ABNORMAL WAVES
ON THE SOUTH EAST COAST OF SOUTH AFRICA

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Much has been said and written recently about the abnormal waves which have been experienced over the years along the eastern seaboard of South Africa. Many theories have been put forward as to the probable causes of these waves which have incurred considerable damage to vessels when steaming in a southwesterly direction down the east coast between Durnford Point and Great Fish Point. It would therefore be of interest to examine the details concerning the individual occurrences as far as they are known. Unfortunately it is not always possible to obtain full details after a period of time has elapsed since the wave was reported, hence in some instances the case histories are incomplete.

It is safe to say that many other ships must have experienced abnormal waves off the South African coast between Durnford Point and Cape Recife, but because the speed of the vessel at the time had been suitably reduced, the ship sustained no damage and hence there was no specific reason for reporting such an occurrence other than as a matter of interest. This is unfortunate because so much more could have been learnt about these phenomena if more specific reports were available, especially if they were to include details on wind and waves, meteorological data, soundings, ship's course and speed. A list of eleven known cases of vessels either having reported encountering abnormal wave conditions or having foundered as a result of storm waves is given in Appendix A. As will be seen they range over a period of 11 years. All except one, i. e. *Southern Cross,* were proceeding in a southwesterly direction. To provide further information for monitoring purposes the Managing Director of Ellerman & Bucknall (Pty.) Ltd. very kindly arranged with the masters of the Bucknall Line ships to send reports on the weather conditions experienced on the southeast coast, especially when they appeared to be favourable for exceptionally high waves to be generated. Five of these reports are included in this study and provide valuable monitoring information. Because the tracks taken by these ships are inside the 100 fathom line, as was anticipated no abnormal waves have been reported by them. The *City of Worcester* recorded the heavy

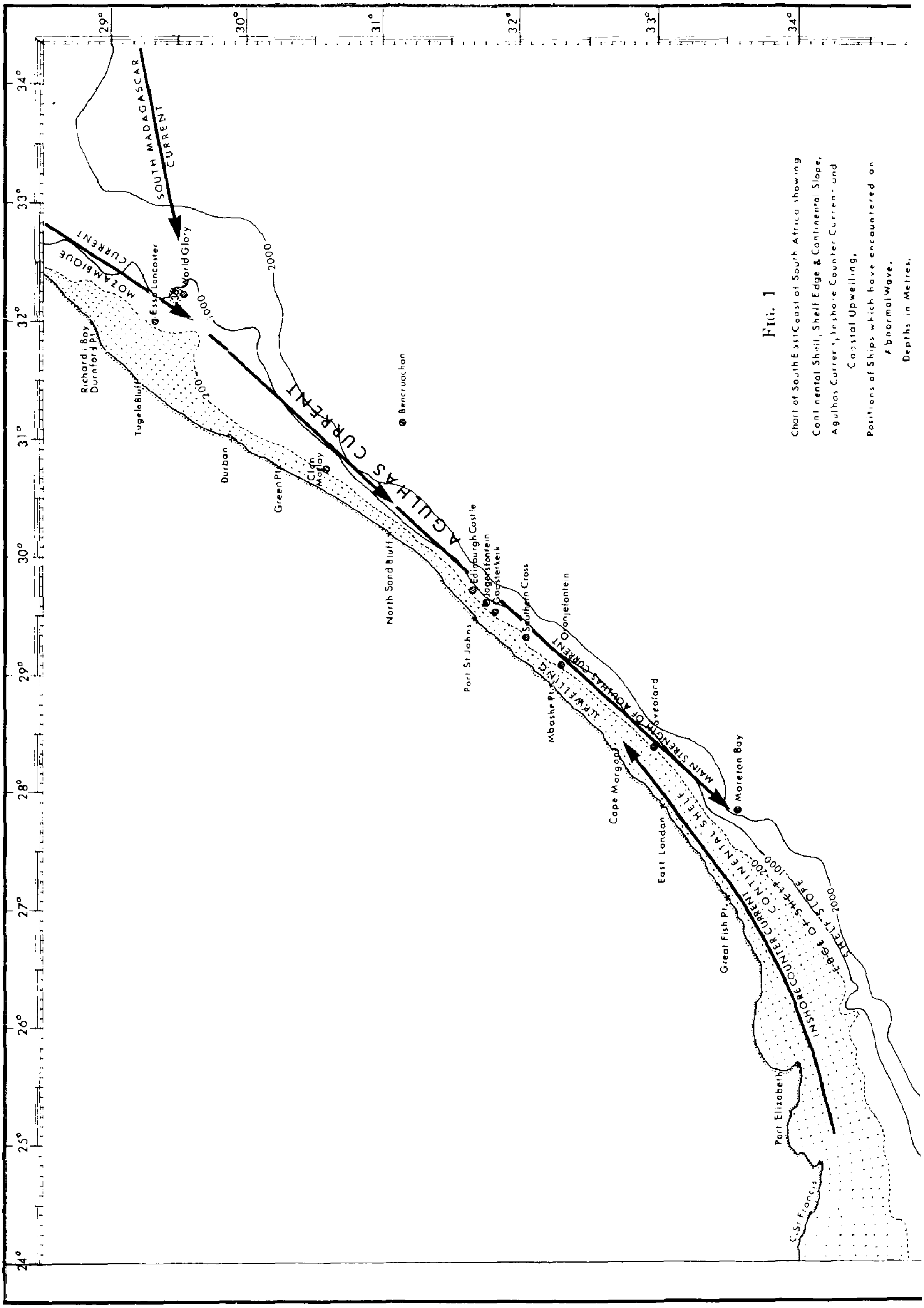

FIG. 1

Chart of South East Coast of South Africa showing Continental Shelf, Shelf Edge & Continental Slope, Agulhas Current, Inshore Counter Current and Coastal Upwelling, Positions of Ships which have encountered an Abnormal Wave. Depths in Metres.

weather and sea conditions during a particularly boisterous passage between Durban and Port Elizabeth whilst the *City of Lancaster* made an interesting recording of an echo on the radar which could well have been an abnormal wave just outside the 100 fathom line. These reports are referred to in the text which follows.

ENVIRONMENTAL BACKGROUND

It will be noted that reports of abnormal waves have only been received from vessels in the area from Durnford Point to Port Elizabeth, hence it is necessary to examine this section of the South African coast in detail to determine whether there are any unique features to which can be ascribed the possible cause of such a phenomenon.

Firstly the *submarine topography* is of importance because this has a direct influence on the movement of the water masses in the area. We find on examining the bathymetric charts compiled over the past 10 years that generally speaking the continental shelf is relatively narrow. Between Durnford Point and The Bluff, Durban, it is approximately 20 miles wide but then it narrows abruptly and remains at 5 miles until off Port St. Johns, whence it gradually widens until off Great Fish Point it is 20 miles wide, remaining at that width until to the west of Cape Recife. (see fig. 1).

Along the coast between Port St. Johns and East London the continental slope, i. e. the seaward edge of the continental shelf, is much steeper than usual, the 1 000 fathom (2 000 m) line being within 15 miles of the edge of the continental shelf. Numerous deep canyons are located along this stretch of the continental slope, but because of the lack of soundings outside the 100 fathom (200 m) line, the full extent of these canyons has not yet been plotted.

As far as can be ascertained the continental slope and rise is free of sea mounts or other protrusions except that in (approx.) position Lat. 29° 32′ S, Long. 32° 10′ E a reported shoal of 22 fathoms (36 m) is shown on the Admiralty Charts 2088 and 3851. However, as has already been stated, the area has not been closely examined so further shoal areas may exist.

THE AGULHAS CURRENT

The mighty Agulhas Current sweeps down South Africa's southeast coast moved by its own momentum and the dynamic forces acting in this part of the ocean. It has its origin in the trade wind area of the Central Indian Ocean where the surface drift is known as the South Equatorial Current. This drift current impinges on the east coast of Madagascar and the coast of Mozambique, forming two stream currents, one flowing southwards down the coast of Madagascar and the other along the Mozambique

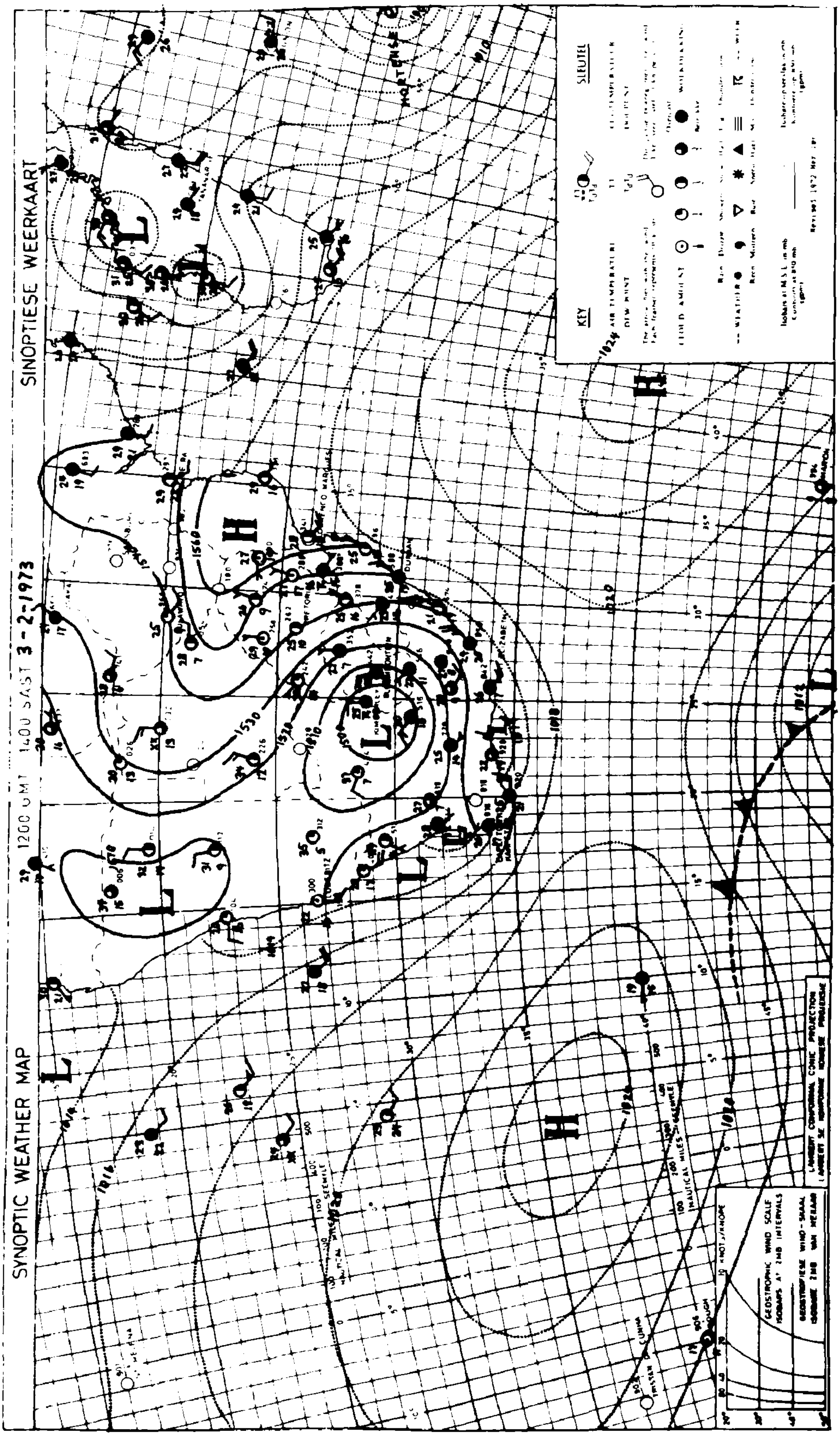

Fig. 2. — Typical summer conditions.

coast. The Madagascar section on reaching the southern extremity of the island veers across the Mozambique Channel towards the coast of Natal where it meets the Mozambique Current between Durnford Point and Durban and then flows southwards as a tremendous oceanic river, the Agulhas Current (see fig. 1).

