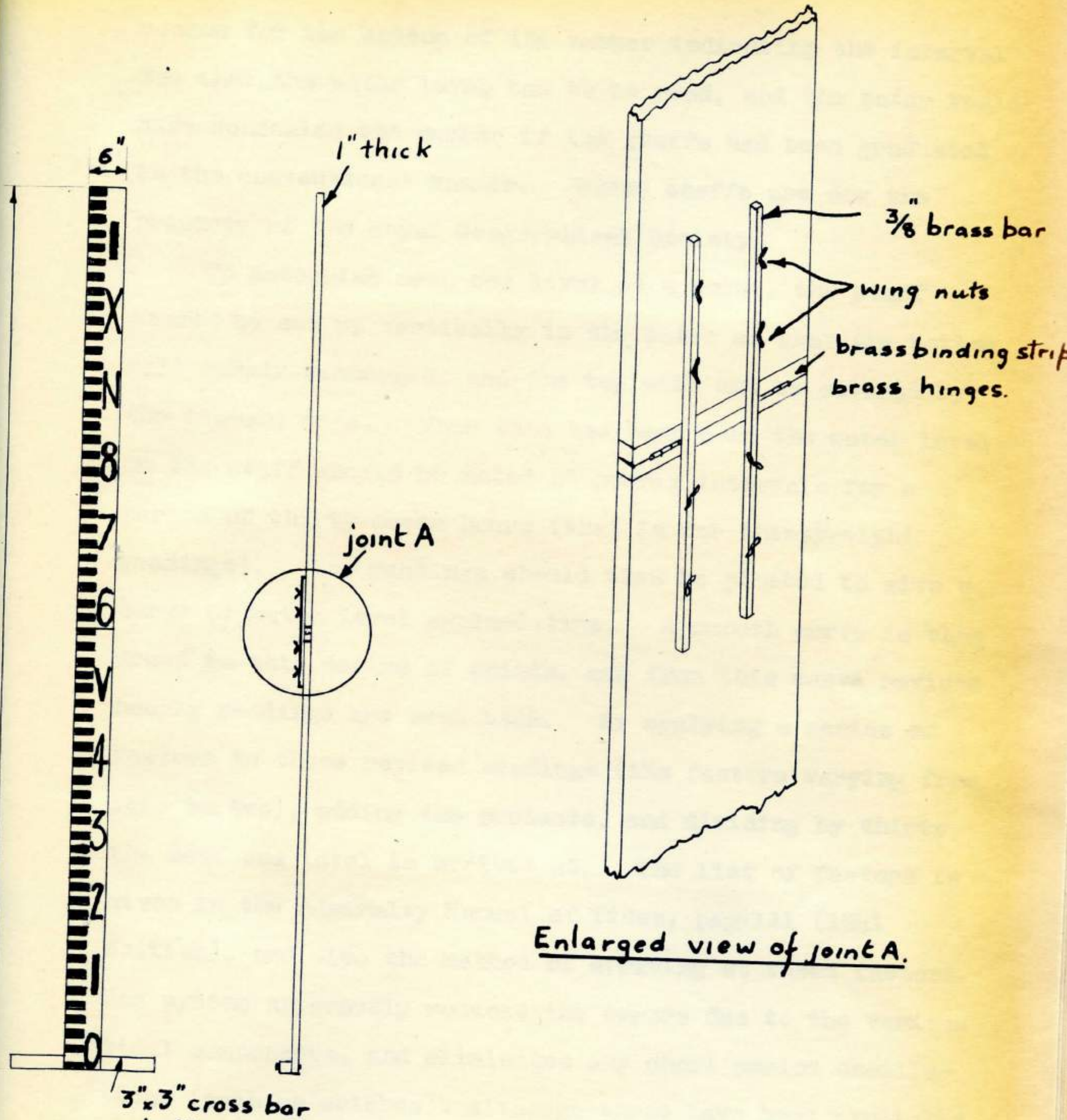
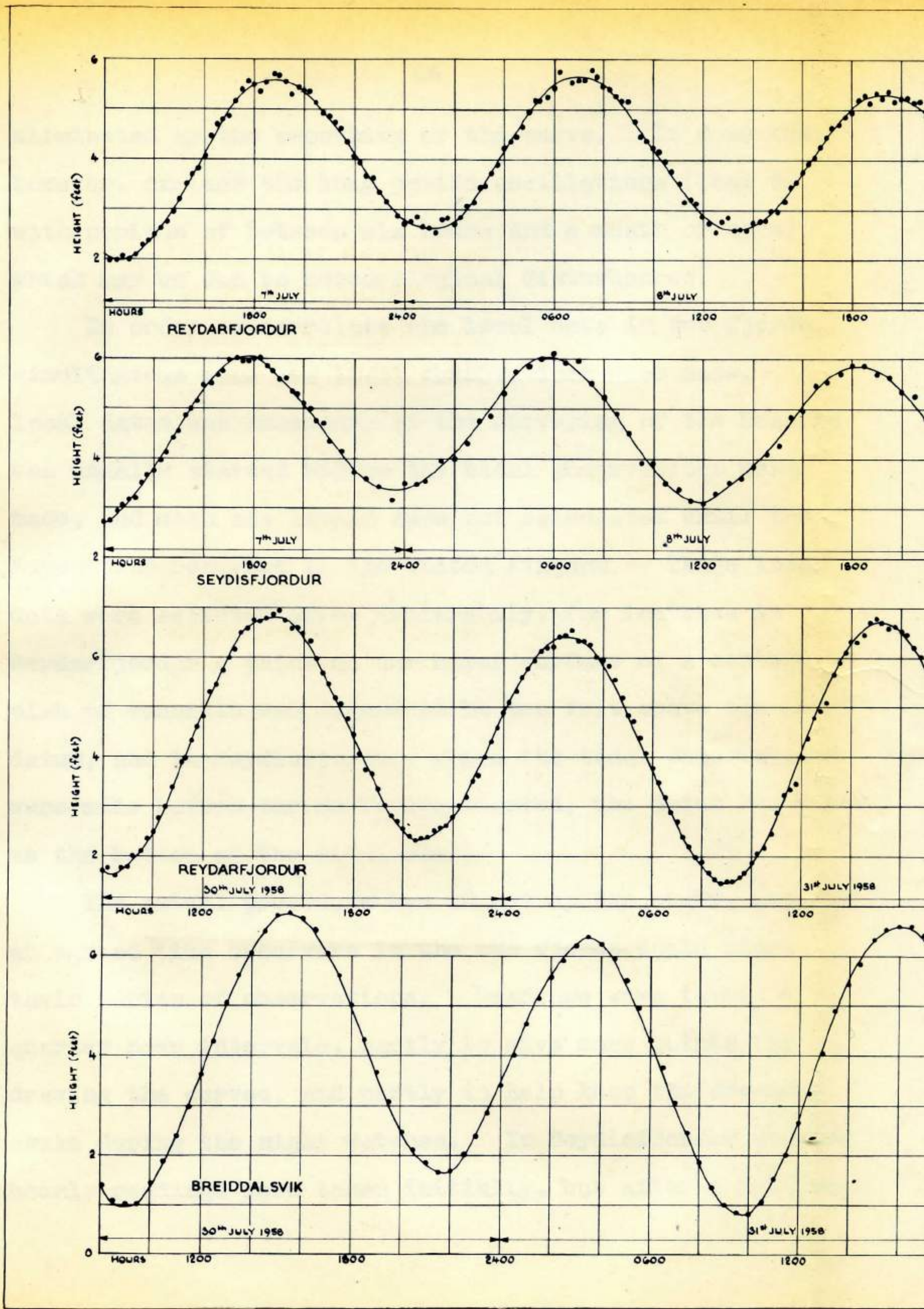
