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The Norse merman as an optical phenomenon

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Mediaeval Norse writings that describe the merman are considered accurate observations of a natural phenomenon. Images of common sea mammals, severely distorted by strong, non-uniform atmospheric refraction, fit the mediaeval descriptions remarkably well. Three examples are presented: computer-generated images of a killer whale and a walrus, and a photograph of a suitably distended boulder. The mediaeval correlation of a merman sighting with the advent of storms is also verified.

MEDIAEVAL manuscripts contain occasional passages, apparently deriving from invention or superstition, for which a basis can be found in observation or experience. However, some texts, such as those that describe the merman, have defied positive identification. In the seventeenth century it was first suggested that the merman was simply a dugong or manatee[1], a view that was generally accepted by the end of the nineteenth century[2]. Although this interpretation is very unsatisfactory, it has remained the most prevalent theory[3].

In general, modern scientists have avoided the study of such anomaly sightings, partially because it is regarded as a non-soluble problem, and partially because it can be so easily distorted[4].

This article considers the merman, as conceived by twelfth and thirteenth century authors. The natural source of the merman legend will be identified, and the high level of sophistication attained by the Norse in observing and correlating natural phenomena will be demonstrated. Finally, the concept of the merman will be traced through its subsequent evolution.

Mediaeval accounts

The *King's Mirror*, written in the mid-thirteenth century, is noted for its highly accurate descriptions of sea mammals and other natural phenomena[5]. The section dealing with the North Atlantic contains only three items that assume an aspect of the marvellous: the *hafgerdingar* and the merman, found in the Greenland Sea, and the *hafgufa*, or kraken, in the Iceland Sea[6]. The explanation of the *hafgerdingar* (sea fences) as a visual effect created by anomalous atmospheric refraction[7] suggests that the merman be reconsidered.

The author of the *King's Mirror* describes the merman as:

> "This monster is tall and of great size and rises straight out of the water.... It has shoulders like a man's but no hands. Its body apparently grows narrower from the shoulders down, so that the lower down it has been observed, the more slender it has seemed to be. But no one has ever seen how the lower end is shaped, ... No one has ever observed it closely enough to determine whether its body has scales like a fish or skin like a man. Whenever the monster has shown itself, men have always been sure that a storm would follow."

He proceeds to discuss its mate, the mermaid, which differs from the merman in that it possesses heavy hair, breasts, large webbed hands, and a fish's tail, but also "rarely appears except before violent storms".

An earlier account of the merman is found in the *Historia Norvegiae*, written[8] about 1170:

> "there is the whale, and there is the merman, the largest wild beast, but without head and tail, thus it is just like a treetrunk when it leaps up and down, and it does not show itself without its foretelling danger for seafarers."

These two passages, the only descriptions of the merman that have survived from mediaeval times, will be analysed here. First the merman's shape will be considered as an optically distorted image; then the correlation between such a sighting and the advent of storms will be briefly assessed.

Atmospheric optics

The atmosphere occasionally produces optical distortion strong enough to make ordinary objects unrecognizable, even at fairly close distances. Such distortions have been suggested as the source for many of the sightings, both ancient and modern, of lake and sea monsters[9]. Common sea mammals, so distorted, fit the mediaeval merman descriptions.

The underlying optical theory, here briefly summarized, is given elsewhere[10–12]. Light rays travelling nearly horizontally follow paths whose vertical curvature κ depends on the distribution of atmospheric density ρ with elevation z. The curvature is given by

$$\kappa = \frac{\varepsilon}{1+\varepsilon\rho}\frac{d\rho}{dz}$$

where $1+\varepsilon\rho$ is the refractive index of air ($\varepsilon = 0.000226$). The density is related to the more easily measured absolute temperature T by[13]

$$\rho = \frac{\beta p_0}{T(z)}\exp\left[-g\beta\int_0^z \frac{dz'}{T(z')}\right]$$

where p_0 is the surface pressure, g the acceleration due to gravity, and $\beta = 3.49\times10^{-3}$, a constant of proportionality. Temperature inversions, with their associated stable atmosphere, cause a downward refraction of light rays. Irregularities in the temperature profile, especially thermoclines, create the irregularities in refraction necessary for severe image distortion.