The course of this "river" is greatly influenced by the submarine topography due to the depth to which the core of the current penetrates, i. e. over 1 000 feet (305 m). Being deeper than the edge of the continental shelf, and because the shelf slope is so steep in this area between Durban and East London, the main core of the current is generally speaking confined to the seaward side of the continental shelf and being a western boundary current it attains its maximum velocity just seawards of this shelf edge where speeds of 4 to 5 knots are experienced between Port St. Johns and East London, especially during the southern summer and autumn when the NE Monsoon is blowing in the Arabian Sea ensuring a maximum flow through the Mozambique Channel. The width of the Agulhas Current is from 50 to 90 miles (90-165 km). Under certain circumstances the southerly flow extends across the continental shelf to the coast but as will be explained later this is subject to change due to meteorological influences.

METEOROLOGICAL CONDITIONS

On this southeast section of the South African coast the wind regime is motivated by two distinct seasonal sets of meteorological conditions. During the summer months, November to May (see fig. 2) a low pressure area is situated over the interior of South Africa whilst a high pressure system extends over the SW Indian Ocean, south of Madagascar, resulting in the prevailing winds on the SE coast being from the NE to E, i. e. with the current and therefore contributing towards its velocity. Occasionally during the summer, a low pressure system will originate on the South West African coast in the vicinity of Walvis Bay, caused by the large difference in the temperature of the air over the sea and over the land. This low pressure system travels rapidly southwards along the coast and around Cape Agulhas and up the southeast coast. Strong westerly to southwesterly winds are experienced in association with the passage of these lows but are of short duration with a short fetch.

During these summer months the depressions moving from west to east across the Southern Ocean in regular succession around the Antarctic continent are usually centred too far south to influence the coastal conditions to any great extent, although at times a heavy swell associated with such storms rolls in from the SW, but it is usually of a fairly regular character, and abnormal waves have only been reported once, i. e. *Jagersfontein* on 18 December 1959. On this occasion a very deep depression 976 mbs was centred at Marion Island 12 hours previously, which was unusual for this time of year.

During the winter months the meteorological pattern changes. (see

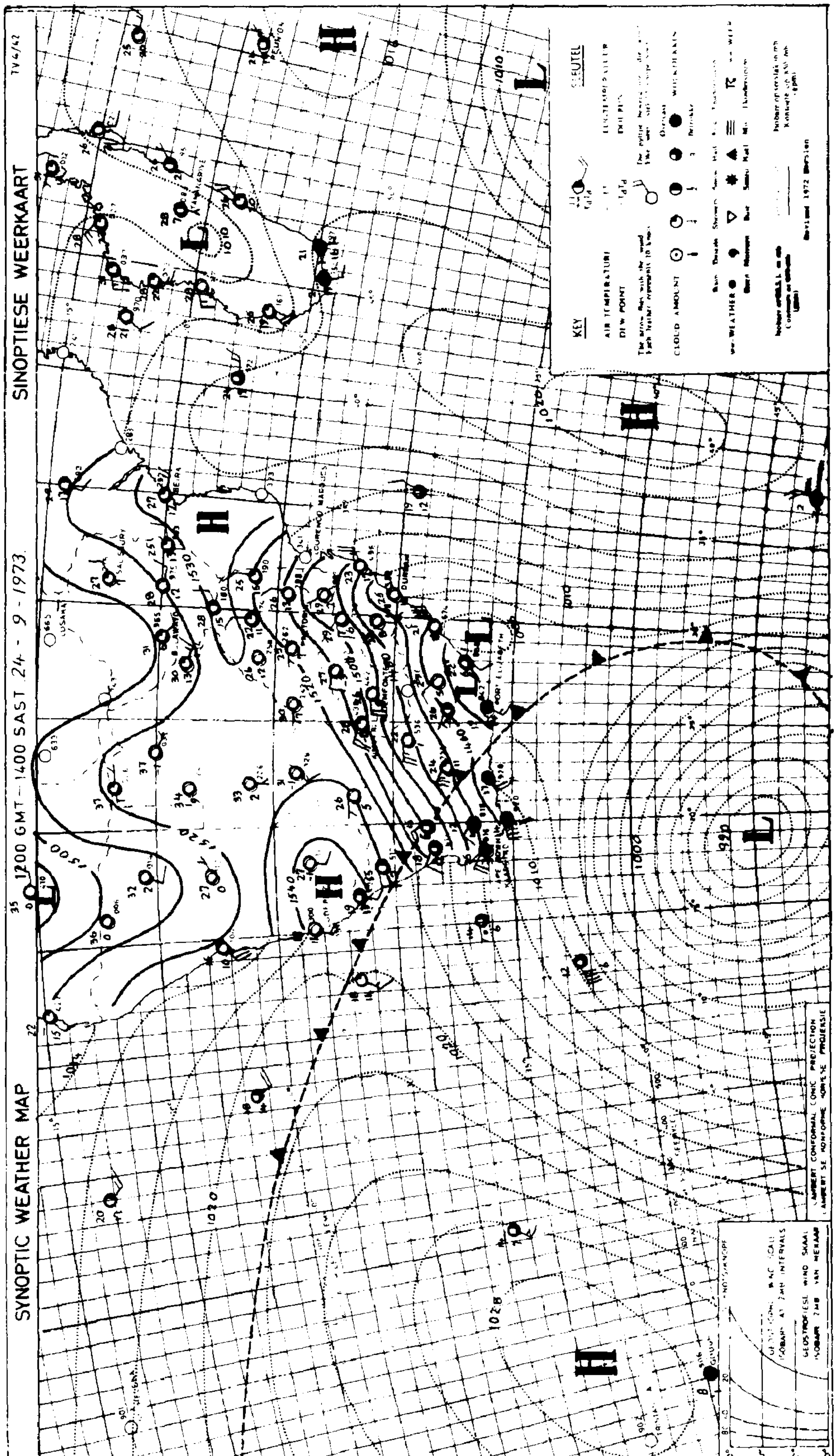

FIG. 3. — Typical winter conditions.

fig. 3). The low pressure area in the interior of South Africa fills up and the southern depressions extend further northwards with the result that from late May to mid-October their influence is felt all along the southern and southeastern coasts of South Africa. This results in strong southwesterly winds blowing parallel to the SE seaboard for 24 to 48 hours after the passage of the cold front.

On studying the weather maps of 24, 25 and 26 September 1973 (see appendix F, G and H) it will be noted that the isobars run parallel to the SE coast during these three days. This is a noticeable feature on this part of the S. African coast and one which is perhaps unique as it covers the same area as that in which the Agulhas Current is especially concentrated along the outer edge of the continental shelf. Further to the west isobars move round more rapidly and hence the wind backs to the south sooner. Furthermore, in that area the current has spread out and lost a good deal of its velocity.

COUNTER CURRENT

There is one further aspect to be considered before we look at the wave regime. With the passage of a cold front along the southern and eastern seaboard, a counter current flows in an easterly to northeasterly direction at about 1 to 2 knots. (see fig. 1). This counter current flows close inshore, within about 3 to 4 miles of the coast and hence inside the southward flowing Agulhas Current. It begins to flow about six hours prior to the passage of the cold front and is probably caused by a combination of the wind-driven surface current, an ingress of the West Wind Drift, a retroflection of the Agulhas Current south of Mossel Bay and a gradient current due to the lowering of the atmospheric pressure as the depression moves eastwards, and hence the raising of mean sea level.

One other feature on this coast has to be noted. Prior to the passage of a cold front the wind on the coast is usually from the ENE to NE Force 6 to 7 for 24 hours or more. (see fig. 3). This wind acts on the surface water on the continental shelf which, being subject to Coriolis Force, moves away from the coast, resulting in upwelling occurring close inshore. At the same time sea level in the vicinity of the 100 fathom (200 m) line is raised thus creating a gradient which tends to increase the velocity of the Agulhas Current along the edge of the continental shelf.

THE WAVE REGIME

The waves on this section of the African coast are not only those directly associated with the wind blowing at the time but are a combination of the locally generated waves and those coming up from the Southern

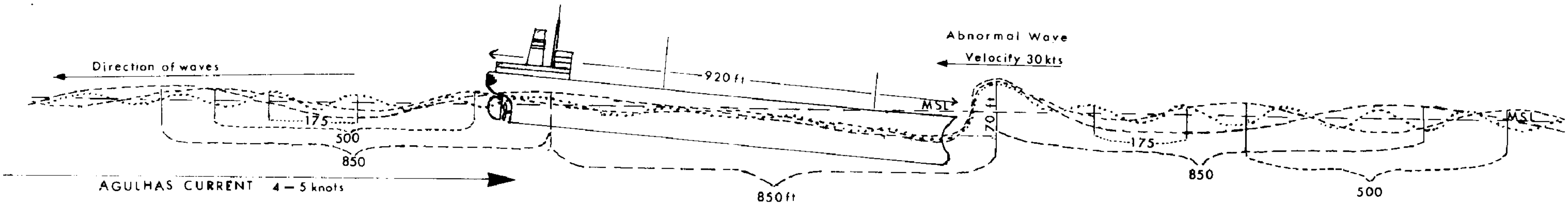

Fig. 4. — Diagramatic profile showing sinusoidal curves of three wave trains having wave lengths of 850, 500 and 175 feet which become in-phase for a short period thereby creating an abnormal wave about 70 feet high.
In advance of the wave is a long deep trough.

Ocean, where they have been generated over vast distances up to 1 200 miles. It has been stated that the centre of the depression, the outskirts of which reach the southern and southeastern shores of South Africa, usually passes over Marion Island during the winter months, May to October, and as will be seen from the reproduction of the synoptic weather map, shown in fig. 3, the fetch of the southwesterly wind is 1 200 miles or more, hence the waves generated by this wind are fully developed and will therefore have reached their maximum height and length by the time they reach the vicinity of Port Elizabeth. These maxima will of course depend upon the velocity of, and the duration for which the wind has been blowing.