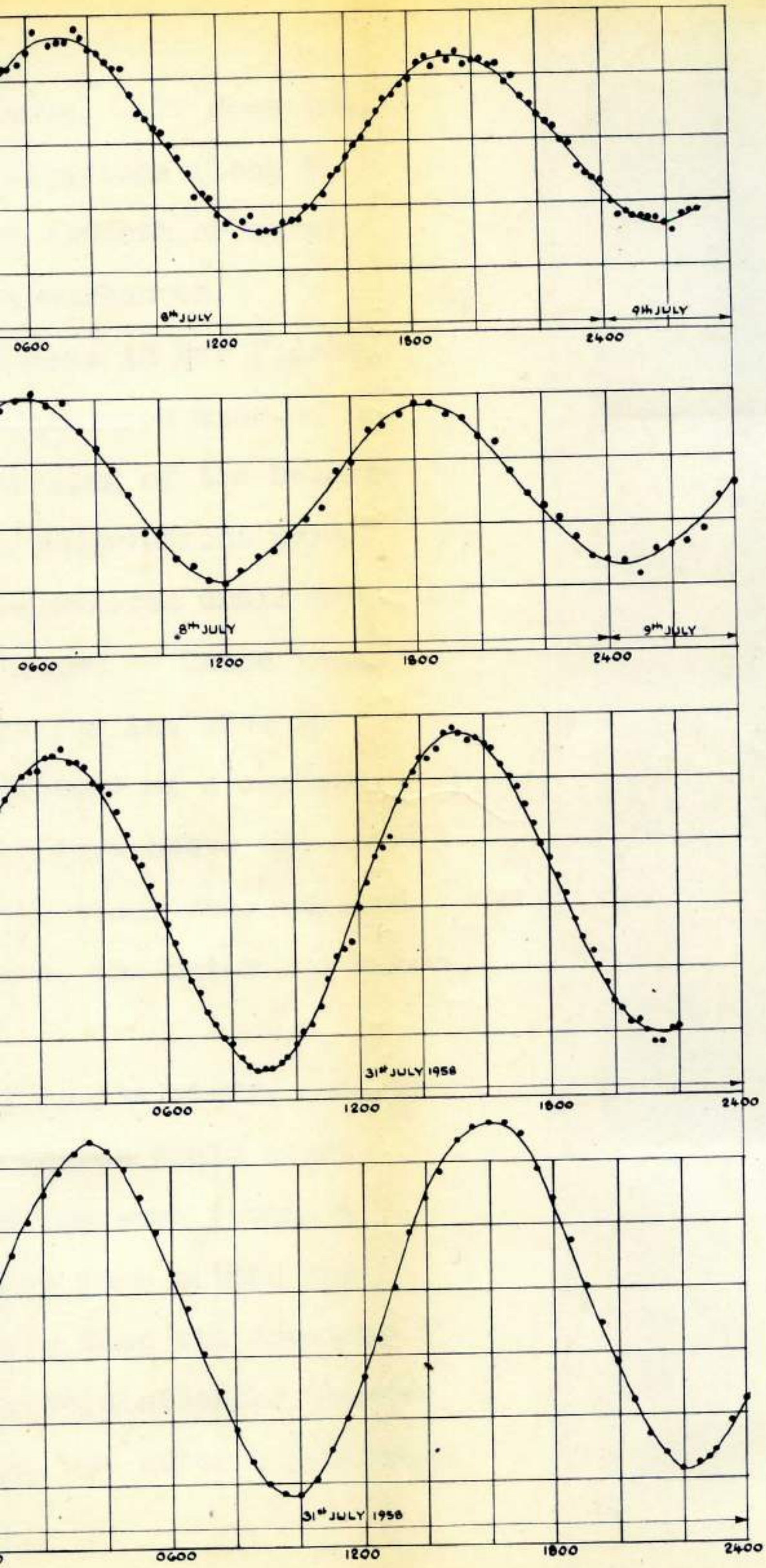


