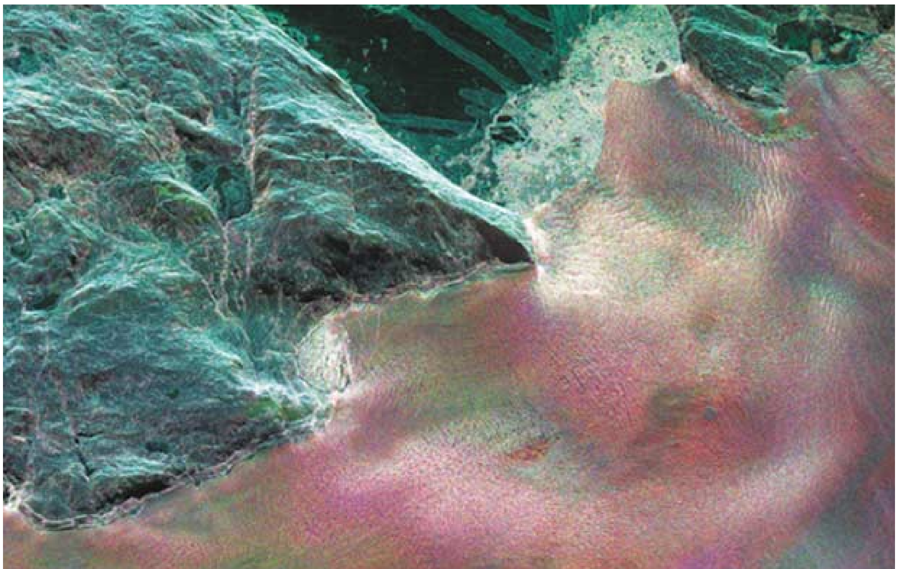
What happened at Qaqortoq?

In December last year, a fireball streaked across the sky above the north Atlantic and hit the ground somewhere in Greenland. **Jonathan Tate** reports on the story so far.


A coloured radar image 12 km across over the likely impact region, near Fredrikshab Isblink, Greenland (DCRS).

There is no doubt that at 08.11 UT on Tuesday 9 December 1997 something unusual happened about 50 km north-east of Narsarsuaq airport in southern Greenland. Word began to filter out to the world on 11 and 12 December that it was likely that there had been a substantial meteorite fall in the region, but since then controversy has surrounded the whole affair. Indeed, echoes of the Tunguska event in 1908 are already evident.

Interest was first kindled by numerous eyewitness accounts of a bright fireball, which was seen by a number of individuals, including police officers, a storekeeper, and the crews of at least four trawlers. In addition, a bright flash lasting for about two seconds, and the bolide itself appear on a videotape taken in a Nuuk car park by a surveillance camera, though only reflected in a car bonnet!

The skipper of the Danish trawler Timmarut reported that his position was 60° 30′ N, 46° 43′ W, and his heading was 290–300° when he observed a bright fireball to port. The fireball crossed his heading and disappeared at the horizon to his front, and starboard. The first mate on the same vessel reported a bright fireball that crossed the sky at high altitude from roughly 270–290° to 90°. The path was curved, and there was no terminal flash. The event lasted for about five seconds, and the colour of the fireball was observed to be reddish.

The captain of the trawler Halten Traal, located at 62.05 N, 41.10 W was travelling north-east at about 08.10 UT when he observed a large fireball travelling in a south-westerly direction until it disappeared over the horizon at a bearing of 230–240°. He described the colour as bluish, and there was a bright flash as the bolide disappeared. The whole event took place in silence, and there was no electrical disturbance.

At about 08.10 UT the trawler Nicoline C was off Fiskenaesset in south Greenland (62.55 N, 51.35 W) under a clear sky. Although he did not observe the fireball directly, his wheelhouse and the mountains ashore were strongly illuminated by a yellow-red light. Shadow movement indicated that the phenomenon was moving in a southerly direction, and it seemed to brighten as it passed. Again the whole event was silent, and no electrical disturbances were observed.