More details concerning these wave characteristics are given in the sections "Examination of previous reports" and "Conclusions" of the present article. Even though the wind along the coast may not be very strong these ocean waves still come rolling in. There may be more than one source generating such fully fledged waves, having differing wave lengths and frequencies. The locally generated waves are shorter and steeper. All these are greatly affected by the southwesterly flowing Agulhas Current which tends to shorten the wave length and raise the height of the sea, and this effect is of course more pronounced where the opposing current is strongest, i. e. just outside the 100 fathom (200 m) line. Because the wave lengths of the local waves and the long distance waves differ to a considerable degree, they are frequently being momentarily superimposed one upon another, thereby increasing the height.

It may so happen that there are occasions when all the wave trains are in conjunction, and a gigantic wave forms for a few minutes, after which the separate waves become disunited and the wave heights return to normal.

These abnormally high waves are naturally associated with correspondingly deep troughs. If these were of a normal sinusoidal character, the ship if handled in a seamanlike manner would rise up to the approaching wave and consequently, other than taking some green water over the bow, no severe damage would occur.

However, this is not the case with these abnormal waves, hence the reason why they have been referred to previously as "freak" waves. It would appear that as the differing orbital motions of the waves become integrated, whilst under the influence of the current flowing strongly against the direction of the waves, an abnomally high steep wave is formed. These waves have been reported to be in excess of 60 feet (18 m) in height, and have always been associated with a correspondingly long deep trough — which occurs in advance of the wave. It is this phenomenon which constitutes the great danger to a vessel steaming into the sea at speed, and which has given rise to the expression "a hole in the sea". (see fig. 4).

CORRELATION OF AVAILABLE DATA

From the foregoing it is obvious that the meteorological conditions play a vital role in this riddle of the abnormal wave, therefore we need to examine this aspect very closely to determine whether any particular pattern is common to the reported incidences of abnormal waves.

In order to ascertain what meteorological conditions existed in the area prior to the vessel encountering an abnormal wave, all the relevant facts have been extracted from the weather maps and tabulated in appendix A, for the 11 ships which have either reported such waves or have foundered as a result of storm damage which could have been caused by an abnormal wave (*World Glory*).

In addition five monitoring vessels have supplied extracts of log for the passage between Durban and Port Elizabeth when the conditions were expected to be similar to those which gave rise to abnormal waves.

There is also a report from the research vessel *Thomas B. Davie* for the period 24-25 September which fills the gap between that given by the *City of London* for the period 22-23 September and the report received from the tanker *Svealand* of an encounter with an abnormal wave on 25 September when off East London, which caused severe structural damage. It should be noted that all five monitoring vessels and *Thomas B. Davie* were inside the 100 fathom line on their passage south. *Thomas B. Davie* did however move out towards the edge of the shelf on a couple of occasions and found the sea conditions became markedly heavier on crossing the 100 fathom line.

Because the reports from *City of London* and *Thomas B. Davie* follow so closely upon one another, and being closely linked in time and space with *Svealand's* encounter, they provide data for an ideal case history of such an event.

EXAMINATION OF CASE HISTORY

Having considered the environmental conditions which may be encountered along the SE coast leading to the probable build-up of an abnormal wave, let us consider this case history of the occurrences of such a wave which severely damaged a supertanker, During the period 0800/22 September to 1700/25 September 1973, two ships *City of London* and *Thomas B. Davie* (97 feet overall) provided data concerning the conditions on the southeast coast between Durban and East London whilst at 1647 SAST on 25th the 258 000 ton ore/oil tanker *Svealand*, fully laden, steaming southwest was severely damaged by an abnormal wave when in a position one mile outside the 100 fathom line (200 m), 23 miles 085° from Hood Point light steaming in a southwesterly direction at reduced speed. Let us follow the sequence of environmental conditions leading up to this occurrence.

To do this there are the Synoptic Weather Maps published by the S.A. Weather Bureau for the period 20 September to 26 September (appendices B, C, D, E, F, G, H), the extract of log provided by the Master of the *City of London* for his vessel's passage from Durban to Seal Point from 0800/22 to 1200/23 September (appendix I) and the extract of log provided by the Master of the *Thomas B. Davie* for his vessel's research cruise in the area

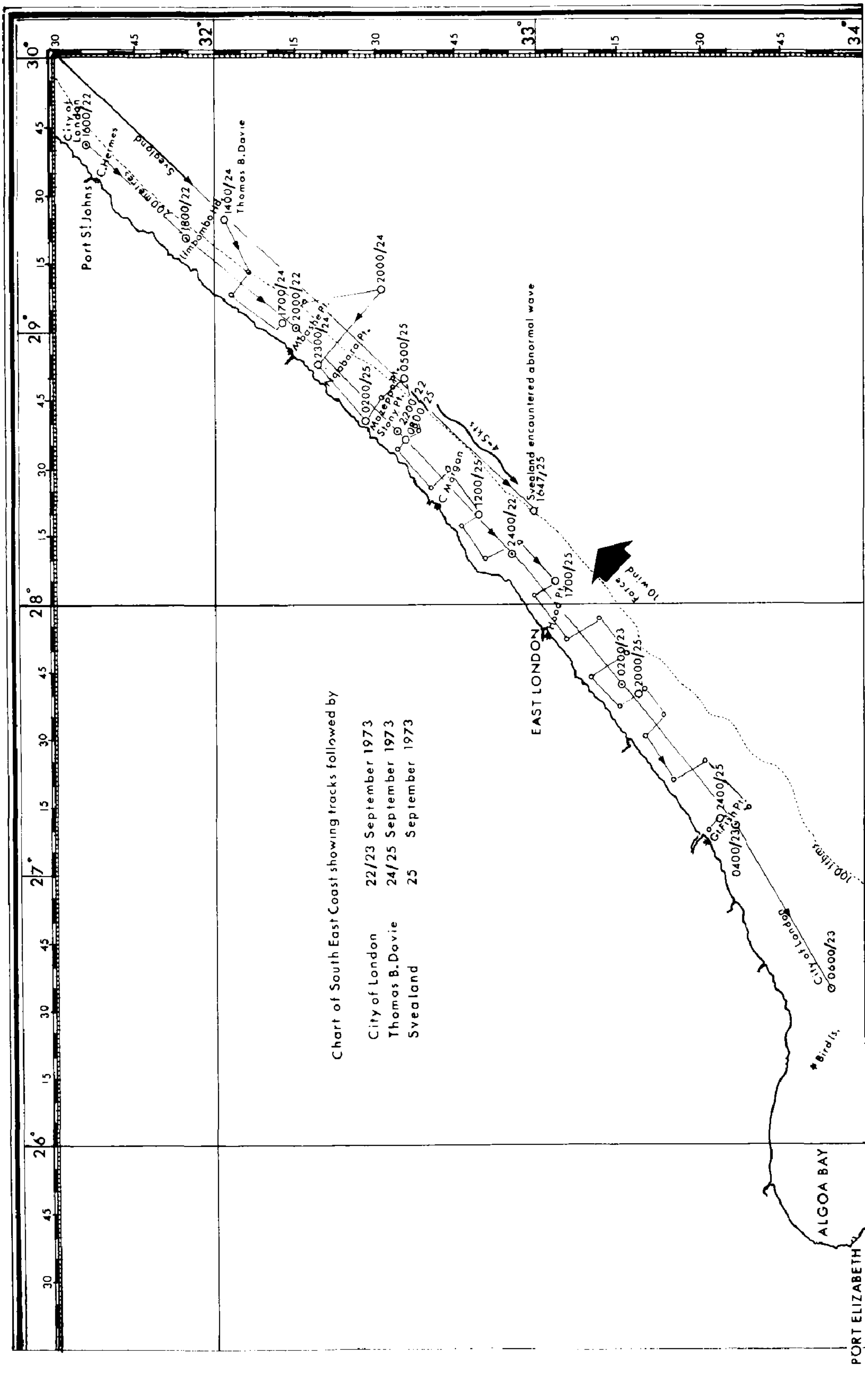
Chart of South East Coast showing tracks followed by
City of London 22/23 September 1973
Thomas B. Davie 24/25 September 1973
Svealand 25 September 1973
Svealand encountered abnormal wave 1647/25
10 wind force
PORT ELIZABETH
ALGOA BAY
C. Recife
Bird Is.
EAST LONDON
Port St Johns
C. Hermes
Umbomba Hd.
C. Morgan
Stony Pt.
100 fthms.
200 metres
4-5 kts
Svealand
Thomas B. Davie
City of London

FIG. 5

from Bashee Point to Great Fish Point from 1400/24 to 2400/25 September (appendix J). (See the portion of the Admiralty Chart on which the tracks and positions of the three vessels involved are recorded, fig. 5).

In the first instance we must examine the weather map for 1400 SAST on 21 September (appendix C) where it is to be noted that a cold front is moving eastwards along the SE coast having just passed over East London. Fresh southwesterly winds are blowing along the coast having a fetch of 1 200 miles from approximately 45 S and 10 E. The weather map for the following day, 22nd (appendix D) shows that the cold front has moved to the north of Lourenço Marques, and that strong southwesterly winds are still blowing along the SE coast having a fetch of 800 — 900 miles.

On the 23rd the influence of the depression has been superseded by an anticyclone centred to the SSE of Durban giving rise to strong northeasterly winds of purely local significance (appendix E). A cold front is approaching the S.W. Cape which, as we see in the weather map for the 24th (see appendix F) has almost reached Port Elizabeth. A sudden change of direction from NE to SW is taking place in advance of the cold front as is indicated by the arrows superimposed upon the weather map.

Then on the crucial 25 September (see Appendix G) we note that the south westerly wind which has been blowing in the vicinity of East London for close on 24 hours with a fetch of 1 200 miles is continuing to blow and likely to do so for at least 24 hours which is borne out by the weather map of the 26 September (see appendix H).

Having examined the sequence of weather conditions from these daily charts from 21st to 26th now let us examine the extracts of log covering the majority of this period.

The *City of London* left Durban at 0800 on 22 Sept. and headed into a southwesterly wind, Force 6, with a rough head sea and moderate swell. As she proceeded further south the swell became short and heavy and this continued until off Great Fish Point at 0400 on 23rd the wind began to moderate, the sea calmed down but the heavy swell persisted, caused no doubt by the southwesterly gale approaching the S. W. Cape. When nearing Seal Point a northeasterly wind began to blow, raising a moderate sea but the heavy southwesterly swell continued. It should be noted that the *City of London*'s track throughout the passage from Durban to Seal Point was on or inside the 50 fathom (100 m) line. It will also be noted that the wind experienced conformed with that given in the weather maps and that the weather map of the 23rd explains the continued heavy southwesterly swell. Until 2400/22nd the barometer was rising. Then it remained steady till nearing Seal Point when it began to fall.