DIAGRAM OF TIDAL STAFF

reason for the bottom of the number indicating the interval was that the water level had to be read, and the water would have concealed the number if the staffs had been graduated in the conventional manner. These staffs are now the property of the Royal Geographical Society.

To determine mean sea level at a point, the staff should be set up vertically in the water so that the bottom will remain submerged, and the top will not be covered by the highest tide. When this has been done the water level on the staff should be noted at hourly intervals for a period of thirty-seven hours (that is for thirty-eight readings). The readings should then be plotted to give a curve of water level against time. A smooth curve is then drawn to this series of points, and from this curve revised hourly readings are read back. By applying a series of factors to these revised readings (the factors varying from zero to two), adding the products, and dividing by thirty, the mean sea level is arrived at. The list of factors is given in the Admiralty Manual of Tides, page111 (1941 Edition), and also the method of arriving at these factors. The system apparently reduces the errors due to the various tidal components, and eliminates any short period oscillations (such as seiches), although these have been partially


HEIGHT (feet)
7th JULY
8th JULY
HOURS
1800
2400
0600
1200
REYDARFJORDUR
SEYDISFJORDUR
30th JULY 1958
31st JULY 1958
BREIDDALSVIK



PARTICULAR TIDAL CYCLES FOR VARIOUS PLACES IN EASTERN ICELAND DURING THE SUMMER OF 1958

Data are arbitrary

Time is G.M.T.

RECORDED BY IMPERIAL COLLEGE ICELANDIC EXPEDITION 1958 reason for the bottom of the number indicating the interval was that the water level had to be read, and the water would have concealed the number if the staffs had been graduated in the conventional manner. These staffs are now the property of the Royal Geographical Society.