The trawler Regina C was, at about 08.10 UT, positioned at 60.55 N, 42.15 W. The first mate saw a large fireball coming from the north. It passed approximately 10° above the horizon before disappearing behind mountains at about 320–330°. The mountains were silhouetted by the light, and then there was a powerful flash. He described the colour as being pale green at the centre of the fireball, and pieces fell onto the mountains from the glowing trail. There was no sound from the event, and no disturbance of electronic instruments. From this description it has been calculated that the end of the track lies behind and between the mountains of Kap Olfert Fischer og Nuk.

The captain of the cutter Tasiilaq was sailing on a southerly course, and at approximately 08.10 UT was at 62.01 N, 41.13 W when he noticed a bright white flash on the horizon. The cutter and its surroundings were lit up "like daylight" by the event, and the captain observed a jagged column of fire, or tail stretching about 10° above a point in the mountains. He obtained an accurate bearing of 285° true to the column, which persisted for a few seconds.

Two police officers on patrol in Nuussuaq observed a fireball "about the size of the Moon" at between 08.10 and 08.15 UT. They estimated that it passed to the west of them at an elevation of about 70–75°. The colour of the fireball was described as orange-yellow, and there was no sound.

The atmospheric "plume"

International interest began to peak when the images from the National Oceanic and Atmospheric Administration (NOAA) 14 weather satellite, taken on 9 December at 14.24 UTC were analysed and published on the Internet. In both visible light and near IR there is a clear and distinct cloud "plume" visible over the possible impact site. The cloud in the images was about 120 km across, and was still visible in frames taken 26 hours later. The Tycho Brahe Planetarium estimated the cloud height as 6–8 km. A number of observers immediately leaped to the conclusion that this was the result of a major impact, and began a series of calculations to derive further data.

Before long, however, dissent arose. Satellite images from November and December 1996 and November and December 1997 (up to 9 December) showed similar cloud formations over southern Greenland. Other observations concerning the time of impact and the appearance of the cloud were also contradictory.

On 13 December the claim that the NOAA cloud formation was linked to a meteorite impact was officially withdrawn, there being evidence that the cloud existed long before the impact date, but the debate continues. Efforts are underway in Canada to determine the cause of the cloud. It is important to note that this withdrawal also affects some of the early estimates of the mass and size of the bolide.

Seismic evidence

Seismic data obtained from two separate locations, Spitzbergen and Finmarka, clearly show a high-frequency event coincident with the expected arrival times of seismic waves at these locations (08.21 for Spitzbergen and 08.22 for Finmarka). The event produced two peaks about eight seconds apart at Spitzbergen, and similar, but more diffuse patterns at Finmarka. These patterns are consistent with the signals resulting from a sonic boom as the meteorite headed for Greenland. They are not the type of signals that would result from an impact. Further analysis using signals from seismic arrays could produce information about the trajectory of the bolide. From the limited data available at the time of writing, it appears that the trajectory was steep.

Physical evidence

The best way of proving an impact and determining the nature of the perpetrator is to find a crater and/or fragments of the impactor. Search operations in Greenland are being hampered by poor weather. There has been a report of an impact crater approximately 1 km in diameter located about 170 km east of Nuuk. A pilot who flew over the area at an altitude of 27 000 feet filed the report, but there is no mention of the type of observation (visual, radar etc), and the sighting remains unsubstantiated. An impact capable of excavating a crater of this size would almost certainly have produced seismic and meteorological effects orders of magnitude greater than those reported. The centre of the likely impact zone, deduced from the eyewitness reports, was originally thought to be 61° 25′ N, 44° 26′ W, but this position was likely to be accurate only to some tens of kilometres. More recent calculations indicate a site further north at 63° 10′ N, 46° 30′ W. The area of uncertainty is elliptical in shape, 100 km long and 40 km wide along a bearing of 270° (the deduced terminal flight direction).

The Danish Centre for Remote Sensing (DCRS) at the Technical University of Denmark collected radar images of this site and surroundings, with no sign of a crater. The image they have released of Fredrikshab Isblink, is a field of view of 11 by 12 km, in which north is to the lower left. It is an area of complex morphology, with mountains and icefields: the blueish area in the upper part of the image is mountainous, and the reddish region lower down is a glacier. Although the rugged terrain would make recognition difficult, there is nothing on this image identifiable as a crater. The DCRS plans to look for new features through selective area radar interferometry, a technique that compares an image from before the impact with one from afterwards. This should find a crater if there is one and if it is larger than 30–50 m across.