Computer programs developed for ray tracing[13,14] have been used to identify temperature profiles that create merman images. The reconstructions that follow are based on inversions with thermoclines situated a few metres above the sea.

Example 1: A killer whale projecting its head vertically out of the water is an excellent source for merman images. Such activity, called 'spy-hopping', is common among cetaceans of many sorts[15,16]. It is also specifically mentioned by Shackleton[17] as a hunting procedure used by killer whales[18].

In the image-construction process, several quantities can be manipulated: shape of temperature profile, elevation of observer's eye and distance from observer to object. After some computer experimentation with all of these elements, the following typical conditions were chosen to illustrate the effect. Figure 1*a* shows the temperature profile: a moderate inversion of total strength 7.5 °C and with a thermocline at elevation 2.2 m. The atmosphere is assumed laterally homogeneous over the short ranges involved, so that this temperature profile prevails everywhere between object and observer. If the observer's eye is now placed at an elevation of 2.1 m, the light rays entering the eye follow the paths shown in Fig. 1*c*. The elevations at which these rays intersect an object plane at some distance from the eye are plotted as a transfer characteristic in Fig. 1*b*. These curves determine the nature of the image perceived by the observer. The eye assumes each incoming ray to be straight, and projects it back on to the object plane to give an (apparent) image point. A complete set of curved rays, as in Fig. 1*b*, thus causes a redistribution of all the object points on the

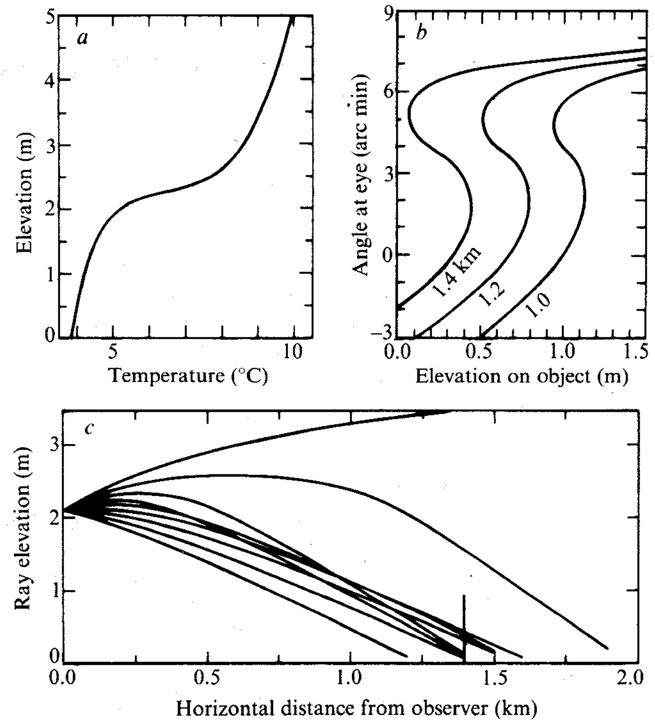

Fig. 1 *a*, Temperature profile used in *Example 1*. *b*, Transfer characteristics generated by the profile of *a*, for object distances of 1.0, 1.2 and 1.4 km. Eye elevation is 2.1 m. *c*, Paths described by light rays in temperature conditions of *a*. The uppermost ray enters the eye at an angle of +9′; the lowest with −3′. The angular increment between successive rays is 1.5′; the spacing of 0.5′ used to plot *b* is too dense to produce a meaningful plot at this scale. The ordinate measures ray elevation above the (curved) surface of the sea. The location and height of the whale's head (see Fig. 2*a*) is indicated by the vertical bar at 1.4 km.

object plane. As the ray bending is in a purely vertical plane no lateral image distortion is present.

The original and distorted images are compared in Fig. 2*a* and *b*, respectively, for an object distance of 1.4 km. Figure 2*a* is adapted from a photograph of a killer whale[19]. The distorted image in Fig. 2*b* is unlikely to be recognized as a whale.