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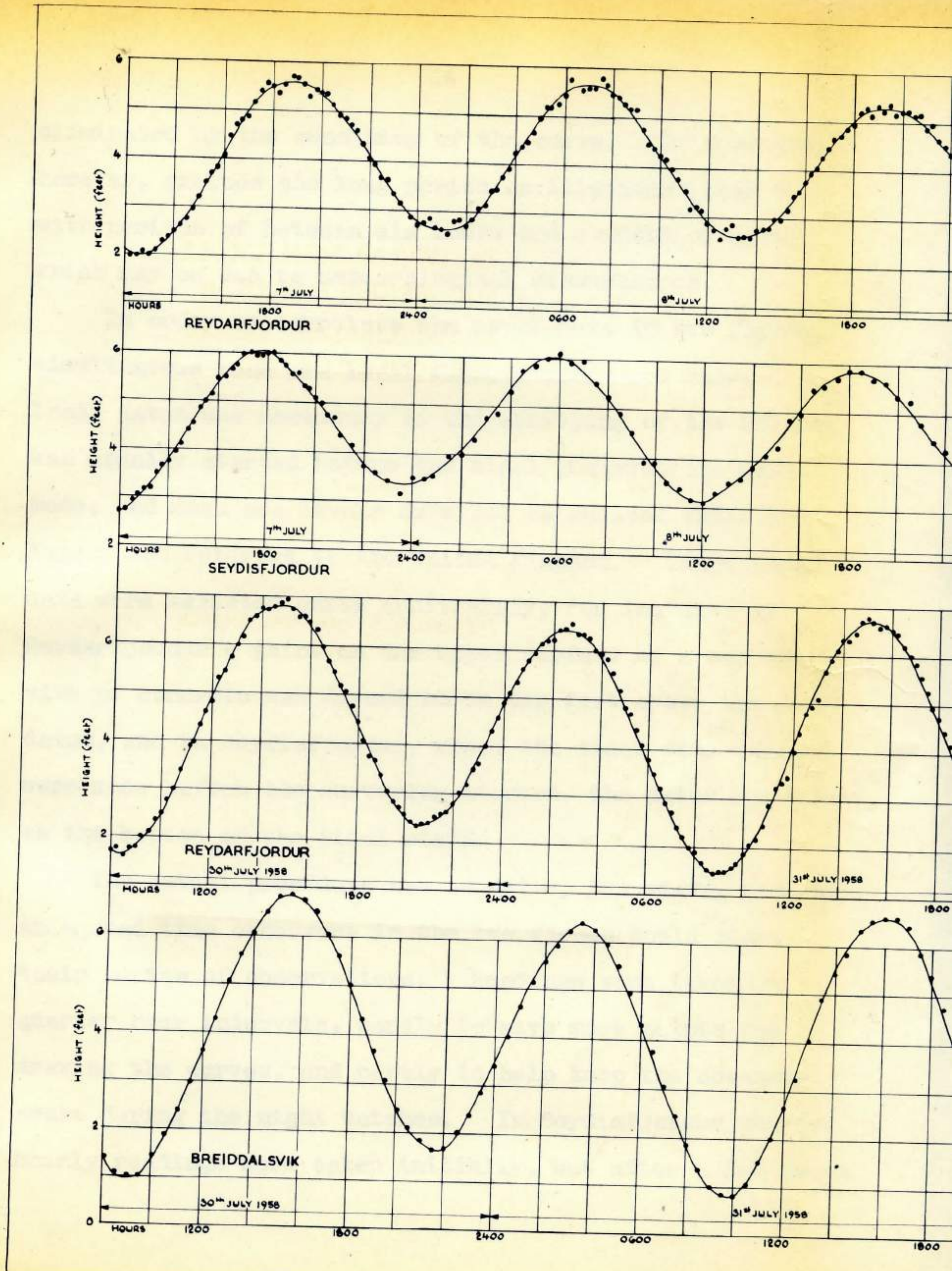
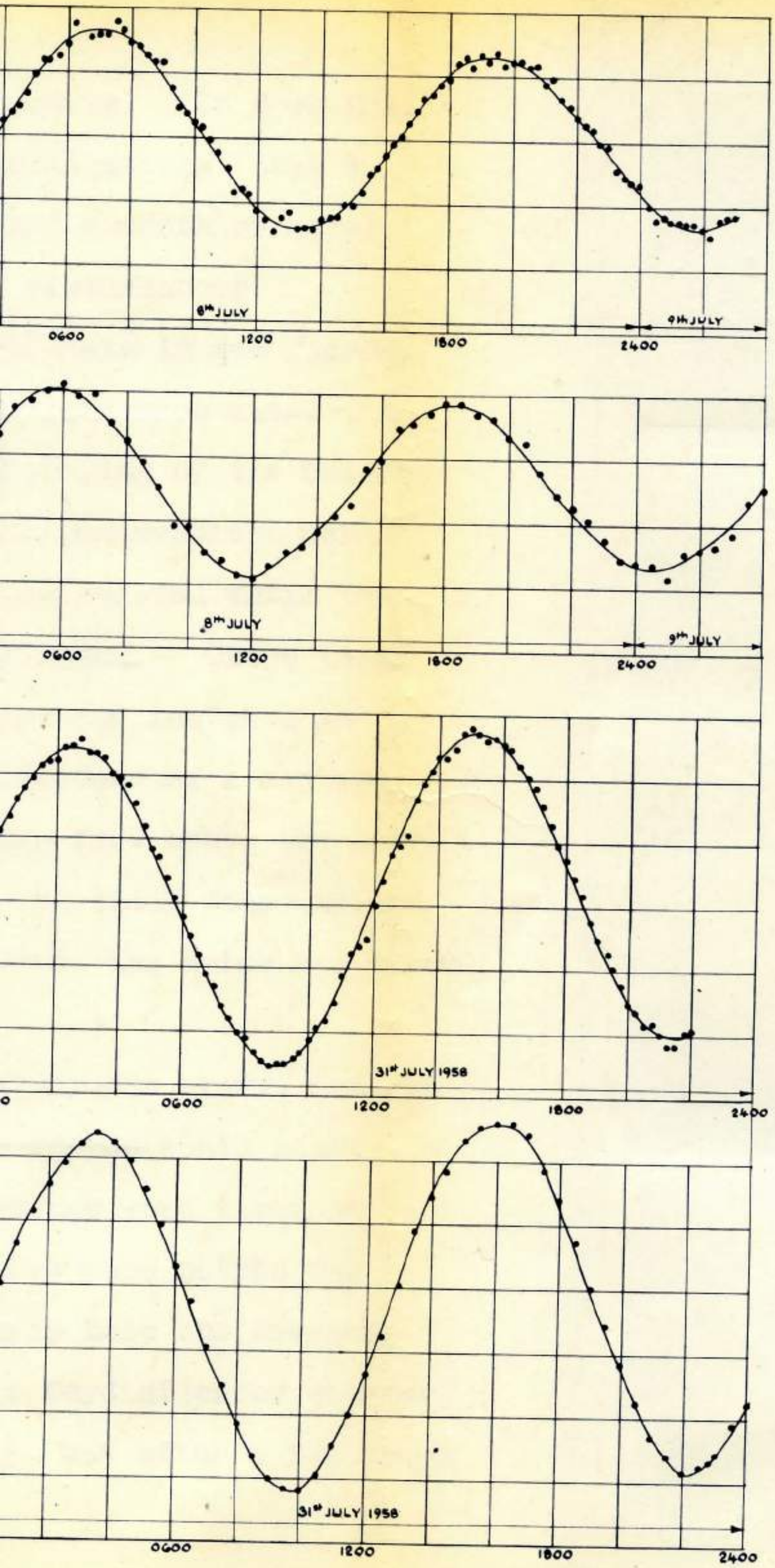