Now we turn to the *Thomas B. Davie* and note that she was on a geological sampling cruise covering the continental margin and was working her way to the south. At 1700 on 24 September the vessel was on the 50 fathom (100 m) line 5 miles NE of Bashee Point. The wind at the time was NE/5 with a heavy southwesterly swell. The vessel steamed out on a southerly leg to reach a position 20 miles off Nqabara Point at 2000 when the wind was E/4, still with a heavy southwesterly swell. Course was set for Nqabara Point and at 2300 she was 3 miles east of the Point with the wind now blowing from the SW Force 8. Rough sea and very heavy southwesterly swell.

The ship steamed slowly southwest into the weather which remained at Force 8 with a very heavy sea until 0200 on 25th when 2 miles off Mazeppa Point. The ship then steamed out on a southeasterly course across the shelf and because the wind had decreased to Force 7, the ship was then edged out past the 100 fathom (200 m) line so that the scientists could determine whether bottom sampling could be carried out. However, on crossing the edge of the shelf the seas became even higher, so at 0500 the course was set back on to the shelf and research work was continued inside the 100 fathom line. At 1200 she was 7 miles south of Cape Morgan, the wind having now increased to Force 9 and the sea having become high and the swell very heavy.

At 1700 when Hood Point lighthouse bore 275 distance 10 miles the wind had increased in velocity to Force 10, high seas and mountainous swell. The waves were estimated to be 20-25 feet (6-8 m) high. After 2000 when the wind was still blowing at Force 10, the conditions then began to moderate so that at 2400 when the vessel was off Great Fish Point the wind had decreased to Force 7. The barometer had begun to rise at 1700 on 24th when it was 1005.5 mbs and by 2400 on 25th stood at 1020.2 mbs.

If we follow on with the inspection of the weather maps from the day the *City of London* left the area at 1200 on 23rd, to include the two days covering the report of the *Thomas B. Davie,* i. e. 24th and 25th, (Appendix F and G) we will note that at 1400 on 24th September the new cold front was at Plettenberg Bay moving rapidly east. Strong northeasterly winds were still blowing at Port St. Johns whilst at East London the wind had already switched to SW due to the secondary low near the coast off East London. The southwesterly wind had a fetch of some 1 000 miles.

On 25 September the cold front had moved up as far as St. Lucia and fresh to strong southwesterly winds were reported from all coastal stations. It all conforms with the weather conditions as experienced by *Thomas B. Davie* on this day, and by *Svealand* as she steamed down the SE coast.

The weather map for 26 September shows that southwesterly winds were still blowing along the SE coast with a long fetch from deep in the Southern Ocean.

Let us now turn our attention to *Svealand,* a fully laden 258 000 ton vessel 1 109 feet (338 m) long and drawing 72 feet (22 m). The available verbally-received particulars are that this super-vessel on her maiden voyage experienced gale force southwesterly winds from the early hours of 25 September with heavy seas, the waves from 30 to 40 feet (9-12 m) high.

Then at 1647 on 25 September a long deep trough appeared ahead of the ship into which the forward part of the ship plunged.

Before the forepart could lift the advancing mountain of water crashed down on to the first two hatches setting them bodily down by two feet and opening them up. Two crew were injured. The wind was reported to be blowing SW 9/10 at the time that this abnormal wave was encountered.

The position of the ship as already stated was one mile outside the 100 fathom (200 m) line and the current was reported to be SW 4/5 knots.

The ship was reported to be making 3 knots at the time. After the occurrence the ship put about and made for Durban.

The report given by the Master of *Thomas B. Davie* to the effect that as soon as the ship crossed the 100 fathom (200 m) line the height of the waves increased is of great importance because no report of encountering an abnormal wave inside the 100 fathom (200 m) line has been received.

EXAMINATION OF PREVIOUS REPORTS

Having studied this case history of the weather conditions on the coast leading up to the *Svealand's* encounter with the abnormal wave we should now examine the weather maps for the periods covering the previously reported occurrences of such waves bearing in mind that one of the governing criteria appears to be the long fetch of the southwesterly wind from way down in the roaring forties for some considerable period prior to the time of the occurrence.

To facilitate this examination, appendix A contains extracts of the salient features of these weather maps so that the reader can see how similar is the pattern of meteorological events in each case.

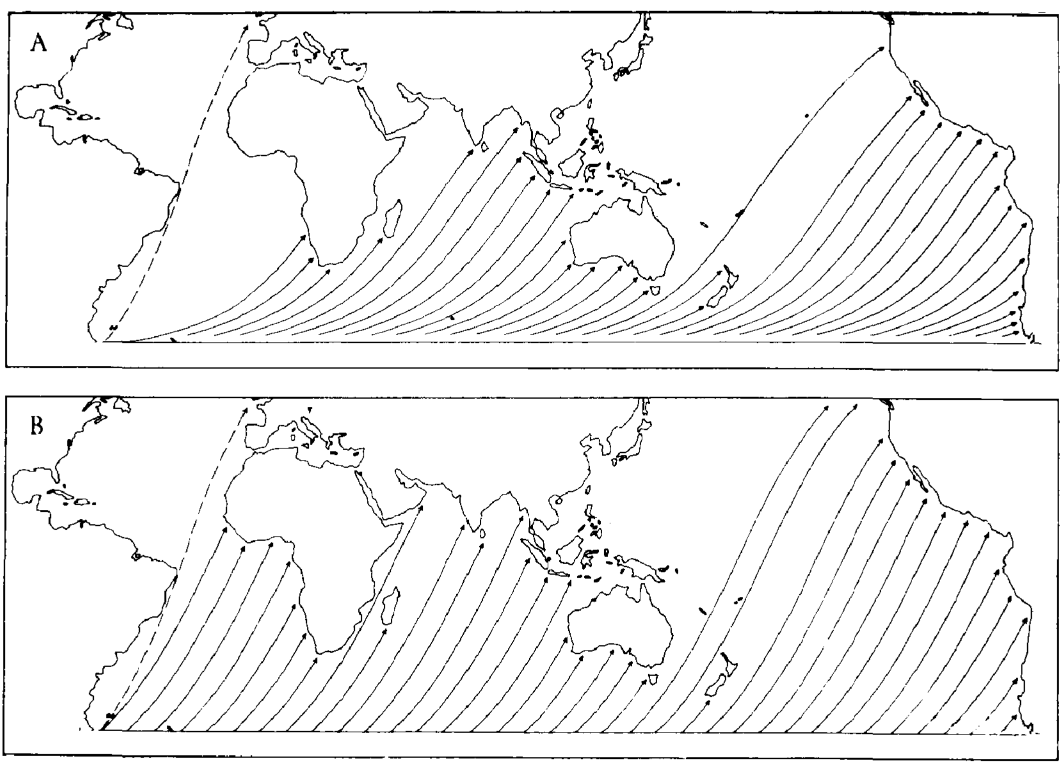

Fig. 6. — Typical great circle paths followed by swell generated at Latitude 55° S by (A) Westerly and (B) Southwesterly gales, according to J.L. Davies. Note the paths parallel to the South-East coast of South Africa.

Looking firstly at the column headed Fetch it is noted that on all the occasions the wind had been blowing over a distance of at least 600 miles from the same direction for 24 hours or more before the encounter with the abnormal wave hence any waves encountered resulting from this wind would be fully developed seas. (see fig. 6).

The next factor to examine is that of the movement of the cold front. In the majority of cases the cold front had passed through the position of the occurrence 5 hours or more before the wave was experienced. In the case of (6) *Esso Lancashire* and (9) *Moreton Bay* the passage of the cold front coincided with the abnormal wave. In both cases the fetch of the wind was 1 200 miles and the barometric pressure at the centre of the depression was 976 or less with a differential of 34 mbs and 40 mbs respectively between it and the position of the occurrence. This means that in these two instances winds of 27 knots or more, i. e. Force 6/7, had been blowing over the whole area from the latitude of Marion Island to the South African coast for 24 hours and the waves would have a significant height of 15-20 feet (5-6 m) in the open ocean and a probable maximum height of 25-30 feet (8-9 m). The wave length would be about 700 feet (210 m) and the period 12 sec.

The third factor of interest is the position of the centre of the depression affecting the weather on the S. E. coast at the time of the occurrence. In appendix A we note that in cases 1, 2, 3, 4, 6, 9 and 11 it was at Marion Island, and in all cases with the exception of 2 the fetch of the southwesterly wind was 1 200 miles for 24 hours. In the case of 2 the fetch was 1 000 miles for 36 hours.

In the cases of 5, 7, 8 and 10 the centre of the depression was much nearer the South African coast, between 400 and 600 miles, whilst the fetch was 800 miles, i. e. sufficient for the waves to be fully developed. It would of course depend on the average velocity of the wind over this distance as to what the significant wave height would be at the time of the occurrence, but it could certainly be assumed that it was no less than 25 to 30 knots hence the wave height would be at least 20 feet (6 m) with a maximum isolated height of 30 feet (9 m).

Taking into account the various factors acting in conjunction with one another we find that under fairly specific meteorological circumstances, i. e. a deep low pressure system centred about Marion Island or occasionally further north of it, persistent strong southwesterly winds with a fetch of from 600 to 1 200 miles blow across the Southern Ocean, raising a fully developed sea having a significant height of at least 20 feet (6 m) and a probable maximum height of 30 feet (9 m), a wave length of about 700 feet (210 m) and a period of 12 sec.

EXISTENCE OF SEA-BED CANYONS

It will be noted from columns 4-5 of the environmental log appendix A that ship Nos. 1, 3, 4 and 8 experienced the abnormal wave when close to the position of a known canyon in the continental slope. A theory has been propounded that this topographic feature on the sea bed could be the cause of the abnormal wave but considerably more investigation is needed to determine whether any of the other vessels which were near the 100 fathom line, i. e. Nos. 2, 6, 7 and 11 were also near canyons. The bathymetric surveys in this area do not as yet indicate this. This theory will be investigated more fully as more detailed bathymetric information becomes available.

CONCLUSIONS

We have now examined all the circumstances which contribute towards an abnormal wave but before making any specific pronouncement on the effect of this wave let us first of all summarise the course of events leading up to its formation :

(a) Prior to the passage of a cold front along the S. E. coast, a strong northeasterly wind accentuates the speed of the Agulhas Current, that tremendous body of water up to 100 miles wide and 1 000 feet (305 m) deep, flowing in a southwesterly direction, having its maximum velocity and depth just outside the 100 fathom (200 m) line. The velocity can be as high as 5 knots but averages 3-4 knots between Port St. Johns and East London.

(b) A very rapid change in direction of the wind occurs with the passage of the cold front, which is travelling at about 25 knots along the coast. Records show that a change from NE Force 6 to SW Force 6/7 occurs in about 4 hours.

(c) The effect of the southwesterly wind on the sea state immediately takes place. The southwesterly wind comes away suddenly at anything up to gale force, and immediately brings with it a very rough sea. These local wind generated waves are within an hour of the onset of the wind up to 10 feet (3 m) high having a wave length of approx. 200 feet (60 m) and a period of 6-7 sec.

(d) The effect of this southward flowing current shortens the wavelength of the locally generated waves and raises their height. As a result these waves would be 12 or more feet (4 m) high with a length of about 175 feet (53 m).