Space restrictions mean that the many possible variations of the image cannot be displayed. With changes in the determining parameters, the shape can appear more or less slender; the midsection can become quite a narrow 'neck' or 'waist'; and the white eye-spot may not be imaged in the 'head'.

Example 2: A similar image-constructing process was carried out for a walrus. As this is a smaller animal, a shorter range was chosen (0.7 km) to have a sufficient horizontal angle subtended at the eye. A steeper temperature profile was required to produce the necessary refraction over the reduced range. Figure 3*a* shows the temperature profile, an inversion of strength 11 °C with a thermocline at about 1.5 m elevation. The transfer characteristics corresponding to an eye elevation of 1.45 m are shown in Fig. 3*b*.

Figure 4 compares the original with the distorted image. A walrus photographed in its natural habitat[20] forms the basis for Fig. 4*a*. The distorted image for the stated conditions is in Fig. 4*b*. Again many variations are possible in this distortion: the figure can become stockier or narrower; it need not have a thin 'waist'; and the apparently fierce 'mouth' and 'teeth' at the top of the figure can become much larger.

Example 3: A photograph of a present-day merman is given in Fig. 5*b*. It appeared over Lake Winnipeg on 2 May 1980, a hot calm day, while there was still some ice on the lake. The inland temperature at the time was about 28 °C, while the lake surface was near 0 °C. The source of the apparition, subsequently identified, was an insignificant boulder (Fig. 3*a*) sited 1.10 km from the camera.

Comparison with mediaeval descriptions

The author of the *King's Mirror* describes the merman with great care, while the less well-informed author of the *Historia Norvegiae* provides only a very general description. Yet the overall impression is identical.

Both accounts describe the merman as a huge animal rising straight out of the water. The lack of detail in the *Historia Norvegiae* implies that the animal had only been seen at some distance, a fact confirmed by direct statement in the *King's Mirror*. The enormous size could, therefore, only have been estimated by comparing its appearance with that of known objects at apparently similar distances.

The man-like shape implied by its name is consistent with the visual impression of an object viewed at some distance, when vertically elongated. As the horizontal dimension remains unchanged, the resulting image acquires a large height-to-width ratio, a form identified with man.

The accounts diverge only in the detailed configuration and in the specific features. The *Historia Norvegiae* suggests a cylindrical body, while the *King's Mirror* gives it shoulders like a man's, with a tapering body. As shown in Figs 2*b*, 4*b* and 5*b*, both shapes are a natural consequence of refractive distortion. Further, the *Historia Norvegiae* claims the merman has no head at all, while the *King's Mirror* lists a pointed head, having eyes, mouth, nose, chin and neck. Again, the process of refraction permits various upper terminations, and refracted markings in approximately the right place (Figs 2*b*, 4*b*) can create the impression of a face. As small atmospheric irregularities tend to disintegrate the image, producing a whiskery or hairy effect[9], such characteristics could be attributed to its mate, the mermaid. At the distances implied in the *King's Mirror*, the human eye, whose resolving power is between 0.5 and 1 arc min, registers only the major outlines; finer details are interpolated by the perception process. Eventually, numerous sightings similar in overall impression but differing somewhat in detail would result in a generalized description and the identification of a species.

The elevation of the observer is important in all optically induced anomaly sightings. The refractive distortion generally diminishes if the image can be viewed from above the thermocline. However, such variations would go unnoticed by Norse mariners, for the working of their ships was carried out from the deck, a few metres above the sea[21]. The subsequent use of much