REYDARFJORDUR
HEIGHT (feet)
7th JULY
8th JULY
HOURS
1800
2400
0600
1200
1800
SEYDISFJORDUR
HEIGHT (feet)
7th JULY
8th JULY
HOURS
1800
2400
0600
1200
1800
REYDARFJORDUR
HEIGHT (feet)
30th JULY 1958
31st JULY 1958
HOURS
1200
1800
2400
0600
1200
1800
BREIDDALSVIK
HEIGHT (feet)
30th JULY 1958
31st JULY 1958
HOURS
1200
1800
2400
0600
1200
1800



PARTICULAR TIDAL CYCLES FOR VARIOUS PLACES IN EASTERN ICELAND DURING THE SUMMER OF 1958

Data are arbitrary

Time is G.M.T.

RECORDED BY IMPERIAL COLLEGE ICELANDIC EXPEDITION 1958 eliminated by the smoothing of the curve. It does not, however, exclude the long period oscillations (that is with periods of between six hours and a month or more) which may be due to meteorological disturbances.

In order to correlate the local data in two fjords, simultaneous mean sea level observations were made. A local datum was necessary as the surveying of the beaches was usually started before the tidal observations were made, and mean sea levels were not calculated until the Expedition returned to the United Kingdom. These local data were selected quite arbitrarily, for instance in Reydarfjordur a point on the upper surface of a certain slab of concrete was deemed to be ten feet above the local datum, and in Seydisfjordur, where the tidal observations were made before the surveying started, the datum was taken as the bottom of the tidal staff.

The actual procedure was to set up the staff, and, at an agreed time observers in the two fjords would start their series of observations. Readings were taken at quarter hour intervals, partly to give more points for drawing the curves, and partly to help keep the observer awake during the night watches. In Seydisfjordur quarter hourly readings were taken initially, but after a few hours

Fig. 10: Tidal pole as established at Seydisfjordur

these were discontinued, and half hourly readings taken instead. The period of observation was extended to forty hours so that in case the observers on one fjord were not ready to start at the appointed time there was still a reasonable chance of getting thirty-seven hours of simultaneous observation. When the two parties of observers had been out of contact for some time, time synchronisation was achieved by checking watches at the local Post Offices.

It was decided that the tidal observations should be made in Reydarfjordur, Seydisfjordur and Breiddalsvik, these being the locations of the main groups of beaches (as observed on aerial photographs of the region by Dr. Walker). The Admiralty had established a bench-mark in Seydisfjordur and it was decided that this should be used to indicate our datum, (the mark being 10.76 feet above datum, which was defined as "a point seldom, if ever, uncovered by the tide"). The plan was therefore to carry out simultaneous observations in Seydisfjordur and Reydarfjordur, and then later in Seydisfjordur and Breiddalsvik.

Soon after setting up Base Camp a party left Reydarfjordur for Seydisfjordur, set up their staff, and at the agreed time started observations. Unfortunately the Admiralty bench-mark could not be found, even though detailed instructions had been given as to its location. After about two weeks surveying the beaches in Seydisfjordur this party then carried out their second series of observations, but because of transport difficulties the other party had not reached Breiddalsvik. The Seydisfjordur party did not discover this until they returned to Base Camp. This work was not entirely wasted since all the tidal observations were later supplied to the Admiralty to supplement their data on tides in Icelandic waters.