(e) Fully developed waves up to 20 feet (6 m) high or more, generated by the southwesterly wind over a tremendously long fetch, accentuate the height of the locally generated waves. These waves travelling at about 30 to 35 knots, when they come up against the southflowing current are slowed down but their heights are increased as a result, probably by about 25 percent to 25 feet (8 m) on a wave length of about 500 feet (150 m).

(f) A superimposing of two or more waves of different wavelengths creates an abnormally high wave up to 60 feet (18 m) high, which however only lasts a relatively short period of time, perhaps a matter of a few minutes.

(g) Because this abnormally high wave is travelling in the opposite direction to the fast flowing current, the northern or leeward face of the wave becomes extremely steep, with the crest almost at breaking point.

(h) A long abnormally deep trough also occurs on the northeastern side of the wave possibly due to a suction effect caused by the combination of the two or three waves moving against the fast-flowing current.

(i) 8 of the 10 ships which have reported abnormal waves were within two or three miles outside the edge of the continental shelf. None of them was inside the 100 fathom line.

(j) 4 of the 10 ships were near known canyons on the shelf slope.

(k) On 7 of the 10 occasions, there was a deep atmospheric depression centred at or near Marion Island during the 24 hour period preceding the occurrence. On the other 3 occasions active depressions were so situated that strong southwesterly winds had been blowing over distances of about 1 000 miles towards the position of encounter. In other words on every reported occasion southwesterly winds with a fetch exceeding 1 000 miles had been blowing for some considerable time before the occurrence.

(l) None of the monitoring vessels or the *Thomas B. Davie* which were navigating inside the 100 fathom (200 m) line reported sighting abnormal waves, although all do record very rough seas and very heavy swell of up to 25 feet (8 m) in height. The wind regime and atmospheric pressure conditions were however of a similar nature to those referred to in (k) above.

EFFECTS OF AN ABNORMAL WAVE ON A VESSEL

So then what is the effect of this abnormal wave on a vessel heading into it ?

The ship may be steaming at a reduced speed, although with a large vessel there is often a tendency to consider she is able to plough her way at full speed through the normal seas being experienced, i.e. up to 25 feet (8 m). Then suddenly without any warning the bow falls into a long sloping trough, probably greater than the length of the ship, so that she virtually ends up by steaming down hill wih increased momentum (see fig. 4). At the bottom of the sloping trough a very steep mountain of water probably more than 60 feet (18 m) high and almost about to break is racing towards the ship at up to 30 knots or 50 feet (15 m) per second. Under these circumstances nothing can be done to help the ship overcome the tremendous pressures and weights which are about to be exerted on the hull. The ship's forepart has no time to lift to the onrushing mountain of water, hence it buries itself into the wave, which then becomes unstable and crashes down with a mighty force on to the deck, usually striking it in the vicinity of the break between Nos. 1 and 2 hatches or about 100 feet (30 m) abaft the stem.

The buoyancy potential of the forepeak, chain locker and any other empty spaces in the forepart gives this foremost part of the ship an upward lifting motion as it struggles to rise to the surface, whilst at the same time the tremendous weight of the sea crashing down on to the deck abaft of this buoyant area, places a colossal strain and stress not only on the deck itself but also on the internal members of the ship's structure in the vicinity of the bulkhead between Nos. 1 and 2 hatches, which results in considerable internal structural misplacement.

THE SOLUTION

Because these abnormal waves occur without any warning there seems to be no way in which a vessel could be manoeuvred to avoid damage if it occurs in the direct track of the vessel. But there is one obvious criterion which does give a distinct guide as to how to avoid meeting an abnormal wave and that is to keep away from the vicinity of the outer edge of the continental shelf or 100 fathom (200 m) line between Richards Bay and Great Fish Point, when steaming to the southwest with a falling barometer, a fresh northeasterly wind blowing, and a change to fresh to strong southwesterly winds forecast in the next twelve hours, by standing in towards the coast, so that when the wind changes, the ship will be inshore of the 100 fathom (200 m) line, then to remain inside the 100 fathom (200 m) line until the wind and sea have moderated sufficiently to edge gradually out beyond the 100 fathom (200 m) line.

It is to be noted that shipping steaming in a northeasterly direction usually remains within 3-4 miles of this part of the South African coast in order to take advantage of the inshore counter current referred to above. Southbound traffic should therefore avoid closing the coast more than is necessary especially between Durban and Bashee river light.

It is also to be noted that certain vessels, which, by virtue of the nature of their cargo, are required to keep a specified distance clear of the coast should, under the above weather conditions, keep beyond the influence of the core of the Agulhas Current, i.e. not less than 20 miles seaward of the edge of the continental shelf where there is less risk of encountering an abnormal wave. When off Great Fish Point course can then be altered to keep within the winter loadline limits.

Psalm 107 verses 23-31.

ACKNOWLEDGMENTS

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Commander A. S. POMEROY, Mr. N. D. BANG, Mr. F. SHILLINGTON, for their scientific advice.

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(Manuscript submitted in English).

APPENDIX A
ENVIRONMENTAL LOG

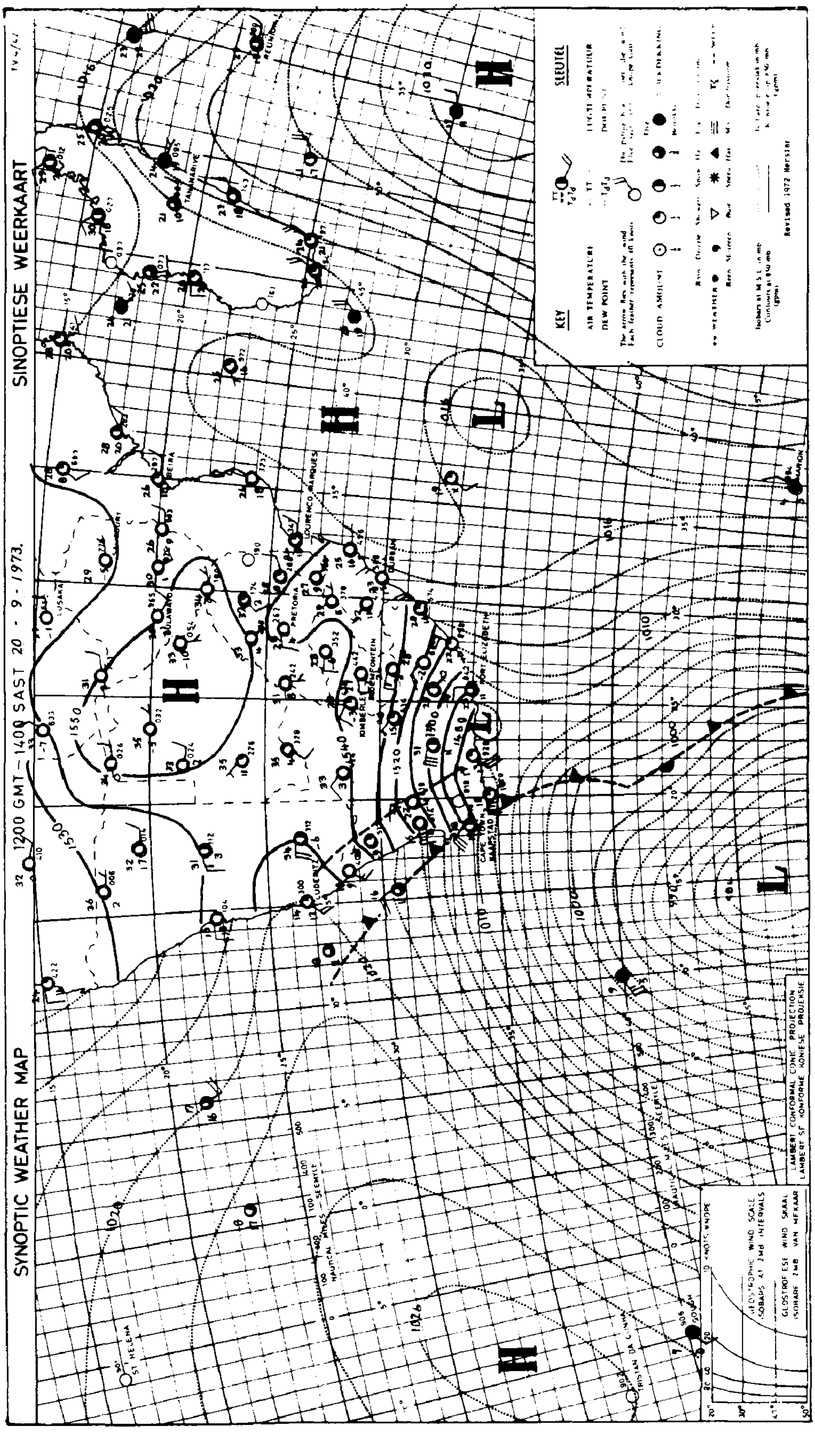
1 Ship's Name	2 Date	3 Time SAST	4 Lat. 5 Long. Topogr. features	6 Wind waves	7 Fetch of SWly wind and duration	8 Movement of cold front.	9 Pos'n of Depression ; Barometric Pressure	10 Change in Bar. in 24 hrs at position	11 Remarks
1. *Guastekerk* (Damage unknown)	11. 4.52	0120	31-47 29-32 Close outside 100 fthm near canyon.	SSW 4 Moderating	1200 miles for past 24 hrs	Passed thro' pos'n of ship at time of encounter	Marion Is. 1400/10 Lower than 996 mbs.	12 mb. rise (18 mbs)	SWly force 10 at 1400/10 in vicinity
2. *Oranjefontein* (Damage on deck)	7. 9.53	0105	32-18 29-02 Close outside 100 fthm line.	SSW 4 Moderating	1000 miles for past 36 hrs.	Passed thro' pos'n at 1400/6. 11 hrs before	Marion Is. 1400/6 Lower than 920 mbs	4 mb rise (24 mbs)	Superficial damage sustained
3. *Jagersfontein* (Damage unknown)	18.12.59	0115	31-45 29-39 Close outside 100 fthm line between 2 deep canyons.	SW 7	1200 miles for past 24 hrs.	Passed thro' pos'n at 1400/17. 11 hrs before	Marion Is. 1400/17 976 mbs	4 mb rise (36 mbs)	Weather map shows fresh SW winds during past 24 hrs.
4. *Edinburgh Castle* (Damage on deck)	21. 8.64	About midnight 20/21	31-39 29-46 Close outside 100 fthm line near canyon.	SW 6	1200 miles for past 24 hrs.	Passed thro' pos'n at 1600/20. 8 hrs before	Marion Is. 1400/21 974 mbs.	9 mb rise (44 mbs)	Isobars on weather map indicate strong SWly winds during past 24 hours.
5. *World Glory* (Broke in half)	13. 6.68	1500	29-38 32-15 Close to reported shoal patch	SW 9	800 miles for past 24 hrs.	Passed thro' pos'n prior to 1400/12	Lat. 36S Long. 42 E 1400/12. 990 mbs (600 miles)	2 mb rise (16 mbs)	Depression almost stationary for past 24 hrs. Geostrophic winds SW/7 for 48 hrs on coast
6. *Esso Lancashire* (Damage unknown)	5. 8.68	1045	29-20 32-00 Close outside 100 fthm line.	SW 8	1200 miles for past 24 hrs.	Passed thro' pos'n at time of wave	Marion Is. 1400/4 976 mbs.	12 mb rise (34 mbs)	
7. *Clan Maclay* (Deck cargo damaged)	10.10.69	1126	30-35 30-44 Close outside 100 fthm line	SW 3 Moderating	800 miles for past 24 hrs.	Passed thro' pos'n at 1330/9. 22 hrs before	37°S 35 E at 1400/9 990 mbs. 37° S 40E at 1400/10 (540 miles)	(18 mbs) 4 mb rise	Depression moving slowly eastwards