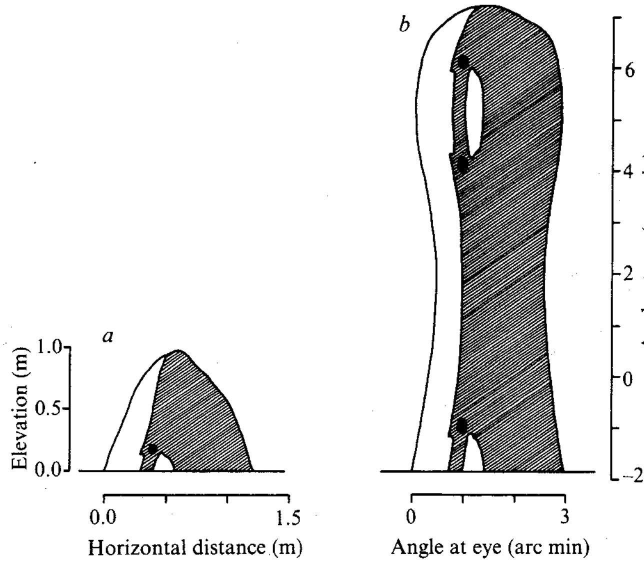

Fig. 2 *a*, A killer whale, spy-hopping. *b*, The distorted image of the whale, seen from a distance of 1.4 km in the temperature conditions of Fig. 1*a*. If the same temperature profile were to prevail for some distance beyond the whale, then the *hafgerdingar* would be present; the apparent horizon would be above the top of the image, at an elevation of +10′, about 10 km from the observer. For a normal atmosphere these values are −2.5′ and 5.7 km.

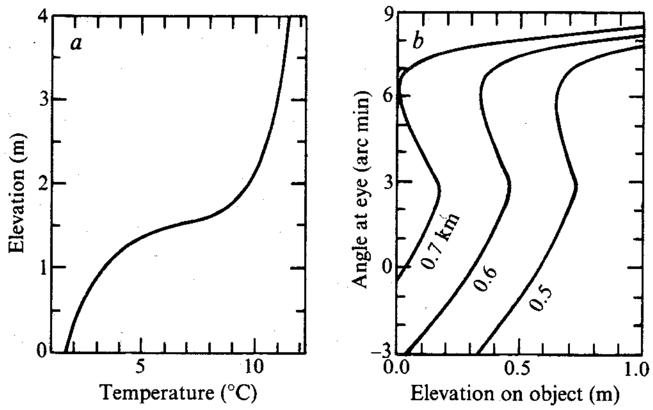

Fig. 3 *a*, Temperature profile used in *Example 2*. *b*, Corresponding transfer characteristics, for object distances of 0.5, 0.6 and 0.7 km. Eye elevation is 1.45 m.

higher decked ships and the establishment of elevated lookouts would explain the infrequent merman sightings in later centuries.

Finally, the distorted boulder of Fig. 5*b* bears a striking resemblence to the *umibohzu*, or "priest of the sea", a giant-like monster known to the Japanese[22]. An even stronger likeness occurs in a narrow-necked version of Fig. 2*b*, in which the *umibohzu*'s eyes are produced by the whale's white eye patch. Clearly the Japanese were interpreting the same visual phenomena in much the same way as did the Norse.

Correlation with the environment

The thermoclines that generate merman images are best created when a warm air mass slowly moves over significantly cooler surface air. In conditions of relative calm, the boundary between the two air masses will possess the flatness and uniformity necessary for well-defined (but distorted) images.

A typical situation is illustrated by the last stages of a warm front, when the warm–cool interface has almost descended to the surface. This has been experimentally verified by Wegener's observations of good superior mirages in the North Atlantic[11,23], which he later correlated with the arrival of warm fronts[24]. However, neither he nor subsequent polar researchers have studied the fine structure of the temperature distributions that the lowest air layers must possess to produce merman images.

Scoresby[25], an experienced Arctic whaler, recorded numerous examples of anomalous refraction which strongly resemble the marvels of the *King's Mirror*: the elevated horizon, a dense appearance of the atmosphere, and the vertically elongated hulls of ships as if in a heeling position. Though Scoresby recognized some forms of refraction phenomena and correlated them with an easterly wind, he attributed others to vapours in the atmosphere, or confused them with ice-blink. He thus associated unusual visual effects with storms but did not identify them with refraction. The dead calm followed by a sudden rise in temperature, the typical conditions noted by Scoresby just before a major storm, are ideally suited to the development of a thermocline. I have observed such an effect on a very localized scale, in the Canadian Arctic, over the Beaufort Sea: the sudden appearance of a medium-range mirage, followed within 40 min by a sudden temperature rise, rainstorms, and disappearance of the mirage. The amount of optical distortion depends directly on the temperature difference between the two air masses, which in turn determines the strength of the front and the severity of the subsequent storms.