As the bench-mark in Seydisfjordur had not been found, it could not be used to indicate a datum, and so it was decided that the second correlation should be made between Reydarfjordur and Breiddalsvik. This was carried out without further difficulty.

The final datum for the whole survey was taken as the mean sea level in Reydarfjordur as calculated from the two sets of tidal observations.

When beaches were to be surveyed which were remote from the local datum standard one of three methods of transfer was used. Either (1) an observation of high tide was made, at a point conveniently near the beaches, during the tidal observations, or (2) the water level at a specific time at a point conveniently near the beaches was observed during the tidal observations, or (3) the water level was noted simultaneously both at a point conveniently near the beaches, and another conveniently near the local datum standard (the height of the latter point being related to the local datum standard at a later date). These three methods were used in Reydarfjordur to transfer the local datum to Eskifjordur (method 1), to the beaches on the north side of the fjord at the eastern end, and to Nordfjordur (method 3), and to the beaches along the south shore opposite base camp and Eskifjordur (method 2).

In Seydisfjordur levels were carried for some considerable distances by tacheometric levelling (about ten miles in all), and in order to check against gross errors this level was brought back to the local high tide mark. This was done three times during the traverse, and provided a useful check, revealing at least one major arithmetical blunder in the reduction of the readings. This method of checking was also used during the traverse round the head of Reydarfjordur to the beaches at the western end of the south side.

Levelling:

The tacheometric levelling was carried out using two

Hilger and Watts Microptic No. 1 theodolites, with the circles graduated down to 20 minutes of arc, and an optical micrometer to subdivide these divisions down to 20 seconds of arc. One was loaned to the Expedition by the Royal Geographical Society, and the other by the Mining Department of the Imperial College. Though they were essentially the same, they differed in minor details, these differences making the "Mining" theodolite easier to use than the "R.G.S." It had a more powerful telescope, so allowing longer sights to be taken with the same accuracy, and was fitted with a telescope bubble which meant that it could be used as an ordinary level if necessary. The "Mining" theodolite was part of a "three tripod traverse" set, and so had a special tripod head, which though it made the tripod unduly heavy, and awkward, allowed the theodolite to be removed quickly and easily. The carrying systems for the two theodolites were different too, the "R.G.S." instrument being carried in a special leather case which could easily be slung on the back, whereas the other was in the standard waterproof metal case, in which it was clamped down.

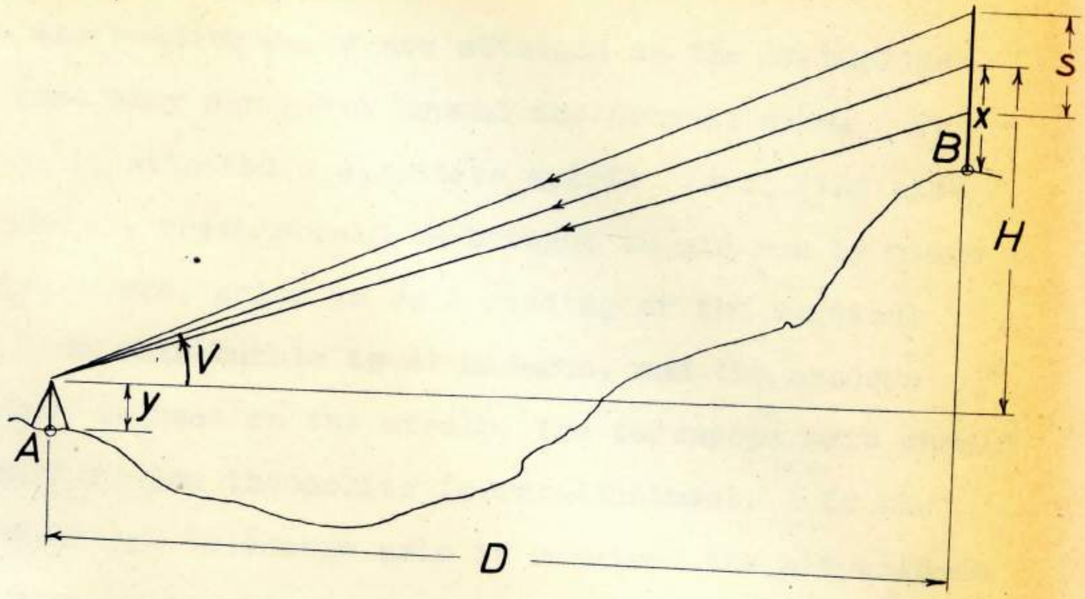
The method of attachment of the "R.G.S." theodolite to the tripod was faulty. The instrument was secured by a screw through the head of the tripod into the base of the instrument. This screw was several threads too short, and soon after arriving at Breiddalsvik, the theodolite fell from the tripod, and was severely damaged. The survey team carried on with their work, not being able to ascertain the extent of the damage, and only when the results were plotted in England was it discovered that the errors were random, and large. It had been hoped that these errors could be eliminated, but this was found to be impossible.