1 Ship's Name	2 Date	3 Time SAST	4 5 Lat. Long. Topogr. features	6 Wind waves	7 Fetch of SWly wind and duration	8 Movement of cold front.	9 Pos'n of Depression : Barometric Pressure	10 Change in Bar. in 24 hrs at position	11 Remarks
8. *Southern Cross* (Steaming NE)	11.10.69	1900	32-02 29-17 Close outside 100 fthm line near canyon.	SW 7/8	800 miles for past 48 hrs.	Passed thro' pos'n at 1430/11. 5 hrs before.	38° S 31E at 1400/11 (400 miles) 38°S 37E at 1400/12	(8 mbs) 4 mb rise	Secondary depression caused a continuation of SWly winds
9. *Moreton Bay* (Damage unknown)	5. 8.71	0900	33-36 27-30 In deep water	WSW 11	1200 miles for past 24 hrs.	Passed thro' pos'n at time of wave	Marion Is. 1400/5 970 mbs.	Nil (40 mbs)	At 1400/5 the depression centred at Marion Island was extremely deep 970 mbs giving rise to gale force winds in the whole area.
10. *Bencruachan* (Severe structural damage for'd)	3. 5.73	0400	31-10 31-10 In deep water	SW 7	600 miles for past 36 hrs.	Passed thro' pos'n at 1400/1.1d.14 hrs before	35°S 39 E at 1400/2 (600 miles) 1004 mbs	4 mb rise (14 mbs)	Weather map for 1400 - 3rd May queried.
11. *Svealand* (Severe structural damage for'd)	25. 9.73	1647	33-00 28-21 1 mile outside 100 fthm line.	SW 9/10 30-40 ft waves.	1200 miles for past 24 hrs.	Passed thro' pos'n at 2000/24. 21 hrs before.	45°S 19E at 1400/24 Marion Is. 1400/25	10 mb rise 24th-25th (22 mbs)	Sustained gale force winds in area since 2000/24. Storm force winds along the coast.
Monitoring Vessels on passages from Durban to the southwest.									
City of Wellington	28. 7.73 to 29. 7.73	1200 0800	Durban to East London	SW 6 to NE 5	Local winds associated with an anticyclone	C. St. Lucia 1400/27	38°S 39E at 1400/27 moving rapidly east and filling up.	Steady (14 mbs at 1400/27)	Weather on coast associated with passage of anticyclone. Wind changed to NE at about 0600/29.

1 Ship's Name	2 Date	3 Time SAST	4 5 Lat. Long. Topogr. features	6 Wind waves	7 Fetch of SWly wind and duration	8 Movement of cold front.	9 Pos'n of Depression ; Barometric Pressure	10 Change in Bar. in 24 hrs at position	11 Remarks
City of Ripon	17. 8.73 to 18. 8.73	0700 0800	Durban to Cape Recife	SSW 4 to NE 6	Winds associated with passage of anticyclone	Passed thro' Durban at 1400/16	East of Marion Is. at 1400/16	(16 mbs at 1400/16)	Long heavy swell off Margate caused by strong winds blowing SE quadrant of anticyclone. Wind changed to NE at 1400/17
City of Worcester	20. 8.73 to 21. 8.73	1600 2200	Durban to P.E. Inside 100 fthm line.	SW 8-6 throughout passage	1200 miles for past 24 hrs.	Passed thro' Durban at 1400/20	Secondary 35°S 37E 1400/20. Marion Is. 1400/21 998 mbs. Secondary 33°S 44E 1400/21	Ship's record 17mb rise 1600/20 - 21 (28 mbs at 1400/21)	17 ft high swell reported
City of Lancaster	4. 9.73 to 5. 9.73	1600 1800	Durban to P.E. Inside 100 fthm line.	NNE 5/6 to SW 8/2	500 miles from 2130 4	Passed thro' pos'n at ship 31.35°S 30E 2130/4	44°S 17E at 1400/4 Secondary centred between PE & EL 1400/4. moving east in advance of main cold front. Marion Is. 1400/5 982 mbs	12 mbs from 2200/4 to 1600/5 (38 mbs at 1400/5)	Echo on radar at 0500/5 which could have been high wave 1 mile outside 100 fthm line. Wind at time SW 6. Wind changed from NNE 6/5 - SW 7/8 at 2130/5
City of London	22. 9.73 to 23. 9.73	0800 1200	Durban to Seal Pt. On or inside 50 fthm (100 m) line.	SW 6-7 to NE 4	1200 miles for past 24 hrs.	Passed thro' Durban at 0200/22	Marion Is. 1200/21 984 mbs	Ship's record 6.5 mbs rise 0800/22 to 2400/22 (28 mbs)	Anticyclone moved rapidly along coast in rear of depression hence NEly winds as from 1000/23. Heavy SWly swell.
Thomas B. Davie	24. 9.73 to 25. 9.73	1400 2400	Research cruise between Bashee Pt. & Grt. Fish Pt.	NE 6 to SW 10/7	1000 miles from 1400/24 to 2400/25	Passed thro' pos'n of ship 32.26°S 29E at 2130/24	Marion Is. 1400/25 994 mbs.	Ship's record 15 mbs. 1700/24 - 2400/25 (22 mbs)	20 - 25 feet waves on continental shelf.

Note. The figures in brackets in column 10 are the difference between the barometric heights at the position and time of encounter and the centre of the depression.