Similar refractive distortions will have provided the Norse with sufficient opportunity to observe elongated images of the sea mammals which they used as navigational guides[26]. Because Severin's experience in the *Brendan* indicates that whales do not avoid small sailing vessels[27], the limiting factor would have been the frequency of suitable atmospheric conditions rather than the presence of a suitable subject. These observations belonged to the thirteenth century mariner's general body of knowledge, and were recorded as such in the *King's Mirror*. It is fitting that the *King's Mirror* places both phenomena, the *hafgerdingar* and the merman, together in its text. From the optical reconstruction, as well as Scoresby's observations, clearly some form of *hafgerdingar* will be observed along with the merman. Both are correctly associated with the advent of storms on the open sea, and are located in the Greenland Sea where such extreme conditions were also observed by Scoresby.

Subsequent development

The precise descriptions in the *King's Mirror* directly contrast with those of Olaus Magnus three centuries later. His monsters, composites of several species assembled from fragmented reports[19], reflect the general level to which Norse maritime knowledge had declined. As knowledge of the North Atlantic was regained by western European explorations, unrecognizable sightings reminiscent of the merman were occasionally reported[28,29]. Nevertheless, the Norse merman had become largely a legendary creature, and skepticism as to its existence hardened when scientists identified it with the newly discovered dugong and manatee, both warm water mammals. To clarify this problem, Pontoppidan collected written accounts, as well as verbal reports from reliable witnesses. His attempt to isolate the factual from the mythical established the North European merman as an existing species with some well-defined characteristics. This study formed the basis for all future work even though Pontoppidan did not have access to the *King's Mirror*, a manuscript long believed lost[1].

It is of interest to examine the evolution of the thirteenth century merman into Pontoppidan's eighteenth century composite. Not only had the natural habitat of the merman shifted from the Greenland Sea to the coastal waters of northern Europe, but the conditions in which the merman was sighted had also changed. Many of the sightings accepted by Pontoppidan were reported on very warm, calm days. These observations suggest that the characteristic vertically distended appearance of an optically distorted image was still being identified as a merman; for such weather conditions, though different from those of the advancing front, also develop strong temperature gradients and consequent refraction. Further, while the specific correlation with frontal activity on the open sea had totally disappeared, the fear of the merman had survived as a generalized bad omen. Finally, the species had become approachable;

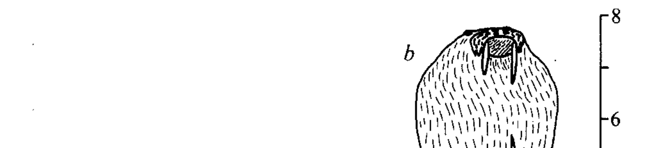

Fig. 4 *a*, Walrus. *b*, The distorted image of the walrus, seen from a distance of 0.7 km in the temperature conditions of Fig. 3*a*. Again, the *hafgerdingar* will be present if the same temperature profile exists over a sufficiently wide area. The horizon elevation would be +13′, at a distance of 15 km, compared with −2′ at 4.8 km for a normal atmosphere.