The tripods used with the theodolites were of the standard collapseable type, and were not interchangeable, owing to the "Mining" having the special head. This head was protected in transit by a leather "bucket", to which was attached a carrying strap.

Two ten-foot Bannon, or folding, staffs were taken to be used in conjunction with the theodolites in the levelling, and two sets of Redmond's tables for reducing the readings to differences in height. These are standard tacheometric tables, but they are only calculated for a twenty minute of arc vertical angle interval. This reduces the bulk of the tables, and with the instruments used, aided the manipulation.

The basic principle of tacheometric levelling is to measure the inclined distance between two points (one of which is of known height, and the height of the other is wanted) and then to measure the inclination to the horizontal of the line along which the distance was measured. Then by simple trigo-

TACHEOMETRIC LEVELLING



for Microptic no. 1 theodolite:

$$D = k_1 s \cos^2 V$$

$$H = \frac{1}{2} k_1 s \sin 2V$$

difference in height between points A and B

$$= H - x + y.$$

values of D and H were obtained from Redmond's Tacheometric Tables.

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cope, and the reading marks are attached to the theodolite frame so that they can pivot around the transit axis. To the readers is attached a sensitive spirit level (the alt-alidade bubble), which should be brought to mid-run by means of the thumbscrews, prior to each reading of the vertical circle. When this bubble is at mid-run, and the readers indicate zero degrees on the circle, the telescope axis should be horizontal if the theodolite is in adjustment. If the inclination of the telescope axis is required the alt-alidade bubble is brought to mid-run, and the vertical circle reading taken. The reading may be in any of the four quadrants depending on whether the telescope is depressed or elevated, and whether the vertical circle is to the left or the right of the telescope as viewed from the eyepiece.

When this angle is measured the difference in height between the transit axis of the theodolite and the point indicated on the staff by the horizontal cross-wire can be calculated by a formula (see figure). If the height of the transit axis is measured above the point of known height, or the unknown point, (vertically below the centre of the theodolite), and the staff is on the other point, and the horizontal cross-wire reading is noted, the difference in height between the two points can be calculated. To simplify these calculations tables have been compiled giving the

EXAMPLE OF BOOKING

1	2	3	4	5	6	7	8	9	10	11	12	13
B.S. /F.S.	T.A. hght.	stadia 1	stadia 2	horiz. crosswire	circle left		circle right		mean intercept	height diff.	reduced height	Remarks
					vert. ∠	crosswire	vert. ∠	crosswire				
		Date: 9th July 1958				weather: mod. breeze, cloudy, showery						
											32 86	
B.S.		3·00	8·19	5·59	358 00	5·75	182 00	5·15	5·45	+18·10		
F.S.		3·00	8·40	5·70	359 20	4·46	180 40	3·84	4·15	−6·28	45·98	B.M. 107
											122·33	
B.S.				7·61		Level	Shot		7·61			
F.S.				1·82		Level	Shot		1·82		128·12	

columns 10,11,12 were completed in camp
column 10 is the mean of 7 & 9.
11 is the value of H from Redmond
12 is the reduced height of the point sighted

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horizontal distance, and the height difference between the transit axis and the cross-wire reading point on the staff, for given distances and vertical angles.

The tables used (Redmond - Tacheometric Tables - Technical Press) give these values for distances up to 850 feet, and vertical angles which are multiples of twenty minutes of arc up to 29° 40'. In order to use them to full advantage the stadia readings were taken in the usual manner (that is placing the upper stadia wire on a convenient mark on the staff before reading the other wire), and then changing the inclination of the telescope axis to the nearest 20' interval before noting the horizontal cross-wire reading and the vertical angle reading.

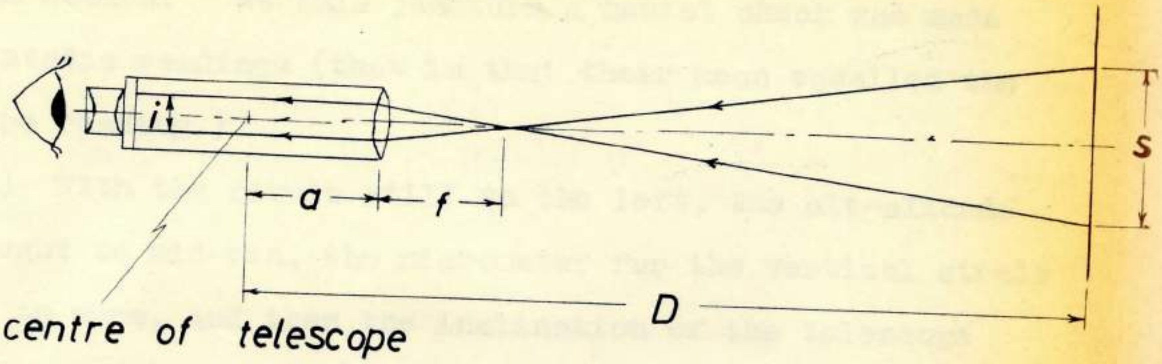
The actual manipulations carried out in the field were as follows:

(1) The tripod was set up about 150 yards from the staff (100 yards for the "R.G.S." theodolite), and roughly levelled, all the screws then being tightened.