APPENDIX B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LAMBERT CONFORMAL CONIC PROJECTION
LAMBERT SE KONFORME KONIESE PROJEKSIE
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BULAWAYO
BEIRA
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KIMBERLEY
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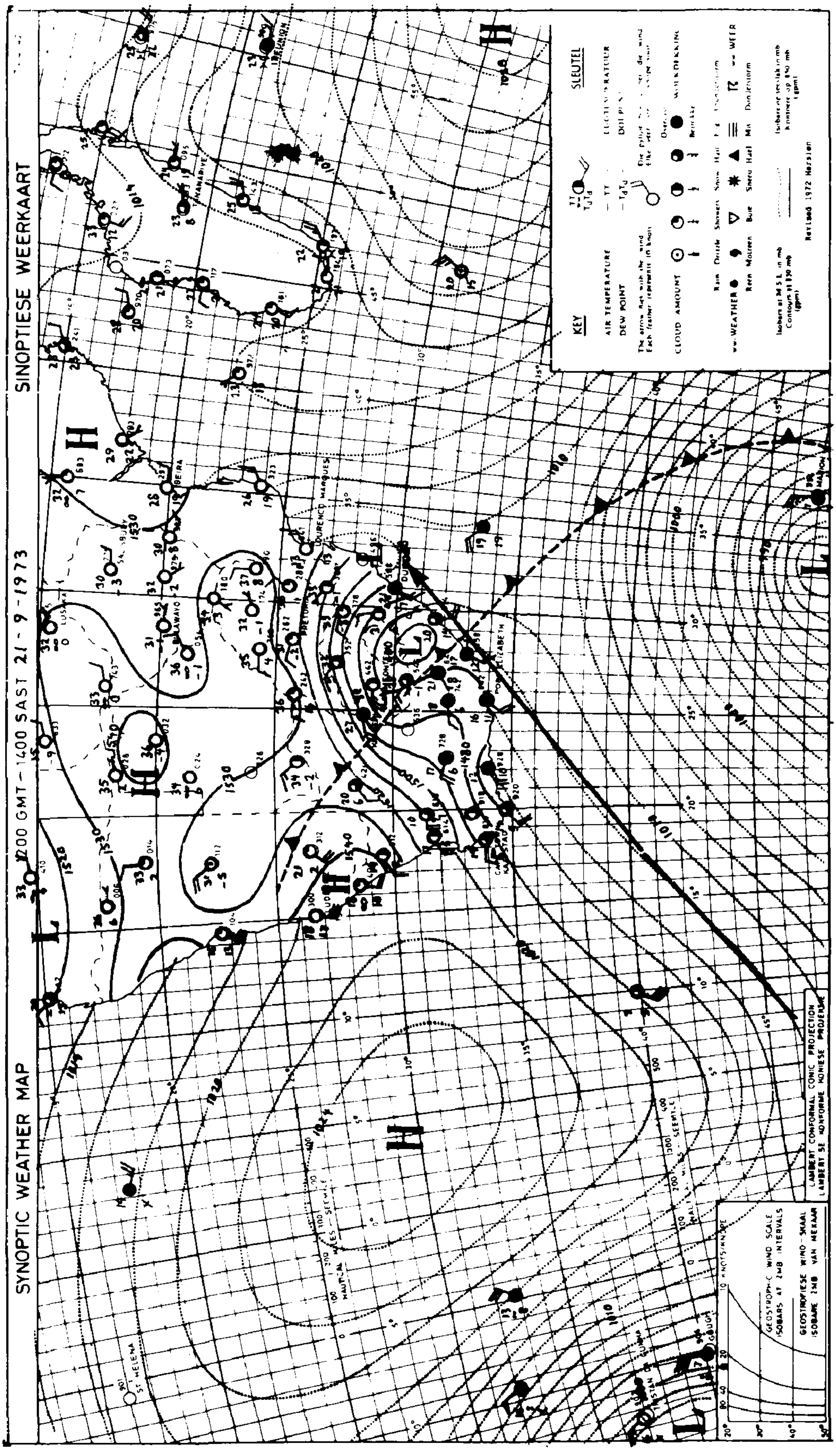
APPENDIX C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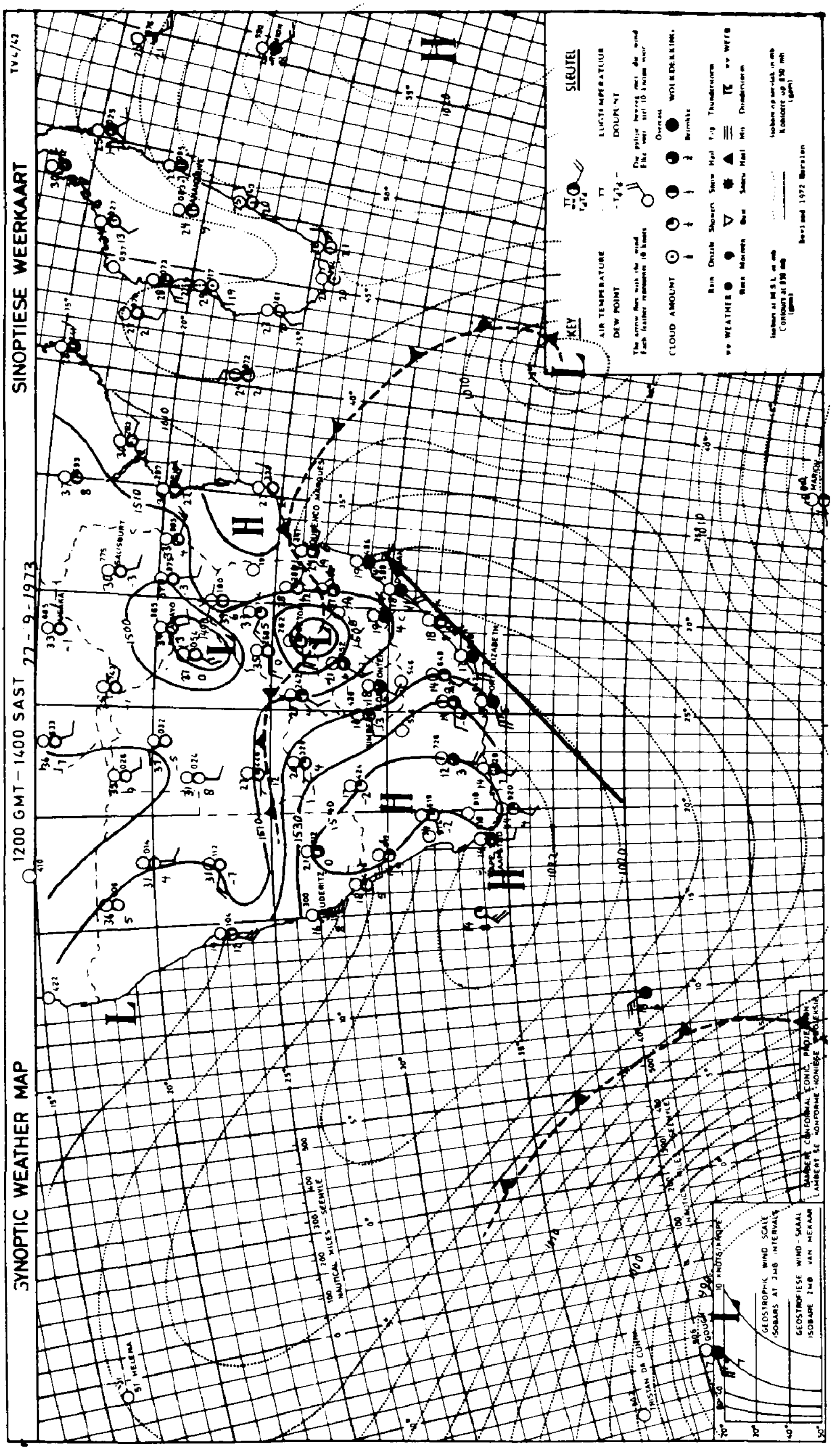
APPENDIX D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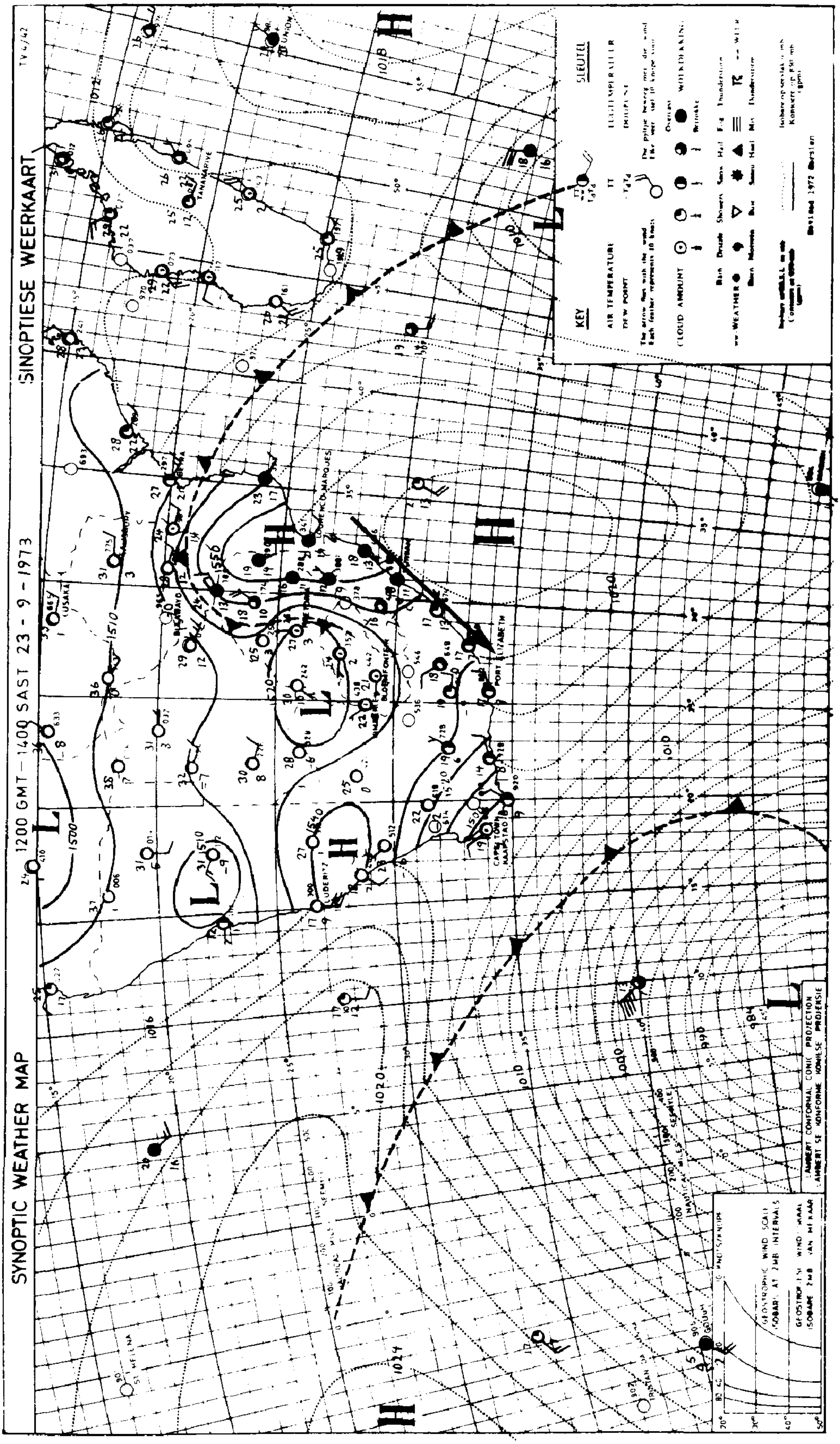
APPENDIX E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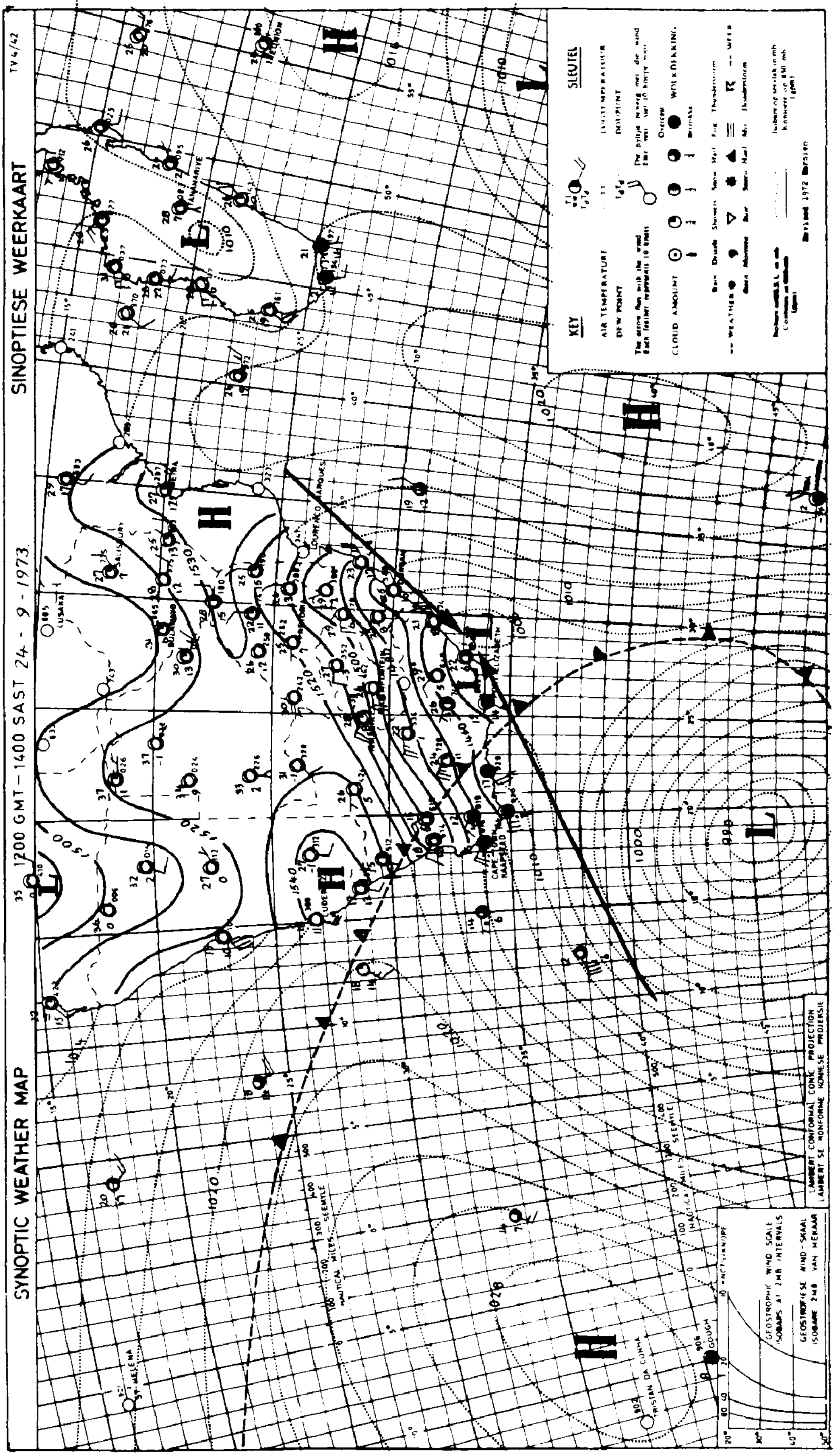
AIR TEMPERATURE
DEW POINT
CLOUD AMOUNT
LAMBERT CONFORMAL CONIC PROJECTION
LAMBERT SE KONFORME KONIESE PROJEKSIE
PORT ELIZABETH
CAPE TOWN
KAAPSTAD
LUSAKA
TANANARIVE
ST HELENA