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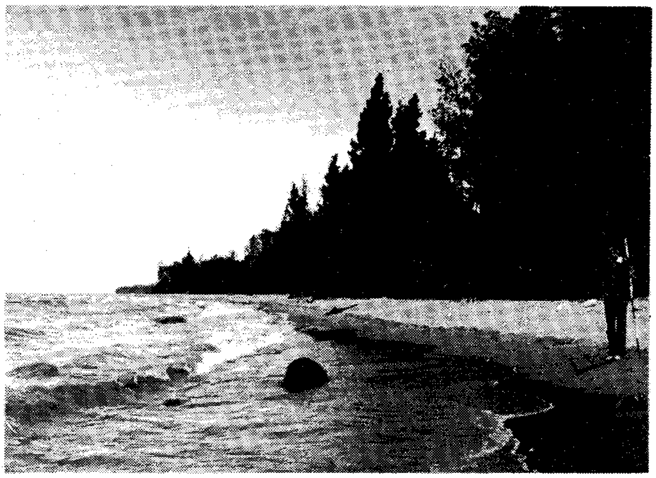

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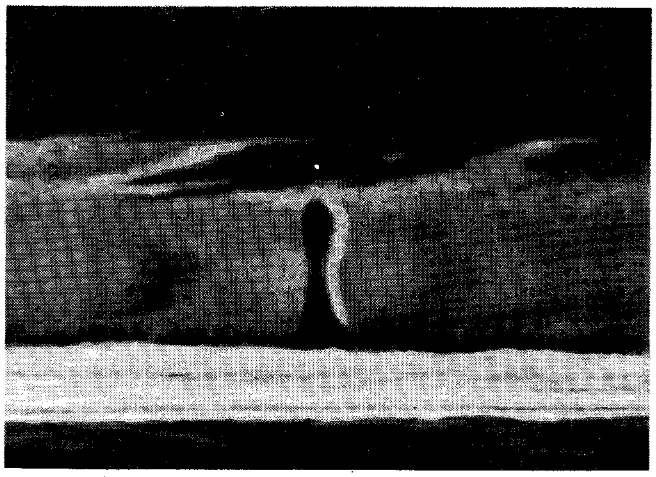

Fig. 5 *a*, Lake Winnipeg, 28 May 1980. The boulder in centre foreground was identified as the source of the image in Fig. 5*b*. It is ~68 cm wide and should show 30–35 cm above water on a calm day. *b*, The boulder distorted into a merman shape, 3 : 17 p.m. CDT (central daylight time), 2 May 1980. The image subtends 5.4′ vertically and 2.2′ horizontally. The photograph was made from a distance of 1.10 km using a mirror lens (focal length 1,250 mm) on Kodachrome 64 film. the exposure was 1/250 s at *f*/11, and the lens elevation was 2.5 m above the lake. A photograph taken just previously, at 3 : 15.5 p.m., shows the distortion as incompletely developed. The merman image of this boulder lasted for only a few minutes. Such conditions occur almost every spring on Lake Winnipeg.

whereas the early Norse reported only distant sightings, actual catches and findings of partially decomposed remains were claimed in the seventeenth and eighteenth centuries.

A similar evolution can be traced for the *hafgufa*. As originally described, it was a featureless monster of enormous dimensions in the Iceland Sea[6]. So few sightings had ever been reported that the author of the *King's Mirror* estimated its world population at one or perhaps two, and hesitated to include it in a compendium of sea life. By the eighteenth century, this monster had multiplied remarkably to inhabit the entire North Atlantic, especially the coastal waters of Norway. Pontoppidan recorded the varied accounts of this creature but found the information so diverse and inconsistent that he did not attempt to identify it with any known species[1]. However, by the end of the nineteenth century, the kraken had assumed the characteristics of a giant squid, an idea which has become increasingly accepted[2].

The *King's Mirror* is so accurate in its description of the merman and the *hafgerdingar* that a serious effort should be made to identify a natural phenomenon closely fitting the original *hafgufa*. Its appearance suggests that it may be a consequence of submarine volcanic activity in Icelandic waters. Steenstrup[26] used this theory to explain the *hafgerdingar*. But the *hafgerdingar* are much better described as an optical phenomenon, while Steenstrup's theory is a superior match, both in appearance and location, to the thirteenth century *hafgufa*.

Following the deterioration of contact between Iceland, Greenland and Norway, the merman and the *hafgufa* had become culturally isolated. Cut off from their origins, these stories were free to develop according to local conditions. Progress in identifying these marvels was hampered by the fact that they had evolved in time, a problem similar to the one identified in a recent analysis of the Gunnbjorn Skerries[30]. When renewed interest in the North Atlantic stimulated scholars to seek out all previously known information, both the skerries and the marvels of the *King's Mirror* emerged as composite remnants from the mediaeval age.