(2) The theodolite was then attached to the tripod, and levelled. With the "R.G.S." theodolite the three levelling screws were on the instrument, while on the other they were on the tripod head.

(3) With the vertical circle to the left of the telescope the staff was sighted and the stadia line intercept read

DISTANCE MEASUREMENT



f = focal length of objective

i = separation of stadia lines

s = intercept on staff

$$\frac{i}{s} = \frac{f}{D - a - f}$$

$$D = \frac{sf}{i} + f + a$$

$$= k_1 s + k_2$$

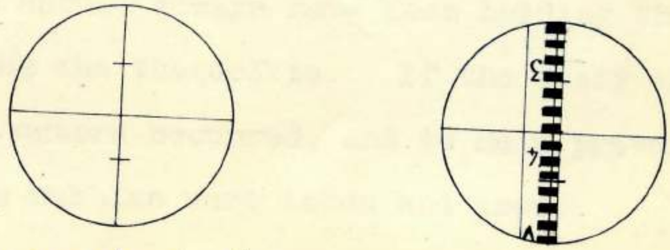
where k_1 is the stadia constant

and k_2 is the additive constant

with the Microptic no. 1 Theodolite

$$k_1 = 100$$

k_2 is very small



crosswire only

view through telescope

off, and booked. At this juncture a mental check was made of the stadia readings (that is that their mean equalled the crosswire reading.)

(4) With the circle still to the left, the alt-alidade was brought to mid-run, the micrometer for the vertical circle brought to zero, and then the inclination of the telescope adjusted so that the vertical circle reading was the nearest exact multiple of 20', and the horizontal crosswire still cut the image of the staff. The reading of the circle was noted, and also the horizontal crosswire reading.

(5) Operation (4) was repeated with the circle to the right.

(6) The staffman was signalled to proceed to the next station, about 150 yards ahead of the theodolite, and operations (3) - (5) repeated.

(7) Having checked that all the relevant data had been noted, the theodolite was removed from the tripod, put in its case for carrying to the next set-up, and the tripod collapsed.

(8) Operations (1) - (7) were repeated et cetera.

The staffman should always have been holding the staff upright, and facing the theodolite. If the staff was not held upright then errors occurred, and to help prevent this from happening rob bubbles were taken and used.

If it was apparent that a "level shot" could be taken, that is, with the telescope axis level the image of the staff through the telescope was still seen to be cut by the horizontal crosswire, then with the "Mining" theodolite the following procedure was adhered to:

(1) Operations (1) and (2) were carried out as above, except in that if both of the shots from that particular set-up were to be level shots, then the levelling only needed to be very rough.

(2) If a cross-section were being done on a beach, then the stadia readings were taken to give an indication of the length of the shot, but if it were just a matter of carrying a level through then this was ignored.

(3) The telescope was carefully levelled using the telescope bubble, and whilst it was level the reading of the horizontal crosswire on the staff was noted.

Care had to be taken whenever a bubble was being adjusted because of the strong sun, the heat from which distorted the glass of the bubble, and so caused erroneous readings. It became a standard practice to shield the bubble being adjusted from the direct sunlight during the adjustment, but even so difficulty was experienced in centralising the bubble.

During the actual cross-sectioning of the beaches the height of the transit axis of the theodolite above the ground was measured either with a steel tape, or with the staff.

During some of the cross-sectioning it was necessary to deviate quite considerably from the straight line of the traverse. In this case the horizontal angle swept out was noted too (to the nearest twenty minutes of arc), and the plan of the profile later plotted. In order to increase the number of heights determined on a profile and yet not increase the number of set-ups necessary, intermediate shots were sometimes taken, only the circle left reading being taken.

In some cases it was found that shots with depressions or elevations of greater than 20° were needed. In Redmond there are abbreviated tables up to 29°40'. Readings were reduced each evening when the party returned to camp, and the heights checked.

During the carrying through of levels, bench-marks were cut in suitable places, usually on horizontal surfaces. This would have proved useful for checking if it had been necessary, or time had allowed. It was also essential when a long traverse was being carried through, and the cross-sectioning was to be done on the return journey. An attempt was made to bring each cross-sectioning traverse back to a bench-mark as a check. Near the site of each set of tidal observations a bench-mark was established, and the relationship between some relevant mark on the staff and this bench-mark determined using the theodolite and the survey staff.