APPENDIX F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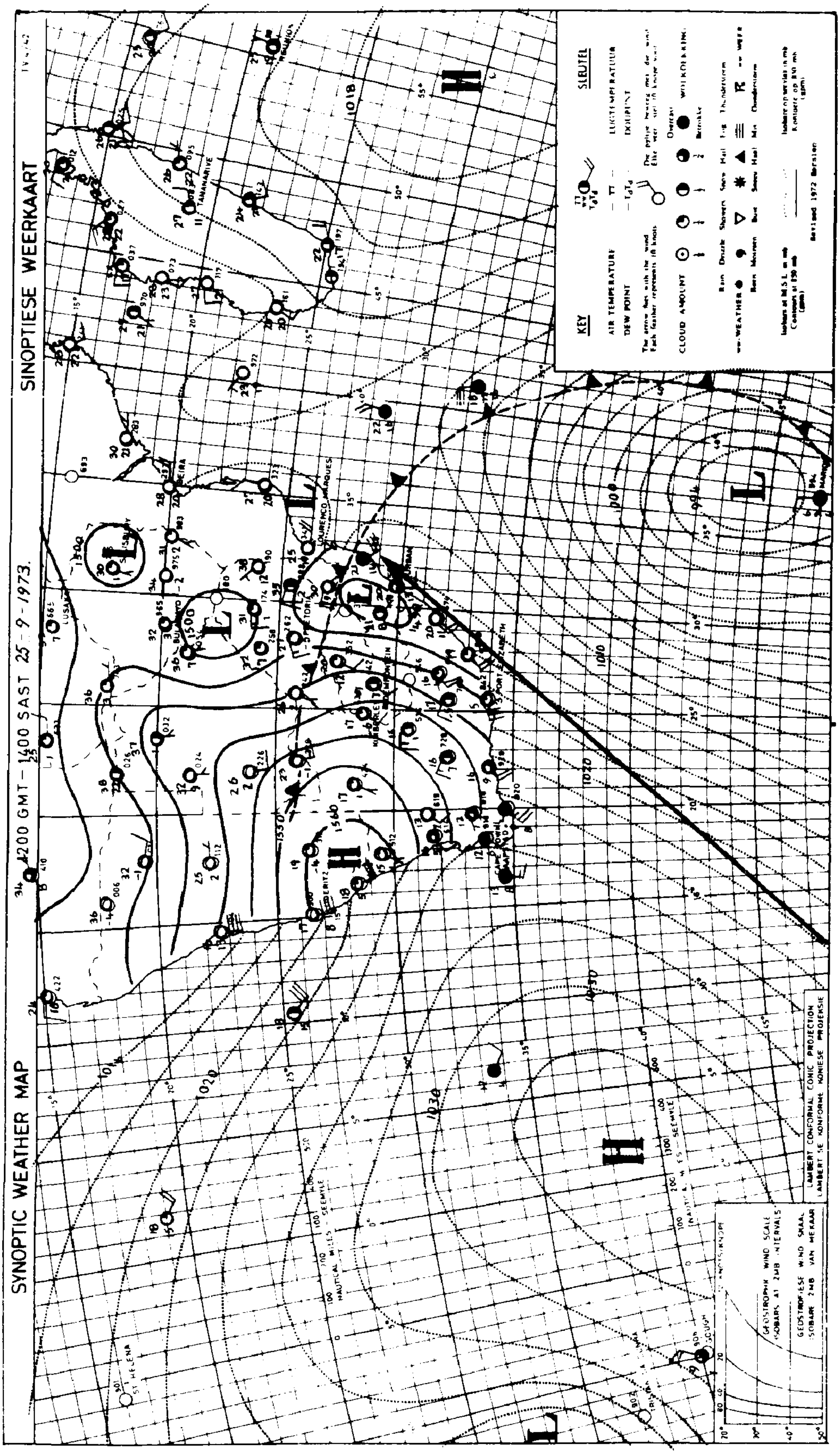
APPENDIX G



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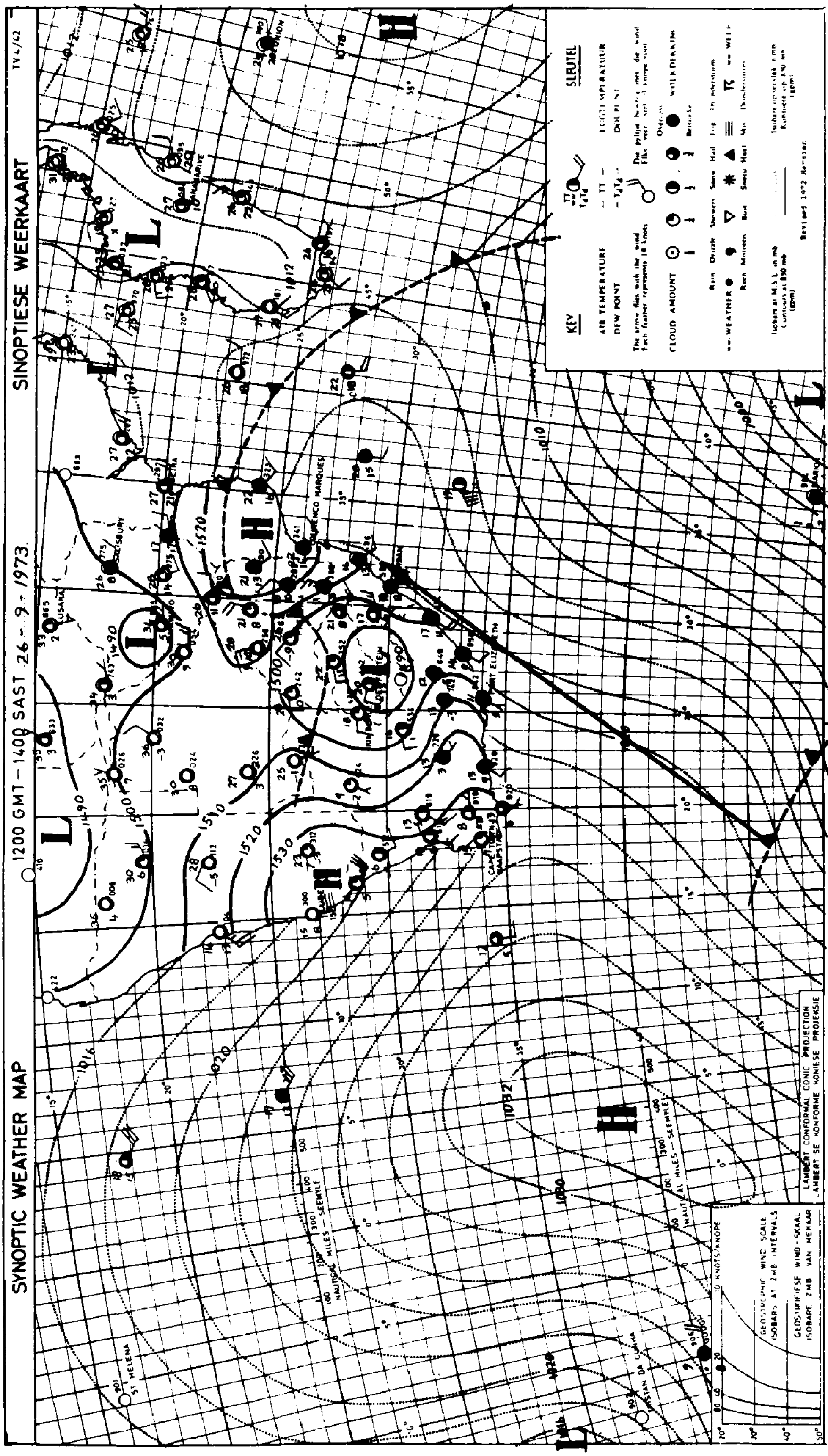
NAUTICAL MILES
SEEMYLE

APPENDIX H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ST HELENA
LOURENCO MARQUES
CAPE TOWN
GOUGH

APPENDIX I

WEATHER LOG BETWEEN DURBAN AND PORT ELIZABETH

From 0800 22 September to 1200 23 September 1973

M. V. *City of London*, Voyage 10, Durban to Cape Town

Time	Position	Air Temp.	Sea Temp.	Baro-meter	Remarks
0800	Cooper Lt. 312 x 6.6′	17.3 C	21.7 C	1016.2	SSW 6 Rough head sea, mod. swell.
1000	Green Pt. 002 x 15′	17.1	19.9	1017.2	SW 6.
1200	N. Sand Bluff 237 x 10.1′	17.2	17.4	1017.9	SW 6 Rough sea, short steep swell.
1400	S. Sand Bluff 264 x 4.8′	17.6	21.7	1017.9	SW 7
1600	C. Hermes 253 x 6.4′	18.0	21.7	1018.5	SW 6/7 Rough sea, short steep swell
1800	Ubombo Head 285 x 3.4′	17.4	22.0	1020.0	SW 6
2000	Mbashe Pt. 283 x 4.25′	16.6	21.7	1020.5	SW 6 Rough head sea, very heavy swell.
2200	Stony Pt. 335 x 4.3′	14.4	21.1	1022.8	WSW 5
2400	Hood Pt. 246 x 17′	14.0	20.6	1022.9	WSW 5 Rough sea, short steep swell
0200	Hood Pt. 033 x 16.6′	13.2	20.0	1022.5	WSW 5
0400	Gt. Fish Pt. 326 x 5.6′	13.0	20.0	1022.6	WSW 5 Rough sea, heavy swell
0600	Bird Is. 282 x 15.2′	13.0	20.0	1022.2	SW 3
0800	C. Recife 290 x 11.1′	12.5	17.2	1022.5	Var. 4 Slight sea, heavy swell.
1000	Seal Pt. 281 x 17.2′	14.8	18.3	1022.8	NE 2
1200	Seal Pt. 059 x 21′	16.0	18.3	1021.1	NE 4 Moderate sea, heavy swell.

APPENDIX J

R. V. THOMAS B. DAVIE

Extract of Log — 24 and 25 September, 1973

Date	Time	Latitude	Longitude	Wind	Sea State	Barometer
24 Sept.	1400	32°02′ S	29°24′ E	NE 6	NE 5	1006.8
	1700	32 13	29 01	NE 5	NE 5	1005.5
	2000	32 32	29 08	E 4	NE 4	1009.0
	2300	32 20	28 52	SW 8	SW 5	1011.2
25 Sept.	0200	32 29	28 40	SW 8	SW 6	1012.5
	0500	32 25	28 50	SW 8	SW 6	1013.0
	0800	32 36	28 36	SW 7	SW 6	1015.0
	1200	32 49	28 19	SW 9	SW 6	1015.0
	1400	32 58	28 10	SW 9	SW 7	1015.0
	1700	33 06	28 00	SW 10	SW 7	1017.0
	2000	33 20	27 40	SW 10	SW 7	1019.5
	2400	33 35	27 12	SW 7	SW 6	1020.2