Conclusion

The merman described in the early sources, like the *hafgerdingar*, is, in fact, an accurate description of an unusual optical phenomenon. Its appearance is exactly that predicted by computer simulations of anomalous atmospheres, and the weather conditions with which it is associated agree with modern observations in arctic regions. The correspondence of these two marvels with reality leads directly to the conclusion that the *hafgufa* account must also be considered as an observed natural phenomenon.

The extent to which Norse expertise deteriorated, once trans-Atlantic navigation ceased, is clearly demonstrated by the many unrealistic accounts found in sixteenth century sources. Clear and precise reports were superseded by confusion and the supernatural. The tendency of modern scholars has, therefore, been to dismiss as inaccurate or superstitious any observations inconsistent with their own experience. The optical interpretation of the merman and the *hafgerdingar* enables a clear differentiation between thirteenth and sixteenth century concepts and furthers an appreciation of the visual impressions which formed an integral part of Norse maritime experience.

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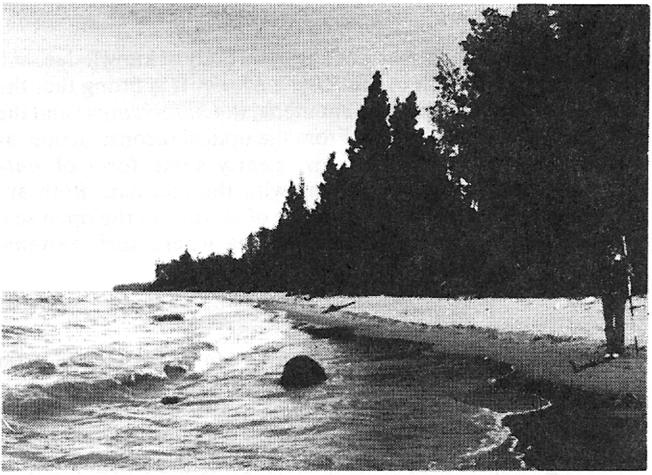

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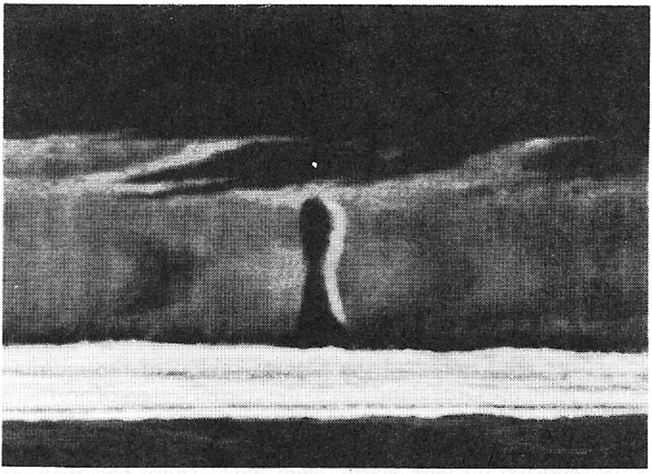

Fig. 5 *a*, Lake Winnipeg, 28 May 1980. The boulder in centre foreground was identified as the source of the image in Fig. 5*b*. It is ~68 cm wide and should show 30–35 cm above water on a calm day. *b*, The boulder distorted into a merman shape, 3:17 p.m. CDT (central daylight time), 2 May 1980. The image subtends 5.4′ vertically and 2.2′ horizontally. The photograph was made from a distance of 1.10 km using a mirror lens (focal length 1,250 mm) on Kodachrome 64 film. the exposure was 1/250 s at *f*/11, and the lens elevation was 2.5 m above the lake. A photograph taken just previously, at 3:15.5 p.m., shows the distortion as incompletely developed. The merman image of this boulder lasted for only a few minutes. Such conditions occur almost every spring on Lake Winnipeg.