The fact that the impact probably occurred on ice will not alter the cratering characteristics of the event, but heavy snowfall may obscure the evidence. Obviously this all depends on the size of the crater, and this will depend on the velocity and mass of the impactor (and clearly the mass will depend on its composition and density). A simple rule of thumb is that a crater will be about 20 times as large as the impactor. However, it is still likely that the bolide disintegrated before striking the ground. Should this be the case, it is unlikely that a crater was formed, though there may be other physical evidence caused by the blast wave. Fragmentation of the impactor may produce sizeable pieces, but, depending on its physical composition, it may now be microscopic dust particles. Due to the time of year, and poor weather conditions, a comprehensive search programme is likely to take some time.

Was it a Geminid?

Duncan Steel has pointed out that the Qaqortoq event occurred during the annual Geminid meteor storm. The Geminids occur each year between 7 and 16 December, usually peaking on the 15th. The Geminid meteors are associated with a suspected dormant comet nucleus, 3200 Phaethon. The radiant for the storm is at RA 07 28, Dec +32. At 08.00 UT on 9 December 1997 the radiant was at an Azimuth of 240° from southern Greenland. There is good correlation between this azimuth and the probable path of the bolide. So initial studies indicate that the Qaqortoq bolide could be a piece of Phaethon, in which case any fragments would be of enormous value.

The concept of "dormant" comet nuclei is relatively new. The Giotto images of the Halley nucleus showed an irregular, black body. The dark colour was totally unexpected, but spectroscopic studies of comets had already indicated the presence of complex hydrocarbons, and it has become clear that the low albedo comes from the deposition of such hydrocarbons on the surface of the nucleus, forming a tarry "skin". It is not hard to imagine a cometary nucleus that has expended all of its volatiles, or where the "skin" has covered the entire surface, preventing any residual volatiles from outgassing. Unlike a normal comet with a coma and tail, it would look just like a dark carbonaceous asteroid. A number of objects previously categorized as asteroids have orbits that are very similar to those of typical short period comets, and it is now believed that many of these are actually comets, albeit dormant ones. New research published at the beginning of 1997 by Bailey and Emel-Yanenko indicates that there may well be a significant population of such dormant comets in Halley type orbits. A piece of such an object would be of immense value to researchers.

Conclusion

There can be little doubt that there was an impact of some sort in southern Greenland on the morning of Tuesday 9 December. Current evidence for the size and extent of the event is muddled and inconclusive, but many of the controversies can be resolved by an on-site inspection of the impact zone. It is highly likely that little or no debris will be discovered, and a crater would be an enormous bonus. As we learned from the Tunguska event, devastating impacts do not always leave evidence of their activities for future generations. But the lack of evidence does not make them any less devastating. Every artilleryman or bombardier knows that the most effective explosion is an airburst. Nature replicates this effect, then covers the tracks like a professional criminal.

Why should we care about this event at all? After all, it happened in a remote Arctic area, no-one was hurt and apparently no damage was done. It is suggested that there are two very good reasons for interest. The first is purely scientific. Any fragments that might be recovered will provide valuable data as to the composition, origin and history of the impacting body. Such studies will offer detailed insights into the physical and chemical properties of the impactor and possibly its progenitor. If a crater has been formed, further studies can be conducted into crater formation and the dynamics of hypervelocity impacts.

The second reason for interest is somewhat more fundamental. The threat to the ecosphere from the impacts of comets and asteroids is becoming an increasingly hot subject. However, significant impacts are rare events, and few have occurred in living memory. Any opportunity to study such an event must be seized. The characteristics of the Greenland impactor will add to the impact database, assisting the process of deducing the likelihood of future events, and the requirements to do something about the hazard. The impacts of Comet Shoemaker–Levy 9 on Jupiter in July 1994 served notice on humankind that our wellbeing on this planet has so far been a matter of luck. The Qaqortoq event may serve as a reminder.

The Tunguska event precipitated decades of heated debate, which still continues today. Let us hope that the mysteries surrounding the Qaqortoq event can be unravelled sometime before the year 2058! ●

Jonathon Tate is a director of Spaceguard UK, an organization that raises awareness of the impact threat, discussed further at "http://dspace.dial.pipex.com/jay_tate/Spaceguard".